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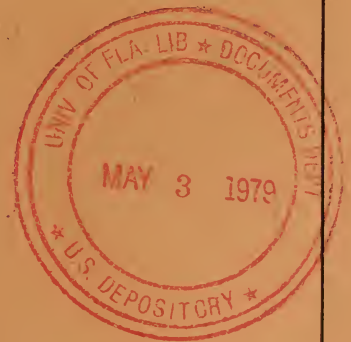
COMMITTEE PRINT

WEATHER MODIFICATION:
PROGRAMS, PROBLEMS, POLICY, AND
POTENTIAL

PREPARED AT THE REQUEST OF
HON. HOWARD W. CANNON, *Chairman*
COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE



MAY 1978



Printed for the use of the
Committee on Commerce, Science, and Transportation



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(II)

LETTER OF TRANSMITTAL

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
November 15, 1978.

To the members of the Committee on Commerce, Science, and Transportation, U.S. Senate:

I am pleased to transmit herewith for your information and use the following report on "Weather Modification: Programs, Problems, Policy, and Potential."

The report was prepared at my request by the Congressional Research Service under the direction of Dr. Robert Morrison, Specialist in Earth Sciences, Science Policy Research Division. We thank Dr. Morrison and the others involved in the study for their extremely thorough and scholarly report. Substantial material on almost all areas of weather modification are included and the report will provide the committee with an excellent reference source for future deliberations on the subject.

The completion of the report is particularly timely due to the upcoming recommendations expected from the Weather Modification Advisory Board and the Department of Commerce (as directed by Public Law 94-490) on the future Federal role in weather modification.

JAMES B. PEARSON,
Ranking minority member.

LETTER REQUESTING STUDY

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
WASHINGTON, D.C., *July 30, 1976.*

DR. NORMAN A. BECKMAN,
*Acting Director, Congressional Research Service,
Library of Congress, Washington, D.C.*

DEAR DR. BECKMAN: Weather modification, although a relatively young science, has over the years stimulated great interest within the scientific, commercial, governmental, and agricultural communities. Such responses are readily understandable. Weather-related disasters and hazards affect virtually all Americans and annually cause untold human suffering and loss of life and result in billions of dollars of economic loss to crops and other property. While weather modification projects have been operational for nearly 25 years and have been shown to have significant potential for preventing, diverting, moderating, or ameliorating the adverse effects of such weather related disasters and hazards, I am greatly concerned regarding the lack of a coordinated Federal weather modification policy and a coordinated and comprehensive program for weather modification research and development. This fact is all the more disturbing in view of the manifest needs, and benefits, social and economic, that can be associated with weather modification activities. These deficiencies in our Federal organizational structure have resulted in a less than optimal return on our investments in weather modification activities and a failure, with few exceptions, to recognize that much additional research and development needs to be carried out before weather modification becomes a truly operational tool.

Reports and studies conducted by such diverse organizations as the National Academy of Sciences, the National Advisory Committee on Oceans and Atmosphere, the General Accounting Office, and the Domestic Council have highlighted the lack of a comprehensive Federal weather modification policy and research and development program. Hearings that I chaired in February of this year reinforced my concerns regarding the wisdom of our continued failure to implement a national policy on this very important issue.

I am therefore requesting the Congressional Research Service to prepare a comprehensive report on weather modification. This report should include a review of the history and existing status of weather modification knowledge and technology; the legislative history of existing and proposed domestic legislation concerning weather modification; socio-economic and legal problems presented by weather modification activities; a review and analysis of the existing local, State, Federal, and international weather modification organizational

structure; international implications of weather modification activities; and a review and discussion of alternative U.S. and international weather modification policies and research and development programs.

If you have any questions with respect to this request, please contact Mr. Gerry J. Kovach, Minority Staff Counsel of the Senate Commerce Committee. He has discussed this study with Mr. Robert E. Morrison and Mr. John Justus of the Science Policy Division, Congressional Research Service.

Very truly yours,

JAMES B. PEARSON,
U.S. Senator.

LETTER OF SUBMITTAL

THE LIBRARY OF CONGRESS,
CONGRESSIONAL RESEARCH SERVICE,
Washington, D.C., June 19, 1978.

HON. JAMES B. PEARSON,
Committee on Commerce, Science, and Transportation,
U.S. Senate, Washington, D.C.

DEAR SENATOR PEARSON: The enclosed report, entitled "Weather Modification: Programs, Problems, Policy, and Potential," has been prepared by the Congressional Research Service in response to your request.

The study reviews the history, technology, activities, and a number of special aspects of the field of weather modification. Activities discussed are those of the Federal, State, and local governments, of private organizations, and of foreign nations. Consideration is given to international, legal, economic, and ecological aspects. There are also an introductory chapter which includes a summary of issues, a chapter discussing inadvertent weather and climate modification, and a chapter summarizing recommendations from major Federal policy studies.

The study has been coordinated by Dr. Robert E. Morrison, Specialist in Earth Sciences, Science Policy Research Division, who also prepared chapters 1, 2, 3, 5, 7, 8, and 9 as well as the Summary and Conclusions. Mr. John R. Justus, Analyst in Earth Sciences, and Dr. James E. Mielke, Analyst in Marine and Earth Sciences, both of the Science Policy Research Division, contributed chapters 4 and 6, respectively. Chapter 10 was prepared by Mrs. Lois B. McHugh, Foreign Affairs Analyst, Foreign Affairs and National Defense Division. Chapter 11 was written jointly by Mrs. Nancy Lee Jones, Legislative Attorney, and Mr. Daniel Hill Zafren, Specialist in American Public Law, both of the American Law Division. Dr. Warren Viessman, Jr., Senior Specialist in Engineering and Public Works, contributed chapter 12; and Mr. William C. Jolly, Analyst in Environmental Policy, Environment and Natural Resources Division, was responsible for chapter 13. In addition, appendixes C, F, Q, and R were assembled by Mrs. McHugh; appendixes D and S were prepared by Mrs. Jones; and information in the remaining appendixes was collected by Dr. Morrison.

I trust that this report will serve the needs of the Committee on Commerce, Science, and Transportation as well as those of other committees and individual Members of Congress who are concerned with weather modification. On behalf of the Congressional Research Service, I wish to express my appreciation for the opportunity to undertake this timely and worthwhile assignment.

Sincerely,

GILBERT GUDE,
Director.



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CONTENTS

	Page
Letter of transmittal.....	III
Letter requesting study.....	v
Letter of submittal.....	VII
Summary and conclusions.....	XIX

CHAPTER 1

Introduction and summary of issues.....	1
Perspective.....	1
Situation.....	1
Advantages.....	3
Timeliness.....	5
Definitions and scope of report.....	7
Summary of issues in planned weather modification.....	9
Technological problems and issues.....	9
Governmental issues.....	12
The role of the Federal Government.....	12
Roles of State and local governments.....	14
Legal issues.....	15
Private rights in the clouds.....	15
Liability for weather modification.....	16
Interstate legal issues.....	17
International legal issues.....	17
Economic issues.....	18
Issues complicating economic analyses of weather modification.....	18
Weather modification and conflicting interests.....	19
Social issues.....	19
Social factors.....	20
Need for public education on weather modification.....	21
Decisionmaking.....	22
International issues.....	23
Ecological issues.....	24

CHAPTER 2

History of weather modification.....	25
Introduction.....	25
History of weather modification prior to 1946.....	26
Prescientific period.....	26
Early scientific period.....	27
Development of scientific fundamentals.....	32
Early cloud-seeding experiments.....	34
Weather modification since 1946.....	35
Chronology.....	35
Langmuir, Schaefer, and Vonnegut.....	37
Research projects since 1947.....	39
Project Cirrus.....	39
The Weather Bureau cloud physics project.....	41
The U.S. experiments of 1953-54.....	42
Arizona Mountain cumulus experiments.....	44
Project Whitetop.....	44
Climax experiments.....	45
Lightning suppression experiments.....	46
Fog dispersal research.....	46
Hurricane modification.....	46
Hail suppression.....	46
Foreign weather modification research.....	47
Commercial operations.....	48
History of Federal activities, committees, policy studies, and reports.....	53

CHAPTER 3

	Page
Technology of planned weather modification.....	55
Introduction.....	55
Assessment of the status of weather modification technology.....	56
Classification of weather modification technologies.....	61
Principles and status of weather modification technologies.....	62
Precipitation augmentation.....	64
Cumulus clouds.....	66
Cumulus modification experiments.....	67
Effectiveness of precipitation enhancement research and operations.....	69
Results achieved through cumulus modification.....	70
Recent advances in cumulus cloud modification.....	71
Orographic clouds and precipitation.....	71
Orographic precipitation modification.....	75
Orographic seeding experiments and seedability criteria.....	77
Operational orographic seeding projects.....	81
Results achieved through orographic precipitation modification.....	82
Hail suppression.....	84
The hail problem.....	84
Modification of hail.....	86
Hail seeding technologies.....	87
Evaluation of hail suppression technology.....	88
Surveys of hail suppression effectiveness.....	89
Conclusions from the TASH study.....	91
Dissipation of fog and stratus clouds.....	92
Cold fog modification.....	93
Warm fog modification.....	93
Lightning suppression.....	96
Lightning modification.....	98
Evaluation of lightning suppression technology.....	99
Modification of severe storms.....	101
Hurricanes.....	101
Generation and characteristics of hurricanes.....	104
Modification of hurricanes.....	108
Tornadoes.....	112
Modification of tornadoes.....	113
Technical problem areas in planned weather modification.....	115
Seeding technology.....	115
Evaluation of weather modification projects.....	118
Extended area effects of weather modification.....	124
Approaches to weather modification other than seeding.....	129
Research needs for the development of planned weather modification.....	131
General considerations.....	131
Recommendations from the 1973 National Academy of Sciences study.....	134
Recommendations of the Advanced Planning Group of NOAA.....	136
Summary of Federal research needs expressed by State officials.....	138
Research recommendations of the AMS Committee on Weather Modification.....	139
Research recommendations related to extended area and time effects.....	143

CHAPTER 4

Inadvertent weather and climate modification.....	145
Introduction.....	145
Terminology.....	145
Climate.....	145
Climatic fluctuation and climatic change.....	146
Weather.....	146
Weather modification.....	146
Climate modification.....	146
Planned climate modification.....	147
Inadvertent climate modification.....	148

	Page
Background	149
Historical perspective	149
Understanding the causes of climatic change and variability	151
The concept of climatic change and variability	152
When and how do climatic changes occur	154
The facts about inadvertent weather and climate modification	156
Airborne particulate matter and atmospheric turbidity	156
Do more particles mean a warming or cooling?	157
Sources of atmospheric particulates: Natural vs. manmade	158
Atmospheric processes affected by particulates	159
The La Porte weather anomaly: Urban climate modification	162
Carbon dioxide and water vapor	164
Increases in atmospheric carbon dioxide concentration:	
What the record indicates	164
Predicting future atmospheric carbon dioxide levels	166
Sources and sinks for carbon dioxide	168
Atmospheric effects of increased carbon dioxide levels	169
Implications of increasing atmospheric carbon dioxide concentrations	169
Implications of a climatic warming	170
Carbon dioxide and future climate: The real climate vs. "model climate"	171
Ozone depletion	172
Concerns regarding ozone destruction	172
Action by the Government on the regulation of fluorocarbons	175
Climatic effects of ozone depletion	176
Waste heat	177
The urban "Heat Island"	177
Albedo	179
Large-scale irrigation	180
Recapitulation	181
Issues in inadvertent weather and climate modification	184
Climatic barriers to long-term energy growth	184
Thoughts and reflections—Can we contemplate a fossil-fuel-free world?	185
Research needs and deficiencies	186

CHAPTER 5

Federal activities in weather modification	193
Overview of Federal activities	193
Legislative and congressional activities	194
Federal legislation on weather modification	194
Summary	194
The Advisory Committee on Weather Control	195
Direction to the National Science Foundation	196
Reporting of weather modification activities to the Federal Government	197
The National Weather Modification Policy Act of 1976	198
Congressional direction to the Bureau of Reclamation	201
Proposed Federal legislation on weather modification	203
Summary	203
Legislation proposed in the 94th Congress and the 95th Congress, 1st sessions	205
Other congressional activities	207
Resolutions on weather modification	207
Hearings	208
Studies and reports by congressional support agencies	209
Activities of the executive branch	209
Introduction	209
Institutional structure of the Federal weather modification program	210
Current status of Federal organization for weather modification	210

XII

	Page
Federal structure; 1946-57.....	214
Federal structure; 1958-68.....	215
Federal structure; 1968-77.....	216
Future Federal organization for weather modification.....	216
Coordination and advisory mechanisms for Federal weather modification programs.....	221
Introduction.....	221
The Interdepartmental Committee for Atmospheric Sciences (ICAS).....	222
The National Academy of Sciences/Committee on At- mospheric Sciences (NAS/CAS).....	226
The National Advisory Committee on Oceans and Atmos- phere (NACOA).....	227
Other coordination and advisory mechanisms.....	228
Weather Modification Advisory Board.....	231
Weather modification activities reporting program.....	232
Background and regulations.....	232
Reporting of Federal activities.....	233
Summary reports on U.S. weather modification activities.....	233
Federal studies and reports on weather modification.....	234
Introduction.....	234
Studies of the early 1950's.....	235
Advisory Committee on Weather Control.....	236
National Academy of Sciences studies.....	237
Studies by the Interdepartmental Committee for Atmos- pheric Sciences (ICAS).....	238
Domestic Council study.....	239
Policy and planning reports produced by Federal agencies.....	239
Federal programs in weather modification.....	241
Introduction and funding summaries.....	241
Department of the Interior.....	246
Introduction.....	246
Project Skywater; general discussion.....	247
The Colorado River Basin Pilot Project (CRBPP).....	254
The High Plains Cooperative Program (HIPLEX).....	258
The Sierra Cooperative Pilot Project (SCPP).....	263
Drought mitigation assistance.....	266
National Science Foundation.....	267
Introduction and general.....	267
Weather hazard mitigation.....	274
Weather modification technology development.....	282
Inadvertent weather modification.....	283
Societal utilization activities.....	287
Agricultural weather modification.....	288
Department of Commerce.....	290
Introduction and general discussion.....	290
The Florida Area Cumulus Experiment (FACE).....	292
Project Stormfury.....	296
Research Facilities Center (RFC).....	300
Global Monitoring for Climatic Change (GMCC).....	301
Lightning suppression.....	302
Modification of extratropical severe storms.....	302
Department of Defense.....	303
Introduction.....	303
Air Force fog dispersal operations.....	303
Army research and development.....	304
Navy research and development.....	304
Air Force research and development.....	305
Overseas operations.....	307
Department of Transportation.....	308
Department of Agriculture.....	309
Department of Energy.....	310

XIII

CHAPTER 6

	Page
Review of recommendations for a national program in weather modification-----	313
Introduction-----	313
Summaries of major weather modification reports-----	314
Final report of the Advisory Committee on Weather Control-----	314
Weather and climate modification: Report of the Special Commission on Weather Modification-----	315
Weather and climate modification: Problems and prospects-----	317
A recommended national program in weather modification-----	318
A national program for accelerating progress in weather modification-----	320
Weather and climate modification: Problems and progress-----	321
Annual reports to the President and Congress by NACOA-----	323
Need for a national weather modification research program-----	324
The Federal role in weather modification-----	325
Trends and analysis-----	326

CHAPTER 7

State and local activities in weather modification-----	331
Overview of State weather modification activities-----	331
Introduction-----	331
North American Interstate Weather Modification Council-----	333
Survey and summary of State interests and activities in weather modification-----	340
State contacts for information on weather modification activities-----	343
Non-Federal U.S. weather modification activities-----	343
Analysis of calendar year 1975 projects-----	344
Preliminary analysis of projects for calendar years 1976-77-----	347
General discussion of local and regional weather modification policy activities-----	348
Weather modification activities within particular States-----	351
California-----	352
State weather modification law and regulations-----	352
Weather modification projects-----	353
State-sponsored emergency projects-----	356
Illinois-----	358
Illinois weather modification law and its administration-----	358
Operational projects-----	359
Research activities-----	360
Kansas-----	361
Kansas Weather Modification Act-----	361
Research activities-----	362
Operational activities-----	364
Emergency Drought Act of 1977-----	364
North Dakota-----	365
Weather modification law and administration of regulations-----	365
Authority and organization for local projects-----	370
North Dakota operational projects in 1975 and 1976-----	371
South Dakota-----	376
Utah-----	381
Washington-----	382

CHAPTER 8

Private activities in weather modification-----	385
Introduction-----	385
Commercial weather modifiers-----	386
Scope and significance of contract activities-----	386
Summary of contract services-----	386
Evaluation and research by commercial firms-----	388
Participation in Federal research programs-----	389
Weather modification organizations-----	389
Professional organizations-----	389
Weather Modification Association-----	390
American Meteorological Society-----	395

XIV

	Page
Opposition to weather modification-----	399
General discussion-----	399
Opposition to the seeding project above Hungry Horse Dam-----	399
Tri-State Natural Weather Association-----	400
Citizens for the Preservation of Natural Resources-----	402
CHAPTER 9	
Foreign activities in weather modification-----	405
Introduction-----	405
World Meteorological Organization register of weather modification projects-----	408
Description of weather modification activities in some foreign nations-----	412
The Union of Soviet Socialist Republics-----	412
Overview of projects in the U.S.S.R.-----	412
Summary of weather modification and related atmospheric research in the U.S.S.R.-----	413
Israel-----	415
Australia-----	416
Canada-----	418
Mexico-----	419
People's Republic of China-----	420
Kenya-----	421
Republic of South Africa-----	422
Rhodesia-----	423
India-----	423
The Swiss hail experiment-----	424
CHAPTER 10	
International aspects of weather modification-----	427
Introduction-----	427
Convention on the prohibition of military or any other hostile use of environmental modification techniques-----	429
Development of the treaty-----	429
Criticism of the convention-----	431
Activities since the United Nations approval of the convention-----	432
Activities of the World Meteorological Organization in weather modification-----	433
Precipitation enhancement program (PEP)-----	434
Other WMO activities in weather modification-----	436
Registration and reporting of weather modification projects-----	436
WMO conferences on weather modification-----	436
Typhoon and serious storm modification-----	437
Global atmospheric research programme-----	437
Legal aspects of weather modification-----	437
United Nations Conference on the Human Environment-----	438
Declaration of the United Nations Conference on the Human Environment-----	438
Action Plan for the Human Environment-----	438
Earthwatch Program-----	439
Study of Man's Impact on Climate-----	439
Other international activities-----	440
United States/Canadian agreement-----	440
North American Interstate Weather Modification Council-----	440
Congressional activities-----	441
Weather modification as a weapon of war-----	441
Senate Resolution 71, prohibiting environmental modification as a weapon of war-----	441
Congressional activities related to hostile use of weather modification, 1974-76-----	442
Other Congressional actions relating to weather modification-----	443
Senate Concurrent Resolution 67—U.S. participation in the world weather program-----	443
National Weather Modification Policy Act of 1976-----	444
Senate Resolution 49-----	444

	Page
U.S. foreign policy-----	444
Various executive branch proposals-----	445
National Advisory Committee on Oceans and Atmosphere-----	447
Activities in 1977-----	448
CHAPTER 11	
Legal aspects of weather modification-----	449
Domestic-----	449
Private rights in the clouds-----	449
Liability for weather modification-----	453
Defenses which may be raised against claims of liability-----	456
Interstate allocation of atmospheric water-----	457
Methods of controlling weather modification-----	459
Congressional authority under the Constitution to regulate or license weather modification activities-----	461
Federalism-----	461
The commerce clause-----	461
The commerce clause generally-----	462
The commerce clause and the regulation of navigable waters-----	463
Limitations on the commerce power-----	464
Fiscal powers-----	465
War powers-----	466
Property power-----	466
Treaty power-----	467
Conclusion-----	467
International-----	468
Certain hostile uses of weather modification are prohibited-----	471
Nations are responsible for environmental conduct which causes injury or damage in or to other nations-----	471
Nations are liable for injuries sustained by aliens within their territory caused by tortuous conduct in violation of inter- national law-----	472
Nations or their citizens may be liable for injury and damage they caused to citizens of another nation occurring in that nation-----	472
CHAPTER 12	
Economic aspects of weather modification-----	475
Introduction-----	475
Economic setting-----	476
Economic aspects of weather modification procedures-----	477
Fog dispersal-----	477
Precipitation augmentation-----	478
Orographic cloud seeding-----	478
Convective cloud seeding-----	478
Precipitation augmentation and energy considerations-----	479
Hail suppression-----	480
Lightning suppression and reduction in storm damage-----	480
Analytic methods for economic analysis-----	481
Case studies of the economics of weather modification-----	482
Hungry Horse Area, Montana-----	482
Connecticut River basin-----	483
State of Illinois-----	483
Nine-county Southeastern Crop Reporting District, South Dakota-----	483
Colorado River-----	484
Conclusions-----	486
CHAPTER 13	
Ecological effects of weather modification-----	487
Introduction-----	487
Modification of weather and climate-----	487
Ecology and ecological systems-----	487
Knowledge of ecological implications of applied weather modifi- cation technologies-----	488

XVI

	Page
Important variables.....	490
Temporal considerations.....	491
Season of modification effort.....	491
Duration of effort: Short- v. long-term.....	491
Regularity of modification effort.....	491
Ecosystem type.....	492
Aquatic v. terrestrial systems.....	492
Cultivated v. natural systems.....	492
Arid v. humid systems.....	492
Cumulative and synergistic effects.....	492
Effects of silver iodide.....	493
Deliberate weather modification.....	496
Precipitation enhancement.....	496
Increased rainfall.....	496
Snowpack augmentation.....	497
Severe storm abatement.....	498
Fog dispersal.....	499
Hail suppression.....	499
Alteration or arrest of lightning discharges.....	499
Inadvertent weather modification.....	499
Extra-area effects.....	499
Long-term, climatic, and global implications.....	500
Summary and conclusions.....	501

APPENDIXES

A. Statement on weather modification in Congressional Record of June 17, 1975, by Congressman Gilbert Gude, containing White House statement on Federal weather modification policy.....	503
B. Department of Defense statement on position on weather modification.....	509
C. Text of United Nations Convention on the prohibition of military or any other hostile use of environmental modification techniques.....	510
D. State statutes concerning weather modification.....	514
Arizona.....	515
California.....	516
Colorado.....	520
Connecticut.....	528
Florida.....	529
Hawaii.....	531
Idaho.....	531
Illinois.....	533
Iowa.....	541
Kansas.....	543
Louisiana.....	549
Minnesota.....	550
Montana.....	554
Nebraska.....	557
Nevada.....	565
New Hampshire.....	571
New Mexico.....	571
New York.....	573
North Dakota.....	573
Oklahoma.....	584
Oregon.....	591
Pennsylvania.....	599
South Dakota.....	604
Texas.....	606
Utah.....	612
Washington.....	613
West Virginia.....	618
Wisconsin.....	622
Wyoming.....	622
E. List of State contacts for further information on weather modification activities within the States.....	625
F. Agreement on exchange of information on weather modification between the United States of America and Canada.....	627

XVII

	Page
G. Weather modification activities in the United States during calendar year 1975.....	630
H. Selected bibliography of publications in weather modification.....	641
I. Public laws dealing specifically with weather modification.....	646
J. Summary of language in congressional documents supporting public works appropriations for the Bureau of Reclamation's atmospheric water resources program.....	655
K. Membership and charter of the U.S. Department of Commerce Weather Modification Advisory Board.....	660
L. Rules and regulations and required forms for submitting information on weather modification activities to the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, in accordance with requirements of Public Law 92-205.....	662
M. Selected State rules and regulations for the administration of State weather modification statutes.....	676
Illinois.....	676
Kansas.....	683
North Dakota.....	691
Utah.....	707
Washington.....	712
N. Documents of the Weather Modification Association.....	717
O. Policy statement of the American Meteorological Society on purposeful and inadvertent modification of weather and climate.....	722
P. Reporting agencies of member countries and questionnaire circulated to receive weather modification information from members of the World Meteorological Organization.....	724
Q. Report of the World Meteorological Organization/United Nations Environment programme informal meeting on legal aspects of weather modification.....	727
R. Text of Senate Resolution 71; considered, amended, and agreed to July 11, 1973.....	734
S. Reported cases on weather modification.....	740
T. Glossary of selected terms in weather modification.....	741

SUMMARY AND CONCLUSIONS

Weather modification is generally considered to be the deliberate effort to improve atmospheric conditions for beneficial human purposes—to augment water supplies through enhanced precipitation or to reduce economic losses, property damages, and deaths through mitigation of adverse effects of hail, lightning, fog, and severe storms. Not all weather modification activities, however, have been or can be designed to benefit everyone, and some intentional operations have been used, or are perceived to have been used, as a weapon of war to impede the mobility or tactical readiness of an enemy. Furthermore, environmental change is also effected unintentionally and without any purpose at all, as man inadvertently modifies the weather and climate, whether for better or worse scientists are not certain, through activities such as clearing large tracts of land, building urban areas, and combustion of fossil fuels.

Historically, there have been attempts, often nonscientific or pseudo-scientific at best, to change the weather for man's benefit. Until the 20th century, however, the scientific basis for such activities was meager, with most of our current understanding of cloud physics and precipitation processes beginning to unfold during the 1930's. The modern period in weather modification is about three decades old, dating from events in 1946, when Schaefer and Langmuir of the General Electric Co. demonstrated that a cloud of supercooled water droplets could be transformed into ice crystals when seeded with dry ice. Soon afterward it was discovered that fine particles of pure silver iodide, with crystal structure similar to that of ice, were effective artificial ice nuclei, and that seeding clouds with such particles could produce ice crystals at temperatures just below freezing. Silver iodide remains the most often used material in modern "cloud seeding."

By the 1950's, many experimental and operational weather modification projects were underway; however, these early attempts to augment precipitation or to alter severe storm effects were often inconclusive or ineffective, owing to improper experimental design, lack of evaluation schemes, and the primitive state of the technology. Through research programs over the past two decades, including laboratory studies and field experiments, understanding of atmospheric processes essential to improved weather modification technology has been advanced. Sophisticated evaluation schemes have been developed, using elaborate statistical tools; there has also been improvement in measuring instruments and weather radar systems; and simulation of weather processes using numerical models and high speed computers has provided further insights. Meanwhile, commercial weather modifiers, whose number decreased dramatically along with the total area of the United States covered by their operations after the initial surge of the 1950 era, have grown in respectability and competence, and their operations have incorporated improvements as they benefited from their accumulated experience and from the re-

sults of research projects. Since such operations are designed for practical results, such as increased precipitation or reduced hail, however, the sophisticated evaluation procedures now used in most research projects are most often not used, so that the effectiveness of the operations is frequently difficult to assess.

Weather modification is at best an emerging technology. Progress in development of the technology over the past 30 years has been slow, although there has been an increased awareness of the complex nature of atmospheric processes and a steady improvement in basic understanding of those processes which underlie attempts at deliberate modification of weather phenomena. Though most cloud-seeding practices are based on a common theory and form the basis for a number of seeding objectives, there are really a series of weather modification technologies, each tailored to altering a particular atmospheric phenomenon and each having reached a different state of development and operational usefulness. For example, cold fog clearing is now considered to be operational, while, at the other extreme, the abatement of severe storms such as hurricanes remains in the initial research phase. Development progress for each of these technologies appears to be much less a function of research effort expended than a dependence on the fundamental atmospheric processes and the ease by which they can be altered. There continues to be obvious need for further research and development to refine those few techniques for which there has been some success and to advance technology where progress has been slow or at a virtual standstill.

The following summary provides a reasonably accurate assessment of the current status of weather modification technology:

1. The only routine operational projects are for clearing cold fog. Research on warm fog has yielded some useful knowledge and good models, but the resulting technologies are so costly that they are usable mainly for military purposes and very busy airports.

2. Several longrunning efforts to increase winter snowpack by seeding clouds in the mountains suggest that precipitation can be increased by some 15 percent over what would have happened "naturally."

3. A decade and a half of experience with seeding winter clouds on the U.S. west coast and in Israel, and summer clouds in Florida, also suggest a 10- to 15-percent increase over "natural" rainfall. Hypotheses and techniques from the work in one area are not directly transferable to other areas, but will be helpful in designing comparable experiments with broadly similar cloud systems.

4. Numerous efforts to increase rain by seeding summer clouds in the central and western parts of the United States have left many questions unanswered. A major experiment to try to answer them—for the High Plains area—is now in its early stages.

5. It is scientifically possible to open holes in wintertime cloud layers by seeding them. Increasing sunshine and decreasing energy consumption may be especially relevant in the northeastern quadrant of the United States.

6. Some \$10 million is spent by private and local public sponsors for cloud-seeding efforts, but these projects are not designed as scientific experiments and it is difficult to say for sure that operational cloud seeding causes the claimed results.

7. Knowledge about hurricanes is improving with good models of their behavior. But the experience in modifying that behavior is primitive so far. It is inherently difficult to find enough test cases, especially since experimentation on typhoons in the Western Pacific has been blocked for the time being by international political objections.

8. Although the Soviets and some U.S. private operators claim some success in suppressing hail by seeding clouds, our understanding of the physical processes that create hail is still weak. The one major U.S. field experiment increased our understanding of severe storms, but otherwise proved mostly the dimensions of what we do not yet know.

9. There have been many efforts to suppress lightning by seeding thunderstorms. Our knowledge of the processes involved is fair, but the technology is still far from demonstrated, and the U.S. Forest Service has recently abandoned further lightning experiments.¹

Modification processes may also be initiated or triggered inadvertently rather than purposefully, and the possibility exists that society may be changing the climate through its own actions by pushing on certain leverage points. Inadvertently, man is already causing measurable variations on the local scale. Artificial climatic effects have been observed and documented on local and regional scales, particularly in and downwind of heavily populated industrial areas where waste heat, particulate pollution and altered ground surface characteristics are primarily responsible for the perceived climate modification. The climate in and near large cities, for example, is warmer, the daily range of temperature is less, and annual precipitation is greater than if the cities had never been built. Although not verifiable at present, the time may not be far off when human activities will result in measurable large-scale changes in weather and climate of more than passing significance. It is important to appreciate the fact that the role of man at this global level is still controversial, and existing models of the general circulation are not yet capable of testing the effects in a conclusive manner.

Nevertheless, a growing fraction of current evidence does point to the possibility of unprecedented impact on the global climate by human activities, albeit the effects may be occurring below the threshold where they could be statistically detected relative to the record of natural fluctuations and, therefore, could be almost imperceptible amid the ubiquitous variability of climate. But while the degree of influence on world climate may as yet be too small to detect against the background of natural variations and although mathematical models of climatic change are still imperfect, significant global effects in the future are inferred if the rates of growth of industry and population persist.

For over 30 years both legislative and executive branches of the Federal Government have been involved in a number of aspects of weather modification. Since 1947 about 110 weather modification bills pertaining to research support, operations, grants, policy studies, regulations, liabilities, activity reporting, establishment of panels and committees, and international concerns have been introduced in the Con-

¹ Weather Modification Advisory Board. "A U.S. Policy to Enhance the Atmospheric Environment," Oct. 21, 1977. In testimony by Harlan Cleveland, Weather modification. Hearing before the Subcommittee on the Environment and the Atmosphere, Committee on Science and Technology, U.S. House of Representatives, 95th Cong., 1st sess., Oct. 26, 1977, Washington, U.S. Government Printing Office, 1977, pp. 28-30.

gress. Resolutions, mostly concerned with using weather modification as a weapon and promotion of a United Nations treaty banning such activities, have also been introduced in both houses of the Congress; one such resolution was passed by the Senate.

Six public laws specifically dealing with weather modification have been enacted since 1953, and others have included provisions which are in some way relevant to weather modification. Federal weather modification legislation has dealt primarily with three aspects—research program authorization and direction, collection and reporting of information on weather modification activities, and the commissioning of major policy studies. In addition to direction through authorizing legislation, the Congress initiated one major Federal research program through a write-in to an appropriations bill; this program regularly receives support through additional appropriations beyond recommended OMB funding levels.

There are two Federal laws currently in effect which are specifically concerned with weather modification. Public Law 92-205, of December 18, 1971, and its amendments requires the reporting of all non-Federal activities to the Secretary of Commerce and publication "from time to time" of summaries of such activities by the Secretary of Commerce.² The National Weather Modification Policy Act of 1976 (Public Law 94-490), enacted October 13, 1976, directed the Secretary of Commerce to conduct a major study on weather modification and to submit a report containing a recommended Federal policy and Federal research program on weather modification. The Secretary appointed a non-Government Weather Modification Advisory Board to conduct the mandated study, the report on which is to be submitted to the Secretary for her review and comment and subsequent transmittal to the President and the Congress during 1978. It is expected that, following receipt of the aforementioned report, the Congress will consider legislation on Federal weather modification policy, presumably during the 96th Congress.

Congressional interest in weather modification has also been manifested in a number of hearings on various bills, in oversight hearings on pertinent ongoing Federal agency programs, in consideration of some 22 resolutions having to do with weather modification, and in commissioning studies on the subject by congressional support agencies.

The principal involvement in weather modification of the Federal Government has been through the research and development programs of the several Federal departments and agencies. Although Federal research programs can be traced from at least the period of World War II, the programs of most agencies other than the Defense Department were not begun until the 1950's and 1960's. These research and development programs have been sponsored at various times by at least eight departments and independent agencies—including the Departments of Agriculture, Commerce, Defense, Energy, Interior, and Transportation, the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF). In fiscal year

² Although Federal agencies were excluded from the requirements of this act, upon mutual agreement, the agencies also submit information on their weather modification projects to the Secretary of Commerce, so that there is a single repository for information on all weather modification activities conducted within the United States.

1978 six agency programs were reported, those of Transportation and NASA having been phased out, while that of Agriculture was severely curtailed.

Total funding for Federal weather modification research in fiscal year 1978 is estimated at about \$17 million, a decline from the highest funding level of \$20 million reached in fiscal year 1976. The largest programs are those of the Departments of Interior and Commerce and of the NSF. The NSF has supported weather modification research over a broad spectrum for two decades, although its fiscal year 1978 funding was reduced by more than 50 percent, and it is not clear that more than the very basic atmospheric science supportive of weather modification will be sponsored hereafter by the Foundation.

The present structure of Federal organization for weather modification research activities is characterized essentially by the mission-oriented approach, whereby each of the agencies conducts its own program in accordance with broad agency goals or under specific directions from the Congress or the Executive. Programs have been loosely coordinated through various independent arrangements and/or advisory panels and particularly through the Interdepartmental Committee for Atmospheric Sciences (ICAS). The ICAS, established in 1959 by the former Federal Council for Science and Technology, provides advice on matters related to atmospheric science in general and has also been the principal coordinating mechanism for Federal research in weather modification.

In 1958 the National Science Foundation was designated lead agency for Federal weather modification research by Public Law 85-510, a role which it maintained until 1968, when Public Law 90-407 removed this responsibility from NSF. No further action was taken to name a lead agency, although there have been numerous recommendations to designate such a lead agency, and several bills introduced in the Congress would have named either the Department of the Interior or the Department of Commerce in that role. During the 10-year period from 1958 to 1968 the NSF promoted a vigorous research program through grants to various research organizations, established an Advisory Panel for Weather Modification, and published a series of 10 annual reports on weather modification activities in the United States. Since 1968 there has been a lapse in Federal weather modification policy and in the Federal structure for research programs, although, after a hiatus of over 3 years, the responsibility for collecting and disseminating information on weather modification activities was assigned to the Commerce Department in 1971. An important consideration of any future weather modification legislation will probably be the organizational structure of the Federal research program and that for administration of other related functions which may be the responsibility of the Federal Government. Options include a continuation of the present mission-oriented approach with coordination through the ICAS or a similar interagency body, redesignation of a lead agency with some autonomy remaining with the several agencies, or creation of a single agency with control of all funding and all research responsibilities. The latter could be an independent agency or part of a larger department; it would presumably also administer other aspects of Federal weather modification responsibilities, such as reporting of activities,

regulation and licensing, and monitoring and evaluation of operations, if any or all of these functions should become or continue to be services performed at the Federal level.

In addition to specific research programs sponsored by Federal agencies, there are other functions related to weather modification which are performed in several places in the executive branch. Various Federal advisory panels and committees and their staffs—established to conduct in-depth studies and prepare comprehensive reports, to provide advice and recommendations, or to coordinate Federal weather modification programs—have been housed and supported within executive departments, agencies, or offices. The program whereby Federal and non-Federal U.S. weather modification activities are reported to the Government is administered by the National Oceanic and Atmospheric Administration (NOAA) within the Commerce Department. The State Department negotiates agreements with other nations which might be affected by U.S. experiments and has arranged for Federal agencies and other U.S. investigators to participate in international meteorological projects, including those in weather modification. In the United Nations, the United States has been active in promoting the adoption of a treaty banning weather modification as a military weapon.

In accordance with the mandates of several public laws or self-initiated by the agencies or interagency committees, the executive branch of the Federal Government has undertaken a number of major weather modification policy studies over the past 25 years. Each of the completed major studies was followed by a report which included findings and recommendations. The most recent study is the one noted earlier that is being conducted by the Weather Modification Advisory Board on behalf of the Secretary of Commerce, pursuant to requirements of the National Weather Modification Policy Act of 1976. Nearly all previous studies emphasized the needs for designation of a lead agency, increased basic meteorological research, increased funding, improvement of support and cooperation from agencies, and consideration of legal, socioeconomic, environmental, and international aspects. Other recommendations have included improvement of program evaluation, study of inadvertent effects, increased regulation of activities, and a number of specific research projects. Although some of the recommended activities have been undertaken, many have not resulted in specific actions to date. Almost invariably it was pointed out in the studies that considerable progress would result from increased funding. Although funding for weather modification research has increased over the past 20 years, most funding recommendations have been for considerably higher levels than those provided. Since fiscal year 1976, the total Federal research funding for weather modification research has, in fact, decreased.

Most States in the Nation have some official interest in weather modification: 29 of them have some form of law which relates to such activities, usually concerned with various facets of regulation or control of operations within the State and sometimes pertaining to authorization for funding research and/or operations at the State or local level. A State's weather modification law usually reflects its general policy toward weather modification; some State laws tend to en-

courage development and use of the technology, while others discourage such activities.

The current legal regime regulating weather modification has been developed by the States rather than the Federal Government, except in the areas of research support, commissioning studies, and requiring reporting of activities. The various regulatory and management functions which the States perform include: (1) issuance, renewal, suspension, and revocation of licenses and permits; (2) monitoring and collecting of information on activities through requirements to maintain records, submission of periodic activity reports, and inspection of premises and equipment; (3) funding and managing of State or locally organized operational and/or research programs; (4) evaluation and advisory services to locally organized public and private operational programs within the State; and (5) miscellaneous administrative activities, including the organization and operation of State agencies and boards which are charged with carrying out statutory responsibilities. Administration of the regulatory and managerial responsibilities pertaining to weather modification within the States is accomplished through an assortment of institutional structures, including departments of water or natural resources, commissions, and special governing or advisory groups. Often there is a combination of two or more of these agencies or groups in a State, separating functions of pure administration from those of appeals, permitting, or advisory services.

Involvement in weather modification operational and research programs varies from State to State. Some support research only, while others fund and operate both research and operational programs. In some cases funding only is provided to localities, usually at the county level, where operational programs have been established. The recent 1976-77 drought led some Western States to initiate emergency cloud-seeding programs as one means of augmenting diminishing water supplies. Research conducted by atmospheric and other scientists at State universities or other research agencies may be supported in part with State funds but is often funded by one of the major Federal weather modification programs, such as that of the Bureau of Reclamation or the National Science Foundation. In a few cases, States contribute funds to a Federal research project which is conducted jointly with the States and partly within their borders.

In 1975, 1976, and 1977, respectively, there were 58, 61, and 88 non-federally supported weather modification projects, nearly all operational, conducted throughout the United States. These projects were sponsored by community associations, airlines, utilities, private interests, municipal districts, cities, and States. Eighty-five percent of all projects in the United States during 1975 were carried out west of Kansas City, with the largest number in California. In that State there were 11 projects in each of the years 1975 and 1976, and 20 projects during 1977. The majority of these operational projects were designed to increase precipitation; others were intended for suppression of hail or dispersal of fogs, the latter principally at airports.

In most instances, the principal beneficiaries of weather modification are the local or regional users, who include farmers and ranchers, weather-related industries, municipalities, airports, and utilities—

those individuals and groups whose economic well-being and whose lives and property are directly subject to adverse consequences of drought or other severe weather. It is at the local level where the need to engage in weather modification is most keenly perceived and also where possible negative effects from such activities are most apparent to some sectors of the population. It follows that both the greatest support and the strongest opposition to weather modification projects are focussed at the local level. The popularity of a particular project and the degree of controversy surrounding it are frequently determined by the extent to which local citizens and local organizations have had a voice in the control or funding of the project. At the local level, decisions to implement or to withdraw from a project can most often be made with minimum social stress. Indeed, studies have shown that most people are of the opinion that local residents or local government officials should make decisions on whether or not to use weather modification technology in a given situation.

Many of the operational weather modification services provided for private groups and governmental bodies within the States are carried out under contract by commercial firms who have developed expertise in a broad range of capabilities or who specialize in particular services essential to both operational or research projects. Contracts may cover only one season of the year, but a number of them are renewed annually, with target areas ranging from a few hundred to a few thousand square miles. In 1976, 6 of the 10 major companies having substantial numbers of contracts received about \$2.7 million for operations in the United States, and a few of these companies also had contracts overseas. Owing to increased demand for emergency programs during the recent drought, it is estimated that 1977 contracts totaled about \$3.5 million.

The initial role of the private weather modification operators was to sustain activities during the early years, when there was often heated scientific controversy with other meteorologists over the efficacy of cloud seeding. Later, their operations provided a valuable data base which permitted the early evaluation of seeding efforts and estimates of potential prospects for the technology, meanwhile growing in competence and public respect. Today, more often than not, they work hand in hand with researchers and, in fact, they often participate in research projects, contributing much of their knowhow acquired through their unique experiences.

Important among private institutions concerned with weather modification are the professional organizations of which research and operational weather modifiers and other interested meteorologists are members. These include the American Meteorological Society, the Weather Modification Association, and the Irrigation and Drainage Division of the American Society of Civil Engineers. Through the meetings and publications of these organizations the scientific, technical, and legal problems and findings on weather modification are aired and discussed. These groups also address other matters such as statements of weather modification policy, opinions on pending legislation, social implications, and professional standards and certification. In addition, the North American Interstate Weather Modification Council is an organization whose membership consists of govern-

ments of U.S. States and Canadian Provinces and the Government of Mexico, which serves as a forum for interstate coordination and exchange of information on weather modification.

Weather modification is often controversial, and both formal and informal opposition groups have been organized in various sections of the country. Reasons for such opposition are varied and are based on both real and perceived adverse consequences from weather modification. Sometimes with little or no rational basis there are charges by these groups that otherwise unexplained and usually unpleasant weather-related events are linked to cloud seeding. There are also cases where some farmers are economically disadvantaged through receiving more, or less than optimum rainfall for their particular crops, when artificial inducement of such conditions may have indeed been planned to benefit those growing different crops with different moisture requirements. Opposition groups are often formed to protect the legitimate rights of farmers under such circumstances.

While the United States is the apparent leader in weather modification research and operations, other countries have also been active. Information on foreign weather modification activities is not uniformly documented and is not always available. In an attempt to assemble uniform weather modification activities information of its member nations, the World Meteorological Organization (WMO) in 1975 instigated a system of reporting and of maintaining a register on such activities. Under this arrangement 25 nations reported weather modification projects during 1976, and 16 countries provided similar information in 1975. The largest weather modification effort outside the United States is in the Soviet Union, where there are both a continuing research program and an expanding operational program. The latter is primarily a program designed to reduce crop damage from hail, the largest such effort in the world, covering about 5 million hectares (15 million acres) in 1976. Other countries with weather modification programs of some note include Canada, Israel, Mexico, and the People's Republic of China. Projects in Rhodesia and the Republic of South Africa are not reported through the WMO register since these countries are not WMO member nations.

Recent years have seen increased international awareness of the potential benefits and possible risks of weather modification technology and increased international efforts to control such activities. The major efforts of the international community in this area are to encourage and maintain the high level of cooperation which currently exists in weather prediction and research and to insure that man's new abilities will be used for peaceful purposes. There has been exchange of ideas on weather modification through international conferences and through more informal exchanges of scientists and research documents. As with many scientific disciplines, however, the problems arising from use of and experiments with weather modification are not just scientific in nature, but are political problems as well.

In addition to the problems of potential damage to countries through commercial or experimental weather modification activities, another growing area of concern is that weather modification will be used for hostile purposes and that the future will bring weather warfare between nations. The United States has already been involved in one

such instance during the Vietnam war when attempts were made to impede traffic by increasing rainfall during the monsoon season. In the future, even the perception that weather modification techniques are available or in use could lead to an increase in international tensions. Natural drought in a region, or any other natural disaster will be suspect or blamed on an enemy.

In light of these problems the international community has made scattered attempts both to further the study of weather and its modification and to insure the peaceful use of this new technology. One such attempt was the development of the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, which was adopted by the General Assembly of the United Nations and opened for signature on May 18, 1977, at which time it was signed by the United States and 33 other nations (though it has not yet been submitted to the U.S. Senate for ratification). Another example of promotion of peaceful use of weather modification is the Precipitation Enhancement Program, sponsored by the WMO, whose aim is to plan, set up, and carry out an international, scientifically controlled precipitation experiment in a semiarid region of the world under conditions where the chances are optimal for increasing precipitation in sufficient amounts to produce economic benefits.

The United Nations Conference on the Human Environment, held in June 1972 in Stockholm, has been the pivotal point in much recent international environmental activity. It too has been an important catalyst in international activities relating to weather modification through portions of its "Declaration," its "Action Plan for the Human Environment," its "Earthwatch Program," and its "Study of Man's Impact on Climate."

Legal issues in weather modification are complex and unsettled. They can be considered in at least four broad categories: private rights in the clouds, liability for weather modification, interstate legal issues, and international legal issues. Since the body of law on weather modification is slight, existing case law offers few guidelines to determine these issues. Regarding the issue of private rights in the clouds, there is no general statutory determination of ownership of atmospheric water, so it is often necessary to use analogies to some general common law doctrines pertaining to water distribution, although each such doctrine has its own disadvantages when applied to weather modification. Some State laws reserve ownership or right to use atmospheric water to the State.

Issues of liability for damage may arise when drought, flooding, or other severe weather phenomena occur following attempts to modify the weather. Such issues include causation, nuisance, strict liability, trespass, negligence, and charges of pollution of the air and water through introduction of artificial nucleants. Statutes of 10 States discuss weather modification liability; however, there is much variation among the specific provisions of the laws in those States. Before a case can be made for liability based on causation, it must be proven that the adverse weather conditions were indeed induced by the weather modifier; but, in fact, no one has ever been able to establish causation of damages through such activities in view of the scientific uncertainties of weather modification.

Significant issues may arise when weather modification activities conducted in one State affect another State as well. There may be, for example, the claim that seeding in one State has removed from the clouds water that should have fallen in an adjacent State or that excessive flooding resulted from cloud seeding in a State upwind. Operation of cloud-seeding equipment near the border of one State may also violate local or State regulations or prohibitions of such operations in that State. There have been some attempts to resolve these and other issues through specific legislation in some States and through informal bilateral agreements. While no formal compacts currently exist, some compacts allocating waters in interstate streams may be applicable.

Because atmospheric processes operate independent of national borders, weather modification is inherently of international concern, and, international legal issues have similarities to domestic interstate activities and dangers. Whereas domestic weather modification law is confused and unsettled, international law in this area is barely in the formative stage. In time, ramifications of weather modification may lead to major international controversy.

Whereas the potential for long-term economic gains through weather modification cannot be denied, current economic analyses are tenuous in view of present uncertainty of the technology and the complex nature of attendant legal and economic problems. Economic evaluation of weather modification activities has therefore been limited to special, localized cases, such as the dispersal of cold fog at airports, where benefit-cost ratios greater than 5 to 1 have been realized through savings in delayed or diverted traffic. It has also been estimated, on the basis of a 15-percent increase in snowpack through seeding orographic clouds, that about 2 million additional acre-feet of water per year could be produced in the Colorado River Basin, at a cost of about \$1.50 per acre-foot.

Costs of most weather modification operations are generally small in relation to other costs in agriculture, for example, and are normally believed to be only a fraction of the benefits which could be achieved from successful operations. However, if all the benefits and all the costs are considered, benefit-cost ratios may be diminished. While direct costs and benefits from weather modification are reasonably apparent, indirect costs and benefits are elusive and require further study of sociological, legal, and ecological implications.

There are numerous cases of both real and perceived economic losses which one or more sectors of the public may suffer while another group is seeking economic advantage through some form of weather modification. Overall benefits from weather modification are accordingly reduced when net gains are determined from such instances of mixed economic advantages and disadvantages. In fact, when mechanisms are established for compensating those who have suffered losses resulting from weather modification, benefits to those groups seeking economic gain through such projects will probably be accordingly reduced.

Economically significant weather modification activities will have an eventual ecological effect, though appearance of that effect may be hidden or delayed by system resilience and/or confused by system

complexity. Prediction of ecological effects may never be possible with any precision; however, the greater the precision with which the weather modifier can predict results of his activities, the more precisely can the ecologist predict ecological effects. Such effects will rarely be sudden or catastrophic, but will result from moderate weather-related shifts in rates of reproduction, growth, and mortality of plants and animals. Adjustments of plant and animal communities will thus occur more slowly in regions of highly variable weather than in those with more uniform conditions which are slowly changing with some regularity over time. Deliberate weather modification, such as precipitation augmentation, is likely to have a greater ecological impact in semi-arid regions than in humid ones.

Widespread cloud seeding, using silver iodide, could result in estimated local, temporary increases in silver concentrations in precipitation approaching those in natural waters, but exchange rates would be an order of magnitude lower than the natural exchange rates. Exchange rates will likely be many orders of magnitude less than those rates at which plants and soils are adversely affected.

Conclusions

1. Weather modification is an emerging technology; there is a wide spectrum of capabilities to modify various weather phenomena, ranging from the operational readiness of cold fog dispersal to little progress beyond initial research in the case of modifying severe storms such as hurricanes.

2. Along with cold fog dispersal, the only other weather modification capability showing near readiness for application is the augmentation of winter snowpack through seeding mountain cloud systems. A probable increase of about 15 percent is indicated by a number of experiments and longrunning operational seeding projects in the western United States.

3. Most scientists and weather modification operators agree that there is continued need for a wide range of research and development activity both to refine weather modification techniques where there has been some success and to advance capabilities in modifying other weather phenomena where there has been much less or little progress.

4. Current Federal policy for weather modification research and development follows the mission-oriented approach, where each agency charged with responsibility for dealing with a particular national problem is given latitude to seek the best approach or solution to the problem; this approach or solution may involve weather modification.

5. The structure of Federal organization for weather modification reflects the mission-oriented approach which is characteristic of the current Federal policy, the programs loosely coordinated through advisory groups and the Interdepartmental Committee for Atmospheric Sciences.

6. The interest of the Congress in weather modification has been shown by the introduction of 110 bills related to the subject since 1947—6 of which have become public law—and the consideration of 22 resolutions on weather modification, one of which was passed by the Senate.

7. A number of major weather modification policy studies have been directed by public law or initiated within the executive branch over

the past 25 years; most of these studies recommended designation of a lead agency, increased basic meteorological research, increased funding, improvement of support and cooperation from agencies, and consideration of legal, socioeconomic, environmental, and international aspects. Although some recommended actions have been undertaken, others have not seen specific action to date.

8. While major policy studies have recommended increased funding for Federal weather modification, research and development and funding has generally increased over the past 20 years, recommended levels have been consistently higher than those provided, and funding has actually decreased since fiscal year 1976.

9. With enactment of the National Weather Modification Policy Act of 1976 and completion of the major policy study mandated by that act, there is a fresh opportunity for the Congress to assess the potential usefulness and problems in application of weather modification technology and to establish a new Federal policy for weather modification research and operations.

10. The principal role in regulating weather modification and in supporting operational programs has been taken by the States, while the role of the Federal Government has been support of research and development programs.

11. The majority of the States (29) have some form of law which relates to weather modification, and the general policy of a State toward weather modification is usually reflected in the weather modification law of that State; laws of some States tend to encourage development and use of the technology, while others discourage such activities.

12. The majority of operational weather modification projects in the United States (58 of a total of 72, or 80 percent in calendar year 1975) are conducted west of Kansas City, and the largest number of projects has been in California (20 during 1977); most operational projects are intended to increase precipitation, while others are designed to suppress hail or disperse fog.

13. Both the greatest support and the strongest opposition to weather modification projects are focused at the local level, where the economic and personal interests of local organizations and individuals are most directly affected; it follows that there is also the least social stress when decisions to apply or withhold weather modification are made at the local level.

14. Commercial weather modification operators have sustained activities since the early days, after which some operations fell into disrepute, providing a valuable data base for evaluation of long-term projects and developing expertise over a broad range of capabilities: most have incorporated improvements into their technology as they have benefited from accumulated experience and from research results.

15. While the United States is the apparent leader in overall research and operational weather modification activities, there have been approximately 20 foreign countries in which activities are conducted annually (25 countries reported such projects for 1976 through the register of the World Meteorological Organization): the largest foreign program is that of the Soviet Union, whose operational hail suppression program covered about 15 million acres in 1976, the largest such effort in the world.

16. The international community has attempted to further the study of weather modification and insure its peaceful use through the recent development of a Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Techniques (adopted by the U.N. General Assembly and opened for signature in May 1977) and through sponsorship by the World Meteorological Organization of an international precipitation enhancement program.

17. Legal issues in weather modification are complex and unsettled; they include resolution of problems of ownership of atmospheric water, issues of liability, conflicting statutes and regulations of respective State laws, and the need to develop a regime of relevant international law.

18. Although the long-term potential for economic gains through weather modification cannot be denied, attempts to quantify benefits and costs from such activities will in most cases be difficult to undertake on a practical basis until the technology is more highly developed and control systems are perfected to permit reliable predictions of outcomes.

19. Economically significant weather modification will always have an eventual ecological effect, though appearance of the effect may be delayed or hidden by system resilience and/or confounded by system complexity; the more precisely the weather modifier can specify effects he will produce, the more precise can be the ecologist's prediction of likely ecological effects.

20. Modification processes may also be initiated or triggered inadvertently rather than purposefully; man is already causing measurable variations unintentionally on the local scale, and artificial climate effects have been observed on local and regional scales. Although not verifiable at present, the time may not be remote when human activities will result in measurable large-scale changes in weather and climate of more than passing significance.

CHAPTER 1

INTRODUCTION AND SUMMARY OF ISSUES

(By Robert E. Morrison, Specialist in Earth Sciences, Science Policy Research Division, Congressional Research Service)

PERSPECTIVE

"It is entirely possible, were he wise enough, that man could produce favorable effects, perhaps of enormous practical significance, transforming his environment to render it more salutary for his purposes. This is certainly a matter which should be studied assiduously and explored vigorously. The first steps are clear. In order to control meteorological matters at all we need to understand them better than we now do. When we understand fully we can at least predict weather with assurance for reasonable intervals in the future.

"With modern analytical devices, with a team of sound background and high skills, it is possible today to do a piece of work in this field which will render immediate benefits, and carry us far toward a more thorough understanding of ultimate possibilities. By all means let us get at it."

—Vannevar Bush¹

SITUATION

Two decades after completion of a major study and report on weather modification by the Advisory Committee on Weather Control and after the assertions quoted above, many would agree that some of the more fundamental questions about understanding and using weather modification remain unsolved. There is a great difference of opinion, however, on the state of technology in this field. According to Grant, "Some believe that weather modification is now ready for widespread application. In strong contrast, others hold that application of the technology may never be possible or practical on any substantial scale."² It has been demonstrated that at least some atmospheric phenomena can be modified with some degree of predictable success, as a consequence of seeding supercooled clouds with artificial ice nuclei, and there is some promise that the present technology will be expanded to include a greater scope of weather modification capabilities. Nevertheless, a systematic approach and reasonable progress in development of weather modification technology have been impeded by a number of problems.

Changnon asserts that a continuing and overriding problem restricting progress has been the attempt to apply an ill-defined technology to increase rain or suppress hail without an adequate scientific under-

¹ From statement of Dec. 2, 1957, quoted in final report of the Advisory Committee on Weather Control, Washington, D.C., U.S. Government Printing Office, 1958, vol. I, p. 1.

² Grant, Lewis O., "Scientific and Other Uncertainties of Weather Modification." In William A. Thomas (editor), Legal and Scientific Uncertainties of Weather Modification, Proceedings of a symposium convened at Duke University, Mar 11-12, 1976, by the National Conference of Lawyers and Scientists, Durham, N.C., Duke University Press, 1977, p. 7.

standing and predictable outcome.³ Experimentation has been poorly conducted, intermittent, or too short; and "results have not been integrated with those of other projects so as to develop a continuing thread of improving knowledge."⁴

In response to the query as to why progress in weather modification has been so slow, Fleagle identifies three broad, general impediments. "First, the physical processes associated with clouds have turned out to be especially complex and difficult * * *. A second possibility may be that the atmosphere is inherently stable, so that within broad limits, no matter what we do to increase precipitation, the results are likely to be small and roughly the same * * *. A third reason * * * is that progress has been hamstrung by fragmentation of resources, by submarginal funding, ineffective planning and coordination, and a general lack of administrative toughness and fiscal stability."⁵

Droessler points out the need to "formulate a comprehensive national weather modification policy which has the broad support of the scientific community, the general public, private industry, and the Government," contending that "the greatest deterrent in getting on with the task of preparing a satisfactory national policy is the lack of a consensus about the national goals for weather modification."⁶

Although operational readiness varies from one form of weather modification to another, as a result of the degree of understanding and the complexity of decisionmaking in given situations, the prospects for successful weather modification are sufficiently promising that attempts to develop effective applications will continue. This was one of the major areas of consensus at a recent symposium on the uncertainties of weather modification:

There will be increased attempts to modify weather, both because people tend to do what is technically possible and because the anticipated benefits of precipitation augmentation, hail or lightning suppression, hurricane diversion, and other activities often exceed the associated costs.⁷

With the inevitable increases in weather modification capabilities and the increasing application of these capabilities, the development of a technology that is socially useful must be insured through a careful analysis of attendant benefits and disbenefits. According to Fleagle, et al., deliberate efforts to modify the weather have thus far had only marginal societal impacts: however, as future activities expand, "they will probably be accompanied by secondary effects which in many instances cannot be anticipated in detail * * *." Consequently, "rational policy decisions are urgently needed to insure that activities are directed toward socially useful goals."⁸

The lack of a capability to deal with impending societal problems

³ Changnon, Stanley A., Jr., "The Federal Role in Weather Modification," background paper prepared for use by the U.S. Department of Commerce Weather Modification Advisory Board, Mar. 9, 1977, p. 5.

⁴ *Ibid.*, pp. 5-6.

⁵ Fleagle, Robert G., "An Analysis of Federal Policies in Weather Modification," background paper prepared for use by the U.S. Department of Commerce Weather Modification Advisory Board, Mar. 1977, pp. 17-18.

⁶ Droessler, Earl G., "Weather Modification" (Federal Policies, Funding From All Sources, Interagency Coordination), background paper prepared for use of the U.S. Department of Commerce Weather Modification Advisory Board, Mar. 1, 1977, p. 10.

⁷ Thomas, William A. (editor), "Legal and Scientific Uncertainties of Weather Modification," proceedings of a symposium convened at Duke University, Mar. 11-12, 1976, by the National Conference of Lawyers and Scientists, Durham, N.C., Duke University Press, 1977, p. vi.

⁸ Fleagle, Robert G., James A. Crutchefield, Ralph W. Johnson, and Mohamed F. Abdo, "Weather Modification in the Public Interest," Seattle, American Meteorological Society and the University of Washington Press, 1973, p. 3, 31-32.

and emerging management issues in weather modification has been aphoristically summed up in the following statement by Crutchfield:

Weather modification is in the throes of a serious schizoid process. The slow and sober business of piecing together the scientific knowledge of weather processes, developing the capacity to model the complex systems involved, and assessing systematically the results of modification efforts has led to responsible optimism about the future of these new technologies. On the other hand, the "social technology" of evaluation, choice, and execution has lagged badly. The present decisionmaking apparatus appears woefully inadequate to the extraordinarily difficult task of fitting weather modification into man's pattern of life in optimal fashion. There are too many game plans, too many coaches, and a disconcerting proclivity for running hard before deciding which goal line to aim for—or, indeed, which field to play on.

Mounting evidence indicates that weather modification of several types is, or may soon become technically feasible. That some groups will derive economic or other social benefits from such technology is a spur to action. But a whole thunderhead of critical questions looms on the horizon waiting to be resolved before any valid decisions can be made about the scale, composition, location, and management of possible operations.⁹

ADVANTAGES

In a study for the Interdepartmental Committee for Atmospheric Sciences, Homer E. Newell highlighted the potential benefits of intentional weather modification:

The Earth's weather has a profound influence on agriculture, forestry, water resources, industry, commerce, transportation, construction, field operations, commercial fishing, and many other human activities. Adverse effects of weather on man's activities and the Earth's resources are extremely costly, amounting to billions of dollars per year, sometimes causing irreparable damage as when human lives are lost in severe storms. There is, therefore, great motivation to develop effective countermeasures against the destructive effects of weather, and, conversely, to enhance the beneficial aspects. The financial and other benefits to human welfare of being able to modify weather to augment water supplies, reduce lightning, suppress hail, mitigate tornadoes, and inhibit the full development of hurricanes would be very great.¹⁰

More recently, Louis J. Battan gave the following two reasons, with graphic examples, for wanting to change the weather:

First, violent weather kills a great many people and does enormous property damage. A single hurricane that struck East Pakistan in November 1970 killed more than 250,000 people in a single day. Hurricane Camille hit the United States in 1969 and did approximately \$1.5 billion worth of damage. An outbreak of tornadoes in the Chicago area on Palm Sunday of 1965 killed about 250 people, and the tornadoes of April 1974 did likewise. Storms kill people and damage property, and it is reasonable to ask whether it is necessary for us to accept this type of geophysical destruction. I say, "No, it is not—it should be possible to do something."

Second, weather modification involves, and in some respects might control, the production of those elements we need to survive. Water and food are currently in short supply in many areas, and these shortages almost certainly will be more severe in the future. We can develop new strains of wheat and rye and corn and soybeans and rice, but all is for naught if the weather fails to cooperate. If the monsoons do not deliver on schedule in India, residents of that country starve in large numbers. And if the drought that people have been predicting for the last several years does spread over the Great Plains, there will be starvation around the world on a scale never before experienced.

Weather is the one uncontrollable factor in the whole business of agriculture. Hail, strong winds, and floods are the scourges of agriculture, and we should not have to continue to remain helpless in the face of them. It may be impossible

⁹ Crutchfield, James A., "Social Choice and Weather Modification: Concepts and Measurement of Impact." In W. R. Derrick Sewell (editor), *Modifying the Weather: A Social Assessment*, Victoria, British Columbia, University of Victoria, 1973, p. 187.

¹⁰ Newell, Homer E., "A Recommended National Program in Weather Modification." Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS report No. 10a, Washington, D.C., November 1966, p. 1.

for us to develop the kind of technology we would like to have for modification of weather, but to assume failure in such an important endeavor is a course not to be followed by wise men.¹¹

Specific statistics on annual losses of life and economic losses from property damages resulting from weather-related disasters in the United States are shown in table 1, which was developed in a recent study by the Domestic Council.¹² In the table, for comparison, are the fiscal year 1975 expenditures by the Federal Government in weather modification research, according to the several categories of weather phenomena to be modified. Although it is clear that weather disasters can be mitigated only partially through weather modification, even if the technology were fully developed, the potential value, economic and otherwise, should be obvious. The following quotation from a Federal report written over a decade ago summarizes the full potential of benefits to mankind which might be realized through use of this technology:

With advances in his civilization, man has learned how to increase the fruit of the natural environment to insure a livelihood. * * * it is fortunate that growing knowledge of the natural world has given him an increasing awareness of the changes that are occurring in his environment and also hopefully some means for deliberate modification of these trends. An appraisal of the prospects for deliberate weather and climate modification can be directed toward the ultimate goal of bringing use of the environment into closer harmony with its capacities and with the purposes of man—whether this be for food production, relief from floods, assuring the continuance of biologic species, stopping pollution, or for purely esthetic reasons.¹³

TABLE 1.—ANNUAL PROPERTY DAMAGE AND LOSS OF LIFE FROM WEATHER-RELATED DISASTERS AND HAZARDS IN THE UNITED STATES AND FISCAL YEAR 1975 FEDERAL WEATHER MODIFICATION RESEARCH FUNDING (FROM DOMESTIC COUNCIL REPORT, 1975)

Weather hazard	Loss of life ¹	Property damage ¹ (billions)	Modification research (millions)
Hurricanes.....	2 30	2 \$0.8	3 \$0.8
Tornadoes.....	2 140	2.4	4 1.0
Hail.....	.....	5.8	3.9
Lightning.....	6 110	.1	.4
Fog.....	7 1,000	7.5	1.3
Floods.....	8 240	8 2.3	.....
Frost (agriculture).....	.....	7 1.1	.....
Drought.....	.....	7.7	9 3.4
Total.....	1,520	6.7	10.8

¹ Sources: "Assessment of Research on Natural Hazards," Gilbert F. White and J. Eugene Haas, the MIT Press, Cambridge, Mass., 1975, pp 68, 286, 305, 374; "The Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 1976," U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), Washington, D.C., April 1975, p 9; "Weatherwise," February 1971, 1972, 1973, 1974, 1975, American Meteorological Society, Boston, Mass.; "Summary Report on Weather Modification, Fiscal Years 1969, 1970, 1971," U.S. Department of Commerce, NOAA, Washington, D.C., May 1973, pp 72, 81; "Estimating Crop Losses Due to Hail—Working Data for County Estimates," U.S. Department of Agriculture, Economic Research Service, September 1974; "Natural Disasters: Some Empirical and Economic Considerations," G. Thomas Sav, National Bureau of Standards, Washington, D.C., February 1974, p 19; Traffic Safety magazine, National Safety Council, February 1974.

² 1970-74 average.

³ These funds do not include capital investment in research aircraft and instrumentation primarily for hurricane modification, which in fiscal year 1975 amounted to \$9,200,000.

⁴ These funds support theoretical research on modification of extratropical cloud systems and their attendant severe storms such as thunderstorms and tornadoes.

⁵ 1973.

⁶ 1950-72 average.

⁷ Average.

⁸ 1965-69 average.

⁹ These funds support precipitation augmentation research, much of which may not have direct application to drought alleviation.

¹¹ Battan, Louis J., "The Scientific Uncertainties: a Scientist Responds." In William A. Thomas (editor), "Legal and Scientific Uncertainties of Weather Modification," proceedings of a symposium convened at Duke University, Mar. 11-12, 1976, by the National Conference of Lawyers and Scientists, Durham, N.C., Duke University Press, 1977, p. 26.

¹² U.S. Domestic Council, Environmental Resources Committee, Subcommittee on Climate Change, "The Federal Role in Weather Modification," December 1975, p. 2.

¹³ Special Commission on Weather Modification, "Weather and Climate Modification," National Science Foundation, NSF 66-3, Washington, D.C., Dec. 20, 1965, p. 7.

TIMELINESS

The modern period in weather modification is about three decades old, dating from events in 1946, when Schaefer and Langmuir demonstrated that a cloud of supercooled water droplets could be transformed into ice crystals when seeded with dry ice. Activities and interests among scientists, the commercial cloud seeders, and Government sponsors and policymakers have exhibited a nearly 10-year cyclic behavior over the ensuing years. Each of the three decades since the late 1940's has seen an initial burst of enthusiasm and activity in weather modification experiments and/or operations; a midcourse period of controversy, reservations, and retrenchment; and a final period of capability assessment and policy examination, with the issuance of major Federal reports with comprehensive recommendations on a future course.

The first such period ended with the publication of the final report of the Advisory Committee on Weather Control in 1957.¹⁴ In 1959, Dr. Robert Brode, then Associate Director of the National Science Foundation, summarized the significance of that study in a 1959 congressional hearing:

For 4 years the Advisory Committee studied and evaluated public and private cloud-seeding experiments and encouraged programs aimed at developing both physical and statistical evaluation methods. The final report of the committee * * * for the first time placed before the American public a body of available facts and a variety of views on the status of the science of cloud physics and the techniques and practices of cloud seeding and weather modification.¹⁵

The year 1966 was replete with Government weather modification studies, major ones conducted by the National Academy of Sciences, the Special Commission on Weather Modification of the National Science Foundation, the Interdepartmental Committee for Atmospheric Sciences, and the Legislative Reference Service of the Library of Congress. During that year, or thereabouts, planning reports were also produced by most of the Federal agencies with major weather modification programs. The significance of that year of reevaluation and the timeliness for congressional policy action were expressed by Hartman in his report to the Congress:

It is especially important that a comprehensive review of weather modification be undertaken by the Congress at this time, for a combination of circumstances prevails that may not be duplicated for many years. For the first time since 1957 there now exists, in two reports prepared concurrently by the National Academy of Sciences and a Special Commission on Weather Modification, created by the National Science Foundation, a definitive appraisal of the entire scope of this subject, the broad sweep of unsolved problems that are included, and critical areas of public policy that require attention. There are currently before the Congress several bills which address, for the first time since enactment of Public Law 85-510, the question of the formal assignment of Federal authority to undertake weather modification programs. And there is increasing demand throughout the country for the benefits that weather modification may bring.¹⁶

¹⁴ Establishment of the Advisory Committee on Weather Control by the Congress and its activities are discussed in following chapters on the history of weather modification and on Federal activities, chs. 2 and 5, respectively. Recommendations of the final report are summarized in ch. 6. Other reports mentioned in the following paragraphs in this section are also discussed and referenced in chs. 5 and 6.

¹⁵ U.S. Congress, House of Representatives, Committee on Science and Astronautics, "Weather Modification," Hearing, 86th Cong., 1st sess., Feb. 16, 1959, Washington, D.C., U.S. Government Printing Office, 1959, p. 3.

¹⁶ Hartman, Lawton M., "Weather Modification and Control," Library of Congress, Legislative Reference Service, Apr. 27, 1966. Issued as a committee print by the Senate Committee on Commerce, 89th Cong., 2d sess., Senate Rept. No. 1139, Washington, D.C., U.S. Government Printing Office, 1966, p. 1.

Toward the close of the third decade, a number of policy studies and reports appeared, starting in 1973 with a second major study by the National Academy of Sciences, and including others by the U.S. General Accounting Office and by the U.S. Domestic Council. The major study of this period was commissioned by the Congress when it enacted Public Law 94-490, the National Weather Modification Policy Act of 1976, in October of 1976. By that law the Secretary of Commerce was directed to conduct a study and to recommend the Federal policy and a Federal research program in weather modification. That study was conducted on behalf of the Secretary of Commerce by a Weather Modification Advisory Board, appointed by the Secretary, and the required report will be transmitted to the Congress during 1978. The importance of that act and its mandated study was assessed by Dr. Robert M. White, former Administrator of the National Oceanic and Atmospheric Administration (NOAA), the Commerce Department agency with administrative responsibilities and research programs in weather modification:

The National Weather Modification Policy Act of 1976 * * * will influence NOAA to some degree during the next year, and its effect may have a large impact on the agency and the Nation in future years. The comprehensive study of and report on weather modification that will result from our implementation of this act will provide guidance and recommendations to the President and the Congress in the areas of policy, research, and utilization of this technology. We look to this study and report as an opportunity to help set the future course of a controversial science and technology with enormous potential for benefit to the Nation.¹⁷

Thus, conditions once more are ripe and the stage has been set, as in 1957 and again in 1966, for the Congress to act in establishing a definitive Federal weather modification policy, one appropriate at least for the next decade and perhaps even longer. Among other considerations, such a policy would define the total role of the Federal Government, including its management structure, its responsibilities for research and development and for support operations, its authorities for regulation and licensing, its obligation to develop international cooperation in research and peaceful applications, and its function in the general promotion of purposeful weather modification as an economically viable and socially accepted technology. On the other hand, other factors, such as constraints arising from public concern over spending, may inhibit the development of such policy.

While some would argue that there exists no Federal policy, at least one White House official, in response to a letter to the President, made a statement of weather modification policy in 1975:

A considerable amount of careful thought and study has been devoted to the subject of weather modification and what the Federal role and, in particular, the role of various agencies should be in this area. As a result of this study, we have developed a general strategy for addressing weather modification efforts which we believe provides for an appropriate level of coordination.

We believe that the agency which is charged with the responsibility for dealing with a particular national problem should be given the latitude to seek the best approach or solution to the problem. In some instances this may involve a form of weather modification, while in other instances other approaches may be more appropriate.

While we would certainly agree that some level of coordination of weather modification research efforts is logical, we do not believe that a program under

¹⁷ U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, "Briefing on the National Oceanic and Atmospheric Administration," Hearings, 95th Cong., 1st sess., May 17, 18, 1977. Washington, U.S. Government Printing Office, 1977, p. 4-5.

the direction of any one single agency's leadership is either necessary or desirable. We have found from our study that the types of scientific research conducted by agencies are substantially different in approach, techniques, and type of equipment employed, depending on the particular weather phenomena being addressed. Each type of weather modification requires a different form of program management and there are few common threads which run along all programs.¹⁸

Presumably, there will be a resurgence of congressional interest in weather modification policy during the first session of the 96th Congress, when the aforementioned report from the Secretary of Commerce has been reviewed and considered. In view of the recommendations in numerous recent studies and the opinions of the Weather Modification Advisory Board (the group of experts preparing the report for the Secretary of Commerce), it seems unlikely that any action by the Congress would perpetuate the policy expounded in the White House letter quoted above.

It is expected that this present report, intended as an overall review of the subject of weather modification, will be valuable and timely during the anticipated congressional deliberations.

DEFINITIONS AND SCOPE OF REPORT

In the broadest sense, weather modification refers to changes in weather phenomena brought on purposefully or accidentally through human activity. Weather effects stimulated unintentionally—such as urban influences on rainfall or fogs produced by industrial complexes—constitute what is usually termed inadvertent weather modification. On the other hand, alterations to the weather which are induced consciously or intentionally are called planned or advertent weather modification. Such activities are intended to influence single weather events and to occur over relatively short time spans, ranging from a few hours in the case of clearing airport fog or seeding a thunderstorm to perhaps a few days when attempts are made to reduce the severity of hurricane winds. Weather modification experiments or operations can be initiated or stopped rather promptly, and changes resulting from such activities are transient and generally reversible within a matter of hours.

Climate modification, by contrast, encompasses changes of long-time climatic variables, usually affecting larger areas and with some degree of permanence, at least in the short term. Climatic changes are also brought about by human intervention, and they might result from either unintentional or planned activities. There are numerous examples of possible inadvertent climate modification; however, attempts to alter climate purposefully are only speculative. The concepts of inadvertent weather and climate modification are defined more extensively and discussed fully in chapter 4 of this report.

The primary emphasis of this report is on intentional or planned modification of weather events in the short term for the general benefit of people, usually in a restricted locality and for a specific time. Such benefit may accrue through increased agricultural productiv-

¹⁸ Ross, Norman E., Jr., letter of June 5, 1975, to Congressman Gilbert Gude. This letter was the official White House response to a letter of April 25, 1975, from Congressmen Gude and Donald M. Fraser and Senator Claiborne Pell, addressed to the President, urging that a coordinated Federal program be initiated in the peaceful uses of weather modification. The letter to the President, the reply from Mr. Ross, and comments by Congressman Gude appeared in the Congressional Record for June 17, 1975, pp. 19201-19203. (This statement from the Congressional Record appears in app. A.)

ity or other advantages accompanying augmentation of precipitation or they may result from mitigation of effects of severe weather with attendant decreases in losses of life or property. There are broader implications as well, such as the general improvement of weather for the betterment of man's physical environment for aesthetic and cultural reasons as well as economic ones. The following recent definition sums up succinctly all of these purposes:

Weather modification is the deliberate and mindful effort by men and women to enhance the atmospheric environment, to aim the weather at human purposes.¹⁹

The specific kinds of planned weather modification usually considered, and those which are discussed, in turn, in some detail in chapter 3, are the following:

- Precipitation enhancement.
- Hail suppression.
- Fog dissipation.
- Lightning suppression.
- Mitigation of effects of severe storms.

Planned weather modification is usually considered in the context of its net benefits to society at large. Nevertheless, it should be recognized that, in particular instances, benefits to some segment of the population may be accompanied by unintended injuries and costs, which may be real or perceived, to other segments. There is yet another aspect of advertent weather modification, which has engendered much controversy, both in the United States and internationally, not designed for the benefit of those directly affected—the use of weather modification for hostile purposes such as a weapon of war. This aspect is not a major consideration in this report, although there is some discussion in chapters 5 and 10 of congressional concern about such use of the technology, and in chapter 10 there is also a review of recent efforts by the United Nations to develop a treaty barring hostile use of weather modification.²⁰

Following this introductory chapter, with its summary of issues, the second chapter sets the historical perspective for weather modification, concentrating primarily on activities in the United States to about the year 1970. The third chapter attempts to review the scientific background, the status of technology, and selected technical problems areas in planned weather modification; while chapter 4 contains a discussion of weather and climate changes induced inadvertently by man's activities or by natural phenomena.

The weather modification activities of the Federal Government—those of the Congress and the administrative and program activities of the executive branch agencies—are encompassed in chapter 5; and the findings and recommendations of major policy studies, conducted by or on behalf of the Federal Government, are summarized in chapter 6. The seventh, eighth, and ninth chapters are concerned with weather modification activities at the level of State and local governments, by private organizations, and in foreign countries, respectively.

¹⁹ Weather Modification Advisory Board, "A U.S. Policy to Enhance the Atmospheric Environment," Oct. 21, 1977. A discussion paper, included with testimony of Harlan Cleveland, Chairman of the Advisory Board, in a congressional hearing: U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, Weather Modification, 95th Cong., 1st sess., Oct. 26, 1977, Washington, D.C., U.S. Government Printing Office, 1977, p. 25.

²⁰ Copies of the current official position of the U.S. Department of Defense on weather modification and of the draft U.N. convention prohibiting hostile use of environmental modification, respectively, are found in apps. B and C.

The increasingly important international problems related to weather modification are addressed in chapter 10, while both domestic and international legal aspects are discussed in chapter 11. Chapters 12 and 13, respectively, contain discussions on economic and ecological aspects of this emerging technology.

The 20 appendixes to the report provide materials that are both supplementary to textual discussions in the 13 chapters and intended to be valuable sources of reference data. In particular, attention is called to appendix D, which contains excerpts dealing with weather modification from the statutes of the 29 States in which such activities are in some way addressed by State law, and to appendix E, which provides the names and affiliations of individuals within the 50 States who are cognizant of weather modification activities and interests within the respective States. The reader is referred to the table of contents for the subjects of the remaining appendixes.

SUMMARY OF ISSUES IN PLANNED WEATHER MODIFICATION

"The issues we now face in weather modification have roots in the science and technology of the subject, but no less importantly in the politics of Government agencies and congressional committees and in public attitudes which grow out of a variety of historical, economic, and sociological factors."²¹ In this section there will be an identification of critical issues which have limited development of weather modification and which influence the ability to direct weather modification in a socially responsible manner. The categories of issues do not necessarily correspond with the subjects of succeeding chapters dealing with various aspects of weather modification; rather, they are organized to focus on those specific areas of the subject where there has been and there are likely to be problems and controversies which impede the development and application of this technology.

The following sections examine technological, governmental, legal, economic, social, international, and ecological issues. Since the primary concern of this report is with the intentional, planned use of weather modification for beneficial purposes, the issues summarized are those involved with the development and use of this advertent technology. Issues and recommendations for further research in the area of inadvertent weather modification are included in chapter 4, in which that general subject is fully discussed.

TECHNOLOGICAL PROBLEMS AND ISSUES

In a recent discussion paper, the Weather Modification Advisory Board summarized the state of weather modification by concluding that "no one knows how to modify the weather very well, or on a very large scale, or in many atmospheric conditions at all. The first requirement of a national policy is to learn more about the atmosphere itself."²² Representative of the state of weather modification science

²¹ Fleagle, Crutchfield, Johnson, and Abdo, "Weather Modification in the Public Interest," 1973, p. 13.

²² Weather Modification Advisory Board. "A U.S. Policy To Enhance the Atmospheric Environment." Oct. 21, 1977. This discussion paper was included with the testimony of Mr. Harlan Cleveland, Chairman of the Advisory Board, in a recent congressional hearing: U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere. "Weather Modification." 95th Cong., 1st sess. Oct. 26, 1977, Washington, D.C., U.S. Govt. Print. Off., 1977, p. 25.

and technology is the following commentary on the state of understanding in the case of precipitation enhancement, or rainmaking as it is popularly called:

Today, despite the fact that modern techniques aimed at artificial stimulation of rain rest upon sound physical principles, progress is still fairly slow. The application of these principles is complicated by the overwhelming complexity of atmospheric phenomena. It is the same dilemma that meteorologists face when they attempt to predict weather. In both cases, predicting the evolution of atmospheric processes is limited by insufficient knowledge of the effects produced by the fairly well-known interactive mechanisms governing atmospheric phenomena. Moreover, the temporal and spatial variability of atmospheric phenomena presents an additional difficulty. Since any effects that are produced by artificial intervention are always imposed upon already active natural processes, assessment of the consequences becomes even more difficult.²³

Grant recognizes the current progress and the magnitude of remaining problems when he says that:

Important and steady advances have been made in developing technology for applied weather modification, but complexity of the problems and lack of adequate research resources and commitment retard progress. Advances have been made in training the needed specialists, in describing the natural and treated cloud systems, and in developing methodology and tools for the necessary research. Nevertheless, further efforts are required.²⁴

Though it can be argued that progress in the development of weather modification has been retarded by lack of commitment, ineffective planning, and inadequate funding, there are specific scientific and technical problems and issues needing resolution which can be identified beyond these management problems and the basic scientific problem quoted above with respect to working with the atmosphere. Particular technical problems and issues at various levels which continue to affect both research and operational activities are listed below:

1. There is substantial diversity of opinion, even among informed scientists, on the present state of technology for specific types of weather modification and their readiness for application and with regard to weather modification in general.²⁵

2. There are many who view weather modification only as a drought-relief measure, expecting water deficits to be quickly replenished through its emergency use; however, during such periods weather modification is limited by less frequent opportunities; it should, instead, be developed and promoted for its year-round use along with other water management tools.²⁶

3. The design and analysis of weather modification experiments is intimately related to the meteorological prediction problem, which needs further research, since the evaluation of any attempt to modify the atmosphere depends on a comparison between some weather parameter and an estimate of what would have happened naturally.

4. Many of the problems which restrict understanding and prediction of weather modification phenomena stem from imprecise knowledge of fundamental cloud processes; the level of research in funda-

²³ Dennis, Arnett S., and A. Gegin. "Recommendations for Future Research in Weather Modification." U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Boulder, Colo., November 1977, p. 12.

²⁴ Grant. "Scientific and Other Uncertainties of Weather Modification," 1977, p. 17.

²⁵ See table 2, ch. 3, p. 59.

²⁶ Silverman, Bernard A., "What Do We Need in Weather Modification?" In preprints of the Sixth Conference on Planned and Inadvertent Weather Modification, Oct. 10-13, 1977, Champaign, Ill., Boston, American Meteorological Society, 1977, p. 308.

mental cloud physics and cloud modeling has not kept pace with weather modification activity.²⁷

5. Progress in the area of weather modification evaluation methodology has been slow, owing to the complexity of verification problems and to inadequate understanding of cloud physics and dynamics.

6. Most operational weather modification projects, usually for the sake of economy or in the anticipation of achieving results faster and in greater abundance, fail to include a satisfactory means for project evaluation.

7. There are difficulties inherent in the design and evaluation of any experiment or operation which is established to test the efficacy of any weather modification technique, and such design requires the inclusion of proper statistical methods.

8. In view of the highly varying background of natural weather phenomena, statistical evaluation of seeding requires a sufficiently long experimental period; many research projects just barely fail to achieve significance and credibility because of early termination; thus, there is a need for longer commitment for such projects, perhaps 5 to 10 years, to insure that meaningful results can be obtained.²⁸

9. There is a need to develop an ability to predict possible adverse weather effects which might accompany modification of specific weather phenomena; for example, the extent to which hail suppression or diminishing hurricane winds might also reduce beneficial precipitation, or the possibility of increasing hailfall or incidence of lightning from efforts to stimulate rainfall from cumulus clouds.²⁹

10. The translation of cloud-seeding technologies demonstrated in one area to another geographical area has been less than satisfactory; this has been especially so in the case of convective cloud systems, whose differences are complex and subtle and whose classification is complicated and sometimes inconsistent.

11. There is increasing evidence that attempts to modify clouds in a prescribed target area have also induced changes outside the target area, resulting in the so-called downwind or extended area effect; reasons for this phenomenon and means for reducing negative results need investigation.

12. There is the possibility that cloud seeding in a given area and during a given time period has led to residual or extended time effects on weather phenomena in the target area beyond those planned from the initial seeding.

13. The conduct of independent cloud-seeding operations in adjacent locations or in the neighborhood of weather modification experiments may cause contamination of the atmosphere so that experimental results or estimates of operational success are biased.

14. There have been and continue to be conflicting claims as to the reliability with which one can conduct cloud-seeding operations so that the seeding agent is transported properly from the dispensing device to the clouds or portions of the clouds one seeks to modify.

²⁷ Hosler, C. L., "Overt Weather Modification." *Reviews of Geophysics and Space Physics*, vol. 12, No. 3, August 1974, p. 526.

²⁸ Simpson, Joanne, "What Weather Modification Needs." In preprints of the Sixth Conference on Planned and Inadvertent Weather Modification, Oct. 10-13, 1977, Cham-paign, Ill., Boston, American Meteorological Society, 1977, p. 306.

²⁹ Hosler, "Overt Weather Modification," 1974, p. 525.

15. There is need to develop, improve, and evaluate new and currently used cloud-seeding materials and to improve systems for delivery of these materials into the clouds.

16. There is need to improve the capability to measure concentrations of background freezing nuclei and their increase through seeding; there is poor agreement between measurements made with various ice nucleus counters, and there is uncertainty that cloud chamber measurements are applicable to real clouds.³⁰

17. In order to estimate amounts of fallen precipitation in weather modification events, a combination of weather radar and raingage network are often used; results from such measurement systems have often been unsatisfactory owing to the quality of the radar and its calibration, and to uncertainties of the radar-raingage intercalibration.

18. There is continuing need for research in establishing seedability criteria; that is, definition of physical cloud conditions when seeding will be effective in increasing precipitation or in bringing about some other desired weather change.

19. Mathematical models used to describe cloud processes or account for interaction of cloud systems and larger scale weather systems greatly oversimplify the real atmosphere; therefore, model research must be coupled with field research.³¹

GOVERNMENTAL ISSUES

The basic problem which encompasses all governmental weather modification issues revolves about the question of the respective roles, if any, of the Federal, State, and local governments. Resolution of this fundamental question puts into perspective the specific issues of where in the several governmental levels, and to what extent, should goals be set, policy established, research and/or operations supported, activities regulated, and disputes settled. Part of this basic question includes the role of the international community, considered in another section on international issues;³² the transnational character of weather modification may one day dictate the principal role to international organizations.

Role of the Federal Government

Because weather modification cannot be restricted by State boundaries and because the Federal Government has responsibilities for resource development and for reduction of losses from natural hazards, few would argue that the Federal Government ought not to have some interest and some purpose in development and possible use of weather modification technology. The following broad and specific issues on the role of the Federal Government in weather modification are among those which may be considered in developing a Federal policy:

1. Should a major policy analysis be conducted in an attempt to relate weather modification to the Nation's broad goals; that is, improving human health and the quality of life, maintaining national security, providing sufficient energy supplies, enhancing environmental quality, and the production of food and fiber? Barbara Farhar suggests that such a study has not been, but ought to be, undertaken.³³

³⁰ *Ibid.*

³¹ Flengle, et al., "Weather Modification in the Public Interest," 1973, p. 57.

³² See n. 27.

³³ Farhar, Barbara C., "The Societal Implications of Weather Modification: a Review of Issues Toward a National Policy." Background paper prepared for the U.S. Department of Commerce Weather Modification Advisory Board, Mar. 1, 1977, p. 2.

2. Should the Federal Government commit itself to planned weather modification as one of several priority national goals? It can be argued that such commitment is important since Federal program support and political attitudes have an important overall influence on the development and the eventual acceptance and application of this technology.

3. Is there a need to reexamine, define, and facilitate a well-balanced, coordinated, and adequately funded Federal research and development program in weather modification? Many argue that the current Federal research program is fragmented and that the level of funding is subcritical.

4. Is there a suitable Federal role in weather modification activities beyond that of research and development—such as project evaluation and demonstration and operational programs? If such programs are advisable, how can they be identified, justified, and established?

5. Should the practice of providing Federal grants or operational services by Federal agencies to States for weather modification in times of emergency be reexamined, and should procedures for providing such grants and services be formalized? It has been suggested that such assistance in the past has been haphazard and has been provided after it was too late to be of any practical benefit.

6. Should the organizational structure of the Federal Government for weather modification be reexamined and reorganized? If so, what is the optimum agency structure for conducting the Federal research program and other functions deemed to be appropriate for the Federal Government?

7. What is the role of the Federal Government, if any, in regulation of weather modification activities, including licensing, permitting, notification, inspection, and reporting? If such a role is to be modified or expanded, how should existing Federal laws and/or regulations be modified?

8. If all or any of the regulatory functions are deemed to be more appropriate for the States than for the Federal Government, should the Federal Government consider mandating minimum standards and some uniformity among State laws and regulations?

9. Should the Federal Government attempt to develop a means adequate for governing the issues of atmospheric water rights between States, on Federal lands, and between the United States and neighboring countries?

10. Where federally sponsored research or possible operational weather modification projects occupy the same locale as local or State projects, with the possibility of interproject contamination, should a policy on project priorities be examined and established?

11. Should the Federal Government develop a policy with regard to the military use of weather modification and the active pursuit of international agreements for the peaceful uses of weather modification? This has been identified as perhaps one of the most important areas of Federal concern.³⁴

12. Is there a need to examine and define the Federal responsibility for disseminating information about the current state of weather modification technology and about Federal policy, including the capability for providing technical assistance to the States and to others?

³⁴Farhar Barbara C. "What Does Weather Modification Need"—In preprints of the Sixth Conference on Planned and Inadvertent Weather Modification, Oct. 10-13, 1977, Champaign, Ill., Boston, American Meteorological Society, 1977, p. 299.

13. Should there be a continuing review of weather modification technology capabilities so that Federal policy can be informed regarding the readiness of technologies for export to foreign nations, with provision of technical assistance where and when it seems feasible? ³⁵

14. How does the principle of cooperative federalism apply to weather modification research projects and possible operations carried out within the States? Should planning of projects with field activities in particular States be done in consultation with the States, and should cooperation with the States through joint funding and research efforts be encouraged?

15. What should be the role of the single Federal agency whose activities are most likely to be affected significantly by weather modification technology and whose organization is best able to provide advisory services to the States—the U.S. Department of Agriculture? Among the several agencies involved in weather modification, the Department of Agriculture has demonstrated least official interest and has not provided appreciable support to development of the technology. ³⁶

Roles of State and local governments

State and local ³⁷ governments are in many ways closer to the public than the Federal Government—often as a result of more direct contact and personal acquaintance with officials and through greater actual or perceived control by the voters. Consequently, a number of weather modification functions, for both reasons of practical efficiency and social acceptance, may be better reserved for State and/or local implementation. Since weather phenomena and weather modification operations cannot be restricted by State boundaries or by boundaries within States, however, many functions cannot be carried out in isolation. Moreover, because of the economy in conducting research and development on a common basis—and perhaps performing other functions as well—through a single governmental entity, such as an agency or agencies of the Federal Government, it may be neither feasible nor wise for State governments (even less for local jurisdictions) to carry out all activities.

Thus, there are activities which might best be reserved for the States (and possibly for local jurisdictions within States), and those which more properly belong to the Federal Government. In the previous list of issues on the role of the Federal Government, there was allusion to a number of functions which might, wholly or in part, be the responsibility of either Federal or State governments; most of these will not be repeated here. Issues and problems concerned primarily with State and local government functions are listed below:

1. State weather modification laws, where they exist, are nonuniform in their requirements and specifications for licensing, permitting, inspection, reporting, liabilities, and penalties for violations. Moreover, some State laws and policies favor weather modification, while others oppose the technology.

2. Authorities for funding operational and research projects within States and local jurisdictions within States, through public funds

³⁵ Ibid.

³⁶ Changnon, "The Federal Role in Weather Modification," p. 11.

³⁷ "Local" here refers broadly to any jurisdiction below the State level: it could include cities, townships, counties, groups of counties, water districts, or any other organized area operating under public authority.

or through special tax assessments, vary widely and, except in a few States, do not exist.

3. Decisionmaking procedures for public officials appear to be often lacking; these could be established and clarified, especially as the possibility of more widespread application of weather modification technology approaches.

4. Many public officials, usually not trained in scientific and engineering skills, often do not understand weather modification technology, its benefits, and its potential negative consequences. Some training of such officials could contribute to their making wise decisions on the use of the technology, even without complete information on which to base such decisions.

5. Many weather modification decisions have had strong political overtones, with some legislators and other public officials expressing their views or casting their votes allegedly on the basis of political expediency rather than on the basis of present or potential societal benefits.

6. State and local authorities may need to provide for the education of the general public on the rudiments of weather modification, on its economic benefits and disbenefits, and on other societal aspects.

7. To keep communication channels open, mechanisms such as public hearings could be established to receive comments, criticisms, and general public sentiments on weather modification projects from individual citizens and from various interest groups.

8. Criteria and mechanisms have not been established for compensating those individuals or groups within States who might be economically injured from weather modification operations.

9. Questions of water rights within States, as well as between States, have not been addressed and/or resolved in a uniform manner.

LEGAL ISSUES

Legal issues in weather modification are complex and unsettled. They can be discussed in at least four broad categories:

1. Private rights in the clouds;
2. Liability for weather modification;
3. Interstate legal issues; and
4. International legal issues.³⁸

The body of law on weather modification is slight, and existing case law offers few guidelines to determine these issues. It is often necessary, therefore, to analogize weather modification issues to more settled areas of law such as those pertaining to water distribution.

Private rights in the clouds

The following issues regarding private rights in the clouds may be asked:

Are there any private rights in the clouds or in the water which may be acquired from them?

Does a landowner have any particular rights in atmospheric water?

Does a weather modifier have rights in atmospheric water?

³⁸ Questions on regulation or control of weather modification activities through licensing and permitting, while of a basic legal nature, are related to important administrative functions and are dealt with under issues concerned with Federal and State activities.

Some State statutes reserve the ownership or right to use atmospheric water to the State.³⁹

There is no general statutory determination of ownership of atmospheric water and there is no well-developed body of case law. Consequently, analogies to the following general common law doctrines may be helpful, but each has its own disadvantages when applied to weather modification:

1. The doctrine of natural rights, basically a protection of the landowner's right to use his land in its natural condition (i.e., precipitation is essential to use of the land as are air, sunlight, and the soil itself).

2. The *ad coelum* doctrine which states that whoever owns the land ought also to own all the space above it to an indefinite extent.

3. The doctrine of riparian rights, by which the one owning land which abuts a watercourse may make reasonable use of the water, subject to similar rights of others whose lands abut the watercourse.

4. The doctrine of appropriation, which gives priority of right based on actual use of the water.

5. The two main doctrines of ownership in the case of oil and gas (considered, like water, to be "fugitive and migratory" substances); that is, (a) the non-ownership theory, by which no one owns the oil and gas until it is produced and anyone may capture them if able to do so; and (b) the ownership-in-place theory, by which the landowner has the same interest in oil and gas as in solid minerals contained in his land.

6. The concept of "developed water," that is, water that would not be available or would be lost were it not for man's improvements.

7. The concept of "imported water," that is, water brought from one watershed to another.

Liability for weather modification

Issues of liability for damage may arise when drought, flooding, or other severe weather phenomena occur following attempts to modify the weather. Such issues include causation as well as nuisance, strict liability, trespass, and negligence. Other issues which could arise relate to pollution of the air or water through introduction of artificial nucleants such as silver iodide, into the environment. While statutes of 10 States discuss weather modification liability, there is much variation among the specific provisions of the laws in those States.⁴⁰

Before any case can be made for weather modification liability based upon causation it must be proven that the adverse weather conditions were indeed brought about by the weather modifier, a very heavy burden of proof for the plaintiff. In fact, the scientific uncertainties of weather modification are such that no one has ever been able to establish causation of damage through these activities. As weather modification technology is improved, however, the specter of a host of liability issues is expected to emerge as evidence for causation becomes more plausible.

While the general defense of the weather modifier against liability charges is that causation has not been established, he may also use as further defense the arguments based upon immunity, privilege, consent, and waste.

³⁹ See p. 450, ch. 11, and app. D.

⁴⁰ See discussion p. 453 in ch. 11 and app. D.

Interstate legal issues

When weather modification activities conducted in one State affect another State as well, significant issues may arise. The following problem categories are examples of some generally unresolved interstate issues in weather modification:

1. There may be the claim that cloud seeding in one State has removed from the clouds water which should have fallen in a second State or that excessive flooding in a neighboring State has resulted from seeding in a State upwind.

2. Operation of cloud-seeding equipment near the border in one State may violate local or State ordinances which restrict or prohibit weather modification in an adjacent State, or such operations may conflict with regulations for licensing or permitting of activities within the bordering State.

Some States have attempted to resolve these issues through specific legislation and through informal bilateral agreements.⁴¹ Another approach would be through interstate compact, though such compacts require the consent of Congress. No compacts specifically concerned with weather modification currently exist, though some existing compacts allocating waters in interstate streams may be applicable to weather modification.

International legal issues

Because atmospheric processes operate independent of national borders, weather modification is inherently of international concern. International legal issues have similarities to domestic interstate activities and dangers. The following serious international questions, which have arisen in conjunction with a developing capability to modify the weather, have been identified by Orfield:⁴²

Do countries have the right to take unilateral action in all weather modification activities?

What liability might a country incur for its weather modification operations which [might] destroy life and property in a foreign State?

On what theory could and should that State base its claim?

The primary international legal issue regarding weather modification is that of liability for transnational injury or damage, which could conceivably result from any of the following situations:

(1) injury or damage in another nation caused by weather modification activities executed within the United States;

(2) injury or damage in another nation caused by weather modification activities executed in that nation or a third nation by the United States or a citizen of the United States;

(3) injury or damage in another nation caused by weather modification activities executed in an area not subject to the jurisdiction of any nation (e.g., over the high seas), by the United States or a citizen thereof; and

(4) injury or damage to an alien or an alien's property within the United States caused by weather modification activities executed within the United States.

⁴¹ See discussion p. 457 in ch. 11 and app. D.

⁴² Orfield, Michael B., "Weather Genesis and Weather Neutralization; a New Approach to Weather Modification," *California Western International Law Journal*, vol. 6, no. 2, spring 1976, p. 414.

Whereas domestic weather modification law is confused and unsettled, international law in this area is barely in the formative stage. In time, ramifications of weather modification may lead to major international controversy.⁴³

ECONOMIC ISSUES

The potential for long-term economic gains through weather modification cannot be denied; however, current economic analyses are tenuous in view of present uncertainty of the technology and the complex nature of attendant legal and economic problems. Meaningful economic evaluation of weather modification activities is thus limited to special, localized cases, such as the dispersal of cold fog at airports, where benefit-cost ratios greater than 5 to 1 have been realized through savings in delayed or diverted traffic. Various estimated costs for increased precipitation through cloud seeding range from \$1.50 to \$2.50 per acre-foot in the western United States.

Issues complicating economic analyses of weather modification

Costs of most weather modification operations are usually relatively small and are normally believed to be only a fraction of the benefits obtained through such operations. However, if all the benefits and all the costs are considered, benefit-cost ratios may be diminished. While direct costs and benefits from weather modification are reasonably obvious, indirect costs and benefits are elusive and require further study of sociological, legal, and ecological implications.

In analyzing benefit-cost ratios, some of the following considerations need to be examined:

Weather modification benefits must be considered in terms of the costs for achieving the same objectives as increased precipitation, e.g., through importation of water, modified use of agricultural chemicals, or introduction of improved plant strains.

Costs for weather modification operations are so low in comparison with other agricultural investments that farmers may gamble in spending the 5 to 20 cents per acre for operations designed to increase rainfall or suppress hail in order to increase yield per acre, even though the results of the weather modification operations may be doubtful.

Atmospheric conditions associated with prolonged droughts are not conducive to success in increasing precipitation; however, under these conditions, it is likely that increased expenditures may be made for operations which offer little hope of economic return.

Increased precipitation, obtained through a weather modification program sponsored and funded by a group of farmers, can also benefit other farmers who have not shared in the costs; thus, the benefit-cost ratio to those participating in the program is higher than it need be if all share in its costs.

As weather modification technology develops and programs become more sophisticated, increased costs for equipment and labor will increase direct costs to clients; indirect costs resulting from increased State license and permit fees and liability insurance for operators will probably also be passed on to the customer.

⁴³ See ch. 10 on international aspects and p. 468, ch. 11, on international legal aspects of weather modification.

The sophistication of future programs will likely incur additional costs for design, evaluation, and program information activities, along with supporting meteorological prediction services; these costs will be paid from public funds or by private clients, in either case reducing the overall benefit-cost ratios.

Ultimate costs for compensation to those incurring disbenefits from weather modification operations will offset overall benefits and thus reduce benefit-cost ratios.

Weather modification and conflicting interests

There are numerous cases of both real and perceived economic losses which one or more sectors of the public may suffer while another group is seeking economic advantage through some form of weather modification. Overall benefits from weather modification are accordingly reduced when net gains are computed from such instances of mixed economic advantages and disadvantages. Benefits to the parties seeking economic gain through weather modification will be directly reduced at such time when mechanisms are established for compensating those who have suffered losses. The following are some examples of such conflicting situations:

Successful suppression of hail may be valuable in reducing crop damage for orchardists while other agricultural crops may suffer from decrease of rain concomitant with the hail decrease.

Additional rainy days may be of considerable value to farmers during their growing season but may be detrimental to the financial success of outdoor recreational enterprises.

Increased snowpack from orographic cloud seeding may be beneficial to agricultural and hydroelectric power interests but increases the costs for maintaining free passage over highways and railroads in mountainous areas.

Successful abatement of winds from severe storms, such as those of hurricanes, may result in decreased precipitation necessary for agriculture in nearby coastal regions or may redistribute the adverse storm effects, so that one coastal area is benefitted at the expense of others.

SOCIAL ISSUES

It has been said that "weather modification is a means toward socially desired ends, not an end in itself. It is one potential tool in a set of possible societal adjustments to the vagaries of the weather. Identifying when, where, and how to use this tool, once it is scientifically established, is the primary need in weather modification."⁴⁴ It is likely that, in the final analysis, the ultimate decisions on whether weather modification should and will be used in any given instance or will be adopted more generally as national or State programs depends on social acceptance of this tool, no matter how well the tool itself has been perfected. That this is increasingly the case has been suggested by numerous examples in recent years. Recently Silverman said:

Weather modification, whether it be research or operations, will not progress wisely, or perhaps at all, unless it is considered in a context that includes everyone

⁴⁴ Farhar, Barbara C. "What Does Weather Modification Need?" In preprints of the Sixth Conference on Planned and Inadvertent Weather Modification, October 10-13, 1977, Champaign, Ill. Boston, American Meteorological Society, 1977. p. 296.

that may be affected. We must develop and provide a new image of weather modification.⁴⁵

Regardless of net economic benefits, a program is hard to justify when it produces obvious social losses as well as gains.

Research in the social science of weather modification has not kept pace with the development of the technology, slow as that has been. In time, this failure may be a serious constraint on further development and on its ultimate application. In the past, organized opposition has been very effective in retarding research experiments and in curtailing operational cloud-seeding programs. Thus, there is need for an expanded effort in understanding public behavior toward weather modification and for developing educational programs and effective decisionmaking processes to insure intelligent public involvement in eventual application of the technology.

Social issues discussed in this section are those which relate to public behavior and public response to weather modification, while societal issues are generally considered to include economic, legal, and other nontechnical issues as well as the social ones. These other aspects of societal issues were discussed in preceding sections. In the subsections to follow there are summaries of social implications of weather modification, the need for public education, and the problem of decisionmaking.

Social factors

It has been said that social factors are perhaps the most elusive and difficult weather modification externalities to evaluate since such factors impinge on the vast and complex area of human values and attitudes.⁴⁶ Fleagle, et al., identified the following important social implications of weather modification, which would presumably be taken into account in formulation of policies:⁴⁷

1. The individuals and groups to be affected, positively or negatively, by the project must be defined. An operation beneficial to one party may actually harm another. Or an aggrieved party may hold the operation responsible * * * for damage * * * which might occur at the same time or following the modification.

2. The impact of a contemplated weather modification effort on the general well-being of society and the environment as a whole must be evaluated. Consideration should be given to conservationists, outdoor societies, and other citizens and groups representing various interests who presently tend to question any policies aimed at changes in the physical environment. It is reasonable and prudent to assume that, as weather modification operations expand, questioning and opposition by the public will become more vocal.

3. Consideration must be given to the general mode of human behavior in response to innovation. There are cases where local residents, perceiving a cause and effect relationship between economic losses from severe weather and nearby weather modification operations, have continued to protest, and even to threaten violence, after all operations have been suspended.

4. The uniqueness and complexity of certain weather modification operations must be acknowledged, and special attention should be given to their social and legal implications. The cases of hurricanes and tornadoes are especially pertinent. Alteration of a few degrees in the path of a hurricane may result in its missing a certain area * * * and ravaging * * * instead, a different one. The decision on whether such an operation is justified can reasonably be made only at the highest level, and would need to be based on the substantial scientific finding that the anticipated damages would be less than those originally predicted had the hurricane been allowed to follow its course.

⁴⁵ Silverman, Bernard A. "What Do We Need in Weather Modification?" In preprints of the Sixth Conference on Planned and Inadvertent Weather Modification, October 10-13, 1977. Champaign, Ill., Boston, American Meteorological Society, 1977. p. 310.

⁴⁶ Fleagle, Crutchfield, Johnson, and Abdo. "Weather Modification in the Public Interest." 1974. p. 37-38.

⁴⁷ *Ibid.*, p. 38-40.

5. Attention must be given to alternatives in considering a given weather modification proposal. The public may prefer some other solution to an attempt at weather tampering which may be regarded as predictable and risky. Furthermore, alternative policies may tend to be comfortable extensions of existing policies, or improvements on them, thus avoiding the public suspicion of innovation. In an area such as weather modification, where so many uncertainties exist, and where the determination or assigning of liability and responsibility are far from having been perfected, public opposition will surely be aroused. Any alternative plan or combination of plans will have its own social effects, however, and it is the overall impact of an alternative plan and the adverse effects of not carrying out such a plan which, in the final analysis, should guide decisions on alternative action.

6. Finally, it is important to recognize that the benefits from a weather modification program may depend upon the ability and readiness of individuals to change their modes of activity. The history of agricultural extension work in the United States suggests that this can be done successfully, but only with some time lag, and at a substantial cost. Social research studies suggest that public perception of flood, earthquake, and storm hazards is astonishingly casual.

Need for public education on weather modification

The previous listing of social implications of weather modification was significantly replete with issues derived from basic human attitudes. To a large extent these attitudes have their origin in lack of information, misconceptions, and even concerted efforts to misinform by organized groups which are antagonistic to weather modification. As capabilities to modify weather expand and applications are more widespread, it would seem probable that this information gap would also widen if there are no explicit attempts to remedy the situation. "At the very least," according to Fleagle, et al., "a large-scale continuing program of education (and perhaps some compulsion) will be required if the potential social gains from weather modification are to be realized in fact."⁴⁸ Whether such educational programs are mounted by the States or by some agency of the Federal Government is an issue of jurisdiction and would likely depend on whether the Federal Government or the States has eventual responsibility for management of operational weather modification programs. Information might also be provided privately by consumer groups, professional organizations, the weather modification industry, or the media.

It is likely that educational programs would be most effective if a variety of practical approaches are employed, including use of the news media, publication of pamphlets at a semitechnical level, seminars and hearings, and even formal classes. Probably the latter categories would be most appropriate for civic groups, Government officials, businessmen, or other interests who are likely to be directly affected by contemplated operations.

The following list of situations are examples of public lack of understanding which could, at least in part, be remedied through proper educational approaches:

There is much apprehension over claims of potential danger of a long-lasting nature on climate, which could supposedly result from both inadvertent and planned modification of the weather, with little insight to distinguish between the causes and the scales of the effects.

There have been extravagant claims, propagated through ignorance or by deliberate distortion by antagonistic groups, about

⁴⁸ *Ibid.*, p. 40.

the damaging effects of cloud seeding on ecological systems, human health, and air and water quality.

The controversies between opposing groups of scientists on the efficacy of weather modification technologies and between scientists and commercial operators on the readiness of these technologies for application has engendered a mood of skepticism and even mistrust of weather modification on the part of a public which is largely uninformed on technical matters.

The public has often been misinformed by popular news media, whose reporters seek to exploit the spectacular in popular weather modification "stories" and who, themselves usually uninformed in technical aspects of the subject, tend to oversimplify and distort the facts associated with a rather complex science and technology.

There has been an organized effort on the part of groups opposed to weather modification to mount an educational program which runs counter to the objectives of informing the public about the potential benefits of a socially acceptable technology of weather modification.

Portions of the public have acquired a negative impression that meteorologists and Government officials concerned with weather modification are irresponsible as a result of past use, or perceived present and future use, of the technology as a weapon of war.

Lack of information to the public has sometimes resulted in citizen anger when it is discovered that a seeding project has been going on in their area for some time without their having been informed of it.

Decisionmaking

"The nature of weather processes and the current knowledge about them require that most human decisions as to weather modification must be made in the face of uncertainty. This imposes special restraints on public agencies and it increases the difficulty of predicting how individual farmers, manufacturers, and others who are directly affected by weather would respond to changes in weather characteristics."⁴⁹ The situation since 1965 when this statement was made has changed little with regard to predictability of weather processes and their modification. There has also been little progress toward developing decisionmaking processes which can be applied, should the need arise, on whether or not weather modification should be employed.

A number of studies on social attitudes indicate that the preference of most citizens is that decisionmaking in such areas as use or restraint from use of weather modification should be at the local level, owing to the feeling that citizens' rights and property are best protected when decisions are made by officials over whom they have the most direct control. Farhar says that evidence suggests that one important condition for public acceptance of weather modification technology is public involvement in the decision process, especially in civic decisions.⁵⁰ Procedures must then be developed for enabling local

⁴⁹ Special Commission on Weather Modification, "Weather and Climate Modification," NSF 66-3, 1965, p. 96.

⁵⁰ Farhar, Barbara C. "The Public Decides About Weather Modification." *Environment and Behavior*, vol. 9, No. 3, September 1977, p. 307.

officials, probably not technically trained, to make such decisions intelligently. Such decisions must be based both on information received from Federal or State technical advisers and on the opinions of local citizens and interest groups.

INTERNATIONAL ISSUES

International agreements regarding weather modification experiments and operations have been very limited. There exists a United States-Canada agreement, which requires consultation and notification of the other country when there is the possibility that weather modification activities of one country could affect areas across the border.⁵¹ Earlier understandings were reached between the United States and Canada concerning experiments over the Great Lakes and with the United Kingdom in connection with hurricane modification research in the Atlantic.⁵² Recent attempts to reach agreement with the Governments of Japan and the People's Republic of China for U.S. experiments in the Far East on modification of typhoons were unsuccessful, though such research was encouraged by the Philippines. There is current intention to reach an agreement with Mexico on hurricane research in the eastern Pacific off that nation's coast.

During 1976, 25 nations reported to the World Meteorological Organization that they had conducted weather modification activities.⁵³ There have been two principal international activities, dealing with somewhat different aspects of weather modification, in recent years. One of these is the preparation and design of a cooperative experiment under the auspices of the World Meteorological Organization, called the Precipitation Enhancement Experiment (PEP); while the other is the development of a convention by the United Nations on the prohibition of hostile use of environmental modification.⁵⁴

The following international considerations on research and operational weather modification activities can be identified:

1. There is a common perception of a need to insure that the current high level of cooperation which exists in the international community with regard to more general meteorological research and weather reporting will be extended to development and peaceful uses of planned weather modification.

2. There is now no body of international law which can be applied to the potentially serious international questions of weather modification, such as liability or ownership of atmospheric water resources.⁵⁵

3. Past use by the United States, and speculated current or future use by various countries, of weather modification as a weapon have raised suspicions as to the possible intent in developing advertent weather modification technology.

4. There have been charges that weather modification research activities were used to divert severe weather conditions away from the

⁵¹ The United States-Canada agreement on weather modification is reproduced in app. F.

⁵² Taubenfeld, Howard J., "National Weather Modification Policy Act of 1976; International Agreements." Background paper for use of the U.S. Department of Commerce Weather Modification Advisory Board, March 1977, p. 13.

⁵³ See table I, ch. 9, p. 409.

⁵⁴ These activities and other international aspects of weather modification are discussed in ch. 10.

⁵⁵ See previous section on legal issues, p. 17.

United States at the expense of other countries or that such activities have resulted in damage to the environment in those countries.⁵⁶

5. As in domestic research projects, there are allegations of insufficient funding over periods of time too short to achieve significant results in the case of internationally sponsored experiments; in particular, many scientists feel that a means should be devised to insure that the planned Precipitation Enhancement Project (PEP) receives adequate continuous support.

6. Other nations should be consulted with regard to any planned weather modification activities by the United States which might conceivably affect, or be perceived to affect, those countries.

ECOLOGICAL ISSUES

The body of research on ecological effects of weather modification is limited but significantly greater than it was a decade ago. It is still true that much remains unknown about ecological effects of changes to weather and climate.

Economically significant weather modification will always have an eventual ecological effect, although appearance of that effect may be hidden or delayed by system resilience and/or confused by system complexity. It may never be possible to predict well the ecological effects of weather modification; however, the more precisely the weather modifier can specify the effects his activities will produce in terms of average percentage change in precipitation (or other variables), expected seasonal distribution of the induced change, expected year-to-year distribution of the change, and changes in relative form of precipitation, the more precise can be the ecologist's prediction of possible ecological effects.

Ecological effects will result from moderate weather-related shifts in rates of reproduction, growth, and mortality of plants and animals; they will rarely be sudden or catastrophic. Accordingly, weather modifications which occur with regularly over time are the ones to which biological communities will react. Adjustments of plant and animal communities will usually occur more slowly in regions of highly variable weather than in those with more uniform conditions. Deliberate weather modification is likely to have greater ecological impact in semiarid systems and less impact in humid ones. Since precipitation augmentation, for example, would have the greatest potential for economic value and is, therefore, likely to have its greatest potential application in such areas, the ecological impacts in transition areas will be of particular concern.

Although widespread cloud seeding could result in local, temporary increases in concentrations of silver (from the most commonly used seeding agent, silver iodide), approaching the natural quantities in surface waters, the exchange rates would probably be an order of magnitude lower than the natural rates. Even in localized areas of precipitation management, it appears that exchange rates will be many orders of magnitude smaller than those adversely affecting plants and soils. Further research is required, however, especially as other potential seeding agents are introduced.

⁵⁶ For example, there were charges that attempts to mitigate severe effects of Hurricane Fifi in 1975 caused devastation to Honduras, a charge which the United States officially denied, since no hurricanes had been seeded under Project Stormfury since 1971.

CHAPTER 2

HISTORY OF WEATHER MODIFICATION

(By Robert E. Morrison, Specialist in Earth Sciences, Science Policy Research Division, Congressional Research Service)

INTRODUCTION

The history of the desire to control the weather can be traced to antiquity. Throughout the ages man has sought to alleviate droughts or to allay other severe weather conditions which have adversely affected him by means of magic, supplication, pseudoscientific procedures such as creating noises, and the more on less scientifically based techniques of recent times.

The expansion in research and operational weather modification projects has increased dramatically since World War II; nevertheless, activities predating this period are of interest and have also provided the roots for many of the developments of the "modern" period. In a 1966 report for the Congress on weather modification, Lawton Hartman stated three reasons why a review of the history of the subject can be valuable: (1) Weather modification is considerably older than is commonly recognized, and failure to consider this fact can lead to a distorted view of current problems and progress. (2) Weather modification has not developed as an isolated and independent field of research, but for over a century has been parallel to and related to progress in understanding weather processes generally. (3) Earlier experiences in weather modification may not have been very different from contemporary experiences in such matters as experimental design, evaluation of results, partially successful projects, and efforts to base experiments on established scientific principles.¹

Hartman found that the history of weather modification can be conveniently divided into five partially overlapping periods.² He refers to these as (1) a prescientific period (prior to about 1839); (2) an early scientific period (extending approximately from 1839 through 1891); (3) a period during which elements of the scientific framework were established (from about 1875 to 1933); (4) the period of the early cloud-seeding experiments (1921 to 1946); and (5) the modern period, beginning with the work of Langmuir, Schaefer, and Vonnegut (since 1946). This same organization is adopted in discussions below; however, the four earlier periods are collected into one section, while the more significant history of the extensive activities of the post-1946 period are treated separately.

¹Hartman, Lawton M., "History of Weather Modification." In U.S. Congress, Senate Committee on Commerce. "Weather Modification and Control." Washington, D.C., U.S. Government Printing Office, 1966 (89th Cong., 2d sess., Senate Rept. No. 1139; prepared by the Legislative Reference Service, the Library of Congress, at the request of Warren G. Magnuson), p. 11.

²Ibid.

HISTORY OF WEATHER MODIFICATION PRIOR TO 1946

PRESCIENTIFIC PERIOD

From ancient times through the early 19th century, and even since, there have been reported observations which led many to believe that rainfall could be induced from such phenomena as great noises and extensive fires. Plutarch is reported to have stated, "It is a matter of current observation that extraordinary rains pretty generally fall after great battles."³ Following the invention of gunpowder, the frequency of such claims and the conviction of those espousing this hypothesis increased greatly. Many cases were cited where rain fell shortly after large battles. A practical use of this phenomenon was reported to have occurred in the memoirs of Benvenuto Cellini when, in 1539 on the occasion of a procession in Rome, he averted an impending rainstorm by firing artillery in the direction of the clouds, "which had already begun to drop their moisture."⁴

William Humphreys posed a plausible explanation for the apparently high correlation between such weather events and preceding battles. He noted that plans were usually made and battles fought in good weather, so that after the battle in the temperate regions of Europe or North America, rain will often occur in accordance with the natural 3- to 5-day periodicity for such events.⁵ Even in modern times there was the conviction that local and global weather had been adversely affected after the explosion of the first nuclear weapons and the various subsequent tests in the Pacific and elsewhere.⁶ Despite statements of the U.S. Weather Bureau and others pointing out the fallacious reasoning, such notions became widespread and persistent.⁷

In addition to these somewhat rational though unscientific observations, many of which were accompanied by testimony of reliable witnesses, there had been, and there still exist in some primitive cultures, superstitions and magical practices that accompany weather phenomena and attempts to induce changes to the weather. Daniel Halacy relates a number of such superstitiouslike procedures which have been invoked in attempts to bring rain to crops during a drought or to change the weather in some other way so as to be of particular benefit to man:⁸

Primitive rainmakers would often use various intuitive gestures, such as sprinkling water on the soil that they wanted the heavens to douse, blowing mouthfuls of water into the air like rain or mist, hammering on drums to imitate thunder, or throwing firebrands into the air to simulate lightning.

Women would carry water at night to the field and pour it out to coax the skies to do likewise.

American Indians blew water from special pipes in imitation of the rainfall.

It was believed that frogs came down in the rain because many were seen following rain: therefore, frogs were hung from trees so that the heavens would pour down rain upon them.

Sometimes children were buried up to their necks in the parched ground and then cried for rain, their tears providing the imitative magic.

³ Ward, R. De C., "Artificial Rain: a Review of the Subject to the Close of 1889." *American Meteorological Journal*, vol. 8, May 1891-April 1892, p. 484.

⁴ *Ibid.*, p. 493.

⁵ Humphreys, William J., "Rain Making and Other Weather Vagaries." Baltimore, The Williams and Wilkins Co., 1926, p. 31.

⁶ Byers, Horace R., "History of Weather Modification." In Wilnot N. Hess (editor), "Weather and Climate Modification," New York, Wiley, 1974, p. 4.

⁷ *Ibid.*

⁸ Halacy, Daniel S., Jr., "The Weather Changers," New York, Harper & Row, 1968, pp. 52-63.

In China, huge paper dragons were part of religious festivals to bring rain; if drought persisted, the dragon was angrily torn to bits.

North American Indians roasted young women from enemy tribes over a slow fire, then killed them with arrows before eating their hearts and burying their remains in the fields they wanted irrigated with rainfall.

Scottish witches conjured up the wind by beating a stone three times with a rag dipped in water, among intonations like those of characters in a Shakespearean play.

New Guinea natives used wind stones upon which they tapped with a stick, the force of the blow bringing anything from a zephyr to a hurricane.

Pregnant women in Greenland were thought to be able to go outdoors, take a breath, and exhale it indoors to calm a storm.

In Scandinavian countries witches sold knotted bits of string and cloth which, supposedly, contained the wind; untying one knot at sea would produce a moderate wind, two a gale, and three a violent storm.

Australian bushmen thought that they could delay the Sun by putting a clod of dirt in the fork of a tree at just the height of the Sun, or hasten its departure by blowing sand after it.

Bells have been thought to prevent hail, lightning, and windstorms, and sometimes they are still rung today for this purpose.

EARLY SCIENTIFIC PERIOD

James P. Espy was a 19th century American meteorologist known especially for his development of a theory of storms based on convection. Recognizing that a necessary condition for rainfall is the formation of clouds by condensation of water vapor from rising air, Espy considered that rain could well be induced artificially when air is forced to rise as a result of great fires, reviving a belief of the pre-scientific era but using scientific rationale. In the *National Gazette* in Philadelphia of April 5, 1839, he said:

From principles here established by experiment, and afterward confirmed by observation, it follows, that if a large body of air is made to ascend in a column, a large cloud will be generated and that that cloud will contain in itself a self-sustaining power, which may move from the place over which it was formed, and cause the air over which it passes, to rise up into it, and thus form more cloud and rain, until the rain may become more general.⁹

If these principles are just, when the air is in a favorable state, the bursting out of a volcano ought to produce rain; and such is known to be the fact; and I have abundant documents in my possession to prove it.

So, under very favorable conditions, the bursting out of great fires ought to produce rain; and I have many facts in my possession rendering it highly probable, if not certain, that great rains have sometimes been produced by great fires.¹⁰

Later in the same article Espy stated that:

From these remarkable facts above, I think it will be acknowledged that there is some connection between great fires and rains other than mere coincidence. But now, when it is demonstrated by the most decisive evidence, the evidence of experiment, that air, in ascending into the atmosphere in a column, as it must do over a great fire, will cool by diminished pressure, so much that it will begin to condense its vapor into cloud.¹¹

Espy postulated three mechanisms which could prevent great fires from providing rain at all times when they occur: (1) If there is a current of air at some height, it sweeps away the uprushing current of air; (2) the dewpoint may be too low to produce rain at all; and (3) there may be an upper stratum of air so light that the rising

⁹ Espy, James P., "Artificial Rains," *National Gazette*, Philadelphia, Apr. 5, 1839. Reprinted in James P. Espy, "Philosophy of Storms," Boston, Little & Brown, 1841, pp. 493-494.

¹⁰ *Ibid.*, p. 494.

¹¹ *Ibid.*, p. 496.

column may not be able to rise far enough into it to cause rain.¹² He proposed an experiment in which he would set fire to a "large mass of combustibles," which would be ready for the right circumstances and at a time of drought. He added: "Soon after the fire commences, I will expect to see clouds begin to form * * *. I will expect to see this cloud rapidly increase in size, if its top is not swept off by a current of air at a considerable distance above the Earth, until it becomes so lofty as to rain."¹³

For over a decade Espy served as an adviser to the Congress on meteorological problems. He proposed in 1850 what is perhaps the first Federal project for large-scale weather modification. His plan included amassing large quantities of timber in the Western States along a 600- to 700-mile north-south line, to be set on fire simultaneously at regular 7-day intervals. He believed that this fire could have started a "rain of great length" traveling toward the East, not breaking up until reaching "far over the Atlantic Ocean; that it will rain over the whole country east of the place of beginning." The cost of this experiment would "not amount to half a cent a year to each individual in the United States."¹⁴ Congress did not endorse the proposal for reasons which are unknown; however, Fleagle speculates that perhaps this failure was due to the fact that Congress had not yet accustomed itself to appropriating funds for scientific enterprises.¹⁵

There was continuing controversy over whether or not fire could cause increased rainfall. In an article which appeared in *Nature* in 1871, J. K. Laughton stated that, "The idea that large fires do, in some way, bring on rain, is very old; but it was, I believe, for the first time stated as a fact and explained on scientific grounds by the late Professor Espy."¹⁶ Laughton cited instances where burning brush in hot, dry weather did not result in any rainfall, and he concluded that:

Large fires, explosions, battles, and earthquakes do tend to cause atmospheric disturbance, and especially to induce a fall of rain; but that for the tendency to produce effect, it is necessary that other conditions should be suitable. With regard to storms said to have been caused by some of these agencies, the evidence is still more unsatisfactory; and, in our present ignorance of the cause of storms generally, is quite insufficient to compel us to attribute any one particular gale, extending probably over a wide area, to some very limited and comparatively insignificant disturbance.¹⁷

The 1871 Chicago fire also aroused interest, many believing that the fire was stopped by the rainfall which it had initiated. Ward cites a telegram of the time sent to London which read:

This fire was chiefly checked on the third or fourth day by the heavy and continuous downpour of rain, which it is conjectured is partly due to the great atmospheric disturbances which such an extensive fire would cause, especially when we are told that the season just previous to the outbreak of the fire had been particularly dry.¹⁸

¹² *Ibid.*

¹³ *Ibid.*, p. 499.

¹⁴ Espy, James P., "Second Report on Meteorology to the Secretary of the Navy," U.S. Senate, Executive Documents, No. 39, vol. 11, 31st Cong., 1st sess. Washington, Wm. M. Bell 1850, p. 20.

¹⁵ Fleagle, Robert G., "Background and Present Status of Weather Modification." In Robert G. Fleagle (editor), "Weather Modification: Science and Public Policy." University of Washington Press, Seattle 1968, p. 7.

¹⁶ Laughton, J. K., "Can Weather Be Influenced by Artificial Means?" *Nature*, Feb. 16, 1871, p. 206.

¹⁷ *Ibid.*, p. 307.

¹⁸ Reported in Ward, "Artificial Rain; a Review of the Subject to the Close of 1889," 1892, pp. 489-490.

On the other hand, Prof. I. A. Lapham, speaking of the Chicago fire, contradicted the previous account, saying:

During all this time—24 hours of conflagration—no rain was seen to fall, nor did any rain fall until 4 o'clock the next morning; and this was not a very considerable downpour, but only a gentle rain, that extended over a large district of country, differing in no respect from the usual rains. It was not until 4 days afterward that anything like a heavy rain occurred. It is, therefore, quite certain that this case cannot be referred to as an example of the production of rain by a great fire.¹⁹

Lapham goes on to say that, "The case neither confirms nor disproves the Espian theory, and we may still believe the well-authenticated cases where, under favorable circumstances of very moist air and absence of wind, rain has been produced by very large fires."²⁰

Prof. John Trowbridge of Harvard reported in 1872 on his experiments in which he investigated the influence of flares on atmospheric electricity. Noting that the normal atmospheric state is positive and that clearing weather is often preceded by a change from negative to positive charge, he suggested that perhaps large fires may influence the production of rain by changing the electrical state of the atmosphere, since, in his tests, his flame tended "to reduce the positive charge of electricity which generally characterizes the air of fine weather."²¹ He concluded by saying: "The state of our knowledge, however, in regard to the part that electricity plays in atmospheric changes is very meager. The question of the truth of the popular belief that great fires are followed by rain still remains unanswered."²²

Meanwhile, H. C. Russel, president of the Royal Society of South Wales and government astronomer, attempted to dispel the ideas that both cannonading and great fires could be used to produce rain. He hypothesized that, if fire were to have such an effect, rain should arrive within 48 hours following the fire. Reviewing the records of 42 large fires (including two explosions) covering a 21-year period, Russel concluded that there was not one instance in which rain followed within 48 hours as an evident consequence of the fire. He further calculated that to get increased rainfall of 60 percent over a land surface of 52,000 square feet at Sidney would require 9 million tons of coal per day, in an effort to show what magnitude of energy expenditure was necessary and how futile such an attempt would be.²³

Toward the latter part of the 19th century there were a number of ideas and devices invented for producing rain artificially. In 1880 David Ruggles of Virginia patented what he said was "a new and useful mode of producing rain or precipitating rainfalls from rainclouds, for the purpose of sustaining vegetation and for sanitary purposes." His plan included a scheme by which balloons carrying explosives were sent up into the air, the explosives to be detonated in the upper air "by electric currents."²⁴

¹⁹ Lapham, I. A., "The Great Fires of 1871 in the Northwest." *The Journal of the Franklin Institute*, vol. 64, No. 1, July 1872, pp. 46-47.

²⁰ *Ibid.*, p. 47.

²¹ Trowbridge, John, "Great Fires and Rain-storms." *The Popular Science Monthly*, vol. 2, December 1872, p. 211.

²² *Ibid.*

²³ Report of an address by H. C. Russel was given in *Science*, vol. 3, No. 55, Feb. 22, 1884, pp. 229-230.

²⁴ "New Method of Precipitating Rain Falls," *Scientific American*, vol. 43, Aug. 14, 1880, p. 106.

G. H. Bell suggested a rainmaking device, consisting of a hollow tower 1,500 feet high, through which air was to be blown into the atmosphere, the volume of the up-rushing air to be increased through use of a system of tubes around the tower. The inventor considered that the same system could be used to prevent rain, by reversing the blower so that the descending air might "annihilate" the clouds.²⁵

Still other schemes and contrivances were proposed and patented. J. B. Atwater was granted a patent in 1887 for a scheme to dissipate tornadoes by detonating an explosive charge in their centers, and another was granted to Louis Gathman in 1891 for seeding clouds for rain by exploding a shell containing "liquid carbonic acid gas" at cloud height,²⁶ the latter concept antedating by over 50 years the more recent carbon dioxide seeding projects.

There continued to be adherents to the idea that explosions could cause rainfall. This belief was reinforced by "evidence" of such a connection in a book by Edward Powers, called "War and the Weather," published in 1871 and 1890 editions, in which the author recounted the instances in which rain followed battles, mostly from North America and Europe during the 19th century.²⁷

Powers was convinced that:

The idea that rain can be produced by human agency, though sufficiently startling, is not one which, in this age of progress, ought to be considered as impossible of practical realization. Aside from its connection with the superstitions of certain savage tribes, it is an opinion of comparatively recent origin, and is one which cannot be regarded as belonging, in any degree, to a certain class of notions which prevail among the unthinking; * * * on the contrary, it is one which is confined principally to those who are accustomed to draw conclusions only from adequate premises, and * * * founded on facts which have come under their own observation.²⁸

In tones somewhat reminding us of those urging a greater Federal research effort in recent years, Powers proposed that experiments be undertaken for economic benefit:

Judging from the letters which I have received since commencing in 1870 an attempt to bring forward the subject of rains produced by cannon firing, I believe that the country would regard with interest some experiments in the matter, and would not begrudge the expense, even if they should prove unsuccessful in leading to a practical use of the principle under discussion. In some matters connected with science, the Government has justly considered that an expenditure of public funds was calculated to be of public benefit; but where, in anything of the kind it has ever undertaken, has there been so promising a field for such actions as here?²⁹

Powers, upon examining the records of many battles, said:

Let us proceed to facts—facts not one of which, perhaps, would be of any significance if it stood alone and unsupported by the others; but which, taken in the aggregate, furnish the strongest evidence that heavy artillery firing has an influence on the weather and tends to bring rain.³⁰

Perhaps influenced by the arguments of Powers and others, in 1890 the U.S. Congress had become so much interested in and gained

²⁵ "Another Rain Controller," *Scientific American*, vol. 43, Aug. 21, 1880, p. 113.

²⁶ Harrington, Mark W., "Weather-making, Ancient and Modern," *Smithsonian Institution Annual Report*, to July 1894, pp. 249-270.

²⁷ Powers, Edward, "War and the Weather," Delavan, Wis., E. Powers, 1890, revised edition, 202 pp. (An earlier edition was published in Chicago in 1871. Incidentally, the plates for the first edition were destroyed in the Chicago fire, and Powers did not have an opportunity to complete his revision until 1890.)

²⁸ *Ibid.*, p. 5.

²⁹ *Ibid.*, p. 143.

³⁰ *Ibid.*, p. 11.

such faith in the possibility of weather modification that funds were appropriated to support experiments to be carried out under the auspices of the Forestry Division of the U.S. Department of Agriculture. The initial \$2,000 appropriated was increased first to \$7,000, and finally to \$10,000, in the first federally sponsored weather modification project. Of the total appropriated, \$9,000 was to be spent on field experiments. Gen. Robert St. George Dyrenforth was selected by the Department of Agriculture to direct these tests, having earlier conducted tests near Utica, N.Y., and Washington, D.C., using balloons and rockets carrying explosives. The principal experiments were executed near Midland, Tex., using a variety of explosive devices, detonated singly and in volleys, both on the ground and in the air.³¹

According to an interesting account by Samuel Hopkins Adams, Dyrenforth arrived in Texas on a hot day in August 1891 with a company of 80 workers, including " * * * chemists, weather observers, balloon operators, electricians, kitefliers, gunners, minelayers, sappers, engineers, and laborers * * * together with some disinterested scientists, who were to serve as reporters."³² Adams discusses the apparatus which Dyrenforth took with him:

The expedition's equipment was impressive. There were 68 balloons of from 10 to 12 feet in diameter, and one of 20 feet—all to be filled with an explosive mixture of hydrogen and oxygen. There were also sixty 6-inch mortars, made of pipe, and several tons of rackerock (a terrifying blend of potassium chlorate and nitrobenzol that was the general's favorite "explodent"), dynamite, and blasting powder. Finally, there were the makings of a hundred kites, to be assembled on the scene, and sent up with sticks of dynamite lashed to them. The congressional \$9,000 fell considerably short of sufficing for so elaborate an outfit, but expectant Texans chipped in with liberal contributions and the railroads helped out by supplying free transportation.³³

Dyrenforth carried out five series of trials during 1891 and 1892: one period of sustained cannonading coincided with a heavy down-pour, and the apparent connection provided support to the credibility of many people, who accepted the hypotheses as confirmed. Dyrenforth gave optimistic and promising reports of his results; however, meteorologists and other scientists were critical of his work. It does not appear that the Forestry Division was fervently advocating the research program for which it had responsibility. In 1891, Bernhard E. Fernow, Chief of the Division of Forestry, reported to the Secretary of Agriculture his sentiments regarding the experiments which were to be conducted in the coming summer, with a caution reminiscent of the concerns of many meteorologists of the 1970's:

The theories in regard to the causes of storms, and especially their local and temporal distribution, are still incomplete and unsatisfactory. It can by no means be claimed that we know all the causes, much less their precise action in precipitation. It would, therefore, be presumptuous to deny any possible effects of explosions; but so far as we now understand the forces and methods in precipitating rain, there seems to be no reasonable ground for the expectation that they will be effective. We may say, then, that at this stage of meteorological knowledge we are not justified in expecting any results from trials as proposed for the production of artificial rainfall, and that it were better to increase this knowledge first

³¹ Fleagle, "Background and Present Status of Weather Modification," 1968, pp. 7-8.

³² Adams, Samuel Hopkins, *The New Yorker*, Oct. 9, 1952, pp. 93-100.

³³ *Ibid.*, p. 94.

by simple laboratory investigations and experiments preliminary to experiment on a larger scale.³⁴ In 1893, the Secretary of Agriculture asked for no more public funds for support of this project.³⁵

Fleagle tells about the use of 36 "hail cannons" by Albert Stiger, a town burgomaster, on the hills surrounding his district in Austria in 1896:

The hail cannon consisted of a vertically pointing three-centimeter mortar above which was suspended the smokestack of a steam locomotive. This device not only produced an appalling sound, but also created a smoke ring a meter or more in diameter which ascended at about one hundred feet per second and produced a singing note lasting about ten seconds. Initial successes were impressive, and the hail cannon was widely and rapidly copied throughout central Europe. Accidental injuries and deaths were numerous, and in 1902 an international conference was called by the Austrian government to assess the effects of the hail cannon. The conference proposed two tests, one in Austria and one in Italy, the results of which thoroughly discredited the device.³⁶

Though unsuccessful, the work of Dyrenforth and others had inspired belief in the possibilities of drought alleviation such that a number of unscrupulous "rainmakers" were able to capitalize on the situation. Halacy gives an account of a famous rainmaker of the early 20th century, Charles Warren Hatfield, who operated for about 10 years in the western United States. With a 25-foot platform and a secret device for dispensing chemicals, he claimed to create rain over extensive areas. In 1916, Hatfield contracted with the city of San Diego to alleviate drought conditions and was to be paid \$1,000 for each inch of rain produced. When 20 inches of rain coincidentally fell nearby, the resulting floods destroyed a dam, killed 17 people, and produced millions of dollars damage. Hatfield, faced with a choice of assuming financial responsibility for the lawsuits or leaving the city without pay, chose the latter.³⁷

One of Hatfield's accomplices was a colorful racetrack reporter from New York, who met and joined Hatfield in California in 1912, named James Stuart Aloysius MacDonald, alias Colonel Stingo, "the Honest Rainmaker." Over his half-century career as a writer, mostly for various horseracing journals, MacDonald reportedly involved himself in various schemes for quick profit, including weather changing projects on both the west and east coasts. Contracts with clients were drawn up with terms for remuneration that resembled very much the language of success or failure at the racetrack. By his own admission, MacDonald based his odds for success on past weather data for a given area, which he obtained from records of the U.S. Weather Bureau or the New York Public Library.³⁸ MacDonald, or Colonel Stingo, was the inspiration for a Broadway play called "The Rainmaker" which opened in 1954.

DEVELOPMENT OF SCIENTIFIC FUNDAMENTALS

Espy's 1839 proposal for an experiment on the production of convection currents and water vapor condensation at high altitudes was

³⁴ Fernow, Bernhard E., in report to Jeremiah McClain Rusk, Secretary of Agriculture, 1891, as reported in Ward, "Artificial Rain: a Review of the Subject to the Close of 1889," 1892, p. 492.

³⁵ Byers, "History of Weather Modification," 1974, p. 5.

³⁶ Fleagle, "Background and Present Status of Weather Modification," 1968, p. 9.

³⁷ Halacy, "The Weather Changers," 1968, pp. 68-69.

³⁸ Liebling, A. J., "Profiles," *The New Yorker*, Sept. 20, 1952, pp. 45-71.

based on sound physical principles. Since knowledge of atmospheric processes was expanding and unfolding rapidly at the time, Hartman reminds us that the limited usefulness of Espy's weather modification concepts should not be ascribed to faulty logic, but rather to the primitive understanding at the time of the complex processes in precipitation, many of which are still not understood satisfactorily.³⁹

The understanding which meteorologists have today about precipitation has been learned slowly and sometimes painfully, and, while many of the discoveries have resulted from 20th century research, some important findings of the latter part of the 19th century are fundamental to these processes. Important results were discovered in 1875 by Coulier in France on foreign contaminant particles in the normal atmosphere, and quantitative measurements of the concentrations of these particles were achieved by Aitken in 1879. These events established a basis for explaining the fundamental possibility for occurrence of precipitation. Earlier, it had been learned that high supersaturations were required for the formation of water droplets.⁴⁰ Aitken was the first to imply that there are two types of nuclei, those with an affinity for water vapor (hygroscopic particles) and nuclei that require some degree of supersaturation in order to serve as condensation centers. The Swedish chemist-meteorologists of the 1920's developed a theory of condensation on hygroscopic nuclei and showed the importance of sea-salt particles. In the 1930's in Germany and the United Kingdom, a series of measurements were conducted on the numbers and sizes of condensation nuclei by Landsberg, Judge, and Wright. Data from measurements near Frankfurt, augmented subsequently by results from other parts of the world, have been adopted as the standard of reference for condensation nuclei worldwide.⁴¹

At the beginning of the 1930's important aspects of cloud physics were not yet understood. In particular, the importance of the ice phase to precipitation was not yet clarified, though, ever since the turn of the century meteorologists were aware that water droplets were abundantly present in clouds whose temperatures were well below the freezing point. Little was known about the microphysics of nucleation of ice crystals in clouds; however, it had been noted that rains fell only after visible glaciation of the upper parts of the clouds. Understanding of these processes was essential before scientific seeding of clouds for weather modification could be pursued rationally. In 1933 Tor Bergeron presented and promulgated his now famous theory on the initiation of precipitation in clouds containing a mixture of liquid and ice. W. Findeisen expanded on Bergeron's ideas and published a clearer statement of the theory in 1938; consequently, the concept is generally known as the Bergeron-Findeisen theory.⁴² In his investigation of the formation of ice crystals, Findeisen was of the opinion that they crystallized directly from the vapor (that is, by sublimation) rather than freezing from droplets. He also conjectured that quartz crystals might be the nuclei responsible for this process and even foresaw that the mechanism might be initiated artificially by introducing suitable nuclei.⁴³

³⁹ Hartman, "Weather Modification and Control," 1966, p. 13.

⁴⁰ *Ibid.*

⁴¹ Byers, "History of Weather Modification," 1974, p. 7.

⁴² *Ibid.*, p. 8.

⁴³ *Ibid.*, pp. 8-9.

Findeisen stated emphatically that rain of any importance must originate in the form of snow or hail, though Bergeron had admitted the occurrence of warm rain in the tropics. Though many meteorologists doubted that the ice crystal process was an absolute requirement for rain, they had been unable to collect evidence from aircraft observations. In Germany aerological evidence was obtained on the growth of rain drops by the collision-coalescence process in "warm" clouds, but the papers on this work were published in 1940, and World War II restricted communication of the results to meteorologists worldwide. Meanwhile in the United States, papers were published on the theory of the warm rain process. In 1938, Houghton showed that precipitation could be started by either the Bergeron process or by the collision-coalescence process. He noted that drops could be formed by condensation on "giant" hygroscopic nuclei present in the air and that growth of droplets to raindrop size was possible through collision. G. C. Simpson elucidated further on condensation and precipitation processes in 1941, disagreeing with Findeisen's rejection of "warm" rain formation by the collision-coalescence process.⁴⁴

EARLY CLOUD-SEEDING EXPERIMENTS

Starting about 1920 and continuing for about two decades until the outbreak of World War II, there were a number of experiments and operations intended to produce rain or modify the weather in some other way. Although some of these activities were pursued in a scientific manner, others were less so and were directed at producing immediate results; all of these projects lacked the benefit of the fundamental knowledge of precipitation processes that was to be gained later during this same period, the discoveries of which are discussed in the preceding subsection. Various schemes during this period included the dispensing of materials such as dust, electrified sand, dry ice, liquid air, and various chemicals, and even the old idea that explosions can bring rain. Field tests were conducted in the United States, Germany, the Netherlands, and the Soviet Union.

Byers tells about the experimental work of Dr. E. Leon Chaffee, professor of physics at Harvard, who became interested in the possibility of making cloud particles coalesce by sprinkling electrically charged sand over the clouds:

Dr. Chaffee became enthusiastic about the idea and developed in his laboratory a nozzle for charging sand and dispersing it from an airplane. The nozzle could deliver sand grains having surface gradients of the order of 1,000 V/cm. Flight experiments were carried out in August and September of 1924 at Aberdeen, Md., with an airplane scattering the sand particles in the clear air above clouds having tops at 5,000 to 10,000 feet. Dr. Chaffee reported "success" in the reverse sense, in that several clouds were observed to dissipate after treatment. The tests were well publicized in newspapers and scientific news journals, and this author, then a freshman at the University of California, recalls that his physics professors were enthusiastic about the idea. Chaffee's results probably would not endure the type of statistical scrutiny to which experiments of this kind are subject today.⁴⁵

Chaffee considered several trials successful, since clouds were dissipated after being sprayed with the charged sand. It has been pointed

⁴⁴ *Ibid.*, p. 9.

⁴⁵ *Ibid.*, p. 5.

out, however, in view of the much greater experience in recent years, that scientists must be extremely cautious in ascribing success in such experiments, when the evidence is based largely on visual observations.⁴⁶

In the Netherlands, August Veraart successfully produced rain by seeding clouds with dry ice from a small aircraft in 1930. This was 16 years before the work at General Electric in the United States, when clouds were also seeded with dry ice, initiating the modern period in the history of weather modification. Since Veraart probably did not understand the mechanism involved in the precipitation process which he triggered, he did not realize that the dry ice was effective in development of ice crystals by cooling supercooled clouds, and his success was likely only a coincidence. Byers observes that Veraart's vague concepts on changing the thermal structure of clouds, modifying temperature inversions, and creating electrical effects were not accepted, however, by the scientific community.⁴⁷ He claimed to be a true rain-maker and made wide, sweeping claims of his successes. He died in 1932, a year before Bergeron's theory appeared, not aware of the theoretical basis for his work.⁴⁸

Partly successful experiments on the dissipation of fog were conducted by the Massachusetts Institute of Technology in the 1930's, under the direction of Henry G. Houghton. At an airfield near Round Hill, Mass., fog was cleared using sprays of water-absorbing solutions, particularly calcium chloride, as well as fine particles of dry hygroscopic material. Results of these experiments, which predated some of the present-day fog dispersal attempts by some 30 years, were reported in 1938.⁴⁹

WEATHER MODIFICATION SINCE 1946

CHRONOLOGY

The following chronology of "critical events" relating to weather modification policy, compiled by Fleagle, unfolds only some of the major events and activity periods which have occurred since the historic discoveries of 1946:⁵⁰

1946: Schaefer demonstrated seeding with dry ice.

1947: Vonnegut demonstrated seeding with silver iodide.

1947-55: Irving Langmuir advertised weather modification widely and aggressively.

1947-53: General Electric field experiments ("Cirrus") extended evidence that clouds can be deliberately modified, but failed to demonstrate large effects.

1948-50: Weather Bureau Cloud Physics Project on cumulus and stratiform clouds resulted in conservative estimate of effects.

1948-52: Commercial operations grew to cover 10 percent of United States.

1950: Report of Panel on Meteorology of Defense Department's Research and Development Board (Haurwitz, Chairman) was adverse to Langmuir's claims.

1953: Public Law 83-256 established President's Advisory Committee on Weather Control.

⁴⁶ McDonald, James E., "An Historical Note on an Early Cloud-Modification Experiment." *Bulletin of the American Meteorological Society*, vol. 42, No. 3, March 1961, p. 195.

⁴⁷ Byers, "History of Weather Modification." 1947, p. 6.

⁴⁸ Hartman, "Weather Modification and Control." 1966, p. 15.

⁴⁹ Houghton, Henry G., and W. H. Radford, "On the Local Dissipation of Natural Fog." *Papers in Physical Oceanography and Meteorology*, Massachusetts Institute of Technology and Woods Hole Oceanographic Institution, vol. 6, No. 3, Cambridge and Woods Hole, Mass., October 1938, 63 pp.

⁵⁰ Fleagle, Robert G., "An Analysis of Federal Policies in Weather Modification." Background paper prepared for use by the U.S. Department of Commerce Weather Modification Advisory Board, Seattle, Wash., March 1977, pp. 3-5.

1953-54: "Petterssen" Advisory Committee organized field tests on storm systems, convective clouds, and cold and warm fog (supported by the Office of Naval Research, the Air Force, the Army Signal Corps, and the Weather Bureau). These statistically controlled experiments yielded results which have been substantially unchanged in subsequent tests.

1957: Report of Advisory Committee (Orville, Chairman) concluded that tests showed 15 percent increase in orographic winter precipitation.

1957: Major cut in research support across the board by Defense Department sends major perturbation through research structure.

1958: Public Law 85-510 assigned lead agency responsibility to the National Science Foundation (NSF).

1959: Commercial operations had diminished to cover about one percent of the United States.

1961: First hurricane seeding under Project Stormfury.

1961: Bureau of Reclamation authorized by Congress to conduct research in weather modification.

1961: RAND report on weather modification emphasized complexity of atmospheric processes and interrelation of modification and prediction.

1962-70: Randomized field experiments established magnitude of orographic effects.

1964: Preliminary report of National Academy of Sciences/Committee on Atmospheric Sciences (NAS/CAS) roused anger of private operators and stimulated the evaluation of operational data.

1964-present: Department of the Interior pushed the case for operational seeding to augment water supplies.

1966: NAS/CAS report 1850 laid the basis for expanded Federal programs.

1966: Report of NSF Special Commission on Weather Modification and an NSF symposium called attention to social, economic, and legal aspects.

1966: Interdepartmental Committee for Atmospheric Sciences (ICAS) report (Newell, Chairman) proposed expanded Federal support to \$90 million by 1970.

1966-68: Efforts of the Departments of Commerce and Interior to gain lead agency status were unsuccessful.

1967: ICAS recommended that Commerce be designated as lead agency.

1967: S. 2916, assigning lead agency responsibility to the Department of Commerce; passed the Senate but did not become law.

1967-72: Military operational programs conducted in Vietnam.

1968: Public Law 90-407 removed the NSF mandate as lead agency.

1968: Detrimental effects of acid rain reported from Sweden.

1969: Public Law 91-190 (National Environmental Policy Act) required impact statements.

1970: Massachusetts Institute of Technology Study of Critical Environmental Problems called attention to inadvertent effects on climate.

1970: Stratospheric contamination by SST's suggested.

1971: Departments of Commerce and Interior carried out operational programs in Oklahoma and Florida.

1971: Public Law 92-205 required filing of reports of non-Federal weather modification activities with the Department of Commerce.

1971: International Study of Man's Impact on Climate raised this issue to international level.

1971: NAS/CAS report on priorities for the 1970's emphasized need for attention to management and policy problems of weather modification.

1971: Federal Council for Science and Technology approved seven national projects under various lead agencies.

1971-72: First technological assessments of weather modification projects are favorable to operational programs.

1971-74: Climate impact assessment program (CIAP) of Department of Transportation indicates potentially serious consequences of large SST fleet but suggests ways to ameliorate the problem.

1972: Failure of Soviet wheat crop and drought in Sahel emphasized critical need for understanding climate and the value of effective weather modification.

1973: Weather modification budget reduced by impoundment from \$25.4 million to \$20.2 million.

1973: Five national projects deferred or terminated.

1973: NAS/CAS report on weather and climate modification confirmed earlier conclusions and recommended lead agency status for NOAA.

1974: Stratospheric contamination by freon reported.

1974: Domestic Council organized panels in climate change and weather modification.

1974: General Accounting Office report on weather modification criticized weather modification program and pointed to need for lead agency.

1974: Defense Department released information on operations in Vietnam.

1974: The United States and the U.S.S.R. agreed to a joint statement intended "to overcome the dangers of the use of environmental modification techniques for military purposes."

1975: World Meteorological Organization Executive Committee proposed cumulus experiment perhaps in Africa or Iran.

1975: Department of Transportation CIAP report indicated that a fleet of 500 SST's would deplete ozone significantly, but suggested that cleaner engines could be developed.

1976: Chinese disapproval resulted in abandoning plans for Stormfury in the western Pacific.

1976: Hearings held on three weather modification bills by Senate Commerce Committee.

1976: The National Weather Modification Policy Act of 1976 (Public Law 94-859) enacted requiring study of weather modification.

1977: Exceptionally dry winter in the west stimulates State operational programs intended to increase mountain snowpack.

Since the completion of Fleagle's list above in March 1977, at least three other activities of equivalent significance ought to be noted:

1977: The U.S. Department of Commerce Weather Modification Advisory Board established in April 1977 and initiated a major study on a recommended national policy and Federal program of research in weather modification, in accordance with requirements to be fulfilled by the Secretary of Commerce under Public Law 94-490, the National Weather Modification Policy Act of 1976.

1977: The United Nations General Assembly approved a treaty banning environmental modification activities for hostile purposes on May 18, 1977; and the treaty opened for signature by the member nations.

1978: The Report of the Commerce Department's Weather Modification Advisory Board transmitted through the Secretary of Commerce to the Congress.

The history of the modern period of weather modification which follows is essentially that of the two decades following the monumental discoveries of 1946. An excellent account of the history of weather modification, which emphasizes this period, has been prepared by Byers.⁵¹ This work has been very helpful in some of the material to follow and is referenced frequently. The late 1960's and the 1970's are so recent that events during this period are discussed in various sections of the report as ongoing activities or events leading to current activities in weather modification research programs, operations, and policy decisions rather than in this chapter as an integral part of an updated history of the subject.

LANGMUIR, SCHAEFER, AND VONNEGUT

The modern era of scientific weather modification began in 1946, when a group of scientists at the General Electric Co. demonstrated that, through "seeding," a cloud of supercooled water droplets could be transformed into ice crystals and precipitation could be induced. These were not traditional meteorologists, though their leader, Dr. Irving Langmuir, was a famous physicist and Nobel laureate. He and his assistant, Vincent J. Schaefer, had been working for 3 years on cloud physics research, however, in which they were studying particle sizes, precipitation static, and icing. Their field research was carried on

⁵¹ Byers, "History of Weather Modification," 1974, pp. 3-44.

at the summit of Mt. Washington, N.H., where they observed supercooled clouds which often turned into snowstorms.⁵²

In an attempt to simulate field conditions, Schaefer contrived a laboratory setup using a home freezer lined with black velvet, with a light mounted so as to illuminate ice crystals that might happen to form in the box. Breathing into the box, whose temperature was about -23° C, produced fog but no ice crystals, even when various substances—including sand, volcanic dust, sulfur, graphite, talc, and salt—were dropped in as possible sublimation nuclei.⁵³ On July 12, 1946, Schaefer wanted to lower the freezer temperature somewhat, so he inserted a large piece of dry ice, and, in an instant, the air was full of millions of ice crystals. He discovered that even the tiniest piece of dry ice produced the same effect. In fact, dry ice had no direct effect on the supercooled cloud; producing an air temperature below -39° C was critical.⁵⁴

In his paper on the laboratory experiments, published in the November 15, 1946, issues of "Science" Schaefer stated:

It is planned to attempt in the near future a large-scale conversion of supercooled clouds in the atmosphere to ice crystal clouds, by scattering small fragments of dry ice into the cloud from a plane. It is believed that such an operation is practical and economically feasible and that extensive cloud systems can be modified in this way.⁵⁵

Two days before the paper appeared, on November 13, 1946, Schaefer made his historic flight, accomplishing man's first scientific seeding of a supercooled cloud, as he scattered three pounds of dry ice along a 3-mile line over a cloud to the east of Schenectady, N.Y. At 14,000 feet the cloud temperature was -20° C, and in about 5 minutes after seeding the entire cloud turned into snow, which fell 2,000 feet before evaporating.⁵⁶

Dr. Bernard Vonnegut had also worked on aircraft icing research and in 1946 at General Electric was pursuing a variety of nucleation problems; but, after Schaefer's laboratory experiments, he again turned his attention to ice nucleation research. He discovered that silver iodide and lead iodide had crystal structures close to that of ice and were also insoluble in water, and after repeated initial failures, owing to impurities in the material, Vonnegut was able to produce ice crystals, using very pure silver iodide powder, at temperatures only a few degrees below freezing. Soon means were developed for generating silver iodide smokes, and man's first successful attempt at artificial nucleation of supercooled clouds was accomplished.⁵⁷

Langmuir explained that dry ice could make ice crystals form by lowering the temperature to that required for natural nucleation on whatever might be present as nuclei, or even in the absence of all nuclei; however, the silver iodide provided a nucleus that was much more efficient than those occurring naturally.⁵⁸

⁵² *Ibid.*, pp. 9-10.

⁵³ Halney, "The Weather Changers," 1968, pp. 82-83.

⁵⁴ Langmuir, Irving, "The Growth of Particles in Smoke, and Clouds and the Production of Snow from Supercooled Clouds." *Proceedings of the American Philosophical Society*, vol. 92, no. 3, July 1948, p. 182.

⁵⁵ Schaefer, Vincent J., "The Production of Ice Crystals in a Cloud of Supercooled Water Droplets," *Science*, vol. 104, No. 2707, Nov. 15, 1946, p. 459.

⁵⁶ Byers, "History of Weather Modification," 1974, p. 12.

⁵⁷ *Ibid.*, p. 13.

⁵⁸ Langmuir, Irving, "Cloud Seeding by Means of Dry Ice, Silver Iodide, and Sodium Chloride." *Transactions of the New York Academy of Sciences*, ser. II, vol. 14, November 1951, p. 40.

Following Schaefer's successful flight of November 13, 1946, and in the months and immediate years thereafter, Langmuir was quoted in the popular press as being very optimistic in his predicted benefits from weather modification. In a 1948 paper he said that "* * * it becomes apparent that important changes in the whole weather map can be brought about by events which are not at present being considered by meteorologists."⁵⁹ His publications and informal statements of this character touched off years of arguments with professional meteorologists, by whom refutation was difficult in view of Langmuir's standing in the scientific community. His enthusiasm for discussing the potential extreme effects from weather control was unrestrained until his death in 1957.⁶⁰

RESEARCH PROJECTS SINCE 1947

Project Cirrus

Although the business of the General Electric Co. had not been in meteorology, it supported the early research of Langmuir and his associates because of the obvious importance of their discoveries. Realizing that weather modification research was more properly a concern of the Federal Government, the company welcomed the interest of, and contract support from, the U.S. Army Signal Corps in February 1947. Subsequently, contract support was augmented by the Office of Naval Research, the U.S. Air Force provided flight support, and the U.S. Weather Bureau participated in a consultative role. The entire program which followed, through 1951, under this arrangement, including the field activities by Government agencies and the laboratory work and general guidance by General Electric, was designated "Project Cirrus."⁶¹ According to Byers:

The most pronounced effect produced by Project Cirrus and subsequently substantiated by a number of tests by others, was the clearing of paths through supercooled stratus cloud layers by means of seeding from an airplane with dry ice or with silver iodide. When such clouds were not too thick, the snow that was artificially nucleated swept all the visible particles out of the cloud. * * * In one of the first flights, * * * the supercooled particles in stratus clouds were removed using only 12 pounds of dry ice distributed along a 14-mile line. In later flights even more spectacular results were achieved, documented by good photography.⁶²

Initial Project Cirrus studies were made during the summer of 1947 on cumulus clouds near Schenectady, but the important seeding experiments were conducted the following year in New Mexico. Also during 1947, there was an attempt on October 13 to modify a hurricane east of Jacksonville, Fla., through seeding with dry ice.⁶³ Visual observations, reported by flight personnel, seemed to indicate a pronounced change in the cloud deck after seeding, and, shortly thereafter, the hurricane changed its course and headed directly westward, striking the coasts of Georgia and South Carolina. Even though there was precedent for such erratic behavior of hurricanes, there was speculation about the effect of seeding on the storm path, and the possibility of legal responsibility for damages which might be caused by

⁵⁹ Langmuir, Irving. "The Production of Rain by a Chain Reaction in Cumulus Clouds at Temperatures Above Freezing." *Journal of Meteorology*, vol. 5, No. 5, October 1948, p. 192.

⁶⁰ Byers, "History of Weather Modification," 1974, pp. 13-14.

⁶¹ *Ibid.*, p. 14.

⁶² *Ibid.*

⁶³ See discussion of Project Stormfury in ch. 5, p. 296 ff.

such experiments in the future provided reason to avoid seeding thereafter any storms with the potential of reaching land. The legal counsel of the General Electric Co. admonished Langmuir not to relate the course of the hurricane to the seeding; however, throughout the remainder of his career he spoke of the great benefit to mankind of weather control and of the potential ability to abolish evil effects of hurricanes. As a result, it was expected that the U.S. Weather Bureau would undertake massive efforts in weather control. Meteorologists within and without of the Bureau were in a defensive position, with many other scientists, impressed by Langmuir's arguments, opposing their position. Thus great controversies which developed between Langmuir and the Weather Bureau and much of the meteorological community followed these and other claims, and often resulted from the fact that Langmuir did not seem to fully comprehend the magnitude and the mechanisms of atmospheric phenomena.⁶⁴

Langmuir wanted to work where he thought storms originated rather than in upstate New York. He chose New Mexico as operations area for Project Cirrus, also taking advantage of the opportunity to collaborate there with Dr. E. J. Workman at the New Mexico Institute of Mining and Technology, whose thunderstorm research included radar observations and laboratory experiments on the effects of ice on storm electrification. After cloud-seeding flights there in October 1948, Langmuir reported that, as a result of the seeding, rainfall had been produced over an area greater than 40,000 square miles (about one-fourth the area of the State of New Mexico).⁶⁵

The Project Cirrus group returned to New Mexico in July 1949, and 10 additional seeding flights were conducted. When Langmuir learned that Vonnegut was dispensing silver iodide from a ground generator in the same area and had, in fact, also been doing so during the flights of the previous October, he concluded that both the July 1949 results and the widespread effects of October 1948 were caused by the silver iodide rather than the dry ice seeding as he had theorized previously. Spectacular results continued to be reported by him, spurred on by meteorologists' challenges to his statistical methods and conclusions. Noting that Vonnegut had operated the ground generator only on certain days, Langmuir observed that rainfall responses corresponded to generator "on" times, leading him to his controversial "periodic seeding experiment," to which the remainder of his life was devoted.⁶⁶

In the periodic seeding experiment, the silver iodide generators were operated in an attempt to effect a 7-day periodicity in the behavior of various weather properties. Langmuir was convinced that unusual weekly weather periodicities in early 1950 resulted from periodic seedings begun in New Mexico in December 1949, concluding that the effects were more widespread than he felt earlier and that temperatures and pressures thousands of miles away were also affected. Meteorologists observed that, while these correlations were the most striking seen, yet such periodicities were not uncommon.⁶⁷ The Weather Bureau undertook a study of records from 1919 to 1951 to see if such weather perio-

⁶⁴ *Ibid.*, pp. 14-16.

⁶⁵ *Ibid.*, p. 18.

⁶⁶ *Ibid.*, p. 19.

⁶⁷ *Ibid.*, pp. 19-20.

dicities had occurred in the past. Glenn W. Brier, author of the report on this study, indicated that a 7-day component in the harmonic analysis of the data appeared frequently, though seldom as marked as during the periodic seeding experiment.⁶⁸ Byers' opinion is that the evidence appeared just as reliable for occurrence of a natural periodicity as for one controlled artificially. He contends that the most important discoveries in cloud physics and weather modification were made in the General Electric Research Laboratory before Project Cirrus was organized, that the effect of clearing stratus decks was shown soon after the project was underway, and that the seeding experiments thereafter became more of a "program of advocacy than of objective proof." The project "* * * failed to demonstrate that seeding of cumulus clouds increased rainfall, that seeding initiates self-propagating storms, that the atmosphere responds periodically to periodic seeding, or that a hurricane could be deflected in its path by seeding."⁶⁹

Seeding under Project Cirrus ended in 1951 and the final report appeared in 1953. After the close of the project, Langmuir continued his analyses and wrote two more papers before his death in 1957. The final paper was titled "Freedom—the Opportunity To Profit From the Unexpected," a report that Byers feels provided a fitting philosophical close to his career.⁷⁰ The Defense Department sponsored another series of experiments, called the Artificial Cloud Nucleation Project, from 1951 to 1953.

The Weather Bureau Cloud Physics project

Amid increasing publicity and spectacular claims of results from cloud seeding in Project Cirrus, the U.S. Weather Bureau initiated in 1948 a project to test cloud seeding, with the cooperation of the National Advisory Committee for Aeronautics, the Navy, and the Air Force. The Cloud Physics Project, the first systematic series of seeding experiments in stratiform and cumuliform clouds, continued for 2 years, with flight operations in Ohio, California, and the Gulf States. Findings of Project Cirrus were substantiated in that striking visual cloud modifications occurred; however, there was no evidence to show spectacular precipitation effects, and the experiments led to a conservative assessment of the economic importance of seeding.⁷¹ Cloud dissipation rather than new cloud development seemed to be the general result from seeding, the only precipitation extractable from clouds was that contained in the clouds themselves, and cloud seeding methods did not seem to be promising for the relief of drought.⁷²

Results of the cloud physics experiment had almost no effect on the prevalent enthusiasm at the time for rainmaking through cloud seeding, except in the "hard core" of the meteorology community.⁷³ As a result of these experiments and the interpretation of the results, the Weather Bureau and its successor organizations in the Commerce Department, the Environmental Science Services Administration and the National Oceanic and Atmospheric Administration, have been

⁶⁸ Brier, Glenn W., "Seven-Day Periodicities in May 1952," *Bulletin of the American Meteorological Society*, vol. 35, No. 3, March 1954, pp. 118-121.

⁶⁹ Byers, "History of Weather Modification," 1974, pp. 20-21.

⁷⁰ *Ibid.*, p. 20.

⁷¹ Fleagle, Robert G., "Background and Present Status of Weather Modification," 1968, pp. 9-10.

⁷² Byers, "History of Weather Modification," 1974, pp. 16-17.

⁷³ *Ibid.*, p. 17.

regarded by some critics as unimaginative and overconservative on weather modification.⁷⁴

The U.S. experiments of 1953-54

In 1951 the Weather Bureau, the Army, the Navy, and the Air Force appointed an advisory group, chaired by Dr. Sverre Petterssen of the University of Chicago, under whose advice and guidance the following six weather modification projects were initiated:⁷⁵

1. Seeding of extratropical cyclones, sponsored by the Office of Naval Research and conducted by New York University.
2. Seeding of migratory cloud systems associated with fronts and cyclones, conducted by the Weather Bureau.
3. Treatment of convective clouds, supported by the Air Force and conducted by the University of Chicago.
4. Research on the dissipation of cold stratus and fog, conducted by the Army Signal Corps.
5. Studies of the physics of ice fogs, sponsored by the Air Force and conducted by the Stanford Research Institute.
6. Investigation of a special warm stratus and fog treatment system, sponsored by the Army and conducted by Arthur D. Little, Inc.

Field experiments on these projects were carried out in 1953 and 1954, and reports were published under the auspices of the American Meteorological Society in 1957.⁷⁶

The purpose of the extratropical cyclone seeding project, called Project Scud, was to " * * * ascertain whether or not it would be possible to modify the development and behavior of extratropical cyclones by artificial nucleation. * * * " ⁷⁷ Analysis obtained in Scud from Florida to Long Island showed that " * * * the seeding in this experiment failed to produce any effects which were large enough to be detected against the background of natural meteorological variance." ⁷⁸

The Weather Bureau project on migratory cloud systems was conducted in western Washington on cloud systems that enter the area from the Pacific during the rainy winter months. This project was criticized by commercial seeders since it was conducted in the West, which was considered "their territory," and by those who accused the Weather Bureau of seeking a negative result to support their conservative view toward weather modification. Byers feels that there was an attempt to avoid this negative impression by giving a more positive interpretation to the results than the data possibly justified.⁷⁹ In summarizing results, Hall stated:

Considering the results as a whole there is no strong evidence to support a conclusion that the seeding produced measurable changes in rainfall. * * * the evaluations do not necessarily furnish information on what the effect might have been with more or less intense seeding activity, rate of release of dry ice, etc. Also it

⁷⁴ Fleagle, "Background and Present Status of Weather Modification," 1968, p. 10.

⁷⁵ Byers, "History of Weather Modification," 1974, p. 25.

⁷⁶ Petterssen, Sverre, Jerome Spar, Ferguson Hall, Roscoe R. Braham, Jr., Louis J. Battan, Horace R. Byers, H. J. aufm Kampe, J. J. Kelly, and H. K. Weickmann, "Cloud and Weather Modification; a Group of Field Experiments," Meteorological Monographs, vol. 2, No. 11. American Meteorological Society, Boston, 1957, 111 pp.

⁷⁷ Petterssen, Sverre, "Reports on Experiments with Artificial Cloud Nucleation: Introductory Note," In Petterssen et al., "Cloud and Weather Modification; a Group of Field Experiments," Meteorological Monographs, vol. 2, No. 11. American Meteorological Society, Boston, 1957, p. 3.

⁷⁸ Spar, Jerome, "Project Scud," In Petterssen et al., "Cloud and Weather Modification; a Group of Field Experiments," Meteorological Monographs, vol. 2, No. 11. American Meteorological Society, Boston, 1957, p. 22.

⁷⁹ Byers, "History of Weather Modification," 1974, p. 26.

might be speculated that the seeding increased rainfall on some occasions and decreased it on others.⁵⁰

The aim of the University of Chicago Cloud Physics project was as follows:⁵¹

The formulation of a consistent and immediately applicable picture of the processes of formation of cumulus clouds, charged centers, and precipitation with a view toward testing the possibility that one can modify these processes and influence the natural behavior of clouds.

So that as many cumulus clouds as possible could be tested, work was conducted in the Middle West in the summer and in the Caribbean in the winter, realizing that the warm trade-wind cumulus clouds in the latter region might be amenable to seeding with large hygroscopic nuclei or water spray, and that the ice-crystal process would operate to initiate precipitation in the colder clouds of the Middle West.⁵² Of the numerous conclusions from this project⁵³ a few will serve to indicate the value of the project to the understanding of cloud phenomena and weather modification. In the Caribbean tests, water spray from an aircraft was seen to increase rainfall as determined by radar echoes; analysis showed that the treatment doubled the probability of occurrence of a radar echo in a cloud. From tests on dry ice seeding in the Middle West it was found that in the majority of cases treated clouds showed an echo, while untreated ones did not, although the sample was considered too small to be significant. In all cases clouds were considered in pairs, one treated by seeding and the other untreated, and only those clouds showing no echo initially were chosen for study.⁵⁴

The seeding experiments with supercooled stratus clouds by the Army Signal Corps essentially substantiated the results of Project Cirrus; however, from these carefully conducted tests a number of new relationships were observed with regard to seeding rates, spread of glaciating effect, cloud thickness, overseeding, and cloud formation after seeding.⁵⁵ The report on this project carefully summarized these relationships and conclusions for both dry ice and silver iodide seeding.⁵⁶

The Air Force project on the physics of ice fogs, conducted by Stanford Research Institute, was intended to learn the relationship to such fogs of synoptic situations, local sources of water, and pollution. Investigations in Alaska at air bases showed that most fogs developed from local sources of water and pollution. In the Arthur D. Little investigation for the Army attempts were made to construct generators which were capable of producing space charges, associated with aerosols, that could bring about precipitation of the water droplets in warm fogs and stratus.⁵⁷

⁵⁰ Hall, Ferguson, "The Weather Bureau ACN Project." In Petterssen et al., "Cloud and Weather Modification; a Group of Field Experiments," Meteorological Monographs, vol. 2, No. 11. American Meteorological Society, Boston, 1957, pp. 45-46.

⁵¹ Braham, Roscoe R., Jr., Louis J. Battan, and Horace R. Byers, "Artificial Nucleation of Cumulus Clouds." In Petterssen et al., "Cloud and Weather Modification; a Group of Field Experiments," 1957, p. 47.

⁵² Byers, "History of Weather Modification," 1974, pp. 26-27.

⁵³ Conclusions are precisely spelled out in somewhat technical terms in: Braham, Battan, and Byers, "Artificial Nucleation of Cumulus Clouds," 1957, pp. 82-83.

⁵⁴ Byers, "History of Weather Modification," 1974, p. 27.

⁵⁵ *Ibid.*

⁵⁶ aufm Kampe, H. J., J. J. Kelly, and H. K. Weickmann, "Seeding Experiments in Subcooled Stratus Clouds." In Petterssen et al., "Cloud and Weather Modification; a Group of Field Experiments," Meteorological Monographs, vol. 2, No. 11. American Meteorological Society, Boston, 1957, p. 93.

⁵⁷ Petterssen, "Reports on Experiments With Artificial Cloud Nucleation: Introductory Note," 1957, p. 4.

Byers, in retrospect, wonders why the results of this series of six experiments, which were carefully controlled statistically, did not receive more attention than was accorded them. He attributes some of this lack of visibility to the publication in the somewhat obscure monograph of the American Meteorological Society⁸⁸ and to the delay in publishing the results, since the Petterssen committee held the manuscripts until all were completed, so that they could be submitted for publication together.⁸⁹

Arizona mountain cumulus experiments

After 1954, the University of Chicago group joined with the Institute of Atmospheric Physics at the University of Arizona in seeding tests in the Santa Catalina Mountains in southern Arizona. These experiments were conducted in two phases, from 1957 through 1960 and from 1961 through 1964, seeding mostly summer cumulus clouds, but some winter storms, with silver iodide from aircraft. In the first phase, analysis of precipitation data from the first 2 years revealed more rainfall during seeded than on nonseeded days; however, during the latter 2 years, considerably more rainfall was achieved on nonseeded days. Combining all data for the 4 years of the first phase yielded overall results with more rain on unseeded days than on seeded days; hence, the experiments were modified and the second phase undertaken. Of the 3 years in the second phase, only one showed more rain on seeded days than on nonseeded ones. None of the analyses attempted could support the hypothesis that airborne silver iodide seeding increased precipitation or influenced its areal extent. Byers suggests that the failure to increase rainfall may have been due to the fact that precipitation initiation resulted from the coalescence process rather than the ice-crystal process.⁹⁰

Project Whitetop

According to Byers, perhaps the most extensive and most sophisticated weather modification experiment (at least up to the time of Byers' historical review in 1973) was a 5-year program of summer convective cloud seeding in south-central Missouri, called Project Whitetop. Conducted from 1960 through 1964 by a group from the University of Chicago, led by Dr. Roscoe R. Braham, the purpose of Whitetop was to settle with finality the question of whether or not summer convective clouds of the Midwest could be seeded with silver iodide to enhance or initiate precipitation. Experimental days were divided into seeding and no seeding days, chosen randomly from operational days suitable for seeding, based on certain moisture criteria. Another feature of the project was the attempt to determine the extent of spreading of silver iodide smoke plumes from the seeding line. Precipitation effects were evaluated by radar and by a rain-gage network.⁹¹

Final analysis of all of the Project Whitetop data showed that the overall effect was that, in the presence of silver iodide nuclei, the rainfall was less than in the unseeded areas. Byers attributes these negative

⁸⁸ Petterssen et al., "Cloud and Weather Modification; a Group of Field Experiments," 1957.

⁸⁹ Byers, "History of Weather Modification," 1974, p. 28.

⁹⁰ *Ibid.*, p. 29.

⁹¹ *Ibid.*, pp. 29-30.

results to the physical data obtained from cloud-physics aircraft. "Most of the Missouri clouds produced raindrops by the coalescence process below the freezing line, and these drops were carried in the updrafts and frozen as ice pellets at surprisingly high subfreezing temperatures (-5°C to -10°C)." He further points out that the measured concentrations of ice particles, for the range of sizes present, were already in the natural unseeded conditions equivalent to those hoped for with seeding; consequently, the silver iodide only had the effect of over-seeding.⁹²

Climax experiments

Following the initial General Electric experiments, it was concluded by Bergeron⁹³ that the best possibility for causing considerable rainfall increase by artificial means might be found in seeding orographic⁹⁴ cloud systems. Consequently, there were almost immediate efforts to increase orographic precipitation, the greatest concentration of such work being in the Western United States. Commercial groups such as power companies and irrigation concerns took the early initiative in attempts to augment snowfall from orographic cloud systems in order to increase streamflow from the subsequent snowmelt.

Colorado State University (CSU) began a randomized seeding experiment in the high Rocky Mountains of Colorado in 1960, under the direction of Lewis O. Grant, to investigate snow augmentation from orographic clouds. The project was designed specifically to (1) evaluate the potential, (2) define seedability criteria, and (3) develop a technology for seeding orographic clouds in central Colorado.⁹⁵ It followed the 1957 report of the President's Advisory Committee for Weather Control, in which it had been concluded that seeding of orographic clouds could increase precipitation by 10 to 15 percent, basing this judgment, however, on data from a large number of seeding programs that had not been conducted on a random basis.⁹⁶

The first group of the CSU seeding experiments took place from 1960 to 1965 in the vicinity of Climax, Colo., and has been designated Climax I. A second set of tests in the same area from 1965 to 1970 has been referred to as Climax II. The Climax experiments are important in the history of weather modification because they were the first intensive projects of their kind and also because positive results were reported.⁹⁷ The precipitation for all seeded cases was greater than for all of the unseeded cases by 9, 13, and 39 percent, respectively, for Climax I, Climax II, and Climax IIB. The latter set of data are a subsample of those from Climax II, from which possibly contaminated cases due to upwind seeding by other groups were eliminated.⁹⁸

⁹² *Ibid.*, p. 30.

⁹³ Bergeron, Tor, "The Problem of an Artificial Control of Rainfall on the Globe; General Effects of Ice Nuclei in Clouds," *Tellus*, vol. 1, No. 1, February 1949, p. 42.

⁹⁴ A definition of orographic clouds, a discussion of their formation, and a summary of attempts to modify them are found in ch. 3, p. 71 ff.

⁹⁵ Grant, Lewis O., and Archie M. Kahan, "Weather Modification for Augmenting Orographic Precipitation." In Wilmot N. Hess (editor), "Weather and Climate Modification," New York, Wiley, 1974, p. 295.

⁹⁶ Advisory Committee on Weather Control. Final Report of the Advisory Committee on Weather Control, Washington, D.C., U.S. Government Printing Office, Dec. 31, 1957, vol. I, p. vi. (The establishment of the Advisory Committee and its activities leading to publication of its final report are discussed in ch. 5, under activities of the Congress and of the executive branch of the Federal Government, see pp. 195, 214, and 236.)

⁹⁷ Byers, "History of Weather Modification," 1974, pp. 30-31.

⁹⁸ Grant and Kahan, "Weather Modification for Augmenting Orographic Precipitation," 1974, p. 298.

Lightning suppression experiments

From 1947 until the close of Project Cirrus, interspersed with his other activities, Vincent Schaefer visited U.S. Forest Service installations in the northern Rockies in order to assist in attempts to suppress lightning by cloud seeding. As early as 1949 an attempt was made to seed thunderstorm clouds with dry ice, dumping it from the open door of a twin-engine aircraft flying at 25,000 feet.⁹⁹ This stimulated curiosity among those involved, but also showed that lightning-prevention research would require a long and carefully planned effort. These early activities led to the formal establishment of Project Skyfire in 1953, aimed at lightning suppression, as part of the overall research program of the Forest Service. Throughout the history of the project, research benefited from the cooperation and support of many agencies and scientific groups, including the National Science Foundation, the Weather Bureau, Munitalp Foundation, the Advisory Committee on Weather Control, the National Park Service, General Electric Research Laboratories, Meteorology, Inc., and several universities. The project was phased out by the Forest Service in the 1970's, since results of years of tests were inconclusive, although there had been some reports of success. Skyfire was the longest continuing Federal weather modification research project, enduring for about 20 years.¹

Fog dispersal research

Experiments were conducted on clearing supercooled fog from runways at Orly Airport in Paris since 1962, using sprays of liquid propane. Soon after these successful tests, the method became operational and has already succeeded in various U.S. Air Force installations. The dissipation of cold fog is now operational also at many locations, including some in North America and in the Soviet Union. Warm fogs, however, are more common over the inhabited globe, and efforts to dissipate them had not advanced very far, even by 1970.²

Hurricane modification

In an earlier discussion of the work of Langmuir and his associates under Project Cirrus, an attempt at hurricane modification was mentioned.³ The historical unfolding of hurricane research in the United States thereafter will not be reported here since it is discussed in detail in chapter 5, under Project Stormfury, now a major weather modification research program of the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce.⁴

Hail suppression

The principal lead in research to suppress hail during the 1950's and 1960's was not in the United States, but mainly elsewhere, particularly in Switzerland, France, Italy, the U.S.S.R., Argentina, Bulgaria, Yugoslavia, Kenya, and Canada. Hail suppression is based on the

⁹⁹ Barrows, J. S., "Preventing Fire from the Sky." In U.S. Department of Agriculture, "The Yearbook of Agriculture, 1968: Science for Better Living." Washington, D.C., U.S. Government Printing Office, 1968, p. 219.

¹ For a more detailed discussion of Project Skyfire, see p. 309, under the weather modification program of the Department of Agriculture in ch. 5.

² Byers, "History of Weather Modification," 1974, p. 33.

³ See p. 39.

⁴ See p. 296.

hypothesis that, if a cloud is supplied with a superabundance of ice nuclei, the available water will be used to form a great number of snow crystals, thus depriving the hailstones of sufficient water to grow to damaging size. Most of the early foreign attempts to suppress hail using explosive rockets or ground-based silver iodide generators proved disappointing.⁵

In the Soviet Union, the Caucasus hail suppression experiments of the mid-1960's were of great interest to cloud physicists. Using radar to locate the zone of greatest water content in convective clouds and rockets with explosive warheads to deliver lead iodide with precision into this zone, the Russians claimed success in suppressing hailstorms, based on statistical reduction in crop damages. Operational hail suppression activity is now conducted on a large scale in the Soviet Union.^{6, 7} Most hail suppression efforts in the United States in the 1960's were commercial operations which did not produce data of any significant value for further analysis.

Foreign weather modification research

While the Russians and some other countries have concentrated on hail suppression research, Australia, like the United States, has been principally concerned with augmenting precipitation. Very shortly after Schaefer first seeded a natural cloud with dry ice, Krauss and Squires of the Australian Weather Bureau seeded stratonimbus clouds in February 1947 near Sidney. The Commonwealth Scientific and Industrial Research Organization (CSIRO) subsequently organized, under Dr. E. G. Bowen, what might then have been the world's outstanding group of cloud physics and weather modification scientists. Byers feels that probably "* * *" no other group contributed more to practical cloud physics during the period approximately from 1950 to 1965."⁸

The Snowy Mountain project in Australia, whose object was to produce a significant precipitation increase over the mountains by silver iodide seeding, has attracted most attention. For a 5-year period from 1955 through 1959, this experiment was conducted during the colder part of the Southern Hemisphere year, using silver iodide dispensed from aircraft. Although initial experimental reports indicated successful increases in precipitation over the target, the final 1963 report after complete analysis stated that results were encouraging but inconclusive.⁹

Interesting experiments were carried out in Israel during the 1960's, using airborne silver iodide seeding of mostly cumulus clouds. Statistical analysis of data from the first 5½ years of tests revealed an increase of 18 percent in rainfall.¹⁰

A project called Grossversuch III was conducted on the southern slopes of the Alps in Switzerland. Although initiated as a randomized hail suppression experiment, using ground-based silver iodide generators, the analysis indicated that hail frequency was greater on

⁵ Byers, "History of Weather Modification," pp. 31-32.

⁶ *Ibid.*, p. 32.

⁷ The hail suppression efforts of the U.S.S.R. are discussed in more detail under the status of hail suppression technology in ch. 3, p. 88, and under foreign programs in ch. 9, 412.

⁸ Byers, "History of Weather Modification," 1974, p. 23.

⁹ *Ibid.*, pp. 23-24.

¹⁰ *Ibid.*, p. 31.

seeded than on nonseeded days, but that the average rainfall on seeded days was 21 percent greater than on nonseeded days.¹¹

COMMERCIAL OPERATIONS

In the weeks and months following Schaefer's first cloud seeding experiment public interest grew, and Langmuir and Schaefer spoke before and consulted with groups of water users, farmers and ranchers, city officials, Federal program directors, and scientific societies. As a result there was a burgeoning of new cloud-seeding efforts initiated by commercial operators, industrial organizations, water districts, and groups of farmers. Some used ground generators for dispensing silver iodide obviating the need for airplanes and their attendant high costs, so that many such operations became quite profitable. Many rain-makers were incompetent and some were unscrupulous, but their activities flourished for a while, as the experiments of Schaefer and Langmuir were poorly imitated. Some of the more reliable companies are still in business today, and their operations have provided data valuable to the development of weather modification technology.¹²

Byers relates a few instances of early commercial operations of particular interest.¹³ In 1949-50 the city of New York hired Dr. Wallace E. Howell, a former associate of Langmuir, to augment its water supply by cloud seeding. New York's citizenry became interested and involved in discussions over Howell's activities as the news media made them known. This project was also the first case where legal action was taken against cloud seeding by persons whose businesses could be adversely affected by the increased rain. Although rains did come and the city reservoirs were filled, Howell could not prove that he was responsible for ending the drought.¹⁴ Howell subsequently seeded in Quebec in August 1953 in an attempt to put out a forest fire and in Cuba to increase rainfall for a sugar plantation owner.¹⁵

The Santa Barbara project in California, also a commercial operation designed to increase water supply, received a great deal of attention. In this period water was increased through augmenting rain and snow in the mountains north and northeast of the city. The project was evaluated by the California State Water Resources Board and was unique among commercial contract operations, inasmuch as the clients permitted randomization (that is, random selection of only some storms for seeding) in order to allow adequate evaluation.¹⁶

In the West the earliest commercial operations were developed under Dr. Irving P. Krick, formerly head of the Department of Meteorology at the California Institute of Technology. Asked to monitor aerial dry ice seeding over Mt. San Jacinto in 1947, Krick became interested in weather modification, left Caltech, and formed his own company. Seeding projects were carried out during 1948 and 1949 for ranchers in San Diego County, Calif., in Mexico, and in Arizona. In 1950 he moved to Denver and formed a new company, which began seeding activity over the Great Plains, elsewhere in the West, and in

¹¹ *Ibid.*

¹² *Ibid.*, pp. 17, 21, 22.

¹³ *Ibid.*, pp. 22-23.

¹⁴ *Ibid.*, p. 22.

¹⁵ Halacy, "The Weather Changers," 1968, pp. 96-97.

¹⁶ *Ibid.*, pp. 22-23.

other countries. A number of former students of Krick joined him or formed other cloud seeding companies, mostly in the West during the 1950's.¹⁷ By 1953 Krick had operated 150 projects in 18 States and 6 foreign countries and amassed over 200,000 hours of seeding time. For three winters—1949, 1950, and 1951—his company claimed that they had increased the snowpack in the Rockies around Denver from 175 to 288 percent over the average of the previous 10 years. After 6 months of seeding in Texas in 1953, the water in a drainage basin near Dallas had increased to 363 percent of the January 1 level, while in nearby nonseeded basins water ranged from a 22-percent deficit to an increase of 19 percent.¹⁸

At the start of extensive seeding in the early 1950's there was a sharp increase in commercial operations, accompanied by great publicity as drought began in the Great Plains. During the middle and latter 1950's, however, seeding diminished as did the drought. The some 30 annual seeding projects in the United States during the mid and latter 1950's and the 1960's (excluding fog clearing projects) were conducted for the most part by about five firms, on whose staffs there were skilled meteorologists, cloud physicists, and engineers for installing and maintaining ground and air systems. Most of these projects were in the categories of enhancing rain or snowfall, with a distribution in a typical year as follows: About a dozen in the west coast States, half a dozen in the Rocky Mountains-Great Basin area, half a dozen in the Great Plains, and the remainder in the rest of the United States. Of the projects in the West, six to nine have been watershed projects sponsored by utility companies. Most of these projects endured for long periods of years and many are still underway.¹⁹

Fleagle notes that by the early 1950's, 10 percent of the land area of the United States was under commercial seeding operations and \$3 million to \$5 million was being expended annually by ranchers, towns, orchardists, public utilities, and resort operators. The extent of such commercial operations receded sharply, and by the late 1950's business was only about one-tenth or less than it had been a decade earlier. As noted above, public utilities were among those who continued to sponsor projects throughout this period.²⁰

Figure 1 shows the purposes of weather modification operations for various sections of the United States for the period July 1950 through June 1956. For each geographical section the column graphs represent the percentage of the total U.S. seeding for each of five purposes that was performed in that section. The bar graph in the inset shows the percentage of total U.S. cloud-seeding effort that is undertaken for each of these five purposes. Figure 2 shows the total area coverage and the percent of U.S. territory covered by cloud seeding for each year from July 1950 through June 1956. Both figures are from the final report of the President's Advisory Committee on Weather Control.²¹

¹⁷ Elliott, Robert D., "Experience of the Private Sector," 1974, p. 47.

¹⁸ Halacy, "The Weather Changers," 1968, p. 96.

¹⁹ Elliott, "Experience of the Private Sector," 1974, p. 46-48.

²⁰ Fleagle, "Background and Present Status of Weather Modification," 1968, p. 11.

²¹ Advisory Committee on Weather Control, Final Report, 1958, vol. II. Figures facing p. 242 and 243.

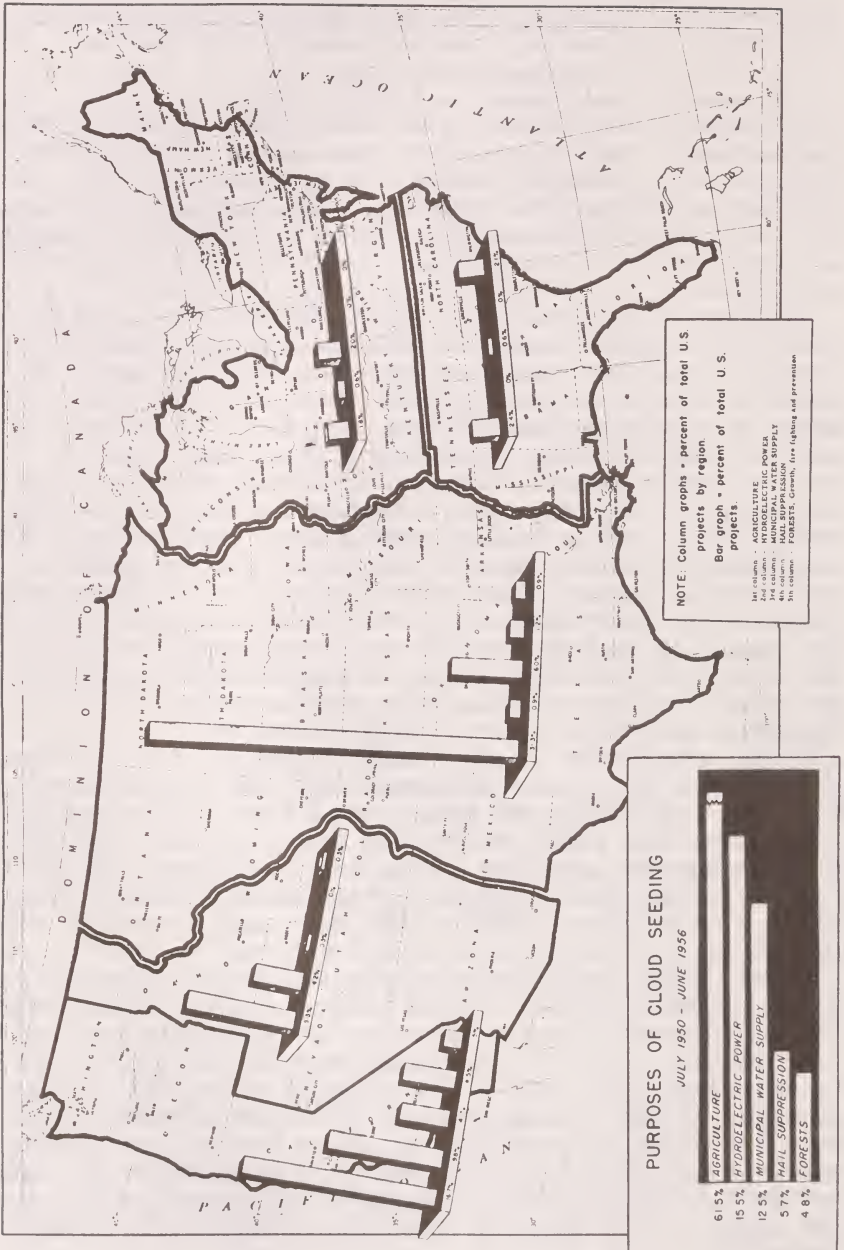


FIGURE 1.—Purposes of weather modification operations conducted in various geographical sections of the United States, July 1950 through June 1956. (From Final Report of the Advisory Committee on Weather Control, 1958.)

CLOUD SEEDING IN THE UNITED STATES

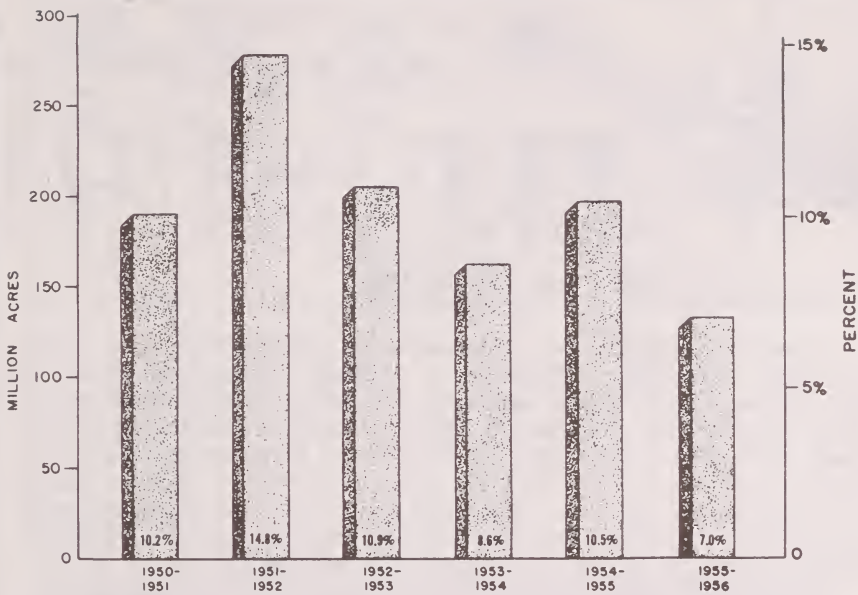


FIGURE 2.—Total area coverage and percent of area coverage for the 48 coterminous States of the United States by weather modification operations for each year, July 1950 through June 1956. (From Final Report of the Advisory Committee on Weather Control, 1958.)

Table 1 is a summary of weather modification operations for fiscal years 1966, 1967, and 1968, compiled by the National Science Foundation from field operators' reports which the Foundation required to be filed. Figure 3 shows the locations in the continental United States for both operational and research weather modification projects during fiscal year 1968. In September 1968, as provided by Public Law 90-407, the National Science Foundation was no longer authorized to require the submission of reports on operational weather modification projects.²² Weather modification activities are now reported to the Department of Commerce, under provisions of Public Law 92-205, and summary reports of these activities are published from time to time.²³

²² See discussions of this law and of the activities of the National Science Foundation as lead weather modification agency through September 1968, pp 196 and 215 in ch. 5.

²³ See discussions of Public Law 92-205 and of the weather modification activities reporting program in ch. 5, 197 and 232. The activities summarized in the latest available Department of Commerce report are discussed in ch. 7 and listed in app. G.

TABLE 1.—SUMMARY OF WEATHER MODIFICATION ACTIVITIES FROM FIELD OPERATORS' REPORTS, FISCAL YEARS 1966, 1967, AND 1968¹ (FROM NSF TENTH ANNUAL REPORT OF WEATHER MODIFICATION, 1968)

Purpose	Area treated (square miles)			Number of projects			Number of States ²			Number of operators ²		
	1966	1967	1968	1966	1967	1968	1966	1967	1968	1966	1967	1968
Rain augmentation and snow- pack increase.....	61,429	62,021	53,369	35	41	37	21	20	21	22	25	23
Hail suppression.....	20,566	20,556	13,510	3	4	4	3	3	5	3	4	4
Fog dissipation.....	100	118	145	22	15	15	15	13	9	17	15	10
Cloud modification.....	19,345	28,300	18,600	9	18	8	8	12	7	8	14	6
Lightning suppression.....	314	314	314	1	1	1	1	1	1	1	1	1
Totals.....	101,744	111,383	85,938	70	79	65	30	23	25	46	44	37

¹ Data for fiscal year 1968 include reports received to Sept. 1, 1968.

² Totals are not the sum of the items since many States and operators are involved in more than one type of activity.

An early commercial hail suppression project was begun in Colorado in 1958. Eventually it involved 5 seeding aircraft and about 125 ground-based generators, making it the largest single cloud-seeding project up to that time. Results of the project were examined at Colorado State University and presented at the International Hail Conference in Verona, Italy, in 1960. This project stimulated the interest of scientists and provided historical roots for what later was established as the National Hail Research Experiment in the same area over a decade later by the National Science Foundation.^{24, 25}

During the 1960's, clearing of cold airport fog through cloud seeding became an operational procedure. Since the techniques used can only be applied to cold fog, they were used at the more northerly or high-altitude airports of the United States, where about 15 such projects were conducted, and are still underway, each winter.²⁶

²⁴ Elliott, "Experience of the Private Sector," 1974, p. 48.

²⁵ The National Hail Research Experiment is discussed in detail under the weather modification program of the National Science Foundation in ch. 5; see p. 274ff.

²⁶ Elliott, "Experience of the Private Sector," 1974, pp. 48-49.

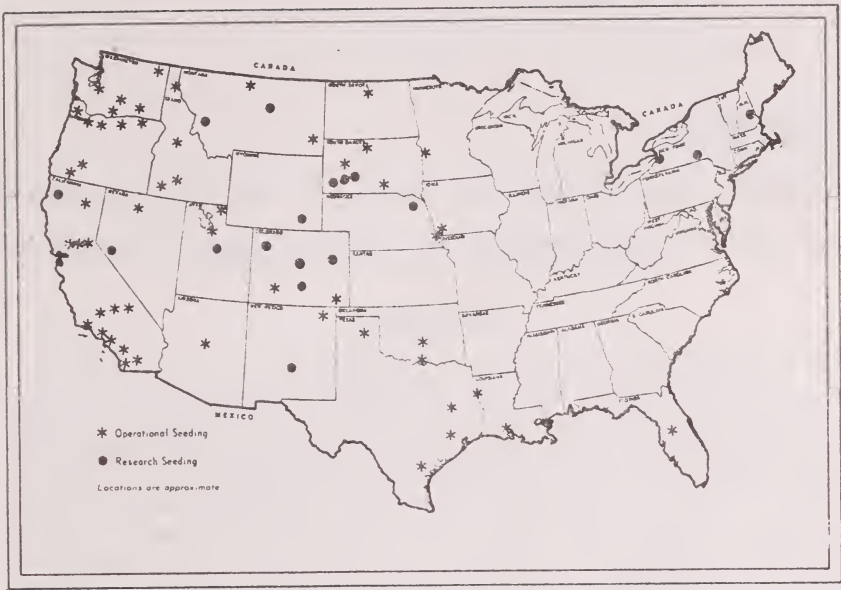


FIGURE 3.—Weather modification projects in the United States during fiscal year 1968. (From NSF Tenth Annual Report on weather modification, 1968.)

HISTORY OF FEDERAL ACTIVITIES, COMMITTEES, POLICY STUDIES, AND REPORTS

In the various discussions under activities of the Congress and the executive branch of the Federal Government in chapter 5, there are historical accounts of legislative actions pertinent to weather modification, of the establishment and functioning of special committees in accordance with public laws or as directed by the executive agencies, and of the policy and planning studies and reports produced by the special committees or by the agencies. Inclusion of a separate historical account of these Federal activities at this point would be largely repetitive, and the reader is referred to the various sections of chapter 5, in which historical developments of various Federal activities are unfolded as part of the discussions of those activities.

CHAPTER 3

TECHNOLOGY OF PLANNED WEATHER MODIFICATION

(By Robert E. Morrison, Specialist in Earth Sciences, Science Policy Research Division, Congressional Research Service)

INTRODUCTION

Although the theoretical basis for weather modification was laid to a large extent during the 1930's, the laboratory and field experiments which ushered in the "modern era" occurred in 1946 and in the years immediately thereafter. By 1950, commercial cloud seeding had become widespread, covering an estimated total U.S. land area of about 10 percent.¹ By the mid-1950's, however, it was apparent that the fundamental atmospheric processes which come into play in weather modification are very complex and were far from being understood. A period of retrenchment and reevaluation began, the number of commercial operators had decreased dramatically, and weather modification had fallen into some disrepute among many meteorologists and much of the public. A period of carefully designed experiments was initiated about two decades ago, supported by increased cloud physics research and increasingly more sophisticated mathematical models and statistical evaluation schemes.

Meanwhile, a small group of commercial operators, generally more reliable and more responsible than the typical cloud seeder of the 1950 era, has continued to provide operational weather modification services to both public and private sponsors. These operators have attempted to integrate useful research results into their techniques and have provided a bank of operational data useful to the research community. The operational and research projects have continued over the past two decades, often in a spirit of cooperation, not always characteristic of the attitudes of scientists and private operators in earlier years. Often the commercial cloud seeders have contracted for important roles in major field experiments, where their unique experiences have been valuable assets.

Through the operational experiences and research activities of the past 30 years, a kind of weather modification technology has been emerging. Actually, though some practices are based on common theory and constitute the basic techniques for meeting a number of seeding objectives, there are really a series of weather modification technologies, each tailored to altering a particular atmospheric phenomenon and each having reached a different state of development and operational usefulness. At one end of this spectrum is cold fog clearing, considered to be operational now, while the abatement of severe storms, at

¹ Fleagle, Robert G., "Background and Present Status of Weather Modification." In "Weather Modification: Science and Public Policy," Seattle, University of Washington Press, 1968, p. 11.

the other extreme, remains in the initial research phase. Progress to date in development of these technologies has not been nearly so much a function of research effort expended as it has depended on the fundamental atmospheric processes and the ease by which they can be altered. There is obvious need for further research and development to refine techniques in those areas where there has been some success and to advance technology where progress has been slow or at a virtual standstill.

ASSESSMENT OF THE STATUS OF WEATHER MODIFICATION TECHNOLOGY

Recently, the following summary of the current status of weather modification technology was prepared by the Weather Modification Advisory Board:

1. The only routine operational projects are for clearing cold fog. Research on warm fog has yielded some useful knowledge and good models, but the resulting technologies are so costly that they are usable mainly for military purposes and very busy airports.

2. Several long-running efforts to increase winter snowpack by seeding clouds in the mountains suggest that precipitation can be increased by some 15 percent over what would have happened "naturally."

3. A decade and a half of experience with seeding winter clouds on the U.S. west coast and in Israel, and summer clouds in Florida, also suggest a 10- to 15-percent increase over "natural" rainfall. Hypotheses and techniques from the work in one area are not directly transferable to other areas, but will be helpful in designing comparable experiments with broadly similar cloud systems.

4. Numerous efforts to increase rain by seeding summer clouds in the central and western parts of the United States have left many questions unanswered. A major experiment to try to answer them—for the High Plains area—is now in its early stages.

5. It is scientifically possible to open holes in wintertime cloud layers by seeding them. Increasing sunshine and decreasing energy consumption may be especially relevant to the northeastern quadrant of the United States.

6. Some \$10 million is spent by private and local public sponsors for cloud-seeding efforts, but these projects are not designed as scientific experiments and it is difficult to say for sure that operational cloud seeding causes the claimed results.

7. Knowledge about hurricanes is improving with good models of their behavior. But the experience in modifying that behavior is primitive so far. It is inherently difficult to find enough test cases, especially since experimentation on typhoons in the Western Pacific has been blocked for the time being by international political objections.

8. Although the Soviets and some U.S. private operators claim some success in suppressing hail by seeding clouds, our understanding of the physical processes that create hail is still weak. The one major U.S. field experiment increased our understanding of severe storms, but otherwise proved mostly the dimensions of what we do not yet know.

9. There have been many efforts to suppress lightning by seeding thunderstorms. Our knowledge of the processes involved is fair, but

the technology is still far from demonstrated, and the U.S. Forest Service has recently abandoned further lightning experiments.²

Lewis O. Grant recently summarized the state of general disagreement on the status of weather modification technology and its readiness for application.

There is a wide diversity of opinion on weather modification. Some believe that weather modification is now ready for widespread application. In strong contrast, others hold that application of the technology may never be possible or practical on any substantial scale.³

He concludes that—

Important and steady advances have been made in developing technology for applied weather modification, but complexity of the problems and lack of adequate research resources and commitment retard progress.⁴

In 1975, David Atlas, then president of the American Meteorological Society, expressed the following pessimistic opinion on the status of weather modification technology:

Almost no one doubts the economic and social importance of rainfall augmentation, hail suppression, fog dissipation, and severe storm abatement. But great controversy continues about just what beneficial modification effects have been demonstrated or are possible. Claims and counterclaims abound. After three decades of intense research and operational weather modification activities, only a handful of experiments have demonstrated beneficial effects to the general satisfaction of the scientific community.

To describe weather modification as a "technology" is to encourage misunderstanding of the state of the weather modification art. The word "technology" implies that the major substantive scientific foundations of the field have been established and, therefore, that all that is required is to develop and apply techniques. But one of the conclusions of the special AMS study on cloud physics was that "the major bottleneck impeding developments of useful deliberate weather modification techniques is the lack of an adequate scientific base."⁵

At a 1975 workshop on the present and future role of weather modification in agriculture, a panel of 10 meteorologists assessed the capabilities for modifying various weather and weather-related phenomena, both for the present and for the period 10 to 20 years in the future. Conclusions from this assessment are summarized in table 1. The table shows estimated capabilities for both enhancement and dissipation, and includes percentages of change and areas affected, where appropriate.⁶

A recent study by Barbara Farhar and Jack Clark surveyed the opinions of 551 scientists, all involved in some aspect of weather modification, on the current status of various weather modification technol-

² Weather Modification Advisory Board, "A U.S. Policy to Enhance the Atmospheric Environment," Oct. 21, 1977. In testimony by Harlan Cleveland "Weather Modification," hearing before the Subcommittee on the Environment and the Atmosphere, Committee on Science and Technology, U.S. House of Representatives, 95th Cong., 1st sess., Oct. 26, 1977, Washington, D.C., U.S. Government Printing Office, 1977, pp. 28-30.

³ Grant, Lewis O., "Scientific and Other Uncertainties of Weather Modification." In William A. Thomas (editor), "Legal and Scientific Uncertainties of Weather Modification," Proceedings of a symposium convened at Duke University, Mar. 11-12, 1976, by the National Conference of Lawyers and Scientists, Durham, N.C., Duke University Press, 1977, p. 7.

⁴ *Ibid.*, p. 17.

⁵ Atlas, David, "Selling Atmospheric Science. The President's Page," Bulletin of the American Meteorological Society, vol. 56, No. 7, July 1975, p. 688.

⁶ Grant, Lewis O. and John D. Reid (compilers), "Workshop for an Assessment of the Present and Potential Role of Weather Modification in Agricultural Production," Colorado State University, Fort Collins, Colo., July 15-18, 1975, August 1975. PB-245-633, pp. 34-44.

ogies.⁷ Table 2 is a summary of the assessments of the level of development for each of 12 such technologies included in the questionnaire to which the scientists responded, and table 3 shows the estimates of effectiveness for 7 technologies where such estimates are pertinent. Results of this study were stratified in accordance with respondents' affiliation, specific education, level of education, age, and responsibility or interest in weather modification, and tabulated summaries of opinions on weather modification in accordance with these variables appear in the report by Farhar and Clark.⁸

TABLE 1.—ASSESSMENT OF THE CAPABILITIES FOR MODIFYING VARIOUS WEATHER AND WEATHER-RELATED NATURAL PHENOMENA, BASED ON THE OPINIONS OF 10 METEOROLOGISTS

[From Grant and Reid, 1975]

Modified variable	Enhancement				Dissipation			
	Now	10 to 20 yr	Amount change (per-cent)	Area (square miles)	Now	10 to 20 yr	Amount change (per-cent)	Area (square miles)
I. Clouds:								
1. Cold stratus	No (8)	Yes (7)	-----	1-1000	Yes (10)	Yes (10)	-----	1-1000
2. Warm stratus	No (10)	No (5)	-----	-----	No (8)	Yes (9)	-----	-----
3. Fog, cold	Yes (10)	Yes (10)	-----	1-10	Yes (10)	Yes (10)	-----	1-1000
4. Fog, warm	Yes (10)	Yes (10)	-----	1-100	Yes (10)	Yes (10)	-----	.1-1
5. Fog, artificial (for temperature control)	Yes (10)	Yes (10)	-----	1-10	N/A	N/A	-----	-----
6. Contrails	Yes (10)	Yes (10)	-----	100-1000	No (10)	No (10)	-----	-----
7. Cirrus	Yes (5)	Yes (10)	-----	100-1000	No (10)	No (8)	-----	-----
8. Carbon black	No (10)	No (6)	-----	-----	N/A	N/A	-----	-----
9. Aerosol	Yes (7)	Yes (10)	-----	-----	N/A	N/A	-----	-----
II. Convective precipitation:								
1. Isolated small	Yes (7)	Yes (10)	100	10-100	Yes (5)	Yes (8)	100	10-100
2. Isolated large	No (6)	Yes (7)	15	100-1000	Yes (5)	Yes (8)	15	10-1000
3. Squall lines	Yes (5)	Yes (5)	20	100-10,000	No (8)	Yes (5)	20	100-10,000
4. Nocturnal	Yes (5)	Yes (6)	100	100-1000	No (8)	Yes (5)	100	100-1000
5. Imbedded cyclonic	Yes (9)	Yes (10)	30	300-6000	Yes (8)	Yes (10)	<5	300-6000
6. Imbedded Orographic	Yes (9)	Yes (10)	20	300-6000	Yes (8)	Yes (10)	20	300-6000
III. Stratiform precipitation:								
1. Orographic	Yes (10)	Yes (10)	10	100-3000	Yes (10)	Yes (10)	10	100-3000
2. Cyclonic	No (10)	No (6)	-----	-----	No (10)	No (6)	-----	-----
3. Cloud water collection	Yes (10)	Yes (10)	-----	-----	N/A	N/A	-----	-----
IV. Hazards:								
1. Hail	Yes (5)	Yes (7)	(¹)	100-60,000	Yes	Yes	30	100-60,000
2. Lightning	Yes (7)	Yes (9)	(¹)	40,000	Yes (7)	Yes (9)	40	40,000
3. Erosion—wind gradient	No (10)	No (10)	-----	-----	No (10)	No (10)	-----	-----
4. Erosion—water drop size	Yes (5)	Yes (7)	(¹)	10,000	Yes (5)	Yes (7)	-----	10,000
5. Wind—hurricane	No (5)	Yes (6)	-----	-----	No (6)	Yes (6)	-----	-----
6. Tornado	No (10)	Yes (5)	-----	-----	No (10)	Yes (5)	-----	-----
7. Blowdown	No (5)	Yes (5)	-----	-----	No (9)	Yes (5)	-----	-----
8. Floods—synoptic	No (10)	No (10)	-----	-----	No (10)	No (3)	-----	-----
9. Floods—mesoscale	No (9)	Yes (6)	-----	-----	No (9)	Yes (6)	-----	-----
10. Drought	No (10)	No (10)	-----	-----	Yes (5)	Yes (6)	-----	-----
V. Other:								
1. Albedo	Yes (5)	Yes (10)	-----	-----	Yes (5)	Yes (10)	-----	-----
2. Surface roughness	No (6)	Yes (6)	-----	-----	No (6)	Yes (6)	-----	-----
3. Topography changes	No (6)	Yes (5)	-----	-----	No (6)	Yes (5)	-----	10-100

¹ Uncertain.

⁷ Farhar, Barbara C. and Jack A. Clark, "Can We Modify the Weather? a Survey of Scientists." Final report, vol. 3 (draft), Institute of Behavioral Science, University of Colorado, Boulder, Colo., January 1978. (Based on research supported by the National Science Foundation under grants No. ENV74-18613 A03, GI-35452, GI-44087, and ERT74-18613, as part of "A Comparative Analysis of Public Support of and Resistance to Weather Modification Projects.") 89 pp.

⁸ Ibid.

TABLE 2.—ASSESSMENT OF THE LEVEL OF DEVELOPMENT OF TWELVE WEATHER MODIFICATION TECHNOLOGIES BASED UPON A SURVEY OF 551 WEATHER MODIFICATION SCIENTISTS

[From Farhar and Clark, 1978]

Weather modification technology	Operations ¹		Research ²		Neither		Don't know		Other		Total No.
	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	
Cold fog dispersal	78	406	8	42	0	1	14	72	0	0	521
Precipitation enhancement, winter orographic, continental	68	357	20	104	1	6	11	57	0	1	525
Precipitation enhancement, winter orographic, maritime	64	337	22	113	1	5	13	70	0	1	526
Hail suppression	46	244	49	256	1	4	4	23	0	1	528
Precipitation enhancement, summer convective, continental	43	227	49	258	2	10	6	31	0	1	527
Precipitation enhancement, summer convective, maritime	42	220	46	244	1	5	11	56	0	2	529
Warm fog dispersal	33	170	48	253	1	3	18	92	0	0	518
Precipitation enhancement with hail suppression	30	156	56	288	2	12	12	62	0	1	519
Precipitation enhancement, general storms	25	128	58	300	5	28	12	64	0	2	522
Lightning suppression	8	42	65	332	4	22	23	119	0	0	515
Hurricane suppression	4	19	75	388	4	23	17	88	0	2	520
Severe storm mitigation	3	13	68	353	9	47	20	101	0	1	515

¹ This category is a combination of two responses: "The technology is ready for operational application" and "The technology can be effectively applied; research should continue."

² This category is a combination of two responses: "The technology is ready for field research only" and "The technology should remain at the level of laboratory research."

TABLE 3.—ESTIMATES OF EFFECTIVENESS FOR SEVEN WEATHER MODIFICATION TECHNOLOGIES, BASED ON A SURVEY OF 551 WEATHER MODIFICATION SCIENTISTS
[From Farhar and Clark, 1978]

Technology	Number responding	Percent don't know	Percent giving estimates	Percent zero	Range of estimates ¹ (percent)	Median of estimates (percent)	Modal response, estimates ² (percent)	Mean estimates (percent)	Standard deviation of estimates (percent)
Hail suppression (reduction in crop damage over a year)-----	534	59.6	40.1	4.9	0 to 82		25 D.K., 50	30.0	9.7
Rainfall increase (continental convective, over a growing season, individual clouds)-----	504	45.0	54.4	3.57	0 to 300		20 D.K., 10	41.0	49.4
Rainfall increase (continental convective, over a growing season, area wide)-----	517	47.6	51.8	7.93	0 to 100		9 D.K., 10	10.5	10.9
Rainfall increase (maritime, over a year, individual clouds)-----	510	57.1	42.4	3.33	0 to 900		26 D.K., 100	63.2	98.5
Rainfall increase (maritime, over a year, area wide)-----	505	61.8	37.8	5.54	0 to 250		9 D.K., 10	15.1	27.1
Snowpack increase (orographic, winter season)-----	534	32.0	63.3	1.31	0 to 100		15 D.K., 15	18.3	16.5
Precipitation effects (tropical storms, coastal areas)-----	532	84.8	15.0	3.6					
Increases-----			7.5		0 to 159		19 D.K., 9	28.2	38.0
Decreases-----			2.1		0 to 69		12 D.K., 19	16.8	16.4
Increases and decreases-----			3.1						

¹ The value of zero was included in all computations of central tendency and distribution.

² Estimates of effectiveness are bimodal, one mode being "Don't know", (D.K.), the other numerical from given estimates.

³ No percentages of estimated effect were available from those predicting both increases and decreases in precipitation for coastal areas from seeding tropical storms.

CLASSIFICATION OF WEATHER MODIFICATION TECHNOLOGIES

In a previous review of weather modification for the Congress, three possible classifications of activities were identified—these classifications were in accordance with (1) the nature of the atmospheric processes to be modified, (2) the agent or mechanism used to trigger or bring about the modification, or (3) the scale or dimensions of the region in which the modification is attempted.⁹ The third classification was chosen in that study, where the three scales considered were the microscale (horizontal distances, generally less than 15 kilometers), the mesoscale (horizontal distances generally between 15 and 200 kilometers), and the macroscale (horizontal distances generally greater than 200 kilometers).¹⁰ Examples of modification of processes on each of these three scales are listed in table 4, data in which are from Hartman.¹¹ Activities listed in the table are illustrative only, and there is no intent to indicate that these technologies have been developed, or even attempted in the case of the listed macroscale processes.

TABLE 4.—WEATHER AND CLIMATE MODIFICATION ACTIVITIES CLASSIFIED ACCORDING TO THE SCALE OR DIMENSIONS OF THE REGION IN WHICH THE MODIFICATION IS ATTEMPTED

[Information from Hartman, 1966]

Scale	Horizontal dimensions	Examples of modification processes
Microscale.....	Less than 15 km.....	Modification of human microclimates. Modification of plant microclimates. Evaporation suppression. Fog dissipation. Cloud dissipation. Hail prevention. Precipitation through individual cloud modification.
Mesoscale.....	15 to 200 km.....	Precipitation from cloud systems. Hurricane modification. Modification of tornado systems.
Macroscale.....	Greater than 200 km.....	Changes to global atmospheric circulation patterns. Melting the Arctic icecap. Diverting ocean currents.

In this chapter the characteristics and status of weather modification activities will be classified and discussed according to the nature of the processes to be modified. This seems appropriate since such a breakdown is more consonant with the manner the subject has been popularly discussed and debated, and it is consistent with the directions in which various operational and research activities have moved. Classification by the second criterion above, that is, by triggering agent or mechanism, focuses on technical details of weather modification, not of chief interest to the public or the policymaker, although these details will be noted from time to time in connection with discussion of the various weather modification activities.

In the following major section, then, discussion of the principles and the status of planned weather modification will be divided accord-

⁹ Hartman, Lawton M. "Characteristics and Scope of Weather Modification." In U.S. Congress, Senate Committee on Commerce, "Weather Modification and Control," Washington, D.C., U.S. Government Printing Office, 1966. (89th Cong., 2d sess., Senate Rept. No. 1139, prepared by the Legislative Reference Service, Library of Congress), p. 20.

¹⁰ *Ibid.*

¹¹ *Ibid.*, pp. 21-31.

ing to the major broad categories of phenomena to be modified; these will include:

- Precipitation augmentation.
- Hail suppression.
- Fog dissipation.
- Lightning suppression.
- Severe storm mitigation.

In subsequent major sections of this chapter there are reviews of some of the specific technical problem areas common to most weather modification activities and a summary of recommended research activities.

In addition to the intentional changes to atmospheric phenomena discussed in this chapter, it is clear that weather and climate have also been modified inadvertently as the result of man's activities and that modification can also be brought about through a number of naturally occurring processes. These unintentional aspects of weather and climate modification will be addressed in the following chapter of this report.¹²

PRINCIPLES AND STATUS OF WEATHER MODIFICATION TECHNOLOGIES

Before discussing the status and technologies for modification of precipitation, hail, fog, lightning, and hurricanes, it may be useful to consider briefly the basic concepts of cloud modification. The two major principles involved are (1) colloidal instability and (2) dynamic effects. Stanley Changnon describes how each of these principles can be effective in bringing about desired changes to the atmosphere:¹³

Altering colloidal stability.—The physical basis for most weather modification operations has been the belief that seeding with certain elements would produce colloidal instability in clouds, either prematurely, to a greater degree, or with greater efficiency than in nature. Most cloud seeding presumes that at least a portion of the treated cloud is supercooled, that nature is not producing any or enough ice at that temperature of the cloud, and that treatment with chemical agents of refrigerants will change a proportion of the cloud to ice. The resultant mixture of water and ice is unstable and there is a rapid deposition of water vapor upon the ice and a simultaneous evaporation of water from the supercooled droplets in the cold part of the cloud. The ice crystals so formed become sufficiently large to fall relative to remaining droplets, and growth by collection enhances the probability that particles of ice or water will grow to be large enough to fall from the cloud and become precipitation.

This process of precipitation enhancement using ice nucleants has been demonstrated for the stratiform type cloud, and generally for those which are orographically-produced and supercooled. Cumulus clouds in a few regions of the United States have also been examined for the potential of colloidal instability in their supercooled portions. This has been founded on beliefs that precipitation (1) can be initiated earlier than by natural causes, or (2) can be produced from a cloud which was too small to produce precipitation naturally.

Seeding in the warm portion of the cloud, or in "warm clouds" (below the freezing level), has also been attempted so as to alter their colloidal instability. Warm-cloud seeding has primarily attempted to provide the large droplets necessary to initiate the coalescence mechanism, and is of value in clouds where insufficient large drops exist. In general alteration of the coalescence process primarily precipitates out the liquid water naturally present in a cloud, whereas the ice-crystal seeding process also causes a release of latent energy that conceivably results in an intensification of the storm, greater cloud growth, and additional precipitation.

Altering cloud dynamics.—The effects to alter the colloidal instability of clouds, or their microphysical processes, have been based on the concept of rain

¹² See p. 145.

¹³ Changnon, Stanley A., Jr. "Present and Future of Weather Modification: Regional Issues." *The Journal of Weather Modification*, vol. 7, No. 1, April 1975, pp. 154-156.

increase through increasing the precipitation efficiency of the cloud. Simpson and Dennis (1972) showed that alterations of cloud size and duration by "dynamic modification" could produce much more total rainfall than just altering the precipitation efficiency of the single cloud. In relation to cumulus clouds, "dynamic seeding" simply represents alteration one step beyond that sought in the principle of changing the colloidal stability. In most dynamic seeding efforts, the same agents are introduced into the storm but often with a greater concentration, and in the conversion of water to ice, enormous amounts of latent heat are hopefully released producing a more vigorous cloud which will attain a greater height with accompanying stronger updrafts, a longer life, and more precipitation. Seeding to produce dynamic effects in cloud growth, whether stratiform or cumuliform types, is relatively recent at least in its serious investigation, but it may become the most important technique. If through controlled cloud seeding additional uplift can be produced, the productivity in terms of rainfall will be higher whether the actual precipitation mechanism involved is natural or artificial.

It has been proposed that the selective seeding of cumulus clouds also can either (a) bring upon a merger of two or more adjacent clouds and a much greater rainfall production through a longer-lived, larger cloud * * * or (b) produce eventually an organized line of clouds (through selective seeding of randomized cumulus). The latter could allegedly be accomplished by minimizing and organizing the energy into a few vigorous systems rather than a larger number of isolated clouds.

Essentially, then, dynamic seeding is a label addressed to processes involved in altering cloud microphysics in a selective and preferential way to bring upon more rainfall through an alteration of the dynamical properties of the cloud system leading to the development of stronger clouds and mesoscale systems. Actually, dynamic effects might be produced in other ways such as alterations of the surface characteristics to release heat, by the insertion of chemical materials into dry layers of the atmosphere to form clouds, or by redistribution of precipitation through microphysical interactions in cloud processes.

The various seeding materials that have been used for cloud modification are intended, at least initially, to change the microphysical cloud structure. Minute amounts of these materials are used with the hope that selected concentrations delivered to specific portions of the cloud will trigger the desired modifications, through a series of rapid multiplicative reactions. Seeding materials most often used are classified as (1) ice nuclei, intended to enhance nucleation in the supercooled part of the cloud, or (2) hygroscopic materials, designed to alter the coalescence process.¹⁴

Glaciation of the supercooled portions of clouds has been induced by seeding with various materials. Dry ice injected into the subfreezing part of a cloud or of a supercooled fog produces enormous numbers of ice crystals. Artificial ice nuclei, with a crystal structure closely resembling that of ice, usually silver iodide smoke particles, can also produce glaciation in clouds and supercooled fogs. The organic fertilizer, urea, can also induce artificial glaciation, even at temperatures slightly warmer than freezing. Urea might also enhance coalescence in warm clouds and warm fogs. Water spray and fine particles of sodium chloride have also been used in hygroscopic seeding, intended to alter the coalescence process. There have been attempts to produce coalescence in clouds or fog using artificial electrification, either with chemicals that increase droplet combination by electrical forces, or with surface arrays of charged wires whose discharges produce ions which, attached to dust particles, may be transported to the clouds.¹⁵

Problems of cloud seeding technology and details of seeding delivery methods are discussed in a later section of this chapter, as are

¹⁴ *Ibid.*, p. 156.

¹⁵ *Ibid.*, pp. 156-157.

some proposed techniques for atmospheric modification that go beyond cloud seeding.¹⁶

PRECIPITATION AUGMENTATION

The seeding of clouds to increase precipitation, either rainfall or snowfall, is the best known and the most actively pursued weather modification activity. Changes in clouds and precipitation in the vicinity of cloud seeding operations have shown unquestionably that it is possible to modify precipitation. There is evidence, however, that such modification attempts do not always increase precipitation, but that under some conditions precipitation may actually be decreased, or at best no net change may be effected over an area. Nevertheless, continued observations of clouds and precipitation, from both seeded and nonseeded regions and from both experiments and commercial operations, are beginning to provide valuable information which will be useful for distinguishing those conditions for which seeding increases, decreases, or has no apparent effect on precipitation. These uncertainties were summarized in one of the conclusions in a recent study on weather modification by the National Academy of Sciences:¹⁷

The Panel now concludes on the basis of statistical analysis of well-designed field experiments that ice-nuclei seeding can sometimes lead to more precipitation, can sometimes lead to less precipitation, and at other times the nuclei have no effect, depending on the meteorological conditions. Recent evidence has suggested that it is possible to specify those microphysical and mesophysical properties of some cloud systems that determine their behavior following artificial nucleation.

Precipitation enhancement has been attempted mostly for two general types of cloud forms, both of which naturally provide precipitation under somewhat different conditions. Convective or cumulus clouds are those which are formed by rising, unstable air, brought about by heating from below or cooling in the upper layers. Under natural conditions cumulus clouds may develop into cumulo-nimbus or "thunderheads," capable of producing heavy precipitation. Cumulus clouds and convective systems produce a significant portion of the rain in the United States, especially during critical growing seasons. Attempts to augment this rainfall from cumulus clouds under a variety of conditions have been underway for some years with generally uncertain success. The other type of precipitation-producing clouds of interest to weather modifiers are the orographic clouds, those which are formed when horizontally moving moisture-laden air is forced to rise over a mountain. As a result of the cooling as the air rises, clouds form and precipitation often falls on the windward side of the mountain. Through seeding operations, there have been attempts to augment precipitation through acceleration of this process, particularly in winter, in order to increase mountain snowpack.

Figures 1 and 2 show regions of the coterminous United States which are conducive to precipitation management through seeding of spring and summer convective clouds and through seeding orographic cloud systems, respectively. The principles of precipitation

¹⁶ See pp. 115 and 129.

¹⁷ National Academy of Sciences, National Research Council, Committee on Atmospheric Sciences, "Weather and Climate Modification: Problems and Progress," Washington, D.C., 1973, p. 4.

enhancement for both cumulus and orographic clouds, and the present state of knowledge and technology for such modification, are discussed in the following sections.

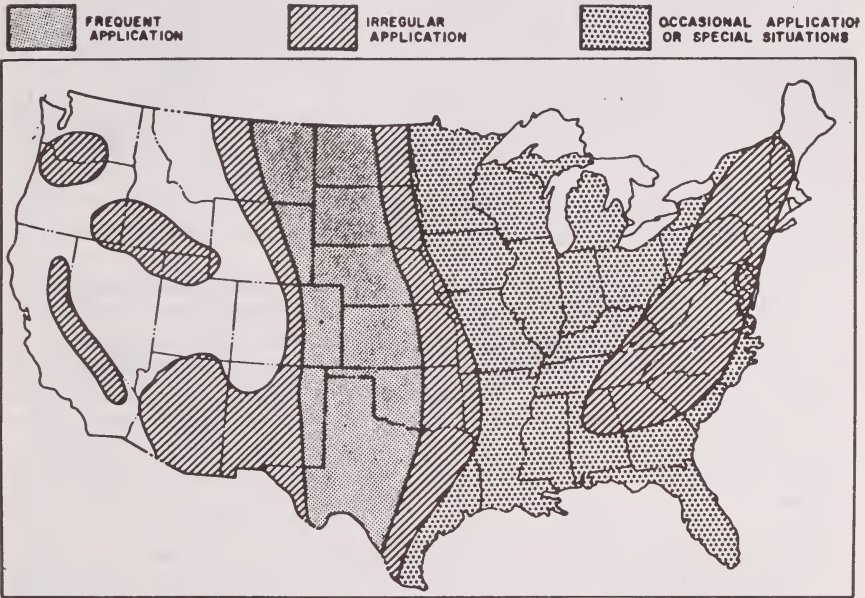


FIGURE 1.—Regions where precipitation management may be applied to enhance rainfall from spring and summer showers.



FIGURE 2.—Regions where precipitation management may be applied to enhance snowfall from winter orographic weather systems, thus augmenting spring and summer runoff from mountain snowpacks.

Cumulus clouds

If air containing moisture is cooled sufficiently and if condensation nuclei such as dust particles are present, precipitation may be produced. This process occurs when air is forced to rise by convection, so that the water vapor condenses into clouds. Cumulus clouds are the woolly vertical clouds with a flat base and somewhat rounded top, whose origin can always be traced to the convection process. They can most often be observed during the summer and in latitudes of high temperature. When updrafts become strong under the proper conditions, cumulus clouds often develop into cumulonimbus clouds, the principal producer of precipitation. About three-fourths of the rain in the tropics and subtropics and a significant portion of that falling on the United States is provided from cumulus clouds and convective systems.

The science of cloud study, begun in the 1930's and greatly expanded following World War II, includes two principal aspects—cloud microphysics and cloud dynamics. Though once approached separately by different groups of scientists, these studies are now merging into a single discipline. In cloud physics or microphysics the cloud particles—such as condensation and freezing nuclei, water droplets, and ice crystals—are studied along with their origin, growth, and behavior. Cloud dynamics is concerned with forces and motions in clouds, the prediction of cloud structure, and the life cycle of updrafts and downdrafts.¹⁸

For cloud modification purposes, present theories of microphysical processes provide an ample basis for field seeding experiments; however, further work is still needed on laboratory experiments, improved instrumentation, and research on assumptions. On the other hand, the processes in cloud dynamics are not completely understood and require continued research.¹⁹

Most cumulus clouds evaporate before they have had opportunity to produce precipitation at the Earth's surface. In fact many clouds begin to dissipate at about the same time that rain emerges from their bases, leading to the impression that they are destroyed by the formation of precipitation within them. This phenomenon is not yet fully understood. Cumulus clouds have a life cycle; they are born, mature, and eventually age and die. Small cumuli of the trade regions live only about 5 to 10 minutes, while medium-sized ones exist for about 30 minutes. On the other hand, a giant cumulonimbus cloud in a hurricane or squall line may be active for one to several hours. In its lifetime it may exchange over 50 million tons of water, producing heavy rain, lightning, and possibly hail. At all times, however, a cumulus cloud struggles to exist; there is a precarious balance between the forces aiding its growth and its destruction.²⁰

The increasing capability to simulate cloud processes on the computer has been a major advance toward understanding cloud modification. The ways in which cloud microphysics influences convective

¹⁸ Simpson, Joanne and Arnett S. Dennis, "Cumulus Clouds and Their Modification." In Wilmet N. Hess (ed.), "Weather and Climate Modification," New York, John Wiley & Sons, 1974, p. 233.

¹⁹ Moschandreass, Demetrios J., and Irving Leichter, "Present Capabilities to Modify Cumulus Clouds," Geomet, Inc. report No. EF-463. Final report for U.S. Navy Environmental Prediction Research Facility, Mar. 30, 1976, p. 209.

²⁰ Simpson and Dennis, "Cumulus Clouds and Their Modification," 1947, pp. 234-235.

dynamics are not well documented or modeled, however. Feedback mechanisms are dynamic and thermodynamic. Dynamically, the buoyancy is reduced by the weight of the particles formed within the cloud, sometimes called "water loading." Modeling suggests that thermodynamic feedback from the microphysics can be even more important, as evaporation at the edges of the cloud produces cooling and thus induces downdrafts. Observations confirm this important influence of evaporation, particularly where the cloud environment is relatively dry, but the effect is minimized in humid tropical regions.²¹

Cumulus modification experiments

An enormous amount of energy is expended in natural atmospheric processes. As much energy as the fusion energy of a hydrogen super-bomb is released in a large thunderstorm, and in a moderate-strength hurricane the equivalent of the energy of 400 bombs is converted each day. In his attempt to modify precipitation from clouds, man must therefore look for some kind of a trigger mechanism by which such energetically charged activities can be controlled, since he cannot hope to provide even a fraction of the energy involved in the natural process. A major problem in evaluating modification efforts is the large natural variability in atmospheric phenomena. A cumulus cloud can, in fact, do almost anything all by itself, without any attempt to modify its activity by man. This high variability has led the layman to overestimate grossly what has been and can be done in weather modification. In designing an experiment, this variability requires that there be sound statistical controls.²²

Precipitation is formed by somewhat different processes in warm clouds and in subfreezing clouds. In the former, droplets are formed from condensation of water vapor on condensation nuclei and grow through collision and coalescence into raindrops. In subfreezing clouds, such as the cumuli under discussion, supercooled water droplets are attached to ice nuclei which grow into larger ice particles. When large enough, these particles fall from the cloud as snow or sleet or may be converted to rain if the temperature between the cloud and the Earth's surface is sufficiently warm. Increasing precipitation through artificial means is more readily accomplished in the case of the subfreezing clouds. In addition, attempts have been made to promote the merging of cumulus clouds in order to develop larger cloud systems which are capable of producing significantly more precipitation than would be yielded by the individual small clouds.

Nearly all cumulus experiments have involved "seeding" the clouds with some kind of small particles. Sometimes the particles are dispersed from the ground, using air currents to move them into the clouds. Most often the materials are dispensed from aircraft, by releasing them upwind of the target clouds, by dropping them into the cloud top, by using the updraft from beneath the cloud, or by flying through the cloud. Although more expensive, aircraft seeding permits more accurate targeting and opportunity for measurements and observations. In the Soviet Union, cumulus clouds have been seeded success-

²¹ Simpson, Joanne, "Precipitation Augmentation from Cumulus Clouds and Systems: Scientific and Technical Foundations," 1975, *Advances in Geophysics*, vol. 19, New York, Academic Press, 1976, pp. 10-11.

²² Simpson and Dennis, "Cumulus Clouds and Their Modification," 1974, pp. 240-241.

fully with artillery shells and rockets, using radar to locate parts of the clouds to be seeded.²³

Augmentation of precipitation in cumulus clouds has been attempted both by accelerating the coalescence process and by initiating ice particle growth in the presence of supercooled water. In fact, these processes are essentially identical in cumuli where the tops extend above the freezing level.

Prior to the 1960's nearly all supercooled seeding experiments and operations were concerned with attempting to increase precipitation efficiency, based on consideration of cloud microstructure.²⁴ This is essentially a static approach, intended to produce precipitation by increasing the total number of condensation nuclei, through the introduction of artificial nuclei injected by seeding into or under the clouds. This approach has been moderately successful in convective storms with conducive cloud microstructure in a number of locations—California, Israel, Switzerland, and Australia—where clouds are often composed of small supercooled droplets, typical of winter convection and of continental air masses.²⁵ On the other hand, the large cumulus clouds originating in tropical and subtropical ocean regions, which are evident over much of the eastern United States during the summer, are much less influenced by this static approach. A technique known as dynamic seeding has shown promise in enhancing precipitation from clouds of this type.

According to dynamic seeding philosophy, the strength, size, and duration of vertical currents within the cloud have stronger control on cumulus precipitation than does the microstructure. In this technique, first demonstrated in the 1960's, the seeding provides artificial nuclei around which supercooled water freezes, liberating large quantities of latent heat of fusion, within the clouds, causing them to become more buoyant and thus to grow to greater heights. This growth invigorates circulation within the cloud, causes increased convergence at its base, fosters more efficient processing of available moisture, and enhances rainfall through processes by which cumuli ordinarily produce such precipitation. Results of the Florida Area Cumulus Experiment (FACE), conducted by the U.S. Department of Commerce, seem to indicate that dynamic seeding has been effective in increasing the sizes and lifetimes of individual cumuli and the localized rainfall resulting from them.²⁶

Success thus far in rain enhancement from dynamic seeding of cumulus has been demonstrated through seeding techniques applied to single, isolated clouds. In addition to the experiments in Florida, dynamic seeding of single clouds has been attempted in South Dakota, Pennsylvania, Arizona, Australia, and Africa, with results similar to those obtained in Florida.²⁷ It appears, however, that a natural process necessary for heavy and extensive convective rainfall is the merger of cloud groups. Thus, this process of cloud merger must be promoted in order for cloud seeding to be effective in augmenting rainfall from

²³ *Ibid.*, p. 242.

²⁴ *Ibid.*, 1974, pp. 246–247.

²⁵ *Ibid.*, p. 247.

²⁶ William L. Woodley, Joanne Simpson, Ronald Blondini, and Joyce Berkeley. "Rainfall Results, 1970–1975; Florida Area Cumulus Experiment," *Science*, vol. 195, No. 4280, Feb. 25, 1977, p. 735.

²⁷ Simpson and Dennis, "Cumulus Clouds and Their Modification," 1974, p. 261.

cumulus clouds. The FACE experiment has been designed to investigate whether dynamic seeding can induce such cloud merger and increased rainfall.²⁸ Area wide cumulus cloud seeding experiments are also planned for the U.S. Department of the Interior's High Plains Cooperative program (HIPLEX), being conducted in the Great Plains region of the United States.^{29, 30} There has been some indication that desired merging has been accomplished in the Florida experiment.³¹ Though this merging and other desirable effects may be achieved for Florida cumulus, it must be established that such mergers can also be induced for other convective systems which are found over most of the United States east of the Great Plains. Changnon notes that, "The techniques having the most promise for rain enhancement from convective clouds have been developed for single, isolated types of convective clouds. The techniques have been explored largely through experimentation with isolated mountain-type storms or with isolated semitropical storms. * * * Weather modification techniques do not exist for enhancing precipitation from the multicellular convective storms that produce 60 to 90 percent of the warm season rainfall in the eastern two-thirds of the United States."³²

Effectiveness of precipitation enhancement research and operations

A major problem in any precipitation enhancement project is the assessment of whether observed increases following seeding result from such seeding or occur as part of the fluctuations in natural precipitation not related to the seeding. This evaluation can be attempted through observations of physical changes in the cloud system which has been seeded and through statistical studies.

Physical evaluation requires theoretical and experimental investigations of the dispersal of the seeding agent, the manner that seeding has produced changes in cloud microstructure, and changes in gross characteristics of a cloud or cloud system. Our understanding of the precipitation process is not sufficient to allow us to predict the magnitude, location, and time of the start of precipitation. Hence, because of this lack of detailed understanding and the high natural variability of precipitation, it is necessary to use statistical methods as well. There is a closer physical link between seeding and observable changes in cloud microstructure; however, even the latter can vary widely with time and position in natural, unseeded clouds, so that statistical evaluation is also required with regard to the measurement of these quantities.³³

It should first be determined whether the seeding agent reached the intended region in the cloud with the desired concentration rather

²⁸ Woodley, et al., "Rainfall Results, 1970-1975; Florida Area Cumulus Experiment," 1977, p. 735.

²⁹ Bureau of Reclamation, U.S. Department of the Interior, "High Plains Cooperative Program: Progress and Planning Report No. 2," Denver, March 1976, p. 5.

³⁰ The history, purposes, organization, and participants in the FACE and HIPLEX programs are discussed along with other programs of Federal agencies in chapter 5 of this report.

³¹ William L. Woodley and Robert I. Sax, "The Florida Area Cumulus Experiment: Rationale, Design, Procedures, Results, and Future Course," U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, NOAA technical report ERL 354-WMPO 6, Boulder, Colo., January 1976, pp. 41-45.

³² Changnon, Stanley A., Jr., "Present and Future of Weather Modification: Regional Issues" 1975, pp. 159-162.

³³ Warner, J., "The Detectability of the Effects of Seeding," In World Meteorological Organization, Weather Modification Programme, position papers used in the preparation of the plan for the Precipitation Enhancement Experiment (PEP), Precipitation Enhancement Project Report No. 2, Geneva, November 1976, annex I, p. 43.

than spreading into other areas selected as controls. When the agent has been delivered by aircraft, this problem is usually minimized, though even in this case, it is desirable to learn how the material has diffused through the cloud. When ground-based seeding generators are used, the diffusion of the material should be studied both by theoretical studies and by field measurements. Such measurements may be made on the seeding agent itself or on some trace material released either with the seeding agent or separately; this latter might be either a fluorescent material such as zinc sulphide or any of various radioactive materials. Sometimes the tracer might be tracked in the cloud itself, while in other experiments it may be sufficient to track it in the precipitation at the surface.³⁴

In looking for cloud changes resulting from seeding, the natural cloud behavior is needed as a reference; however, since the characteristics of natural clouds vary so widely, it is necessary to observe a number of different aspects of the properties and behavior of seeded clouds against similar studies of unseeded clouds in order to be able to differentiate between the two. It is further desirable to relate such behavior being studied to predictions from conceptual and numerical models, if possible. Direct observations should be augmented by radar studies, but such studies should substitute for the direct measurements only when the latter are not possible.³⁵

A statistical evaluation is usually a study of the magnitude of the precipitation in the seeded target area in terms of its departure from the expected value. The expected quantity can either be determined from past precipitation records or through experimental controls. Such controls are established by dividing the experimental time available roughly in half into periods of seeding and nonseeding, on a random basis. The periods may be as short as a day or be 1 or 2 weeks in duration. The precipitation measured during the unseeded period is used as a measure of what might be expected in the seeded periods if seeding hadn't occurred. In another technique, control areas are selected where precipitation is highly correlated with that in the target area but which are never seeded. The target area is seeded on a random basis and its rainfall is compared with that of the control area for both seeded and unseeded periods. Another possibility includes the use of two areas, either of which may be chosen for seeding on a random basis. Comparisons are then made of the ratio of precipitation in the first area to that in the second with the first area seeded to the same ratio when the second is also seeded. There are many variations of these basic statistical designs, the particular one being used in a given experiment depending on the nature of the site and the measuring facilities available. As with the seeding techniques employed and the physical measurements which are made, experimental design can only be finalized after a site has been selected and its characteristics studied.³⁶

Results achieved through cumulus modification

Cumulus modification is one of the most challenging and controversial areas in weather modification. In some cases randomized seeding efforts in southern California and in Israel have produced significant

³⁴ *Ibid.*, p. 44.

³⁵ *Ibid.*

³⁶ *Ibid.*, p. 45.

precipitation from bands of winter cyclonic storms. However, attempts have been less promising in attributing increased rain during summer conditions to definitive experiments. There has been some success in isolated tropical cumuli, where seeding has produced an increase in cloud height and as much as a twofold to threefold increase in rainfall.³⁷

In the Florida area cumulus experiment (FACE), the effects on precipitation over a target area in southern Florida as a result of seeding cumuli moving over the area is being studied under the sponsorship of the National Oceanic and Atmospheric Administration (NOAA). Analysis of the data from 48 days of experimentation through 1975 provided no evidence that rainfall over the fixed target area of 13,000 square kilometers had been altered appreciably from dynamic seeding. On the other hand, there is positive evidence for increased precipitation from seeding for clouds moving through the area.³⁸

When FACE data from the 1976 season are combined with previous data, however, increasing the total number of experimental days to 75, analysis shows that dynamic seeding under appropriate atmospheric conditions was effective in increasing the growth and rain production of individual cumulus clouds, in inducing cloud merger, and in producing rainfall increases from groups of convective clouds as they pass through the target area. A net increase seemed to result from the seeding when rainfall on the total target area is averaged.³⁹

Further discussion of FACE purposes and results is found under the summary of weather modification programs of the Department of Commerce in chapter 5.⁴⁰

Recent advances in cumulus cloud modification

In the past few years some major advances have been achieved in cumulus experimentation and in improvement of scientific understanding. There has been progress in (1) numerical simulation of cumulus processes and patterning; (2) measurement techniques; (3) testing, tracing, delivery, and targeting of seeding materials; and (4) application of statistical tools. Recognition of the extreme difficulty of cumulus modification and the increased concept of an overall systems approach to cumulus experimentation have also been major advances.⁴¹

Orographic clouds and precipitation

In addition to the convection clouds, formed from surface heating, clouds can also be formed when moist air is lifted above mountains as it is forced to move horizontally. As a result, rain or snow may fall, and such precipitation is said to be orographic, or mountain induced. The precipitation results from the cooling within the cloud and charac-

³⁷ Sax, R. I., S. A. Changnon, L. O. Grant, W. F. Hitschfeld, P. V. Hobbs, A. M. Kahan, and J. Simpson, "Weather Modification: Where Are We Now and Where Should We Be Going? An Editorial Overview," *Journal of Applied Meteorology*, vol. 14, No. 5, August 1975, p. 662.

³⁸ Woodley, et al., "Rainfall Results, 1970-1975; Florida Area Cumulus Experiment," 1977, p. 742.

³⁹ Woodley, William L., Joanne Simpson, Ronald Blondini, and Jill Jordan, "NOAA's Florida Area Cumulus Experiment; Rainfall Results, 1970-1976" In preprints from the Sixth Conference on Planned and Inadvertent Weather Modification, Champaign, Ill., Oct. 10-13, 1977. Boston, American Meteorological Society, 1977, p. 209.

⁴⁰ See p. 292.

⁴¹ Sax, et. al. "Weather Modification: Where Are We Now and Where Should We Be Going? An Editorial Overview," 1975, p. 663.

teristically falls on the windward side of the mountain. As the air descends on the leeward side of the mountain, there is warming and dissipation of the clouds, so that the effect of the mountains is to produce a "rain shadow" or desert area. The Sierra Nevada in western North America provide such conditions for orographic rain and snow along the Pacific coast and a rain shadow east of the mountains when moisture laden air generally flows from the Pacific eastward across this range.

The western United States is a primary area with potential for precipitation augmentation from orographic clouds. This region receives much of its annual precipitation from orographic clouds during winter, and nearly all of the rivers start in the mountains, deriving their water from melting snowpacks. The major limitation on agriculture here is the water supply, so that additional water from increased precipitation is extremely valuable. Streamflow from melting snow is also important for the production of hydroelectric power, so that augmentation of precipitation during years of abnormally low natural snowfall could be valuable in maintaining required water levels necessary for operation of this power resource. Orographic clouds provide more than 90 percent of the annual runoff in many sections of the western United States.⁴²

Figure 3 (a) and (b) are satellite pictures showing the contrast between the snow cover over the Sierra Nevada on April 28, 1975, and on April 19, 1977. This is a graphical illustration of why much of California was drought stricken during 1977. The snowpack which customarily persists in the highest elevations of the Sierras until July had disappeared by mid-May in 1977.⁴³

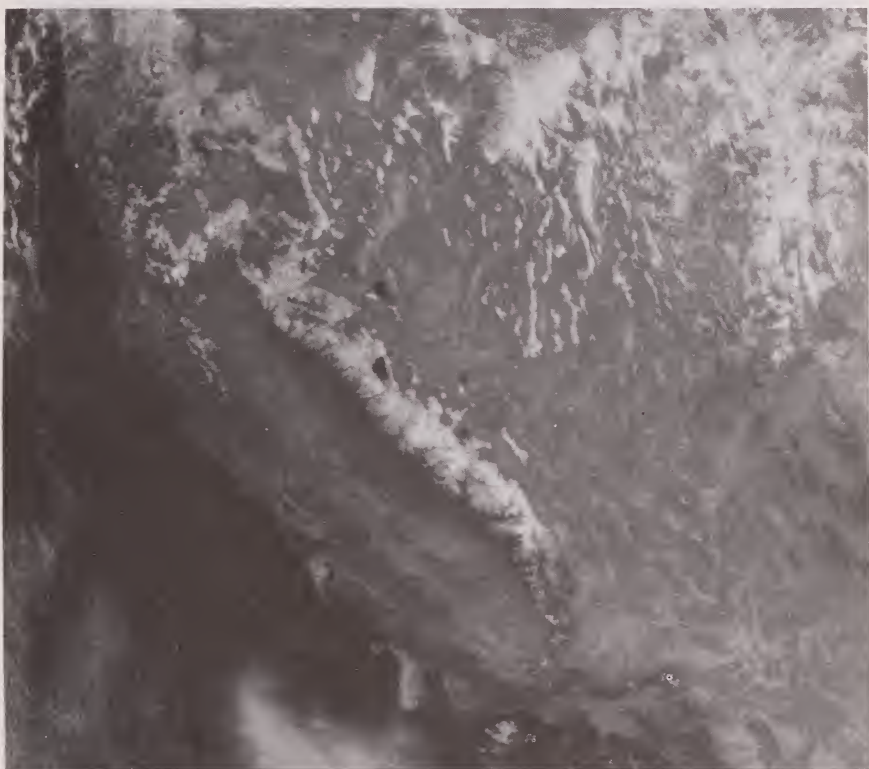
The greatest potential for modification exists in the winter in this region, while requirements for water reach their peak in the summer; hence, water storage is critical. Fortunately, the snowpack provides a most effective storage, and in some places the snowmelt lasts until early July. Water from the snowmelt can be used directly for hydroelectric power generation or for irrigation in the more arid regions, while some can be stored in reservoirs for use during later months or in subsequent dry years. In some regions where the snowpack storage is not optimum, offseason orographic precipitation is still of great value, since the water holding capacity of the soil is never reached and additional moisture can be held in the soil for the following growing season.

Orographic clouds are formed as moist air is forced upward by underlying terrain. The air thus lifted, containing water vapor, cools and expands. If this lifting and cooling continue, the air parcels will frequently reach saturation. If the air becomes slightly supersaturated, small droplets begin to form by condensation, and a cloud develops, which seems to hang over the mountain peak. The location where this condensation occurs can be observed visually by the edge of the cloud on the windward side of the mountain. Upon descent in the lee of the mountain the temperature and vapor capacity of the air parcel again

⁴² Grant, Lewis O. and Archie M. Kahan, "Weather Modification for Augmenting Orographic Precipitation." In Wilmot N. Hess (editor), "Weather and Climate Modification," New York, Wiley, 1974, p. 285.

⁴³ U.S. Department of Commerce, news release, NOAA 77-234. NOAA Public Affairs Office, Rockville, Md., Aug. 17, 1977.

increase, so that any remaining liquid droplets or ice crystals evaporate.⁴⁴



(a) April 28, 1975

FIGURE 3.—NOAA-3 satellite pictures of the snowcover on the Sierra Nevada Mountains in (a) April 1975 and (b) April 1977. (Courtesy of the National Oceanic and Atmospheric Administration.)

⁴⁴ Sax, et al., "Weather Modification: Where Are We Now and Where Should We Be Going?" an editorial overview, 1975, pp. 657-658.



(b) April 19, 1977

The supercooled cloud droplets exist as liquid at temperatures down to about -20°C ; but at temperatures colder than -20°C , small ice crystals begin to form around nuclei that are naturally present in the atmosphere. Once formed, the ice crystals grow rapidly because the saturation vapor pressure over ice is less than that over water. As the crystals increase they may fall and eventually may reach the ground as snow. The temperature at the top of the cloud is an important factor in winter storms over mountains, since natural ice crystals will not form in large quantities if the cloud top is warmer than -20°C . If the temperature is below -20°C , however, a large fraction of the cloud particles will fall as snow from natural processes.⁴⁵

⁴⁵ Weisbecker, Leo W. (compiler), "The Impacts of Snow Enhancement: Technology Assessment of Winter Orographic Snowpack Augmentation in the Upper Colorado River Basin," Norman, Okla., University of Oklahoma Press, 1974, pp. 64-66.

Orographic precipitation modification

According to Grant and Kahan, " * * * research has shown that orographic clouds * * * provide one of the most productive and manageable sources for beneficial weather modification."⁴⁶ In a recent study by the National Academy of Sciences, it was concluded broadly that orographic clouds provide one of the "main possibilities of precipitation augmentation," based on the considerations below:⁴⁷

A supply of cloud water that is not naturally converted into precipitation sometimes exists for extended periods of time;

Efficient seeding agents and devices are available for treating these clouds;

Seeding agents can sometimes (not always) be delivered to the proper cloud location in proper concentrations and at the proper time;

Microphysical cloud changes of the type expected and necessary for seeding have been demonstrated;

Substantial increases in precipitation with high statistical significance have been achieved in some well-designed randomized experiments for clouds that, based on physical concepts, should have seeding potential; and

Augmentation of orographic precipitation can have great economic potential.

Although natural ice crystals will not form in sufficient numbers if the cloud top is warmer than -20°C , it has been shown that particles of silver iodide smoke will behave as ice nuclei at temperatures somewhat warmer than -20°C , so that ice crystals can be produced by such artificial nuclei in clouds with temperatures in the range of -10° to -20°C . Whereas in the natural state, with few active nuclei at these temperatures, the cloud particles tend to remain as water droplets, introduction of the silver iodide can quickly convert the supercooled cloud into ice crystals. Then, the natural growth processes allow the crystals to grow to sufficient size for precipitation as snow.⁴⁸

Meteorological factors which favor increased snowfall from orographic clouds through cloud seeding are summarized by Weisbecker:⁴⁹

The component of the airflow perpendicular to the mountain ridge must be relatively strong.

The air must have a high moisture content. Generally, high moisture is associated with above-normal temperatures.

The cloud, including its upper boundary, should be at a temperature warmer than -20°C . Since temperature decreases with increasing altitude, this temperature criterion limits the altitude of the cloud top. However, it is advantageous for the cloud base to be low, since the water droplet content of the cloud will then be relatively large.

⁴⁶ Grant and Kahan, "Weather Modification for Augmenting Orographic Precipitation," 1974, p. 282.

⁴⁷ Committee on Climate and Weather Fluctuations and Agricultural Production, National Research Council, "Climate and Food: Climatic Fluctuation and U.S. Agricultural Production," National Academy of Sciences, Washington, D.C., 1976, p. 136.

⁴⁸ Weisbecker, "The Impacts of Snow Enhancement; Technology Assessment of Winter Orographic Snowpack Augmentation in the Upper Colorado Basin," 1974, p. 66.

⁴⁹ *Ibid.* pp. 66-67.

It must be possible to disperse silver iodide particles within the cloud in appropriate numbers to serve as ice crystal nuclei. If ground generators are used, the silver iodide smoke must be diffused by turbulence and lifted by the airflow into cloud regions where temperatures are colder than -10° C.

The ice crystals must have time to grow to a precipitable size and to fall to Earth before reaching the downdrafts that exist on the far side of the mountain ridge.

The meteorological conditions which are ideally suited for augmenting artificially the snowfall from a layer of orographic clouds are depicted in figure 4. The figure also shows the optimum location of ground-based silver iodide smoke generators upwind of the target area as well as the spreading of the silver iodide plume throughout the cloud by turbulent mixing. Although there are several seeding agents with suitable properties for artificial ice nuclei, silver iodide and lead iodide appear to be most effective. Owing to the poisonous effects of lead compounds, lead iodide has not had wide use. The optimum silver iodide particle concentration is a function of the temperature, moisture, and vertical currents in the atmosphere; it appears to be in the range from 5 to 100 nuclei per liter of cloud.⁵⁰ While the most common means of dispersing silver iodide in mountainous areas is by ground-based generators, other methods of cloud seeding make use of aircraft, rockets, and balloons.

In contrast to convective clouds, ice crystal formation in orographic clouds is thought to be static, depending primarily on cloud microphysics, and that orographic cloud seeding has little effect on the general patterns of wind, pressure, and temperature. On the other hand, clouds formed primarily by convection, such as summer cumulus or hurricane clouds, are believed to be affected dynamically by seeding as noted above in the discussion of modification of convective clouds.⁵¹ Since the lifting of the air in winter mountain storms is mainly caused by its passage over the mountain barrier, the release of latent energy accompanying this lifting has little effect upon the updraft itself. In convective cases, however, heat released through seeding increases buoyancy and lifting, with attendant effects on the wind and pressure fields. The static nature of the processes involved in orographic cloud modification therefore suggests that there is less chance that the storm dynamics downwind of the target area will be altered appreciably as a result of the modification activities.⁵²

⁵⁰ *Ibid.*, p. 68.

⁵¹ See p. 68.

⁵² *Ibid.*, pp. 70-71.

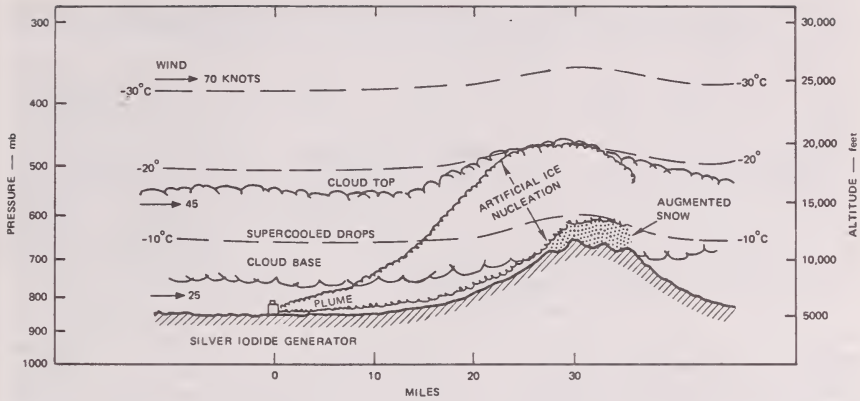


FIGURE 4.—Idealized model showing meteorological conditions that should lead to increased snowfall if clouds are seeded with silver iodide particles. (From Weisbecker, 1974.)

Orographic seeding experiments and seedability criteria

A randomized research weather modification program with winter orographic storms in central Colorado was initiated by Colorado State University in 1959. Data on precipitation and cloud physics were collected for 16 years under this Climax program, named for the location of its target area near Climax, Colo. Analysis of data has shown precipitation increases between 100 and 200 percent when the average temperatures of seeded clouds at the 500 millibar level were -20°C or warmer. When corresponding temperatures were -26°C to -21°C , precipitation changes ranged between -5 and $+6$ percent. For temperatures colder than -26°C , seeded cloud systems produced decreases in precipitation ranging from 22 to 46 percent.⁵³

While the results of Climax have provided some useful guidelines in establishing seedability criteria of certain cloud systems, it has been learned from other experimental programs that direct transfer of the Climax criteria to other areas is not warranted.⁵⁴ In particular, this nontransferability has been evident in connection with analysis of results from the Colorado River Basin Pilot Project, conducted from 1970 through 1975 in the San Juan Mountains of southwest Colorado, sponsored by the Bureau of Reclamation of the U.S. Department of the Interior.⁵⁵

Difficulties are frequently encountered in attempting to evaluate experimental cloud-seeding programs. A major problem in assessing results of all cold orographic cloud-seeding projects stems from the high natural variability of cloud properties. Frequent measurements are therefore required in order to monitor these properties carefully and consistently throughout the experiment. Another set of problems which have troubled investigators in a number of experimental programs follow from improper design. Such a deficiency can easily re-

⁵³ Hjernstad, Lawrence M., "San Juan and Climax." In proceedings of Special Weather Modification Conference; Augmentation of Winter Orographic Precipitation in the Western United States, San Francisco, Nov. 11-13, 1975, Boston, American Meteorological Society, 1975, p. 1 (abstract).

⁵⁴ *Ibid.*, pp. 7-8.

⁵⁵ This project, part of Project Skywater of the Bureau of Reclamation, is discussed along with other programs of Federal agencies in chapter 5 of this report, see p. 254.

sult, for example, if insufficient physical measurements have been taken prior to establishment of the design of the experiment.⁵⁶

Under Project Skywater the Bureau of Reclamation has carried out an analysis of data from seven past weather modification projects in order to identify criteria which define conditions when cloud seeding will increase winter snowfall in mountainous terrain and when such seeding would have no effect or decrease precipitation. The seven projects examined in the study were conducted in the Rocky Mountains, in the Sierra Nevada, and in the southern coast range in California during the 1960's and 1970's, in areas which represent a wide range of meteorological and topographical conditions.⁵⁷

Figure 5 shows the locations of the seven projects whose results were analyzed in the Skywater study, and table 5 includes more detailed information on the locations and dates of seeding operations for these projects. General seedability criteria derived from this study were common to all seven projects, with the expectation that the criteria will also be applicable to all winter orographic cloud-seeding projects. While there have been other efforts to integrate results from several projects into generalized criteria, based only on a few meteorological variables, Vardiman and Moore considered 11 variables which depend on mountain barrier shapes and sizes and on characteristics of the clouds. Some of these variables are physically measurable while others are derived from simple computations.⁵⁸



FIGURE 5.—Locations of winter orographic weather modification projects whose results were used to determine generalized cloud seeding criteria. (From Vardiman and Moore, 1977.

⁵⁶ Hobbs, Peter V., "Evaluation of Cloud Seeding Experiments; Some Lessons To Be Learned From the Cascade and San Juan Projects." In proceedings of Special Weather Modification Conference; Augmentation of Winter Orographic Precipitation in the Western United States, San Francisco, Nov. 11-13, 1975. Boston, American Meteorological Society, 1975, p. 31.

⁵⁷ Vardiman, Larry and James A. Moore, "Generalized Criteria for Seeding Winter Orographic Clouds." Skywater monograph No. 1, U.S. Department of the Interior, Bureau of Reclamation, Division of Atmospheric Water Resources Management, Denver, July 1977, 133 pp.

⁵⁸ *Ibid.*, p. 15.

TABLE 5.—LIST OF WINTER OROGRAPHIC WEATHER MODIFICATION PROJECTS, GIVING SITES AND SEASONS OF OPERATIONS, USED IN STUDY TO DETERMINE GENERALIZED CLOUD SEEDING CRITERIA

[From Vardiman and Moore, 1977]

Project	Site	Seeding operations
Bridger Range Project (BGR).....	Rocky Mountains, Montana.....	1969-70 to 1971-72 (3 seasons).
Climax Project (CMX).....	Rocky Mountains, Colorado.....	1960-61 to 1969-70 (10 seasons).
Colorado River Basin Pilot Project (CRB).....	Rocky Mountains, Colorado.....	1970-71 to 1974-75 (5 seasons).
Central Sierra Research Experiment (CSR).....	Sierra Nevada, California.....	1968-69 to 1972-73 (5 seasons).
Jemez Mountains Project (JMZ).....	Rocky Mountains, New Mexico.....	1968-69 to 1971-72 (4 seasons).
Pyramid Lake Pilot Project (PYR).....	Sierra Nevada, California/Nevada.....	1972-73 to 1974-75 (3 seasons).
Santa Barbara Project (SBA).....	Southern Coast Range, California.....	1967-68 to 1973-74 (7 seasons).

Detailed analyses were conducted on four variables calculated from topography and vertical distributions of temperature, moisture, and winds. These are (1) the stability of the cloud, which is a measure of the likelihood that seeding material will reach a level in the cloud where it can effect the precipitation process; (2) the saturation mixing ratio at cloudbase, a measure of the amount of water available for conversion to precipitation; (3) the calculated cloud top temperature, a measure of the number of natural ice nuclei available to start the precipitation process; and (4) the calculated trajectory index, a measure of the time available for precipitation particles to form, grow, and fall to the ground.⁵⁹

Results of the study thus far are summarized below :

Seeding can increase precipitation at and near the mountain crest under the following conditions:

Stable clouds with moderate water content, cloud top temperatures between -10 and -30° C, and winds such that the precipitation particles would be expected to fall at or near the crest of the mountain barrier.

Moderately unstable clouds with moderate-to-high water content, cloud top temperatures between -10 and -30° C, and a crest trajectory for the precipitation.

Seeding appears to decrease precipitation across the entire mountain barrier under the following condition:

Unstable clouds with low water content, cloud top temperatures less than -30° C, and winds such that the precipitation particles would be carried beyond the mountain crest and evaporate before reaching the ground.⁶⁰

⁵⁹ Bureau of Reclamation, Division of Atmospheric Water Resources Management, "Summary Report; Generalized Criteria for Seeding Winter Orographic Clouds." Denver, March 1977, p. 1. (This is a summary of the report by Vardiman and Moore which is referenced above.)

⁶⁰ *Ibid.*, pp. 1-2.



Rime ice conditions at sensing device which measures intensity of snowfall.
(Courtesy of the Bureau of Reclamation.)

Results quoted above represent only a portion of the analyses which are to be carried out. Seeding "window" bounds must be refined, and the expected effect must be converted into estimates of additional precipitation a target area might experience during a winter season. It is very unlikely that observed effects could have occurred by chance in view of the statistical tests which were applied to the data.⁶¹

Operational orographic seeding projects

For several decades commercial seeding of orographic clouds for precipitation augmentation has been underway in the western United States, sponsored by specific users which include utility companies, agricultural groups, and State and local governments. Much of the technology was developed in the late forties and early fifties by commercial operators, with some improvements since. The basic technique most often used involves release of silver iodide smoke, usually from ground-based generators, along the upwind slopes of the mountain where clouds are seeded, as shown schematically in figure 6. It is the opinion of Grant and Kahan that this basic approach still appears sound for seeding orographic clouds over many mountain barriers, but that in all aspects of these operating programs, there have been "substantial improvements" as a result of research and development programs.⁶² They summarized the following major deficiencies of past operational orographic seeding programs:

1. The lack of criteria for recognizing the seedability of specific clouds.
2. The lack of specific information as to where the seeding materials would go once they are released.
3. The lack of specific information as to downwind or broader social and economic effects from the operations.
4. The lack of detailed information on the efficiency of seeding generators and material being used for seeding clouds with differing temperatures.⁶³



FIGURE 6.—Schematic view of silver iodide generators placed upwind from a target area in the mountains, where orographic clouds are to be seeded for precipitation enhancement. (From Weisbecker, 1974.)

⁶¹ Ibid., p. 2.

⁶² Grant and Kahan, "Weather Modification for Augmenting Orographic Precipitation," 1974, p. 307.

⁶³ Ibid., pp. 307-308.

Results achieved through orographic precipitation modification

Results from several projects in the western United States have shown that winter precipitation increases of 10 to 15 percent are possible if all suitable storms are seeded.⁶⁴ From randomized experiments at Climax, Colo., precipitation increases of 70 to 80 percent have been reported. These results, based on physical considerations, are representative of cases which have a high potential for artificial stimulation.⁶⁵

⁶⁴ U.S. Department of the Interior, Bureau of Reclamation, "Reclamation Research in the Seventies," Second progress report. A water resources technical publication research report No. 28, Washington, U.S. Government Printing Office, 1977, p. 2.

⁶⁵ National Academy of Sciences, "Climate and Food ; Climatic Fluctuation and U.S. Agricultural Production," 1976, p. 136.



Manually operated cloud seeding generator similar to those used in the Colorado River Basin Pilot Project. (Courtesy of the Bureau of Reclamation.)

HAIL SUPPRESSION

The hail problem

Along with floods, drought, and high winds, hail is one of the major hazards to agriculture. Table 6 shows the estimated average annual hail loss for various crops in the United States, for each of the 18 States whose total annual crop losses exceed \$10 million. Also included in the table are total losses for each crop and for each of the 18 States and the aggregate of the remaining States.

The following vivid description of a hailstorm conveys both a sense of its destructiveness and some notion of its capricious nature:

At the moment of its happening, a hailstorm can seem a most disastrous event. Crashing stones, often deluged in rain and hurled to the surface by wind, can create instant destruction. Picture windows may be broken, cars dented, or a whole field of corn shredded before our eyes.

Then quite quickly, the storm is over. Now the damage is before us, we perceive it to be great, and we vow to do something to prevent its happening again.

But what we have experienced is "our" storm. Hail did not happen perhaps a mile away. We may see another the same day, or never again. Thus, the concept of hail suppression is founded in a real or perceived need, but the assessment of this solution must be considered in terms of the nature of hail.⁶⁶

TABLE 6.—ESTIMATED AVERAGE HAIL LOSSES BY CROP, FOR STATES WITH LOSSES GREATER THAN \$10,000,000

[In millions of dollars]¹

State	Wheat	Corn	Soybeans	Cotton	Tobacco	Coarse grains ²	Fruits and vegetables	Total
Texas.....	16.7		1.5	49.1		16.1	2.8	86.2
Iowa.....	.1	31.3	31.6			3.5	.3	66.8
Nebraska.....	16.8	27.2	4.1			4.7	7.7	60.5
Minnesota.....	2.3	17.6	18.7			7.5	2.2	48.3
Kansas.....	36.1	2.8	.9			4.7	1.3	45.8
North Dakota.....	28.8	.6	.8			12.5	1.6	44.3
North Carolina.....	.2	.8	.3	.5	24.2	.1	1.9	28.0
Illinois.....	1.2	12.1	12.8			.5	.9	27.5
South Dakota.....	8.9	9.2	1.6			7.6	.1	27.4
Colorado.....	14.4	4.1				2.6	5.9	27.0
Montana.....	16.7	.1				5.0	2.2	24.0
Oklahoma.....	15.7	.2	.1	2.7		3.3		22.0
Kentucky.....	.1	.4			15.9	.1	.3	16.8
Missouri.....	1.8	4.7	5.2	1.4	.3	.1	.7	14.2
South Carolina.....	.1	.6	1.1	1.7	6.4	.1	2.3	12.3
Idaho.....	2.6	.1				1.2	7.6	11.5
California.....	.2	.1		.5		1.8	8.5	11.1
Indiana.....	.9	3.8	4.7		.4	.3	.7	10.8
Other States.....	8.4	7.8	7.6	18.3	17.9	15.1	20.4	95.5
Total.....	172.0	123.5	91.0	74.2	65.1	86.6	67.4	680.0

¹ 1973 production and price levels.² Coarse grains: Barley, rye, oats, sorghum.

Source: "National Hail Research Experiment" from Boone (1974).

A major characteristic of hail is its enormous variability in time, space, and size. Some measure of this great variability is seen in figure 7, which shows the average annual number of days with hail at points within the continental United States. The contours enclose points with equal frequency of hail days.⁶⁷

⁶⁶ Changnon, Stanley A., Jr., Ray Jay Davis, Barbara C. Farhar, J. Eugene Haas, J. Lorena Ivens, Marvin V. Jones, Donald A. Klein, Dean Mann, Griffith M. Morgan, Jr., Steven T. Sonka, Earl R. Swanson, C. Robert Taylor, and Jon Van Blokland, "Hail Suppression: Impacts and Issues," Final report—"Technology Assessment of the Suppression of Hail (TASH)," Urbana, Ill., Illinois State Water Survey, April 1977 (sponsored by the National Science Foundation, Research Applied to National Needs Program), p. 9.

⁶⁷ *Ibid.*

Hail forms in the more active convective clouds, with large vertical motions, where large quantities of water vapor condense under conditions in which large ice particles can grow quickly. The kinds of convective clouds from which hail can be formed include (1) supercells (large, quasi-steady-state, convective storms), (2) multicell storms (active convective storms with multiple cells), (3) organized convective storms of squall lines or fronts, and (4) unstable, highly convective small cumuli (primarily occurring in spring).⁶⁸ While hail generally occurs only in thunderstorms, yet only a small proportion of the world's thunderstorms produce an appreciable amount of hail. Based upon several related theories, the following description of the formation of hail is typical:

Ice crystals or snowflakes, or clumps of snowflakes, which form above the zone of freezing during a thunderstorm, fall through a stratum of supercooled water droplets (that is, water droplets well below 0° C). The contact of the ice or snow particles with the supercooled water droplets causes a film of ice to form on the snow or ice pellet. The pellet may continue to fall a considerable distance before it is carried up again by a strong vertical current into the stratum of supercooled water droplets where another film of water covers it. This process may be repeated many times until the pellet can no longer be supported by the convective updraft and falls to the ground as hail.⁶⁹

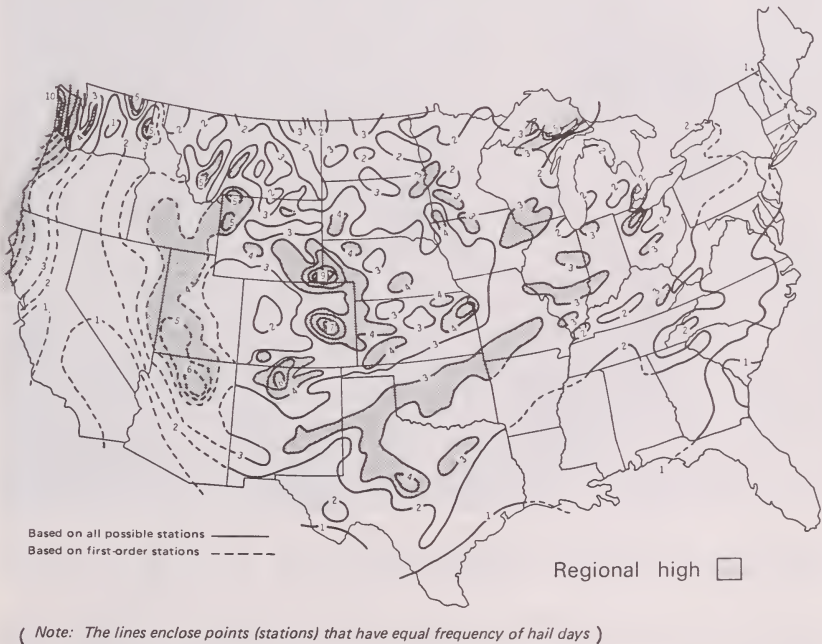


FIGURE 7.—Average annual number of days with hail at a point, for the contiguous United States. (From Changnon, et al., TASH, 1977.)

⁶⁸ National Academy of Sciences, "Climate and Food; Climatic Fluctuation and U.S. Agricultural Production," 1976, p. 141.

⁶⁹ Koeppe, Clarence E. and George C. de Long, "Weather and Climate," New York, McGraw-Hill, 1958, pp. 79-80.

Modification of hail

According to D. Ray Booker, "Hail modification seeding has been done operationally for decades in the high plains of the United States and in other hail prone areas of the world. Thus, there appears to be a significant market for a hail-reduction technology."⁷⁰ In the United States most attempts at hail suppression are conducted by commercial seeders who are under contract to State and county governments and to community associations. There are also extensive hail suppression operations underway in foreign countries. Although some successes are reported, many important questions are still unanswered with regard to mitigation of hail effects, owing largely to lack of a satisfactory scheme for evaluation of results from these projects.

In theory, it should be possible to inhibit the formation of large ice particles which constitute hailstones by seeding in order to increase the number of freezing nuclei so that only smaller ice particles will develop. This would then leave the cloud with insufficient precipitation water to allow the accretion of supercooled droplets and the formation of hail of damaging size. This simplistic rationale, however, does not provide insight into the many complications with which artificial hail suppression is fraught; nor does it explain the seemingly capricious responses of hailstorms to seeding and the inconsistent results which characterize such modification attempts. As with all convective systems, the processes involved are very complex. They are controlled by the speed of movement of the air parcels and precipitation particles, leading to complicated particle growth, evaporation, and settling processes.⁷¹ As a result, according to Changnon, the conclusions from various hail suppression programs are less certain than from those for attempts to enhance rain from convective clouds, and they are best labeled "contradictory."⁷²

Changnon identifies two basic approaches that have been taken toward hail modification:

Most common has been the intensive, high rates of seeding of the potential storm with silver iodide in an attempt to transform nearly all of the supercooled water into ice crystals, or to "glaciate" the upper portion of the clouds. However, if only part of the supercooled water is transformed into ice, the storm could actually be worsened since growth by accretion is especially rapid in an environment composed of a mixture of supercooled drops and ice crystals. Importantly, to be successful, this frequently used approach requires massive seeding well in advance of the first hailstone formation.

The second major approach has been used in the Soviet Union and * * * in the National Hail Research Experiment in Colorado. It involves massive seeding with silver iodide, but only in the zone of maximum liquid water content of the cloud. The hope is to create many hailstone embryos so that there will be insufficient supercooled water available to enable growth to damaging stone sizes.⁷³

⁷⁰ Booker, D. Ray, "A Marketing Approach to Weather Modification," background paper prepared for the U.S. Department of Commerce Weather Modification Advisory Board, Feb. 26, 1977, p. 4.

⁷¹ National Academy of Sciences, "Climate and Food; Climatic Fluctuation and U.S. Agricultural Production," 1976, p. 143.

⁷² Changnon, "Present and Future of Weather Modification; Regional Issues," 1975, p. 162.

⁷³ *Ibid.*



Precipitation instrument site, including, from left to right, hailcube, anemometer, rain/hail separator, and Belfort weighing precipitation gage. (Courtesy of the National Science Foundation.)

Hail seeding technologies

The most significant field programs in hail suppression during recent years have included those conducted in the Soviet Union, in Alberta, in South Africa, and in northeastern Colorado (the National Hail Research Experiment). In the course of each of these projects, some of which are still underway, various procedural changes have been initiated. In all of them, except that in South Africa, the suppression techniques are based on increasing the number of hail embryos by

seeding the cloud with ice nuclei. Usually, the seeding material is silver iodide, but the Russians also use lead iodide, and on occasion other agents such as sodium chloride and copper sulfate have been used. The essential problems in seeding for hail suppression are related to how, when, and where to get the seeding agent into potential hail clouds and how to identify such clouds.⁷⁴

Soviet suppression techniques are based on their hypothesis that rapid hail growth occurs in the "accumulation zone," just above the level of maximum updraft, where liquid water content can be as great as 40 grams per cubic meter. To get significant hail, the maximum updraft should exceed 10 to 15 meters per second, and the temperature in this zone must be between 0 and -25° C. Upper large droplets freeze and grow, combining with lower large droplets, and an increase in particle size from 0.1 cm to 2 or 3 cm can occur in only 4 to 5 minutes. In the several Russian projects, the seeding agent is introduced at selected cloud heights from rockets or anti-aircraft shells; the number of volleys required and the position of injection being determined by radar echo characteristics and past experience in a given operational region.⁷⁵

In other hail suppression projects, seeding is most frequently carried out with aircraft, from which flares containing the seeding agent are released by ejection or dropping. Each flare may contain up to 100 grams of silver iodide; and the number used as well as the spacing and height of ignition are determined from cloud characteristics as well as past experience in a given experiment or operation. In each case it is intended to inject the seeding material into the supercooled portion of the cloud.

Evaluation of hail suppression technology

It appears that mitigation of the effects of hail has some promise, based on the collection of total evidence from experiments and operations around the world. In the Soviet Union, scientists have been reporting spectacular success (claims of 60 to 80 percent reduction)⁷⁶ in hail suppression for nearly 15 years; however, their claims are not universally accepted, since there has not been careful evaluation under controlled conditions. Hail-seeding experiments have had mixed results in other parts of the world, although a number of commercial seeders have claimed success in hail damage reduction, but not with convincing evidence.⁷⁷

Successful hail suppression reports have come from a number of operational programs in the United States as well as from weather modification activities in the Soviet Union and in South Africa. Often the validity of these results is questionable in view of deficiencies in project design and data analysis; nevertheless, the cumulative evidence suggests that hail suppression is feasible under certain conditions. There are also reports of negative results, for example, in foreign programs and in the National Hail Research Experiment in the United

⁷⁴ Changnon, Stanley A., Jr., and Griffith M. Morgan, Jr., "Design of an Experiment To Suppress Hail in Illinois." Illinois State Water Survey, ISWS/B-61/76, Bulletin 61, State of Illinois, Department of Registration and Education, Urbana, 1976, pp. 82-83.

⁷⁵ *Ibid.*, p. 83.

⁷⁶ Changnon, "Present and Future of Weather Modification," 1975, p. 162.

⁷⁷ Baffan, Louis J. statement submitted to Subcommittee on Environment and Atmosphere, Committee on Science and Technology, U.S. House of Representatives, at hearings, June 18, 1976, pp. 7-8.

States, which indicate that under some conditions seeding induces increased hail.⁷⁸

Atlas notes that this apparent dichotomy has until recently been attributed to different approaches to the techniques and rates of seeding. However, he observes that both positive and negative results have been obtained using a variety of seeding methods, including ground- and cloud-based generators, flares dropped from above the cloud top, and injection by rockets and artillery.⁷⁹ In discussing the reasons for increased hail upon seeding, Atlas states:

There are at least four physical mechanisms by which seeding may produce increased hail. Two of these occur in situations in which the rate of supply of supercooled water exceeds that which can be effectively depleted by the combination of natural and artificially produced hail embryos. This may occur in supercell storms and in any cold-base storm in which the embryos are graupel rather than frozen raindrops. Moreover, present seeding methods are much more effective in warm-base situations in which the hail embryos are frozen raindrops. Increased hail is also probable when partial glaciation of a cloud is produced and the hail can grow more effectively upon the ice-water mixture than upon the supercooled water alone. Similarly, increases in the amount of hail may occur whenever the additional latent heat resulting from nucleation alters the undraft profile in such a manner as to increase its maximum velocity or to shift the peak velocity into the temperature range from -20° to -30° C, where the accreted water can be more readily frozen. A probable associated effect is the redistribution of precipitation loading by the combination of an alternation in the updraft velocity and the particle sizes such that the hail embryos may grow for longer durations in a more favorable growth environment.⁸⁰

Surveys of hail suppression effectiveness

Recently, Changnon collected information on the effectiveness of hail suppression technology from three different kinds of sources. One set of data was based on the results of the evaluations of six hail suppression projects; another was the collection of the findings of three published assessments of hail modification; and the third was obtained from two opinion surveys conducted among weather modification scientists.⁸¹ The principal statistics on the estimated capabilities for hail suppression from each of these groups of sources are summarized in table 7. Where available, the estimated change in rainfall accompanying the hail modification estimates are also included. Such rainfall changes might have been sought intentionally as part of a hail suppression activity or might result simply as a byproduct of the major thrust in reducing hail. In the table, a plus sign indicates an estimated percentage increase in hail and/or rainfall while a minus sign signifies a percentage decrease.

The six evaluations in part A of table 7 are from both experimental and operational projects, each of which was conducted for at least 3 years in a single locale and in each of which aircraft seeding techniques were used. Thus, the results of a number of earlier experiments, using ground-based seeding generators, were not considered in the estimations. Furthermore, change in hail due to suppression activities was defined on the basis of crop-loss statistics rather than on the basis of frequency of hail days, since Changnon does not consider the latter,

⁷⁸ Atlas, David, "The Paradox of Hail Suppression," *Science*, vol. 195, No. 4274, Jan. 14, 1977, p. 195.

⁷⁹ *Ibid.*

⁸⁰ *Ibid.*, pp. 195-196.

⁸¹ Changnon, Stanley A., Jr., "On the Status of Hail Suppression," *Bulletin of the American Meteorological Society*, vol. 58, No. 1, Jan. 1977, pp. 20-28.

along with other criteria such as number and size of hailstones, hail mass, and radar echo characteristics, to be a reliable indicator.⁸² Note that five of the six projects listed indicate a hail suppression capability ranging from 20 percent to 48 percent. Changnon notes, however, that most of these results are not statistically significant at the 5 percent level, but that most scientists would classify the results as "optimistic."⁸³

TABLE 7.—Status of Hail Suppression and Related Rainfall Modification (Based on information from Changnon. On the Status of Hail Suppression. 1977.)

A. BEST ESTIMATES FROM PROJECT EVALUATIONS

1. Texas: Hail modification was -48 percent (crop-loss cost value); no change in rainfall.
2. Southwestern North Dakota: Hail modification was -32 percent (crop-hail insurance rates); no rain change information available.
3. North Dakota pilot project: Hail modification was -30 percent (a composite of hail characteristics, radar, and crop-loss data); change in rainfall was +23 percent.
4. South Africa: Hail modification was -40 percent (crop-loss severity; change in rainfall was -4 percent.
5. South Dakota "Statewide" project: Hail modification was -20 percent (crop loss); increase in rainfall was +7 percent.
6. National hail research experiment in Colorado:
 - Increase in hail mass was +4 percent to +23 percent, with median of +23 percent;
 - Increase in rainfall was +25 percent.

B. PUBLISHED ASSESSMENTS

1. American Meteorological Society: Positive but unsubstantiated claims and growing optimism.
2. National Academy of Sciences: 30 to 50 percent reductions in U.S.S.R. and 15 percent decreases in France—neither result proven by experimentation.
3. Colorado State University Workshop:
 - 30 percent modification nationwide;
 - 30 percent modification in the High Plains, with ± 10 -percent change in rain; unknown results in the Midwest; also unknown rainfall effects.

C. OPINION SURVEYS (MEDIAN VALUES)

1. Farhar-Grant questionnaire (214 answers): -25 percent crop-hail damage nationwide, although majority—59 percent—admit they do not know.
2. Illinois State Water Survey questionnaire (63 answers):
 - 30 percent hail loss, with +15 percent rain increase in the Great Plains;
 - 20 percent hail loss, with +10 percent rain increase in the Midwest.

The results, shown in part B of table 7, from the recent published assessments of capability in hail suppression reveal a position of "guarded optimism;" however, there is no indication of definitive proof of hail suppression contained in these assessments.⁸⁴ These published assessments are comprised of a statement on the status of weather modification by the American Meteorological Society,⁸⁵ the conclusions of a study on the progress of weather modification by the

⁸² *Ibid.*, p. 22.

⁸³ *Ibid.*, p. 26.

⁸⁴ *Ibid.*

⁸⁵ American Meteorological Society, "Policy Statement of the American Meteorological Society on Purposeful and Inadvertent Modification of Weather and Climate," *Bulletin of the American Meteorological Society*, vol. 54, No. 7, July 1973, pp. 694-695.

National Academy of Sciences,⁸⁶ and a report on a workshop at Colorado State University on weather modification and agriculture.⁸⁷

The third view (part C, table 7) resulting from two opinion surveys, indicates wide-ranging but basically "bipolar" attitudes among the scientists surveyed. The majority of the experts queried felt that a hail suppression capability could not be identified; however, a sizable minority were of the opinion that a moderate capability for modifying hail (greater than 20-percent decrease) does now exist. Changnon says that the results of these opinion surveys show at best that the consensus must be considered to be a pessimistic view of a hail suppression capability.⁸⁸

In his conclusions on the status of hail suppression technology, Changnon states:

These three views of the current status of hail suppression, labeled as (1) optimistic, (2) slightly optimistic, and (3) pessimistic, reflect a wide range of opinion and results. Clearly, the present status of hail suppression is in a state of uncertainty. Reviews of the existing results from 6 recent operational and experimental hail suppression projects are sufficiently suggestive of a hail suppression capability in the range of 20 to 50 percent to suggest the need for an extensive investigation by an august body of the hail suppression capability exhibited in these and other programs.

One of the necessary steps in the wise experimentation and future use of hail suppression in the United States is to cast the current status in a proper light. This can only be accomplished by a vigorous in-depth study and evaluation of the results of the recent projects.⁸⁹

Conclusions from the TASH study

Sponsored by the Research Applied to National Needs program of the National Science Foundation, a major technology assessment of hail suppression in the United States was conducted from 1975 through 1977, by an interdisciplinary research team.⁹⁰ This Technology Assessment of the Suppression of Hail (TASH) study was intended to bring together all of the considerations involved in the application of hail suppression, in the present and in the future, to ascertain the net value of such technology to society. The goals of the study were:

To describe the current knowledge of hail suppression.

To identify long-range expectations for such a technology.

To estimate the societal impacts that might be generated by its wide use.

To examine public policy actions that would most equitably direct its beneficial use.

From its interdisciplinary study of hail suppression and its impacts the TASH team reached the following broad conclusions on the effects of hail and on the potential technology for suppression of hail:

The United States experiences about \$850 million in direct crop and property hail losses each year, not including secondary losses from hail. The key characteristic of hail is its enormous variability in size, time, and space.

Among the alternative ways of dealing with the hail problem, including crop insurance, hail suppression, given a high level of development, appears to be the most promising future approach in high hail loss areas. Economic benefits from effective hail suppression vary by region of the country, with the most benefit to

⁸⁶ National Academy of Sciences, National Research Council, Committee on Atmospheric Sciences, "Weather and Climate Modification: Problems and Progress," Washington, D.C., 1973, pp. 100-106.

⁸⁷ Grant and Reid, "Workshop for an Assessment of the Present and Potential Role of Weather Modification in Agriculture Production," 1975, pp. 33-45.

⁸⁸ Changnon, "On the Status of Hail Suppression," 1977, p. 26.

⁸⁹ *Ibid.*, pp. 26-27.

⁹⁰ Changnon, et al., "Hail Suppression: Impacts and Issues," Technology Assessment of the Suppression of Hail (TASH), 1977, 432 pp.

be derived in the Great Plains area. Any alterations in rainfall resulting from hail suppression would importantly affect its economic consequences.

The effects of cloud seeding on rainfall are more significant than its effects on hail from economic and societal standpoints.

At the present time there is no established hail suppression technology. It may be possible to reduce damaging hail about 25 percent over the growing season in a properly conducted project.

Reducing the scientific uncertainties about hail suppression will require a substantial commitment by the Federal Government for long-term funding of a systematic, well-designed program of research. For the next decade or so, monitoring and evaluation of operational programs will be important.

Benefit-cost analysis revealed that investment in development of the high-level technology would result in a ratio of 14:1, with the present value of benefits estimated to total \$2.8 billion for 20 years. The low-level technology showed a negative benefit-cost ratio. Research and development to provide the high-level technology is the best choice from an economic standpoint; a minimal level of support would be nonbeneficial. In a word, if we are going to develop hail suppression technology, we would need to do it right.

Effective hail suppression will, because of the hail hazard, technological approach, patterns of adoption, and institutional arrangements, lead to regionally coherent programs that embrace groups of States, largely in the Great Plains.

Some would gain and others would lose from widespread application of an effective hail suppression technology. Farmers within adopting regions would receive immediate benefits from increased production. After several years this economic advantage would be diminished somewhat, but increased stability of income would remain. Farmers growing the same crops outside the adopting areas would have no advantages and would be economically disadvantaged by commodity prices lower than they would have been with no hail suppression. The price depressing effects result from increased production in adopting areas. Consumers would benefit from slightly decreased food prices. The impacts generated by a highly effective technology include both positive and negative outcomes for various other stake-holder groups in the Nation. For the Nation as a whole, the impacts would be minor and beneficial. On balance, the positive impacts outweigh the negative impacts if a high-level technology can be developed.

An adequate means of providing equitable compensation on an economically sound basis for persons suffering from losses due to cloud seeding has not been developed. Some better procedure for compensating losers will be necessary. In addition, present decision mechanisms and institutional arrangements are inadequate to implement the technology in a socially acceptable manner. Some mechanism for including potential opponents in the decisionmaking process will be required.

It is unlikely that widespread operational hail suppression programs would have serious adverse environmental impacts, although lack of sufficient knowledge indicates that adverse impacts should not be ruled out. Long-term environmental effects are not known at the present time.⁹¹

DISSIPATION OF FOG AND STRATUS CLOUDS

Fog poses a hazard to man's transportation activities, particularly to aviation, where as a result of delays air carriers lose over \$80 million annually. Highway accidents attributed to fog are estimated to cost over \$300 million per year.⁹² Most often the impetus to develop effective fog and stratus cloud dispersal capabilities has come from the needs of commercial and military aircraft operations.

There are two basic kinds of fog, and the suppression of each requires a different approach. Supercooled fog and stratus clouds are comprised of liquid water droplets whose temperature is below freez-

⁹¹ Farhar, Barbara C., Stanley A. Changnon, Jr., Earl R. Swanson, Ray J. Davis, and J. Eugene Haas. "Hail Suppression and Society. Summary of Technology Assessment of Hail Suppression," Urbana, Ill., "Illinois State Water Survey, June 1977," pp. 21-22. (This document is an executive summary of the technology assessment by Changnon, et al., "Hail Suppression: Impacts and Issues.")

⁹² National Oceanic and Atmospheric Administration, "Summary Report: Weather Modification; Fiscal Years 1969, 1970, 1971," Rockville, Md., May 1973, p. 72.

ing (i.e., 0° C or below). Supercooled fogs account for only about 5 percent of all fog occurrences in the United States, although they are prevalent in certain parts of northeastern and northwestern North America. The remainder of North American fogs are warm fogs (water droplets warmer than 0° C).⁹³ Although cold fog has been amenable to modification, so that there essentially exists an operational technology for its dissipation, practical modification of warm fogs, on an economical basis, has not yet been achieved.

Cold fog modification

Dispersal of cold fog by airborne or ground-based techniques has been generally successful and has become an operational weather modification technology. In the United States cold fog dispersal operations have been conducted, for example, by commercial airlines, usually with dry ice as the seeding agent. The U.S. Air Force has also operated ground-based liquid propane systems, at domestic and foreign bases, which have been effective in dissipating cold fog over runways, thus reducing flight delays and diversions.⁹⁴ Conducted largely at airports, cold fog suppression is usually accomplished using aircraft, which drop various freezing agents, such as dry ice or silver iodide as they fly over the fog-covered runways. The agents initiate ice crystal formation and lead to precipitation of the growing crystals.⁹⁵ Ground-based systems for cold fog dispersal have also been used and have some advantages over airborne systems. Such a system can operate continuously for extended time periods more economically and more reliably.

Warm fog modification

The remainder of North American fogs are "warm fogs" for which a suitable dispersal capability remains to be developed. Crutchfield summarizes the status of warm fog dispersal technology and its economic potential:

The much more extensive warm fogs which cause delays, accidents, and costly interruptions to every type of transportation have proved intractable to weather modification thus far. Some success has been achieved on occasion by heavy seeding with salt and other materials, but results have not been uniformly good, and the materials used have presented environmental problems in the areas treated. Heating airport runways has been of some benefit in dealing with warm fog, but at present is not generally effective in cost-benefit terms and can interrupt air traffic.

Nevertheless, the research and technology problems involved in the dispersal of warm fog appear to be of manageable proportions, and the benefits from an environmentally acceptable and predictable technique for dealing with warm fog would be of very real interest in terms of economic gain.⁹⁶

A number of field techniques have been attempted, with some measure of success, for artificial modification of warm fogs. Seeding is one technique, where the seeding agents are usually hygroscopic particles, solution drops, or both. There are two possible desired effects of seeding warm fogs, one being the evaporation of fog droplets, resulting in visibility improvement. A second desired effect of seeding, results from the "coalescence" process, in which the solution droplets, falling

⁹³ Changnon, "Present and Future of Weather Modification," 1975, p. 165.

⁹⁴ National Oceanic and Atmospheric Administration "Summary Report: Weather Modification; Fiscal Year 1973." Rockville, Md., December 1974, pp. 39-40.

⁹⁵ Changnon, "Present and Future of Weather Modification," 1975, p. 165.

⁹⁶ Crutchfield, James A., "Weather Modification: The Economic Potential." Paper prepared for U.S. Department of Commerce Weather Modification Advisory Board. University of Washington, Seattle, May 1977, pp. 5-6.

through the fog layer, collect the smaller fog droplets, increasing visibility as the fog particles are removed in the fallout.⁹⁷ There is a wide diversity of hygroscopic particles which can and have been used for warm fog dissipation. Sodium chloride and urea are the most common, but others have included polyelectrolyte chemicals, an exceedingly hygroscopic solution of ammonium-nitrate urea, and some biodegradable chemicals. Seeding particle size is critical to the effectiveness of a warm fog dispersal attempt; it has been found that polydispersed particles (i.e., material with a distribution of particle sizes) are more effective in inducing fog modification than are extra fine particles of uniform size, which were only thought to be optimum in earlier experiments. Other problems which are the subject of continuing study relate to the seeding procedures, including the number of flights, number of aircraft to be used, and flight patterns in accordance with the local terrain and wind conditions. One of the most difficult operational problems in the seeding of warm fog is that of targeting. One solution to this problem, suggested by the Air Force, is the implementation of wide-area seeding instead of single-line seeding, which is so easily influenced by turbulence and wind shear.⁹⁸

Another technique for dissipation of warm fog makes use of heating. The physical principle involved is the vaporization of the water droplets through introduction of sufficient heat to vaporize the water and also warm the air to such a temperature that it will hold the additional moisture and prevent condensation. Knowing the amount of liquid water in the atmosphere from physical measurements, the necessary amount of heat energy to be injected can be determined.⁹⁹ The feasibility of this approach was first demonstrated in England during World War II, when it was necessary to fly aircraft in all kinds of weather in spite of frequent fogbound conditions in the British Isles. The acronym FIDO, standing for Fog Investigations Dispersal Of, was applied to a simple system whereby fuel oil in containers placed along the runways was ignited at times when it was necessary to land a plane in the fog. Although burning as much as 6,000 gallons of oil for a single airplane landing was expensive and inefficient, it was justified as a necessary weather modification technique during wartime.^{99a}

Initial and subsequent attempts to disperse fog by burning liquid fuel were found to be hazardous, uneconomical, and sometimes ineffective, and, as a result, not much was done with this heating technique until the French revised it, developing the Turboclair method for dissipating fog by heating with underground jet blowers. After 10 years of development and engineering testing, the system was tested successfully by the Paris Airport Authority at Orly Airport. This program has given a new interest and stimulated further research and development of this technique both in the United States and elsewhere. In the United States, the Air Force conducted Project Warm Fog to test the effectiveness of heating to remove warm fog. It is clear that this method is promising; however, further studies are needed.¹

⁹⁷ Moschandreas, Demetrios J., "Present Capabilities to Modify Warm Fog and Stratus," Geomet, Inc., report No. EF-300. Technical report for Office of Naval Research and Naval Air Systems Command, Rockville, Md., Jan. 18, 1974, p. 13.

⁹⁸ *Ibid.*, pp. 16-17.

⁹⁹ *Ibid.*, pp. 24, 30.

^{99a} Halacy, Daniel S., Jr., "The Weather Changers," New York, Harper and Row, 1968, pp. 105-107.

¹ Moschandreas, "Present Capabilities to Modify Warm Fog and Stratus," 1974, pp. 30-40.

Research and development on warm fog dispersal systems has continued under sponsorship of the U.S. Air Force, using both passive heat systems, and thermokinetic systems which combine both heat and mechanical thrust. A thermokinetic system, known as the Warm Fog Dispersal System (WFDS), consists of three components: The combustors, the controls, and the fuel storage and distribution hardware. Testing of the WFDS by the Air Force is to be conducted during late 1978 and 1979 at Otis Air Force Base in Massachusetts, after which it is to be installed and operational at an Air Force base by 1982.² Discussion of the Air Force development program and of the concurrent studies and interest on the Federal Aviation Administration in this thermokinetic fog dispersal system is found in chapter 5 of this report.³

There have been attempts to evaporate warm fogs through mechanical mixing of the fog layer with warmer, drier air from above. Such attempts have been underway using the strong downwash from helicopters; however, such a technique is very costly and would likely be employed only at military installations where a number of helicopters might be available.

The helicopters hover or move slowly in the dry air above the fog layer. Clear dry air is moved downward into the fog by the circulation of the helicopter rotors. The mixture of dry and cloudy air permits the fog to evaporate, and in the fog layer there is created an opening whose size and lifetime are determined by the meteorological conditions in the area, by the flight pattern, and by the kind of helicopter.

Conclusions reached by scientists involved in a series of joint U.S. Air Force-Army research projects using helicopters for fog dispersal follow:

The downwash method by a single helicopter can clear zones large enough for helicopter landing if the depth of the fog is less than 300 feet (100 meters).

Single or multiple helicopters with flight patterns properly orchestrated can maintain continuous clearings appropriate for aircraft takeoff and landing in fogs of less than 300 feet (100 meters) deep.⁴

In addition to the more commonly applied experimental techniques, such as seeding, heating, and mechanical mixing, other attempts have been made to disperse warm fogs. These have included the injection of ions or charged drops into the fog and the use of a laser beam to clear the fog. Further research is needed before definitive results can be cited using these methods.⁵

Table 8 is a summary of research projects on warm fog dispersal which had been conducted by various organizations in the United States between 1967 and 1973. Note that, in addition to field experiments, research included modeling, field measurements and observations of fog, chamber tests, statistical interpretation, model evaluation, and operational assessment.

On the basis of his study of research projects through 1973 and claims projected by the scientists involved in the various warm fog

² Kunkel, Bruce A., "The Design of a Warm Fog Dispersal System." In preprints of the Sixth Conference on Planned and Inadvertent Weather Modification, Champaign, Ill., Oct. 10-13, 1977. Boston, American Meteorological Society, 1977, pp. 174-176.

³ See pp. 305 and 308.

⁴ Moschandreas, "Present Capabilities To Modify Warm Fog and Stratus," 1974, p. 45.

⁵ *Ibid.*, p. 14.

modification programs, Demetrios Moschandreas formulated the following conclusions on warm fog dispersal:

Seeding with hygroscopic particles has been successful; however, targeting problems would require the wide-area approach to seeding. Urea has also been projected as the agent which is most effective and least harmful to the environment.

The heating technique is very promising and very efficient; studies for further verification of its capabilities are in order.

The helicopter technique by itself has not been as promising as the combination of its use with hygroscopic seeding.

Studies on the other less often used techniques have not reached the stage of wide field application.

Numerical modeling has provided guidelines to the field experiments and insights to the theoretical studies of fog conditions.

The laboratory experiments have given the scientists the controlled conditions necessary to validate a number of theories. The unique contribution of chamber tests to a better understanding of the dynamics of fog formation has been widely recognized.⁶

TABLE 8.—SUMMARY OF PRINCIPAL RESEARCH RELATIVE TO WARM FOG DISPERSAL IN THE UNITED STATES, THROUGH 1973¹

[From Moschandreas, 1974]

Area of effort	Year of publication						
	1967 ²	1968	1969	1970	1971	1972	1973
Modeling and numerical experiments.	NWRF	CAL	CAL AFCRL GEOMET	AFCRL MRI NWRF NCAR	CAL MRI GEOMET NWC	CAL AFCRL GEOMET EPRF	AFCRL GEOMET
Field measurements; fog observations.		CAL	CAL MRI EG&G	AFCRL MRI CAL		CAL AFCRL FAA NWC	
Chamber tests		CAL	CAL	USNPGS	CAL	CAL	
Field experiments			CAL MRI EG&G	CAL AFCRL MRI		AFCRL FAA NWC AFCRL	
Statistical interpretation						AFCRL	
Model validation							
Assessment of operational Use.	NWRF		FAA EG&G			AFCRL	AFCRL

¹ Research is listed by agency conducting the research, or sponsoring it, when reporting its contractor's efforts; or by contractor's name when contractor's report is principal reference; individual researchers are not listed because these change, even though the continuity of effort is maintained.

² Work reported prior to 1967 is not included here.

Key: CAL—Cornell Aeronautical Laboratory, Inc.; AFCRL—Air Force Cambridge Research Laboratories; GEOMET—GEOMET, Inc.; MRI—Meteorology Research, Inc.; NWRF—U.S. Navy Weather Research Facility; EPRF—U.S. Navy Environmental Research Facility; EG&G—EG&G Environmental Services Operation; FAA—Federal Aviation Administration; NCAR—National Center for Atmospheric Research; NWC—Naval Weapons Center; USNPGS—U.S. Naval Postgraduate School.

LIGHTNING SUPPRESSION

At any given time over the whole Earth there are about 2,000 thunderstorms in progress, and within these storms about 1,000 cloud-to-ground discharges are produced each second.⁷ Lightning is essentially a long electric spark, believed to be part of the process by which an electric current is conducted from the Earth to the ionosphere, though

⁶ *Ibid.*, pp. 92–93.

⁷ National Science Board, "Patterns and Perspectives in Environmental Science," National Science Foundation, Washington, D.C., 1972, p. 157.

the origin of the lightning discharge is still not fully understood. In fair weather the atmosphere conducts a current from the positively charged ionosphere to the ground, which has a negative charge.

The details of the charge-generating process within a thunderstorm are not well understood, though theories have been proposed by cloud physicists. Probably a number of mechanisms operate together to bring about cloud electrification, though, essentially, the friction of the air on the water droplets and ice crystals in the storm strips off electrons which accumulate near the base of cumulonimbus clouds, while positive charge collects in the upper part. The negative charge near the cloud base induces a local positive charge on the Earth's surface beneath, reversing the normal fair weather situation. When the electrical potential between the cloud and ground becomes sufficiently large, an electrical discharge occurs, in which electrons flow from the cloud to the ground. In addition, there are discharges between clouds and between oppositely charged portions of the same cloud.

In the rapid sequence of events which comprise a lightning stroke, the initial, almost invisible, flow of electrons downward from cloud to Earth, called the leader, is met by an upward-moving current of positive charges, establishing a conducting path of charged particles. A return stroke, much larger, then rushes from the ground to the cloud. All of these events appear as a single flash since they occur in about fifty microseconds; however, while most people perceive the lightning stroke as travelling from cloud to ground, it is actually the return stroke which provides the greatest flash.⁸

In the United States, lightning kills about 200 people annually, a larger toll than that caused by hurricanes. Since 1940, about 7,000 Americans have lost their lives from lightning and related fires.⁹ These casualties occur most often singly or occasionally two at a time, so that they are not nearly so newsworthy as are the multiple deaths and dramatic property damage associated with hurricanes, tornadoes, and floods. On the other hand, a lightning problem affecting large areas is the ignition of forest fires, some 10,000 of which are reported each year in the United States, where the problem is most acute in the Western States and Alaska.¹⁰ Such fires inflict damage on commercial timber, watersheds, scenic beauty, and other resources, causing an estimated annual damage cost of \$100 million.¹¹ Other examples in which lightning can be especially dangerous and damaging include discharges to aircraft and spacecraft and effects on such activities as fuel transfer operations and the handling of explosives.

Because of the relative isolation of personal accidents due to lightning, the only feasible controls over loss of life are through implementation of safety measures which prevent exposure or by protection of relatively small areas and structures with lightning arresters. Forested areas, however, require large area protection from lightning-caused fires in order to promote sound forest management. It is hoped

⁸ Anthes, Richard A., Hans A. Panofsky, John C. Cabir, and Albert Rango, "The Atmosphere," Columbus, Ohio, Charles E. Merrill, 1975, p. 174.

⁹ U.S. Department of Commerce, "Peak Period for Lightning Nears; NOAA Lists Safety Rules," News Release NOAA 77-156, Washington, D.C., June 19, 1977, p. 1.

¹⁰ Fuquay, Donald M., "Lightning Damage and Lightning Modification Caused by Cloud Seeding." In Wilmot N. Hess (ed.), "Weather and Climate Modification," New York, John Wiley & Sons, 1974, p. 605.

¹¹ *Ibid.*, p. 604.

that the widespread damage to forest resources resulting from the lightning-fire problem can be alleviated through use of weather modification techniques.

Lightning modification

General approaches to lightning suppression through weather modification, which have been contemplated or have been attempted, include:

Dissipation of the cloud system within which the thunderstorm originates or reduction of the convection within the clouds so that vigorous updrafts and downdrafts are suppressed.

Reduction of the number of cloud-to-ground discharges, especially during critical fire periods.

Alteration of the characteristics of discharges which favor forest fuel ignition.

Use of other weather modification techniques to produce rains to extinguish fires or to decrease the probability of ignition through increase of ambient relative humidity and fuel moisture.

Lightning is associated with convective clouds; hence, the most direct suppression method would involve elimination of the clouds themselves or of the convection within them. Removal of the clouds would require changes to gross properties such as temperature instability and moisture content of the air; thus, such modification is not technically, energetically, or economically feasible. However, it might be possible to reduce somewhat the convection within the clouds.¹²

The formation of convective clouds depends on the upward motion of moist air caused by thermal instability and the subsequent production of water through cooling. This condensation releases more heat, which, in turn, causes further buoyancy and rising of the cloud. At these heights the temperature is low enough that the water can freeze, releasing more latent heat and enabling the cloud particles to rise even higher. As a result of the presence of nuclei which are naturally present in the cloud, glaciation proceeds continuously. Through artificial nucleation, by seeding, natural glaciation may be reinforced and development of the cloud assisted. Rapid, premature seeding, however, would still promote buoyancy but could also introduce so much turbulence that the cloud is unable to develop, because colder air entering the cloud by turbulent mixing would lower the changes of the cloud reaching moderate altitudes. Since there is a high correlation between cloud height, convective activity, and lightning, such early nucleation of a cloud should reduce the likelihood of intense electrical activity. Seeding would be accomplished by releasing silver iodide into the cores of growing cumulus clouds; it could be delivered from ground dispensers or from aircraft into the updraft under the cloud base. The amount of seeding material must be chosen carefully, and, in order to increase the chances for cloud dissipation, overseeding is probably most effective, though such overseeding will also tend to reduce precipitation. On the other hand, rainfall may be advantageous for other purposes, including its inhibiting lightning-caused forest fires by providing moisture to the forest fuel. Consequently, the advantages which might be achieved through reducing cloud con-

¹² Stow, C. D., "On the Prevention of Lightning," Bulletin of the American Meteorological Society, vol. 50, No. 7, July 1969, p. 515.

vection and its attendant electrical activity must be weighed against the possible advantages lost through reduced precipitation.¹³

A more efficient lightning-suppression approach might involve interference with the processes which bring about charge separation in the cloud. At least five different mechanisms by which cloud electrification is established have been theorized, and possibly all or most of these mechanisms are active in any given situation, although on different occasions it is likely that some are more effective than others, depending on meteorological conditions and geographical locations.¹⁴ Data are as yet insufficient for determining which mechanisms will predominate. It is not considered likely that a single treatment method would suffice to suppress all lightning activity through prevention of charge buildup, though it is conceivable that a given treatment may be capable of suppressing more than one charge-generating process.¹⁵ In addition to glaciation of the cloud by overseeding (described above in connection with convection reduction), accumulation of charge can be inhibited through seeding with various chemicals which affect the freezing of water. Another technique uses seeding with a conducting chaff (very fine metalized nylon fibers), which increases conductivity between oppositely charged regions of the storm and keeps the electric field from building up to the lightning-discharge level. The chaff fibers are of the type that have been used for radar "jamming," which can be dispensed underneath a thunderstorm from an aircraft. Experiments have shown this attempt at lightning suppression to have some promise.¹⁶

Although reduction in the number of cloud-to-ground discharges through cloud seeding would undoubtedly be instrumental in decreasing the total number of forest fires, ignition is also influenced by such factors as the type of discharge, surface weather conditions, the terrain-fuel complex, and the influence of preceding weather on fuel moisture. The kind of discharge most frequently causing forest fires has been observed and its characteristics have been measured. Observations indicate that ignition is most often caused by hybrid cloud-to-ground discharges having long continuing current phases, whose duration exceeds 40 milliseconds and that the probability of ignition is proportional to the duration of the continuing current phase.¹⁷

Evaluation of lightning suppression technology

Seeding experiments to date have yielded results which suggest that both the characteristics and the frequency of lightning discharges have been modified. The physical processes by which lightning is modified are not understood; however, basic physical charging processes have been altered through massive overseeding with silver iodide freezing nuclei. Direct measurements of lightning electricity have also shown that lightning strokes which contain a long continuing current are probably responsible for most lightning-ignited forest fires. Reduction of the duration of the long continuing current discharge through weather modification techniques may, therefore, be more significant in

¹³ *Ibid.*

¹⁴ *Ibid.*, pp. 516-519.

¹⁵ *Ibid.*, p. 519.

¹⁶ Kasemir, Heinz W. "Lightning Suppression by Chaff Seeding and Triggered Lightning." In Wilmot N. Hess (editor), "Weather and Climate Modification," New York, Wiley, 1974, N pp. 612-622.

¹⁷ Fuquay, "Lightning Damage and Lightning Modification Caused by Cloud Seeding," 1974, p. 606.

reducing forest fires than reduction of the total amount of lightning produced by storms.

From experiments in lightning suppression carried out under Project Skyfire by the U.S. Forest Service of the Department of Agriculture between 1965-67, Fuquay summarizes the following specific results, based on a total of 26 individual storms (12 seeded and 14 unseeded):¹⁸

Sixty-six percent fewer cloud-to-ground discharges, 50 percent fewer intracloud discharges, and 54 percent less total storm lightning occurred during seeded storms than during the not-seeded storms.

The maximum cloud-to-ground flash rate was less for seeded storms: over a 5-minute interval, the maximum rate averaged 8.8 for not-seeded storms and 5 for seeded storms; for 15-minute intervals, the maximum rate for not-seeded storms averaged 17.7 and 9.1 for seeded storms.

The mean duration of lightning activity for the not-seeded and seeded storms was 101 and 64 minutes, respectively. Lightning duration of the not-seeded storms ranged from 10 to 217 minutes, while that of seeded storms ranged from 21 to 99 minutes.

There was no difference in the average number of return strokes per discrete discharge (4.1 not-seeded versus 4 seeded); however, a significant difference was found for hybrid discharges (5.6 not-seeded versus 3.8 seeded).

The average duration of discrete discharges (period between first and last return stroke) decreased from 235 milliseconds for not seeded storms to 182 milliseconds for seeded storms.

The average duration of continuing current in hybrid discharges decreased from 187 milliseconds for not-seeded storms to 115 milliseconds for seeded storms.

In a recent Federal appraisal of weather modification technology it was concluded that results of field experiments to suppress lightning through silver iodide seeding have been ambiguous.¹⁹ Although analysis of data previously obtained is continuing, the experimental seeding program of the Forest Service has been terminated. In more recent experiments, thunderstorms have been seeded from below with chaff (very fine metalized nylon fibers). Based on an analysis of 10 chaff-seeded thunderstorms and 18 unseeded control storms, the number of lightning occurrences during the seeded storms was about 25 percent of those observed in the control storms. This observed difference was statistically significant even though the experiments were not strictly randomized.²⁰

Experiments in lightning modification through cloud seeding have given results showing that, in some cases, lightning can be modified in a beneficial manner. From these results and the measured characteristics of lightning strokes, a hypothesis of lightning modification is being developed. There has been progress in identifying significant correlations between occurrence of lightning and such variables as storm

¹⁸ Fuquay, "Lightning Damage and Lightning Modification Caused by Cloud Seeding," 1974, p. 611.

¹⁹ U.S. Domestic Council, Environmental Resources Committee, Subcommittee on Climate Change, "The Federal Role in Weather Modification," Washington, D.C., December 1975, p. 10.

²⁰ *Ibid.*

size, updraft characteristics, precipitation rates, and hail occurrence. According to Fuquay, such early successes ought not obscure the magnitude of the research yet required in order to identify and quantify the degree and applicability of lightning modification to the lightning-fire problem.²¹ He also warns that:

Until more is known about the adverse effects of seeding incipient thunderstorms, unexpected and adverse effects must be considered, although improved numerical models that accurately predict cloud development and the effects of seeding should minimize the risk of unexpected events.²²

MODIFICATION OF SEVERE STORMS

Severe storms have a greater immediate impact on human life and property than most other weather phenomena. A major portion of losses due to natural disasters results from two of the most destructive kinds of severe storms—hurricanes and tornadoes. During an average year the U.S. mainland is threatened by 8 tropical storms and experiences over 600 tornadoes.²³ Among the results of the annual devastation from these storms are the loss of hundreds of lives and the accumulation of hundreds of millions of dollars in property damage.

Perhaps the most important problems to be attacked in weather modification are associated with the abatement of severe storms. While rainfall augmentation promises borderline economic value at best, alternatives which can contribute more significantly to severe water shortages may prove more suitable. On the other hand, the annual threat of tolls in damages and fatalities from hurricanes and tornadoes will persist year after year, and research directed toward modification of these severe phenomena requires continued support. There have been dramatic attempts, with some successes, in demonstrating the potential reduction of the hazards of hurricanes; however, almost no research has been directed toward tornado suppression.

Hurricanes

A hurricane is an intense cyclone which forms over tropical seas, smaller in size than middle-latitude cyclones, but much larger than a tornado or a thunderstorm. With an average size of 500 miles (800 kilometers) in diameter, the hurricane consists of a doughnut-shaped ring of strong winds in excess of 64 knots which surrounds an area of extremely low pressure and calm at the storm's center, called the eye.²⁴ The generic name for all vortical circulations originating over tropical waters is "tropical cyclone." When fully developed with sufficiently strong winds, such storms are called hurricanes in the Atlantic and the eastern Pacific Oceans, typhoons in the northwest Pacific, baguios in the Philippines, Bengal cyclones in the Indian Ocean, and willy-willies near Australia. For a tropic cyclone whose winds are in the range of 33 to 64 knots, the official name in the United States is a tropical storm. The hurricane season is that portion of the year having a relatively

²¹ Fuquay, "Lightning Damage and Lightning Modification Caused by Cloud Seeding," 1974, p. 612.

²² *Ibid.*, p. 606.

²³ Federal Coordinator for Meteorological Services and Supporting Research, "Federal Plan for Meteorological Services and Supporting Research: Fiscal Year 1973." U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington, D.C., January 1972, p. 1.

²⁴ Anthes, Richard A., Hans A. Panofsky, John J. Cahir, and Albert Rango. "The Atmosphere." Columbus, Ohio, Charles E. Merrill, 1975, p. 150.

high incidence of hurricanes and usually is regarded as the period between June and November in the Northern Hemisphere.²⁵

Owing to their duration, which exceeds that of earthquakes, and to their violence, which approaches that of tornadoes, hurricanes are the most destructive natural phenomena. Prior to Hurricane Agnes in 1972, whose total damage exceeded \$3 billion, the annual hurricane property losses in the United States amounted to about \$450 million, although two hurricanes in the 1960's, Betsy (1965) and Camille (1969), each caused damage exceeding \$1.4 billion.²⁶ Improved techniques in hurricane detection and warning have dramatically reduced the number of deaths caused by hurricanes; however, property losses have continued to grow, as a result of increased population and activities in vulnerable coastal areas, with the attendant concentration of new houses, buildings, and other facilities of higher replacement value. Figure 8 shows the simultaneous increase in property losses and decrease in deaths due to hurricanes in the United States in the 20th century through 1969.

Devastation and fatalities occur essentially from three phenomena associated with hurricanes: the force of the winds in the storm itself, the storm surge on coastal areas, and flooding which can result from excessive and widespread rainfall as the storm moves inland. Since wind force varies with the square of the wind speed, a 50-mile-per-hour wind exerts four times as much force as a 25-mile-per-hour wind. Accordingly, a 10-percent reduction in maximum windspeed yields a decrease in wind force of about 20 percent.²⁷ Attempts to modify hurricane winds can thus be expected to reduce storm damage caused by winds in approximate proportion to the corresponding reduction in wind force.

²⁵ Federal Coordinator for Meteorological Services and Supporting Research, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, "National Hurricane Operations Plan," FCM 77-2, Washington, D.C., May 1977, pp. 6-7.

²⁶ Gentry, R. Cecil, "Hurricane Modification." In Wilmot N. Hess (ed.). "Weather and Climate Modification," New York, John Wiley & Sons, 1974, p. 497.

²⁷ *Ibid.*, p. 498.

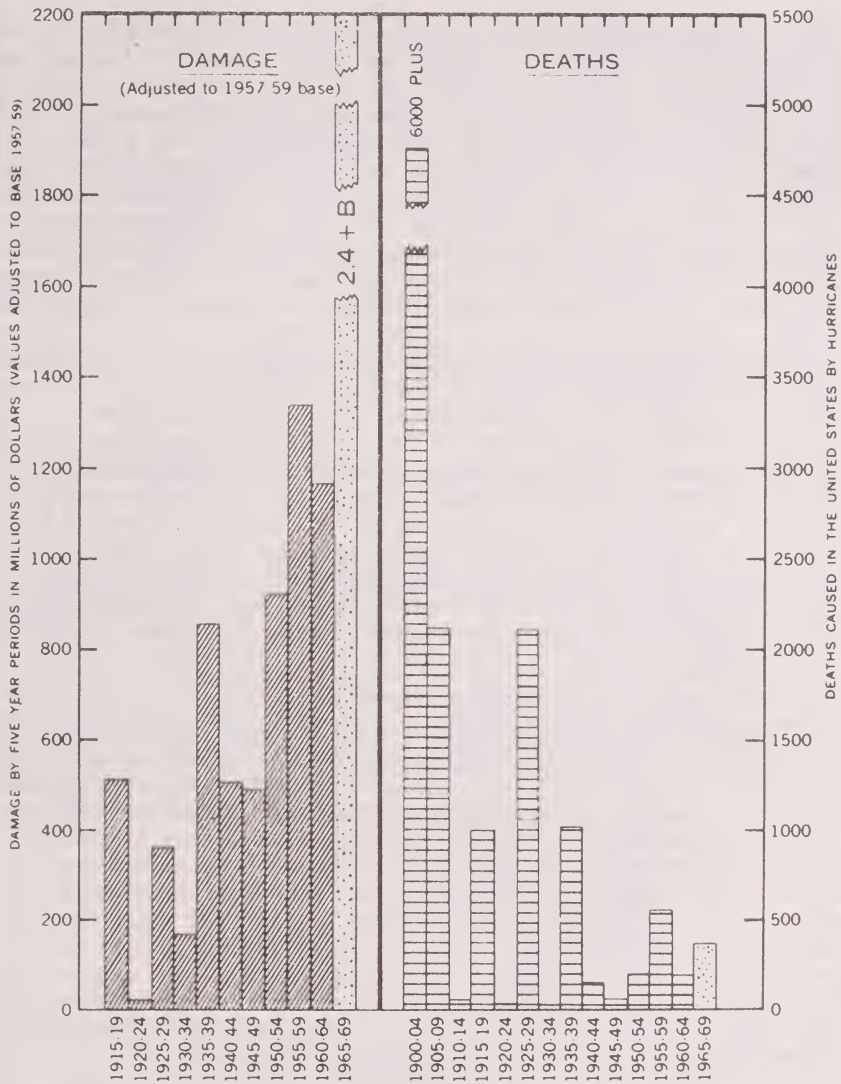


FIGURE 8.—Losses in the United States from hurricanes, 1915 through 1969, in 5-year periods (from National Oceanic and Atmospheric Administration).

As a hurricane moves across the coast from the sea, the strong winds pile up water to extreme heights, causing storm surges. The resulting onrushing water wreaks damage to shoreline and coastal structures. The severity of the storm surge is increased by the hurricane-generated wind waves which are superimposed on the surge. From Hurricane Camille, the storm surge at Pass Christian, Miss., was 24.6 feet, higher than any previous recorded tide. As a result, 135 people were killed, 63,000 families suffered personal losses, and Mississippi alone sustained \$1 billion in damage.²⁸ The height of the storm surge depends both on

²⁸ Anthes, Panofsky, Cahir, and Rango, "The Atmosphere," 1975, p. 159.

the windspeed and the shape and slope of the sea bottom offshore. If there is a sharp dropoff in depth not far off the beach, the rise of the sea level will be small, for example. Nearshore attempts to modify a hurricane could lead to uncertain results, depending upon local conditions. If the windspeed is reduced without moving the position of maximum winds along the coast, the overall effect would likely be a reduction in storm surge. However, should the modification activity result in developing a new windspeed maximum at a different location, the surge might increase or decrease, depending on bathymetry and bottom topography.²⁹ Solutions are not yet clear, and the storm surge prediction problem is being studied intensely with the use of numerical models.

Major hurricane damage can often be attributed to heavy rains and the massive and sudden flooding which can result as the storm moves inland. In mountainous regions especially, the floods from such rainfall can be devastating in losses to both life and property. Such flooding was a major contributor to the 118 deaths and \$3.5 billion in property destruction³⁰ which resulted in June 1972 from Hurricane Agnes, which set the record of achieving the greatest damage toll of all U.S. hurricanes. Ironically, Agnes caused almost no major damage as it went ashore. Hurricane modification activities which have been attempted or are contemplated are unfortunately not designed to reduce the rains significantly, but are intended rather to reduce the maximum winds.³¹

Generation and characteristics of hurricanes

A hurricane can be thought of as a simple heat engine driven by temperature differences between the center of the storm and its margins. At each level the central column must be warmer than the surrounding area to insure maintenance of the strong convection on which the storm depends.³² While the energy which forms extratropical cyclones is provided by temperature differences between different air masses, the energy which generates and maintains hurricanes and other tropical cyclones is derived from a single air mass through condensation of water vapor, and there are seldom present any of the frontal activities which are characteristic of storms originating in temperate latitudes. The moisture-laden winds continuously supply water vapor to the tropical storm, and the condensation of each gram of the vapor releases about 580 calories of latent heat. Within this thermally driven heat engine tremendous quantities of energy are converted from heat to mechanical motion in a short time, a fact readily apparent from the fury of the winds. The daily power of the energy liberated within a hurricane has been estimated to be about ten thousand times the daily power consumption in the United States.³³ The importance of the ocean in providing moisture to a hurricane is seen in the weakening and dissipation of the storms after they have crossed coastlines and travel over land.

²⁹ Gentry, "Hurricane Modification," 1974, p. 499.

³⁰ National Advisory Committee on Oceans and Atmosphere, "The Agnes Floods: a Cost-Audit of the Effectiveness of the Storm and Flood Warning System of the National Oceanic and Atmospheric Administration," a report for the Administrator of NOAA, Washington, D.C., Nov. 22, 1972, p. 1.

³¹ Gentry, "Hurricane-Modification," 1974, p. 499.

³² Donn, William L. "Meteorology." 4th edition. New York, McGraw-Hill, 1975, p. 336.

³³ *Ibid.*, p. 338.

Exactly how hurricanes form is not yet fully understood. They are all generated in the doldrums (a region of equatorial calms), though rarely if ever within latitudes closer than 5 degrees from the Equator, over water whose temperature is at least 27° C. The relatively high surface temperature is necessary for initiation of the convection. Hurricanes are relatively rare features even of the tropics, and the exact triggering mechanism is not yet known.³⁴ Their origin is usually traced to a low pressure disturbance which originates on the equatorial side of the trough of an easterly wave.

Such a tropical disturbance moves slowly westward and slightly poleward under the direction of the tropical east winds. If conditions are right, this cluster of thunderstorms intensifies as it reaches the region near the boundary between the tropical easterlies and the middle-latitude westerlies, at about 25° latitude. It may then follow a path which reverses toward the east as it leaves the tropics. The tracks of 13 major hurricanes in the Northwest Atlantic Ocean are shown in figure 9.

The development of the intense storm which might result from the conditions noted above is described in the following way by Anthes et al.:

The increased inflow toward the center of falling pressure produces increased lifting of air, so that the thunderstorms become more numerous and intense. The feedback cycle is now established. The inflowing air fuels more intense thunderstorm convection, which gradually warms and moistens the environment. The warmer air in the disturbance weighs less, and so the surface pressure continues to fall. The farther the pressure falls, the greater the inflow and the stronger the convection. The limit to this process would occur when the environment is completely saturated by cumulonimbus clouds. Further condensation heating would not result in additional warming, because the heat released would exactly compensate for the cooling due to the upward expansion of the rising air.³⁵

³⁴ Ibid.

³⁵ Anthes, Panofsky, Cahir, and Rango, "The Atmosphere," 1975, p. 154.

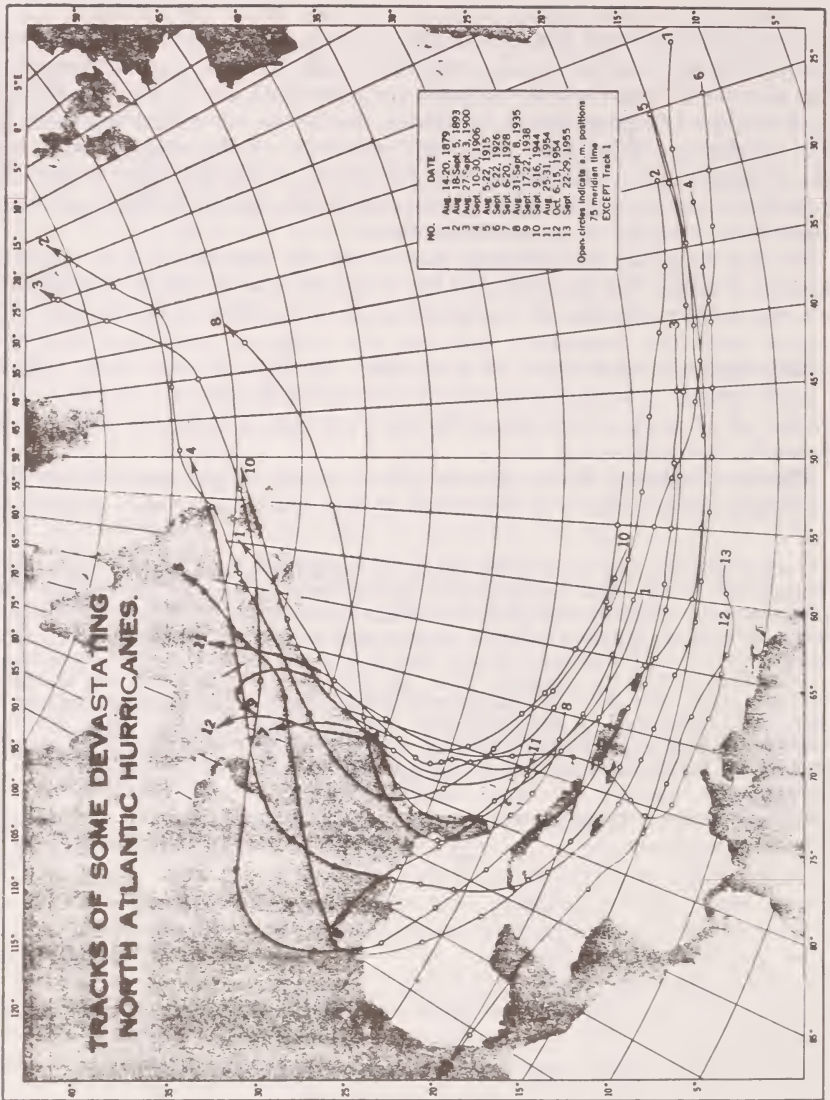


FIGURE 9.—Tracks of thirteen major hurricanes in the North Atlantic from 1879 through 1955 (from U.S. Naval Oceanographic Office, Publication No. 21, Sailing Directions for the West Indies, 1958).

As the storm forms, the winds begin to strengthen about the center, increasing especially to the right of the direction in which the center is moving, normally on the poleward side. The clouds organize themselves into a system and dense cirrus move forward in the direction of the movement of the center. Suddenly, the pressure falls over a small area and hurricane force winds form a tight band of 20 to 40

miles radius around the center. The well-organized clouds show a spiraling structure, and the storm acquires an eye, a small nearly circular area, coinciding with the region of lowest pressure. The winds in the eye are light and variable and the clouds are scattered or entirely absent.³⁶ As the storm matures, the pressure ceases to fall and the maximum winds do not increase further. Now the storm expands horizontally and large amounts of air are drawn in. As the storm expands to a radius of about 200 miles or more it becomes less symmetrical. Figure 10 is a vertical cross-section of the structure of a typical mature hurricane, showing the direction of flow and cloud distribution.³⁷

In spite of the great damage and fatalities caused by hurricanes, their effects are not completely destructive. In many areas of Southeast Asia and the west coast of Mexico, tropical storms are depended upon for a large part of the water supply. Throughout the Southern United States, hurricanes have also provided valuable drought relief.³⁸ Hurricane and other tropical cyclones are always characterized by high wind velocities and by torrential rains. Wind velocities of 60 to 70 knots and more are normal for such storms. The air rotates rapidly, moving spirally toward the center. Maximum gusts exceed 100 knots and may reach 200 knots, although such high speeds are unrecorded since instruments are blown away or made inoperable at these wind speeds.³⁹

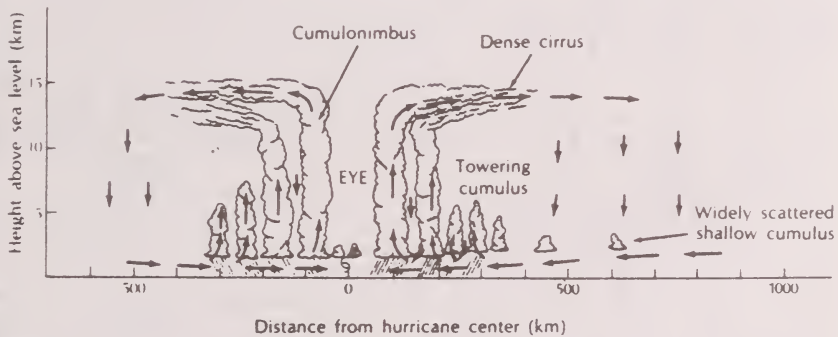


FIGURE 10.—Vertical cross section through a hurricane, showing typical cloud distribution and direction of flow, as functions of height and distance from the eye. (From Anthes, Panofsky, Cahir, and Rango, 1975.)

Compared with extratropical storms, hurricanes are generally small, circularly shaped zones of intense low pressure, with very steep pressure gradients between the center and the periphery. The pressure drop between the eye and the periphery is quite large, 20 to 70 millibars being typical. The winds are in a constant circular cyclonic motion (counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere); however, the center of the storm is a

³⁶ Pettersen, Sverre. "Introduction to Meteorology," second edition, New York, McGraw-Hill, 1958, pp. 242-243.

³⁷ Anthes, Panofsky, Cahir, and Rango, "The Atmosphere," 1975, p. 157.

³⁸ Rehl, Herbert, "Introduction to the Atmosphere," New York, McGraw-Hill, 1965, pp. 178-179.

³⁹ Gentill, J., "Tropical Cyclones." In Rhodes W. Fairbridge (ed.), "The Encyclopedia of Atmospheric Sciences and Astrogeology," Reinhold, New York, 1967, p. 1028.

calm region of low pressure, called the eye, which is about 10 miles across on the average. The warm dry character of this region is due to subsiding air, which is necessary for existence of the storm. Around the eye is the wall, consisting of cumulonimbus clouds and the attendant extreme instability and rising motion; in the wall area adjacent to the eye, heavy rains fall. Out from the central zone altostratus and nimbostratus clouds mix to form a layer with a radius as great as 200 miles. At higher altitudes and reaching to the outer regions of the storm is a mixture of cirrus and cirrostratus clouds.⁴⁰

In a mature hurricane a state of relative equilibrium is reached eventually, with a particular distribution of wind, temperature, and pressure. Such distributions for a typical hurricane are shown schematically in figure 11. Note that the greatest pressure change and the maximum windspeeds are in the region of the wall clouds, near the center of the storm.⁴¹

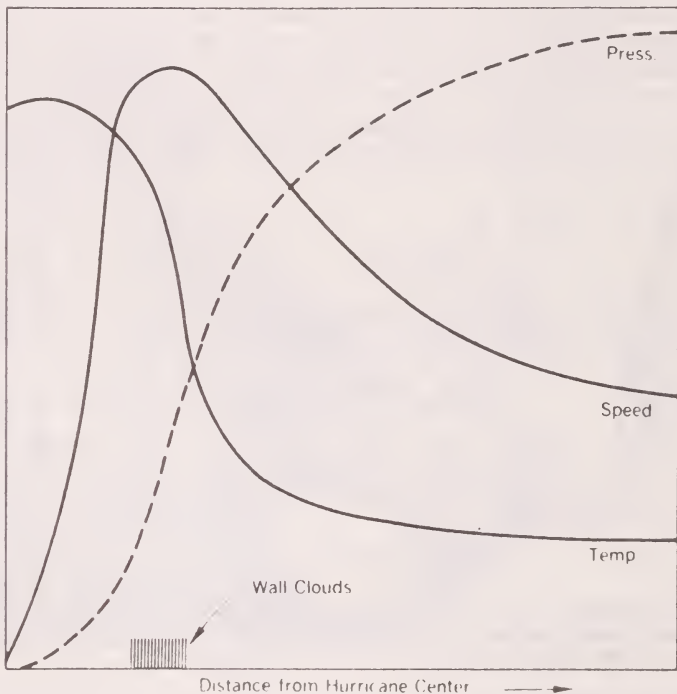


FIGURE 11.—Radial profiles of temperature, pressure, and windspeed for a mature hurricane. The temperature profile applies to levels of 3 to 14 kilometers; pressure and windspeed profiles apply to levels near the surface. (From Gentry, 1974.)

Modification of hurricanes

Since the damage inflicted by hurricanes is primarily a result of the high windspeeds, the principal goal of beneficial hurricane modifica-

⁴⁰ Jerome Williams, John J. Higginson, and John D. Rohrbough. "Sea and Air: The Naval Environment," Annapolis, Md., U.S. Naval Institute, 1968, pp. 262-263.

⁴¹ Gentry, "Hurricane Modification," 1974, pp. 502-503.

tion is the reduction of the severity of the storm's maximum winds. The winds result from the pressure distribution, which, in turn, is dependent on the temperature distribution. Thus, hurricane winds might be reduced through reduction of temperature contrasts between the core of the storm and the region outside.

Gentry notes that there are at least two important fundamentals of hurricanes which have been established through recent studies, which suggest possible approaches to modification of the severity of the storms:⁴²

The transfer of sensible and latent heat from the sea surface to the air inside the storm is necessary if the hurricane is to reach or retain even moderate intensity.

The energy for the entire synoptic-scale hurricane is released by moist convection in highly organized convective-scale circulations located in and around the eye of the storm and in the major rain bands. The first principle accounts for the fact that hurricanes form only over warm tropical waters and begin to dissipate after moving over land or cool water, since neither can provide sufficient energy flow to the atmosphere to maintain the intensity of the storm. The second principle explains why such a low percentage of tropical disturbances grow to hurricane intensity. Possible field experiments for beneficial modification of hurricanes follow from these principles. On the basis of the first, techniques for inhibiting evaporation might be employed to reduce energy flux from the sea surface to the atmosphere. Based on the second principle, it might be possible to affect the rate of release of latent heat in that small portion of the total storm which is occupied by the active convective-scale motions in such a way that the storm is weakened through redistribution of heating.⁴³

Gentry discusses a number of possible mechanisms which have been suggested for bringing about changes to the temperature field in a hurricane.⁴⁴ Since the warm core development is strongly influenced by the quantity of latent heat available for release in air columns rising near the center of the storm, the temperature might be decreased through reducing the water vapor in these columns, the water vapor originating through evaporation from the sea surface inside the region of high storm winds. It has been suggested that a film spread over the ocean would thus reduce such evaporation. No such film is available, however, which could serve this purpose and withstand rupturing and disintegration by the winds and waves of the storm. Another suggestion, that the cooling of the sea surface might be achieved through dropping cold material from ships or aircraft, is impractical, since such great expenditure of energy is required. It has also been postulated that the radiation mechanisms near the top of the hurricane might be modified through distribution of materials of various radiation properties at selected locations in the clouds, thus inducing changes to the temperatures in the upper part of the storm. This latter suggestion needs further evaluation both from the standpoint of its practicality and from the effect such a change, if included, would theoretically have on storm intensity.

The potential schemes for hurricane modification which seem to be practical logistically and offer some hope for success involve attempts

⁴² *Ibid.*, 1974, p. 503.

⁴³ *Ibid.*, p. 504.

⁴⁴ *Ibid.*, p. 505.

to modify the mechanism by which the convective processes in the eye wall and the rain bands distribute heat through the storm. Since water vapor is condensed and latent heat released in the convective clouds, it should be possible to influence the heat distribution in the storm through changing the pattern of these clouds.⁴⁵ Recent success in modifying cumulus clouds promises some hope of success in hurricane modification through cloud seeding. By modifying the clouds in a hurricane, the storm itself may be modified, since the storm's intensity will be affected through changing the interactions between the convective (cloud) scale and the synoptic (hurricane) scales.⁴⁶ Figure 12 shows how the properties of a hurricane might be redistributed as a result of changing the temperature structure through seeding the cumulus cloud structure outside the wall. The solid curves in the figure represent distributions of temperature, pressure, and windspeed identical with those shown in figure 11 without seeding; the dashed curves represent these properties as modified through seeding.⁴⁷

The first attempt at hurricane modification was undertaken by scientists of the General Electric Co., on a hurricane east of Jacksonville, Fla., on October 13, 1947. Clouds outside of the wall were seeded with dry ice in order to cause freezing of supercooled water, so that the accompanying release of latent heat might alter the storm in some manner. Results of the experiment could not be evaluated, however, owing to the lack of adequate measuring equipment for recording cloud characteristics. Furthermore, the penetration of the wall clouds to the eye or to the area of intense convection in the storm's rain bands was prevented by failure of navigation aids. Based on information acquired from more recent seeding experiments and increased understanding of hurricanes, it seems doubtful that the 1947 seeding could have been effective.⁴⁸

⁴⁵ *Ibid.*

⁴⁶ *Ibid.*, p. 504.

⁴⁷ *Ibid.*, pp. 504-505.

⁴⁸ *Ibid.*, pp. 505-506.

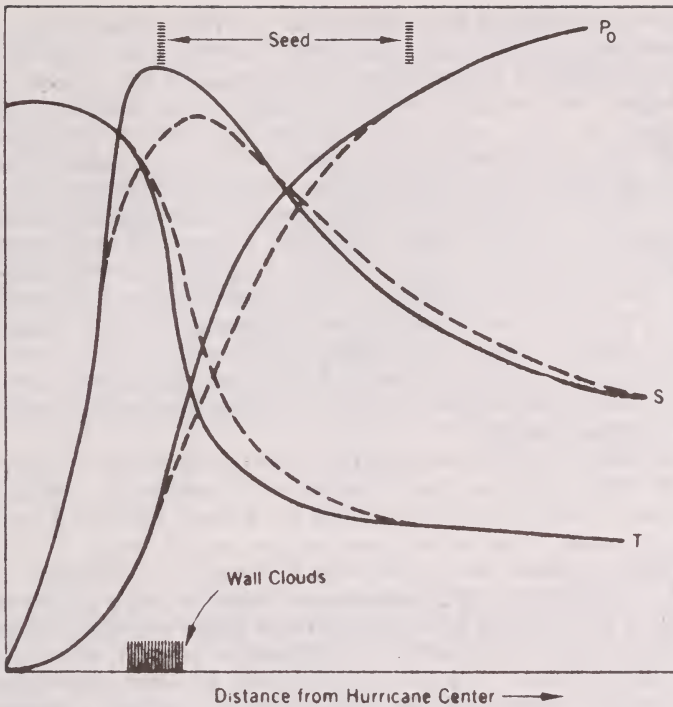


FIGURE 12.—Radial profiles of temperature, pressure, and windspeed for a mature hurricane before (solid curves) and possible changes after (dashed curves) seeding. (The solid curves are the same as those in fig. 11.) (From Gentry, 1974.)

Hurricane seeding experiments were undertaken by the Department of Commerce and other agencies of the Federal Government in 1961, initiating what came to be called Project Stormfury. To date only four hurricanes have actually been seeded under this project—all of them between 1961 and 1971; however, Stormfury has also included investigation of fundamental properties of hurricanes and their possible modification through computer modeling studies, through careful measurements of hurricane properties with research probes, and through improvements in seeding capabilities.

The goal of hurricane seeding is the reduction of the maximum winds through dispersing the energy normally concentrated in the relatively small band around the center of the storm. The basic rationale for seeding a hurricane with silver iodide is to release latent heat through seeding the clouds in the eye wall, thus attempting to change the temperature distribution and consequently weaken the sea level pressure gradient. It is assumed that the weakened pressure gradient will allow outward expansion, with the result that the belt of maximum winds will migrate away from the center of the storm and will therefore weaken. Actually, stimulation of condensation releases much more latent heat than first hypothesized in 1961, and theoretical hurricane models show that a new eye wall of greater diameter can be developed by encouraging growth of cumulus clouds through dynamic seeding.⁴⁹

⁴⁹ Ibid., pp. 510-511.

Following seeding of the four storms in Project Stormfury, changes were perceived, but all such changes fell within the range of natural variability expected of hurricanes. In no case, however, did a seeded storm appear to increase in strength. Hurricane Debbie, seeded first on August 18, 1969, exhibited changes, however, which are rarely observed in unseeded storms. Maximum winds decreased by about 30 percent, and radar showed that the eye wall had expanded to a larger diameter shortly after seeding. After Debbie had regained her strength on August 19, she was seeded again on August 20, following which her maximum winds decreased by about 15 percent.⁵⁰ Unfortunately, data are not adequate to determine conclusively that changes induced in Debbie resulted from seeding or from natural forces. Observations from Hurricane Debbie are partially supported by results from simulated experiments with a theoretical hurricane model; however, simulation of modification experiments with other theoretical models have yielded contrary results.⁵¹

One of the problems in evaluating the results of hurricane modification is related to the low frequency of occurrence of hurricanes suitable for seeding experiments and the consequent small number of such experiments upon which conclusions can be based. This fact requires that hurricane seeding experiments must be even more carefully planned, and monitoring measurements must be very comprehensive, so that data acquired in the few relatively large and expensive experiments can be put to maximum use. Meanwhile theoretical models must be improved in order to show the sensitivity of hurricane characteristics to changes which might be induced through seeding experiments.

Gentry has suggested that the following future activities should be conducted under Stormfury:⁵²

1. Increased efforts to improve theoretical models.
2. Collection of data to further identify natural variability in hurricanes.
3. Expanded research—both theoretical and experimental—on physics of hurricane clouds and interactions between the cloud and hurricane scales of motion.
4. More field experiments on tropical cyclones at every opportunity.
5. Tests of other methods and material for seeding.
6. Further evaluation of other hypotheses for modifying hurricanes.
7. Development of the best procedures to maximize results of field experiments.

Tornadoes

The structure of tornadoes is similar to that of hurricanes, consisting of strong cyclonic winds⁵³ blowing around a very low pressure center. The size of a tornado, however, is much smaller than that of a hurricane, and its wind force is often greater. The diameter of a tor-

⁵⁰ National Oceanic and Atmospheric Administration, "Stormfury—1977 to Seed One Atlantic Hurricane," U.S. Department of Commerce News, NOAA 77-248, Washington, D.C., Sept. 20, 1977, p. 3.

⁵¹ Gentry, "Hurricane Modification," 1974, p. 517.

⁵² *Ibid.*, p. 519.

⁵³ Cyclonic winds blow counterclockwise around a low pressure center in the Northern Hemisphere; in the Southern Hemisphere they blow clockwise.

nado is about one-fourth of a kilometer, and its maximum winds can exceed 250 knots in extreme cases.⁵⁴ On a local scale, the tornado is the most destructive of all atmospheric phenomena. They are extremely variable, and their short lifetime and small size make them nearly impossible to forecast with any precision.

Tornadoes occur in various parts of the world; however, in the United States both the greatest number and the most severe tornadoes are produced. In 1976, there were reported 832 tornadoes in this country,⁵⁵ where their origin can be traced to severe thunderstorms, formed when warm, moisture-laden air sweeping in from the Gulf of Mexico or the eastern Pacific strikes cooler air fronts over the land. Some of these thunderstorms are characterised by the violent updrafts and strong tangential winds which spawn tornadoes, although the details of tornado generation are still not fully understood. Tornadoes are most prevalent in the spring and occur over much of the Eastern two-thirds of the United States; the highest frequency and greatest devastation are experienced in the States of the middle South and middle West. Figure 13 shows the distribution of 71,206 tornadoes which touched the ground in the contiguous United States over a 40-year period.

Even in regions of the world favorable to severe thunderstorms, the vast majority of such storms do not spawn tornadoes. Furthermore, relatively few tornadoes are actually responsible for deaths and severe property damage. Between 1960 and 1970, 85 percent of tornado fatalities were caused by only 1 to 1½ percent of reported tornadoes.⁵⁶ Nevertheless, during the past 20 years an average of 113 persons have been killed annually by tornadoes in the United States, and the annual property damage from these storms has been about \$75 million.⁵⁷

Modification of tornadoes

Alleviation from the devastations caused by tornadoes through weather modification techniques has been a matter of considerable interest. As with hurricanes, any such modification must be through some kind of triggering mechanism, since the amount of energy present in the thunderstorms which generate tornadoes is quite large. The rate of energy production in a severe thunderstorm is roughly equal to the total power-generating capacity in the United States in 1970.⁵⁸ The triggering mechanism must be directed at modifying the circulation through injection of small quantities of energy.

⁵⁴ Anthes, Panofsky, Cahir, and Rango, "The Atmosphere," pp. 150, 180.

⁵⁵ NOAA news. "Skywarn 1977—Defense Against Tornadoes," U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Rockville, Md., Feb. 18, 1977, vol. 2, No. 4, pp. 4-5.

⁵⁶ Davies-Jones, Robert and Edwin Kessler, "Tornadoes." In Wilmot N. Hess (ed.), "Weather and Climate Modification," New York, John Wiley & Sons, 1974, p. 552.

⁵⁷ *Ibid.*

⁵⁸ Anthes, Panofsky, Cahir, and Rango, "The Atmosphere," 1975, p. 185.

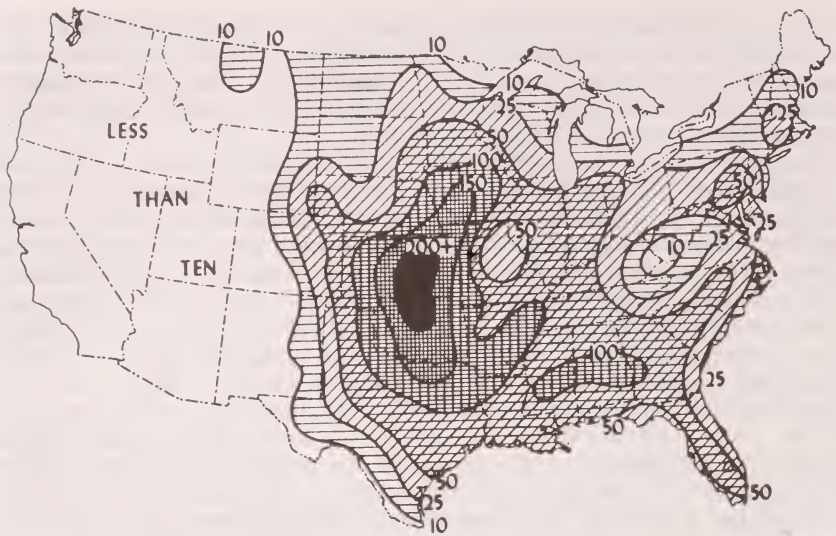


FIGURE 13.—Tornado distribution in the United States, where contours enclose areas receiving equal numbers of tornadoes over a 40-year period. Frequencies are based on number of 2-degree squares experiencing first point of contact with the ground for 71,206 tornadoes. (From Wilkins, 1967, in *Encyclopedia of Atmospheric Sciences and Astrology*, Reinhold.)

Tornado modification has not been attempted in view of the present insufficient knowledge about their nature and the lack of adequate data on associated windspeeds. There are potential possibilities, however, which can be considered for future research in tornado modification. One proposal is to trigger competing meteorological events at strategic locations in order to deprive a tornadic storm of needed inflow. This technique, suggested by the presence of cumulus clouds over forest fires, volcanoes, and atomic bomb blasts could use arrays of large jet engines or oil burning devices. Another approach for dispersal of convective clouds which give rise to thunderstorms might involve the use of downrush created by flying jet aircraft through the clouds. A further possibility would depend on changing the characteristics of the Earth's surface such as the albedo or the availability of water for evaporation.⁵⁹

Tornadoes tend to weaken over rougher surfaces due to reduction of net low-level inflow. Upon meeting a cliff, tornadoes and waterspouts often retreat into the clouds, and buildings also tend to reduce ground level damage. Thus, forests or artificial mounds or ridges might offer some protection from tornadoes, although very severe tornadoes have even left swaths of uprooted trees behind.⁶⁰

Modification of tornadoes by cloud seeding would likely be the cheapest and easiest method. Sodium iodide seeding could possibly shorten the life of a tornado if the storm's cold air outflow became stronger and overtook the vortex sooner, thus cutting off the inflow. Seeding a neighboring cell upstream of the low-level inflow might also be bene-

⁵⁹ Davies-Jones and Kessler, "Tornadoes," 1974, p. 590.

⁶⁰ *Ibid.*

ficial, if the rapidly developing seeded cloud, competing for warm, moist air, reduces the inflow and weakens the rotating updraft. It is also possible that seeding would increase low-level convergence, leading to intensification of a tornado.⁶¹

Davies-Jones and Kessler conclude that :

Any efforts to modify a severe storm with potential or actual tornadoes obviously will have to be carried out with extreme caution * * *. Actual modification attempts on menacing tornadoes are probably several years away. In the meantime, we should seek improved building codes and construction practices and continue research into the actual morphology of convective vortices.⁶²

In spite of the speculations on how tornadoes might be modified, no tests have yet been conducted. The small size and brief lifetime of tornadoes make them difficult and expensive to investigate. However, in view of their destructiveness, they must be given more attention by meteorologists, who should seek ways to mitigate their effects. Only further research into the character of tornadoes, followed by careful investigation of means of suppressing them, can lead to this desired reduction in the effects of tornadoes.

TECHNICAL PROBLEM AREAS IN PLANNED WEATHER MODIFICATION

In this section a number of major problem areas associated with the development of weather modification technology will be addressed. These topics are not necessarily confined to the modification of any one of the weather phenomena discussed in the previous section but apply in general to a number of these categories of phenomena. Some of the problem areas have implications which extend beyond the purely technical aspects of planned weather modification, bearing also on social, economic, and legal aspects as well. Included are discussions on the problems of seeding technology, evaluation of results of weather modification projects, extended area and extended time effects from advertent weather modification, and potential approaches to weather and climate modification which involve techniques other than seeding. The problems of inadvertent weather modification and of potential ecological effects from planned weather modification could also properly be included in this section; however, these topics are addressed in chapter 4 and 13, respectively, in view of their special significance.

SEEDING TECHNOLOGY

In recent years there has been progress in developing a variety of ice-nucleating agents available for cloud seeding, although silver iodide continues to be the principal material used. Other seeding agents which have been studied include lead iodide, metaldehyde, urea, and copper sulfide. Nucleants have been dispensed into the clouds from both ground-based generators or from aircraft. In some foreign countries, such as the Soviet Union, rockets or artillery have been used to place the seeding material into selected regions of the clouds; however, this means of delivery does not seem to be acceptable in the United States.

There have been both difficulties and conflicting claims regarding the targeting of seeding materials, particularly from ground generators, ever since the earliest days of cloud seeding. It is always hoped that

⁶¹ *Ibid.*, pp. 590-591.

⁶² *Ibid.*, p. 591.

the nucleant will be transported from the generator site by advection, convection, and diffusion to parts of the clouds which have been identified for modification. Difficulties have been observed under unstable conditions, where the plume of nucleants was disrupted and wide angle turbulent diffusion was severe. Valley locations in mountainous areas are often subjected also to inversions and to local channeling so that trajectory determinations are extremely difficult. Even plumes of seeding material from aircraft have shown an erratic pattern. The problems of irregular plume geometry appear to increase as distortion occurs near fronts in mountain terrain, that is, under just the circumstances where cloud seeding is often attempted.⁶³

In view of the limited vertical transport of silver iodide observed in some studies (that is, up to 450 meters above the terrain at distances of several kilometers from the generators), some have concluded that, under conditions of the tests, ground-based generators are probably not effective. However, other studies have shown that one cannot generalize that ground generators are not always effective. Thus, more desirable effects can be achieved with generators at high altitudes where there is little chance of inversion trapping of the silver iodide as in other tests.⁶⁴

Much of the ambiguity associated with ground-based generators is reduced when the nucleant material is placed into the cloud directly by an aircraft using flares or rockets. However, airborne seeding also presents important targeting problems. Of course, targeting difficulties are reduced in the case of single cloud seeding, where the aircraft is flying directly beneath the cloud in the active updraft area. However, questions of proper vertical ascent persist when the objective is to lay down from the aircraft an elevated layer of nucleant-rich air that is intended to drift over the target area.⁶⁵

In conclusion, the 1973 National Academy of Sciences study says:

To summarize the results of the past few years' work on targeting, it can be said that earlier doubts about the inevitability of nuclei reaching effective altitudes from ground generators tend to be supported by a number of recent observational studies. Some of these merely confirm the rather obvious prediction that stable lapse rates will be unfavorable to the efficacy of ground generators; others indicate surprising lack of vertical ascent under conditions that one might have expected to favor substantial vertical transport. The recent work also tends to support the view that plumes from ground generators in mountainous terrain must be expected to exhibit exceedingly complex behavior; and each site must be expected to have its own peculiarities with respect to plume transport. Tracking experiments become an almost indispensable feature of seeding trials or operations in such cases.⁶⁶

There are three types of airborne seeding agent delivery systems in common use—burners, flares, and hoppers. Burners are used mainly for horizontal seeding, often at the cloud base as discussed above. Polytechnic flares are of two types—those used in vertical drops, similar to a shotgun shell or flare-pistol cartridge, and the end-burning type, similar to warning flares. The flares contain silver iodide with or without an auxiliary oxidizer, such as potassium nitrate, together with aluminum, magnesium, and synthetic resin binder. Dropping flares are

⁶³ National Academy of Sciences, National Research Council, Committee on Atmospheric Sciences, "Weather and Climate Modification: Problems and Progress," Washington, D.C., 1973, pp. 115-16.

⁶⁴ *Ibid.*, p. 117.

⁶⁵ *Ibid.*, pp. 118, 120.

⁶⁶ *Ibid.*, pp. 119-120.

intended to be dropped into updrafts and to seed the cloud over a vertical depth as great as a kilometer, while burner seeding is intended to be more controlled and gradual. Hoppers dispense materials in solid form, such as the particles of dry ice crushed and dropped into clouds and cold fogs. For warm fog and cloud modification hoppers are used to dispense dry salt or urea. Sometimes these materials are pumped in a solution to nozzles in the wings, where the wingtip vortices help mix the agent into the air.⁶⁷

On the ground there are a number of seeding modes which are frequently used, and types of nucleants used with ground-based generators are commonly of two types—a complex of silver iodide and sodium iodide or of silver iodide and ammonium iodide. Outputs from the generator are usually from 6 to 20 grams per hour, although generators with much greater outputs are used sometimes. One seeding mode involves dispensing continuously into the airstream from a ground generator at a fixed point, the approach used most commonly in mountainous terrain. If the generator is located in flat country at temperatures above freezing, the nucleation level is reached through entrainment of the material into the convection.⁶⁸

The nucleating effectiveness of silver iodide smoke is dependent upon the cloud temperature, where the colder the temperature the greater is the number of ice crystals formed per gram of silver iodide. Tests of nucleating effectiveness are made in the Colorado State University cloud simulation facility, where the nucleant is burned in a vertical wind tunnel and a sample of the aerosol is collected in a syringe and nucleant density calculated from the pyrotechnic burn rate and the tunnel flow rate. The syringe sample is diluted with clean, dry air and injected into a precooled isothermal cold chamber containing cloud droplets atomized from distilled water. Ice crystals which grow and settle out are collected on microscopic slides, so that nucleating effectiveness can be calculated as the ratio of concentrated crystals detected to the mass of nucleating material in the air sample.⁶⁹

As part of the preparations for the 1976 seeding operations in the Florida area cumulus experiment (FACE) of the National Oceanic and Atmospheric Administration (NOAA), Sax et al., carefully evaluated the silver iodide effectiveness of different flares used in FACE. The results of these effectiveness studies, conducted with the Colorado State University facility, are shown in figure 14. It was discovered that a newly acquired airborne flare, denoted as NEI TB-1 in the figure, was considerably more effective than both the Navy flares used earlier and another commercially available flare (Olin WM-105). The superiority of the NEI TB-1 material at warmer temperatures is particularly noteworthy.⁷⁰ In another paper, Sax, Thomas, and Bonebrake observe that crystalline ice concentrations in clouds seeded in FACE during 1976 with the NEI flares greatly exceeded those found in clouds seeded during 1975 with Navy flares.

⁶⁷ Ruskin, R. E. and W. D. Scott, "Weather Modification Instruments and Their Use." In Wilmot N. Hess (ed.), "Weather and Climate Modification," New York, Wiley, 1974, pp. 193-194.

⁶⁸ Elliott, Robert D., "Experience of the Private Sector." In Wilmot N. Hess (ed.), "Weather and Climate Modification," New York, Wiley, 1974, p. 57.

⁶⁹ Sax, Robert L., Dennis M. Garvey, Farn P. Parungo, and Tom W. Slusher, "Characteristics of the AgI Nucleant Used in NOAA's Florida Area Cumulus Experiment." In preprints of the "Sixth Conference on Planned and Inadvertent Weather Modification," Champaign, Ill., Oct. 10-13, 1977. American Meteorological Society, Boston, 1977, p. 193.

⁷⁰ *Ibid.*, pp. 198-201.

They conclude that, if differences in sampling time intervals and effects of instrumentation housing can be ignored, there is indicated a much greater nucleation effectiveness for the NEI flares which were used predominantly after July 1975.⁷¹ The implications of this result are very far reaching, since the borderline and/or slightly negative results of many previous experiments and operational projects can possibly be laid to the ineffectiveness of the silver iodide flares previously used.

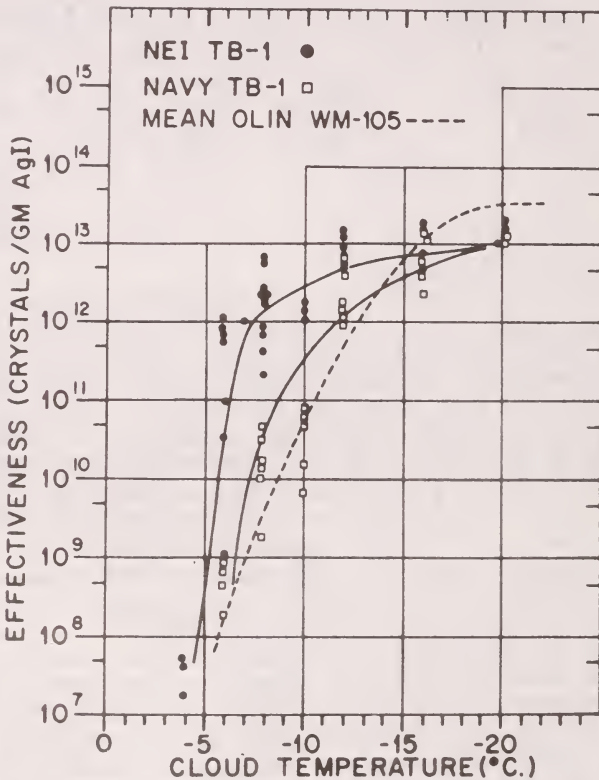


FIGURE 14.—Effectiveness of various silver iodide flares in providing artificial nuclei as a function of cloud temperature. The principal comparison is between the NEI TB-1 and the Navy TB-1 flares (see text); the curve of mean data for the Olin WM-105 flares is included for comparison. The curves show that the NEI flares, used in FACE in late 1975 and 1976 were significantly more effective in producing nuclei at warmer temperatures just below freezing. (From Sax, Garvey, Parungo, and Slusher, 1977.)

EVALUATION OF WEATHER MODIFICATION PROJECTS

There has been much emphasis on evaluation methodology on the part of weather modification meteorologists and statisticians, particularly with regard to precipitation modification. Progress in this

⁷¹ Sax, Robert L., Jack Thomas, Marilyn Bonebrake, "Differences in Evolution of Ice Within Seeded and Nonseeded Florida Cumuli as a Function of Nucleating Agent." In preprints of the "Sixth Conference on Planned and Inadvertent Weather Modification," Champaign, Ill., Oct. 10-13, 1977. Boston, American Meteorological Society, 1977," pp. 203-205.

area has been slow, owing to the complexity of verification problems and to inadequate understanding of cloud physics and dynamics.

Having reviewed previous considerations of evaluation attempts, Changnon discovered a wide variety of results and interpretations, noting that "a certain degree of this confusion has occurred because the methods being used were addressed to different purposes and audiences, and because there has been no widely accepted method of verification among investigators."⁷² He continues:

For instance, if one considers identification of changes in the precipitation processes most important to verification of modification efforts, then he will often undertake evaluation using a physical-dynamic meteorological approach. If he considers statistical proof of surface precipitation changes the best method, he may concentrate verification solely on a statistical approach or make inadequate use of the physical modeling concepts. On the other hand, if the evaluation is to satisfy the public, the consumer, or the governmental decision-maker, it must be economic-oriented also. Hence, a review of the subject of previous evaluation methodology must be constantly viewed with these different goals and concepts in mind.⁷³

Evaluation methodology for weather modification must deal with three fundamental problems which Changnon has identified:⁷⁴

1. There are many degrees of interaction among atmospheric forces that result in enormous variability in natural precipitation, greatly restricting attempts for controlled experiments that are attainable in other physical and engineering sciences.

2. There is an absolute need to evaluate weather modification with statistical procedures; this requirement will exist until all underlying physical principles of weather modification can be explained.

3. The data used in the evaluation must be sufficiently adequate in space and time over an experimental region to overcome and describe the natural variability factors, so that a significant statistical signal may be obtained within the noise of the variability.

It is further recognized that analysis of weather modification experiments is closely akin to the weather prediction problem, since evaluation of weather modification efforts is dependent on a comparison of a given weather parameter with an estimate of what would have happened to the parameter naturally. Thus, the better the prediction of natural events, the better can a weather modification project be designed and evaluated, at the same time reducing the verification time required by a purely statistical approach.⁷⁵

Initially, weather modification evaluation techniques used only the observational or "look and see" approach, improved upon subsequently by the "percent of normal" approach, in which precipitation during seeding was compared with normals of the pre-experimental period. Later, using fixed target and control area data comparisons, regression techniques were attempted, but the high variability of precipitation in time and space made such approaches inapplicable. In the mid-1960's there was a shift in sophisticated experiments toward use of randomization. In a randomized experiment, seeding events are selected according to some objective criteria, and the seeding agent is applied or withheld in sequential events or adjacent areas

⁷² Changnon, Stanley A., Jr., "A Review of Methods to Evaluate Precipitation Modification in North America." Proceedings of the WMO/IAMAP Scientific Conference on Weather Modification. Tashkent, U.S.S.R., Oct. 1-7, 1973. World Meteorological Organization. WMO—No. 399, Geneva, 1974, p. 397.

⁷³ *Ibid.*, p. 398.

⁷⁴ *Ibid.*

⁷⁵ *Ibid.*

in accordance with a random selection scheme. An inherent problem with randomization is the length of experimental time required; consequently, the approach is not often satisfying to those who wish to obtain maximum precipitation from all possible rain events or those who want to achieve results in what appears to be the most economical manner. As a result, commercial projects seldom make use of randomization for evaluation, and such techniques are generally reserved for research experiments.⁷⁶

In very recent years the randomization approach, which to many appeared to be too "statistical" and not sufficiently meteorological in character, has been improved on through a better understanding of atmospheric processes, so that a physical-statistical approach has been adopted.⁷⁷

Changnon reviewed approximately 100 precipitation modification projects in North America and found essentially 6 basic methods that have been employed in project evaluations. He identified these as (1) direct observation (usually for single element seeding trials), (2) one-area continuous with no randomization (involving historical and/or spatial evaluation), (3) one-area randomization, (4) target-control area comparisons, (5) cross-over with randomization, and (6) miscellaneous.⁷⁸ These methods, along with the kinds of data which have been used with each, are listed in table 9.

TABLE 9.—REVIEW OF EVALUATION METHODS FOR PRECIPITATION MODIFICATION AND TYPES OF DATA EMPLOYED

[From Changnon, "A Review of Methods to Evaluate Precipitation Modification in North America," 1974]

Methods		Surface precipitation data	Meteorological elements data	Geophysical-economic data
Direct observation.....		Change in type; duration of precipitation; areal distribution (vs. model).	Cloud parameters; echo parameters; seed and plume.	
One-area continuous (nonrandom).	Historical.....	Area-rain regressions; weekend-weekday rainfall differences; frequency of rain days.	Frequency of severe weather; frequency of smoke days.	Added runoff; crop yields; ecological.
	Spatial.....	Area-rain regressions; pattern recognition; trend surfaces; rain rates; raindrop sizes; frequency of rain days; rain cell differences; precipitation type change; areal extent of rain.	Synoptic weather conditions; cloud parameters; echo parameters; A _{pl} plums; nuclei sources; airflow-plume behaviors; tracers in rain; atmospheric electrical properties.	Runoff increases; crop yields; ecological.
Target control.....		Area rainfall (day, month, season) regressions; area snowfall (day, month, season).	Echo parameters.....	Runoff regressions.
One-area randomized (hours pulsed).	Basically statistical.	Area precipitation; plume area precipitation; change in precipitation type. Period precipitation; echo area; rain rates; echo reflectivity; rain initiation.	Synoptic weather conditions; cloud parameters; seed material in plumes. Echo parameters; A _{pl} in rain; cloud numerical models; storm behavior; cloud base rain rate.	Water yield; runoff; ecosystem (plant and animals) and erosion; avalanche—disbenefits.
	Physical plus statistical.			
Crossover randomized.		Area rainfall; zonal rainfall.	Synoptic types and upper air conditions.	
Miscellaneous (post hoc stratifications).			Upper air: 1. Temperature. 2. Winds. 3. Moisture stability indices. Synoptic weather types.	

⁷⁶ *Ibid.*, p. 399.

⁷⁷ *Ibid.*, p. 400.

⁷⁸ *Ibid.*, p. 407.

The direct observation technique was the first major approach to evaluation and is still used occasionally. In addition to direct observation of the change and type of precipitation at the surface, the time of precipitation initiation, and areal distribution following treatment of a cloud or cloud group, other meteorological elements have been observed; these include radar echo characteristics, plume of the seeding material, and cloud parameters (microphysical properties and dynamical and dimensional properties such as updrafts, cloud size, and rate of growth).⁷⁹

The one-area continuous (nonrandomized) techniques have been employed to evaluate many of the commercially funded projects in North America, recent efforts to investigate inadvertent precipitation modification by large urban-industrial areas, and the statewide South Dakota seeding program. This category includes the largest number of projects, and control data for these nonrandomized projects have included both historical data and data from surrounding areas. The uncertainty of the control data as a predictor of target data is the basic problem in using this approach.⁸⁰

Most federally sponsored weather modification projects have used the one-area randomization method, which involves the use of a variety of precipitation elements, including duration, number of storms, and storm days and months. Projects evaluated with this method fall into two categories, including, as shown in table 9, those using the basic statistical approach and the more recent physical plus statistical techniques. The latter group of projects have been based on a greater knowledge of cloud and storm elements, using this information in defining seedable events and combining it with statistical tests to detect effects. Surface data, including rainfall rates and area mean rainfall differences, are used to evaluate such one-area randomized projects.⁸¹

The target-control method involves a single area that is seeded on a randomized basis and one or more nearby control areas that are never seeded and, presumably, are not affected by the seeding.⁸² The method had been used in about 10 North American projects through 1974. Evaluation data have been mostly area rainfall or snowfall regressions, runoff differences, and radar echo parameter changes.⁸³

The crossover (with randomization) method has been considered by many to be the most sophisticated of the statistical evaluation methods. The crossover design includes two areas, only one of which is seeded at a time, with the area for seeding selected randomly for each time period. As with the target-control method, a problem arises in this method in that there is the possibility of contamination of the control areas from the seeded area.⁸⁴ In the single project to which the method had been applied up to 1974, the evaluation procedure involved classification of potential treatment events according to meteorological conditions, followed by area and subarea rainfall comparisons.⁸⁵ The

⁷⁹ *Ibid.*

⁸⁰ *Ibid.*, pp. 408-409.

⁸¹ *Ibid.*, p. 409.

⁸² Brier, Glenn W. "Design and Evaluation of Weather Modification Experiments." In Wilmot N. Hess (editor), "Weather and Climate Modification," New York, Wiley, 1974, p. 209.

⁸³ Changnon. "A Review of Methods To Evaluate Precipitation Modification in North America," 1974, p. 409.

⁸⁴ Brier. "Design and Evaluation of Weather Modification Experiments," 1974, p. 210.

⁸⁵ Changnon. "A Review of Methods To Evaluate Precipitation Modification in North America," 1974, p. 409.

miscellaneous methods in table 9 refer basically to evaluation efforts that have occurred after but generally within the context of the five methods mentioned above, and have been largely post-hoc stratifications of results classified according to various meteorological subdivisions, followed by re-analysis of the surface rainfall data based on these stratifications.⁸⁶

TABLE 10.—REVIEW OF EVALUATION METHODS FOR HAIL MODIFICATION AND TYPES OF DATA EMPLOYED
[From Changnon "A Review of Methods to Evaluate Precipitation Modification in North America," 1974]

Methods	Surface hail data	Meteorological elements	Geophysical-economic
Direct observation.....	Cessation of hail; hail pattern; hail sizes change; hailstone character.	Echo parameters; cloud parameters; Agl in hail.	
One-area continuous (non-random).	Historical..... Number of hail days..... Spatial..... Number of hail-producing clouds/unit time; hailstreak frequencies; number of hail days; rainfall characteristics; impact energy; location of hail vs. total precipitation area.	Radar echo characteristics.	Crop-hail loss (insurance); insurance rates. Crop-hail loss (insurance)
Target-control.....	Energy; hail day frequency.	Radar echo characteristics.	Hail loss (insurance).
One-area randomization.	Impact energy; hail day frequency; hailfall characteristics.	Radar echo characteristics; Agl in hail-rain.	Ecosystem (Agl); crop-loss data.
Cross-over randomized.	Energy; area of hail; volume of hail.	Agl in hail.	

About 20 projects concerned with hail modification were also analyzed by Changnon with regard to the evaluation techniques used. The five methods used, shown in table 10, include the first five methods listed in table 9 and discussed above for precipitation modification evaluation. A comparison of tables 9 and 10 reveals that the evaluation of rain and snow modification projects uses much less variety of kinds of data, especially the meteorological elements. The evaluation of hail projects is largely statistical, owing to the lack of sophistication in the physical modelling of hailstorms. There has been greater use of economic data in hail evaluation, however, than in evaluation of rainfall projects, due to some extent to the lack of surface hail data in weather records and the consequent need to make use of crop insurance data.⁸⁷

In hail evaluation, the direct observation method has been used to look at physical effects from seeding individual storms and storm systems, involving analysis of time changes in surface hail parameters, radar echo characteristics, and cloud properties. The one-area continuous (non-random) method has been the principal one used in commercial hail projects and in studies of inadvertent urban-industrial effects on hail, using historical and/or spatial data in the evaluation. One major data form in these evaluations is the crop-hail loss from insurance data. The target-control method has made use of hailfall energy, hail-day frequencies, and crop-hail loss as evaluation data.⁸⁸

⁸⁶ *Ibid.*

⁸⁷ *Ibid.*, pp. 412-413.

⁸⁸ *Ibid.*, p. 413.

The one-area randomization method is the method used in the National Hail Research Experiment.⁸⁹ Various degrees of randomization have been used, ranging from 50–50 to 80–20; however, the evaluation data have been similar to those used in other methods. Silver concentrations in samples of rain and hail and elsewhere in the ecosystem have been used as evaluation criteria. The crossover randomized method of evaluation has also been applied to hail projects, using such data as areal comparisons of impact energy, area extent of hail, and total hail volume, noting also the concentrations of seeding material in the hailstones.⁹⁰

A necessary part of any evaluation scheme involves the measurement or estimation of the amounts of precipitation fallen over a given area following seeded or control storm events. Such measurement is part of a more general requirement as well in collecting data for validation of weather predictions, development of prediction models, compilation of climatic records, and forecasting of streamflow and water resources. Although the customary approach to precipitation measurement has been to use an array of rain gages, weather radars have proven to be useful tools for studying generally the spatial structure of precipitation. Depending on the quality of the onsite radar system calibration, there have been varying degrees of success, however, in use of this tool. Often radar and rain gage data are combined in order to obtain the best estimate of precipitation over a given area. In this arrangement, the radar is used to specify the spatial distribution and the gauges are used to determine the magnitude of the precipitation.⁹¹

Exclusive use of rain gauges in a target area in evaluation of convective precipitation modification projects requires a high gauge density to insure adequate spatial resolution. For a large target area, such an array would be prohibitively expensive, however, so that weather radars are often used in such experiments. The radar echos, which provide estimates of precipitation, are calibrated against a relatively smaller number of rain gages, located judiciously in the target area to permit this calibration.

It has been shown that adjusted radar estimates are sometimes superior to either the radar or the gages alone. Furthermore, the best areal estimates are obtained using a calibration factor which varies spatially over the precipitation field rather than a single average adjustment. Erroneous adjustment factors may be obtained, however, if precipitation in the vicinity of the calibration gage is so highly variable that the gage value does not represent the precipitation being sampled by the radar. The technique for calculating the adjustment factor typically involves dividing the gage measurement by the summed rainfall estimates inferred from the radar, to obtain the ratio, G/R , used subsequently to adjust radar estimates over a greater area.⁹²

⁸⁹ The National Hail Research Experiment is discussed as part of the weather modification program of the National Science Foundation, ch. 5, p. 274ff.

⁹⁰ Changnon, "A Review of Methods To Evaluate Precipitation Modification in North America," 1974, p. 413.

⁹¹ Crane, Robert K., "Radar Calibration and Radar-rain Gauge Comparisons." In preprints of the "Sixth Conference on Planned and Inadvertent Weather Modification," Champaign, Ill., Oct. 10–13, 1977. Boston, American Meteorological Society, 1977, p. 369.

⁹² Klazura, Gerald E., "Changes in Gage/radar Ratios in High Rain Gradients by Varying the Location and Size of Radar Comparison Area." In preprints of the "Sixth Conference on Planned and Inadvertent Weather Modification," Champaign, Ill., Oct. 10–13, 1977. Boston, American Meteorological Society, 1977, p. 376.

In the evaluation of hail suppression experiments, or measurements of hailfall in general, there must be some means of determining the extent and the magnitude of the hail. One technique is to use a network of surface instruments called hailpads. Since single storms can lay down hail swaths up to 100 kilometers long and tens of kilometers wide, made up of smaller patches called "hailstreaks," the spacings of hailpads must be reduced to a few hundred meters to collect quantitative data over small areas. Even over small distances of the order of 1 kilometer, it has been discovered that total numbers of hailstones, hail mass, and hail kinetic energy can vary by over a factor of 10.⁹³ Another means of estimating hailfall is through use of crop-damage studies. Such results are obtained through crop-loss insurance data, aerial photography of damaged fields, and combinations of these data with hailpad measurements.⁹⁴

EXTENDED AREA EFFECTS OF WEATHER MODIFICATION

The term "extended area effects" refers to those unplanned changes to weather phenomena which occur outside a target area as a result of activities intended to modify the weather within the specified target area. Such effects have also been called by a variety of other names such as "downwind effects," "large-scale effects," "extra-area effects," "off-target effects," and "total-area effects." When the time dimension is considered, those changes which occur, or are thought to have occurred, either within the spatial bounds of the target area or in the extended area after the intended effects of the seeding should have taken place are referred to as "extended time effects." These inadvertent consequences are usually attributed either to the transport of seeding material beyond the area intended to be seeded or the lingering of such material beyond the time during which it was to be effective.

In a number of experiments there have been indications that an extended area effect occurred. The present state of understanding does not permit an explanation of the nature of these effects nor have the experimental designs provided sufficient information to describe their extent adequately. The subject is in need of additional study, with experiments designed to provide more specific data over pertinent area and time scales. In recent years two conferences on extended area effects of cloud seeding have been convened. The first conference, attended by 18 atmospheric scientists, was held in Santa Barbara, Calif., in 1971 and was organized by Prof. L. O. Grant of Colorado State University and by Robert D. Elliott and Keith J. Brown of North American Weather Consultants. Attendees at the 1971 seminar discussed existing evidence of extended area effects, considered the possible means of examining detailed mechanisms responsible for the effects, and debated the implications for atmospheric water resources management.

A second workshop was held, under the sponsorship of the National

⁹³ Morgan, Griffith M. and Neil G. Towery. "Surface Hail Studies for Weather Modification." In preprints of the "Sixth Conference on Planned and Inadvertent Weather Modification," Champaign, Ill., Oct. 10-13, 1977, p. 384.

⁹⁴ *Ibid.*

Science Foundation, at Colorado State University, Fort Collins, Colo., Aug. 8-12, 1977.⁹⁵ The Fort Collins meeting was attended by 44 participants, composed of social scientists, observationists, physical scientists, modellers, statisticians, and evaluators. The group was exposed to a mass of data from various weather modification projects from all over the world and proposed to accomplish the following objectives through presentations, workshop sessions, and general discussions:

Renew the deliberations of the Santa Barbara seminar.

Expand the scope of participation so as to integrate and interpret subsequent research.

Better define the importance of extended spatial, temporal, and societal effects of weather modification.

Prepare guidelines and priorities for future research direction.⁹⁶

Extended area effects have special importance to the nontechnical aspects of weather modification. From deliberations at the 1977 extended area effects workshop it was concluded that:

The total-area of effect concept adds a new dimension to an already complex analysis of the potential benefits and disbenefits of weather modification. A specified target area may have a commonality of interests such as a homogeneous crop in a farm area or a mountain watershed largely controlled by reservoirs built for irrigation and/or hydroelectric power generation. Socioeconomic analysis of this situation is much more direct than the consideration of the total-area of effect which may well extend into areas completely dissimilar in their need or desire for additional water. The spatial expansion of the area of effect may increase or decrease the economic and societal justification for a weather modification program. The political and legal consideration may also be complicated by this expansion in scope since effects will frequently extend across state or national borders.⁹⁷

The strongest evidence of extended area effects is provided by data from projects which involved the seeding of wintertime storm systems. Statistical analyses of precipitation measurements from these projects suggest an increase in precipitation during seeded events of 10 to 50 percent over an area of several thousand square kilometers. Some of the evidence for these effects, based mostly on post hoc analyses of project data, appears fairly strong, though it remains somewhat suggestive and speculative in general.⁹⁸

Based upon two general kinds of evidence: (1) observational evidence of a chemical or physical nature and (2) the results of large scale/long-term analyses; a workshop group examining the extended area effects from winter orographic cloud-seeding projects assembled the information in table 11. It should be noted that the quality of the evidence, indicated in the last column of the table, varies from "well documented" and "good evidence" to "unknown" and "no documentation available;" however, the general kinds of extended area and extended time effects from a number of winter projects are illustrated.⁹⁹

⁹⁵ Brown, Keith J., Robert D. Elliott, and Max Edelstein, "Transactions of Workshop on Extended Space and Time Effect of Weather Modification," Aug. 8-12, 1977, Fort Collins, Colo. North American Weather Consultants, Goleta, Calif., February 1978, 279 pp.

⁹⁶ *Ibid.*, pp. 7-9.

⁹⁷ *Ibid.*, p. 13.

⁹⁸ *Ibid.*, p. 10.

⁹⁹ Warburton, Joseph A., "Extended Area Effects From Winter-orographic Cloud Seeding Projects," report of workshop panel. In Keith J. Brown, et al. "Transactions of Workshop on Extended Space and Time Effects of Weather Modification," Aug. 8-12, 1977, Fort Collins, Colo. North American Weather Consultants, Goleta, Calif., February 1978, pp. 137-164.

TABLE 11.—EVIDENCE OF EXTENDED AREA EFFECTS FROM WINTER OROGRAPHIC SEEDING PROJECTS, BASED UPON EVIDENCE FROM (A) OBSERVATIONS AND (B) LARGE-SCALE/LONG-TERM ANALYSES

[From Warburton, 1978]					
A. OBSERVATIONAL—PHYSICAL, CHEMICAL					
Observation	Type of effect	Magnitude of effect	Area of effect	Mechanism	Quality of evidence
Ice crystal anvil production from dry ice seeding of cumulus clouds, Blue Mountains, Australia.	Spatial and time.	Produced rain 6–12 mm over 18-hour period.	1500 km ²	Cirrus seeding and transport of crystals from seeding with CO ₂ .	Documentation needed (is available).
Persistence of ice nuclei at Climax—probably AgI for days after seeding.	Time.....	100× natural nuclei concentration.	Unknown.....	Unknown.....	Well documented (is available).
Transport of AgI from Climax generators to 30 km downwind.	Spatial.....	30 N/liter (–20° C).	~40 km ²	Transport of nuclei.	Few aircraft observations.
Silver in snow, Sierra Nevada and Rockies—up to 100 km from generators.	.....do.....	4 to 100× background.	Continuum from generators.	Physical transport of AgI on hydro-meters containing AgI.	5 yr of observations.
Pressure reductions in seeded band periods, Santa Barbara.	Time.....	Max. –2 mb...	Continuum from seeding sites (~1000 km ²).	Dynamic heating.	Fair to moderate documentation.
Cirrus shield produced by airborne seeding, Warragamba, Australia.	.....do.....	Up to 25 percent of seeded days.	2000 km ² (1 aircraft).	Ice crystal seeding of lower clouds.	Documentation needed (is available).
B. RESULTS OF LARGE-SCALE/LONG-TERM ANALYSES					
Projection description	Type of effect	Magnitude of effect	Area of effect	Quality of evidence	
Victoria, Australia, drought relief—non-randomized.	Spatial.....	30 percent > 40-yr, average, 3 successive yr.	35,000 km ² ; continuum from seeding sites.	No documentation available.	
Warragamba and other large-scale experiments—Australia decrease in S/NS ratio wth years of experiment. ¹	Time; long-term.....	10 to 40 percent.....	Artifact of analysis...	Reanalysis needed avoiding ratios and double ratios.	
Israel 1—randomized north and central seeded.	Spatial.....	+25 percent.....	6,000 km ² ; continuum from seeding sites.	Reliable records for analysis.	
Santa Barbara band seeding—randomized.	.....do.....	+25 percent (+50 percent in bands).	3,000 km ² ; continuum from seeding sites.	Moderately well documented.	
Santa Barbara storm seeding of multiple bands.	.....do.....	Unknown.....	Unknown.....	Unknown.	
Santa Barbara duration of seeded/nonseeded bands.	Time.....	Seed/no seed ratios of 1.5 to 4 mean 50 percent-increase.	3,000 km ² ; continuum from seeding sites.	Good evidence.	
Climax and east to plains of Colorado, using "homogeneous" data base determined by new synoptic technique.	Spatial.....	Unknown analysis continuing.	600 km ² ; 130 km east of Climax, 30 to 50 km south of Denver.	Speculative.	

¹ Tasmania experiment may confirm artifact.

Examination of data from summertime convective cloud-seeding projects reveals "more mixed" results by comparison with data from wintertime projects, when extended area effects are considered. This general conclusion accords with the mixed results from evaluations of convective cloud seeding within the target area. It was concluded by participants on a panel at the 1977 Fort Collins workshop that, for summertime convective cloud seeding, there are statistical evidences of both increases and decreases in the extended area, though there are a large number of nonstatistically significant indications. Table 12 was assembled by the panel to summarize the characteristics of these effects for each of the projects examined.¹

¹ Smith, T. B., "Report of Panel on Summer Weather Modification." In Keith J. Brown, et al., "Transactions of Workshop on Extended Space and Time Effects of Weather Modification," Aug. 8–12, 1977, Fort Collins, Colo. North American Weather Consultants, Goleta, Calif., February 1978, pp. 228–326.

TABLE 12.—EVIDENCE OF EXTENDED AREA EFFECTS FROM SUMMERTIME CONVECTIVE WEATHER MODIFICATION PROGRAMS
 [From Smith, "Report of Panel on Summer Weather Modification," 1978]

Project	Size of area			Seeding			Overall effect		Mechanism guesses		
	Target (square miles)	Extended (miles)	Experiment unit	Sample size	Mode	Rate	Material	Target	Extended	Target	Extended
Grossvuch (1957-63)	625	120	Day	145/147	GB in. Mis. AC-6°C. Patrol.	20g 14 hr. 2 to 4 hr.	Agl	+S A	+S A	Dynamic; warm moist air.	Propagation convection. Dynamic stabilization.
Arizona (1957-64)	300	65	Day	106/106	AC CB. Patrol.	2,000 g/hr. 4,000 to 8,000 g/d.	Agl	-NS A	-NS A	Dynamic overseed.	
Whitotop (1960-64)	11,300	180	Day	102/96	3 AC CB. Patrol.	≤6 hr. 30 mi long. 1,700 g/hr. 16,200 g/d.	Agl	-S A	-S A	Pumped all water out top; less moist air. Dynamic overseed with southerly flow.	Do.
Colorado (1966-69)	1,000	200	Day	116/125	GB. 3 gen.	22 hr. 15 g/hr. 1,080 g/d.		A -NS	A -NS	Pumped all water out top; warm moist air. Dynamic overseed.	No effect.
FACE (1970-76)	4,000	120	Day	39/36	AC top. -10°C.	800 g/cloud. 10,000 to 50,000 g/d	Agl	A FT +S TT +NS B	B	Dynamic meso scale organization; sea breeze process.	
NHRE (1972-74)	625	150	Day	27/30	AC CB. Rockets.	3,000 g/d. 1,000/system	Agl	+NS B	C 0	Microphysical static seeding.	Do.
Israel (1972-76)	1,000	50	Day	275 cross-over design.	AC CB. Patrol.	500 g/hr.	Agl	+15% B	(NS) +10%D (S) +30%C B	do	
South Dakota (1966-68)	700		Day	54/54	AC CB. GB	300 g/hr. 15/40 g/hr.	Agl	B -NS -NS	+NS -Upwind	Dynamic and microphysical.	
North Dakota (1969-72)	5,300		Day	277/91	AC CB.	300 g/hr.	Agl				

1 2d-day effect suggested by Howell.

Key: GB—ground based; AC—aircraft; CB—cloud base; S—significant; NS—not significant; A, B, C—data quality.

It was the general consensus of the 1977 workshop participants that seeding can effect precipitation changes over relatively large areas which extend beyond the typical target area. Such changes can be positive or negative and may be of the same sign as the effect in the designated target area or of opposite sign. For example, among summertime projects considered the Israeli experiment provided substantial evidence for positive effects in the target and in the extended areas (see table 12). Project Whitetop and the Arizona experiment, on the other hand, showed strong evidence of precipitation decreases in the target areas, downwind, and in surrounding areas. The Florida area cumulus experiment (FACE) revealed significant rainfall increases in the target area, but seemed to show decreases in surrounding areas, and the 1969-1972 South Dakota project demonstrated negative seeding effects in the target area and positive effects in extended areas. Of all projects reviewed, however, and in view of all the differing results suggested, the combination of target- and extended-area effects which appears to have the least support is that combination most likely to occur to many lay people, i.e., increases in the target area with compensating decreases in some area "downwind"—the "robbing Peter to pay Paul" analogy.²

Statistical evidence of extended area and time effects seems to be reasonably common; however, the mechanics causing these effects are not understood. It appears that there may be a number of mechanisms which come into play, the dominating ones operating under various storm types and seeding techniques. In some projects there is evidence that seeding intensified the storm dynamically through release of latent heat of sublimation. In other cases silver iodide has been transported for distances of 100 kilometers downwind of the seeding area and has persisted for several days in the atmosphere after seeding. Also ice crystals produced from seeding may, in turn, seed lower clouds downwind.³

With particular regard to extended area or time effects in cumulus seeding experiments, Simpson and Dennis have identified the following list of possible causes:

1. Physical transport of the seeding agent.
2. Physical transport of ice crystals produced by a seeding agent.
3. Changes in radiation and thermal balance, as for example, from cloud shadows or wetting of the ground.
4. Evaporation of water produced.
5. Changes in the air-earth boundary, such as vegetation changes over land or changes in the structure of the ocean boundary layer following cloud modification.
6. Dynamic effects:
 - (a) Intensified subsidence surrounding the seeded clouds, compensating for invigorated updrafts.
 - (b) Advection or propagation of intensified cloud systems which subsequently interact with orography or natural circulations.
 - (c) Cold thunderstorm downdrafts, either killing local convection or setting off new convection cells elsewhere.

² Brown, et al., "Transactions of the Workshop on Extended Space and Time Effects of Weather Modification," 1978, p. 11.

³ *Ibid.*, p. 12.

(d) Extended space-time consequences of enhancement or suppression of severe weather owing to cumulus modification.

(e) Alteration, via altered convection, of wind circulation patterns and/or their transports which could interact with other circulations, perhaps at great distances.⁴

Recommended research activities to further explore and develop understanding of extended area and extended time effects of weather modification are summarized in the final section of this chapter, along with other research recommendations.⁵

APPROACHES TO WEATHER MODIFICATION OTHER THAN SEEDING

Nearly all of the techniques discussed earlier for modifying the weather involve some kind of "cloud seeding." The exception is in the case of warm fog dispersal, where attempts to dissipate have also included mechanical mixing or application of heat. While most cloud-seeding techniques involve the use of artificial ice nuclei such as those provided by silver iodide particles, other "seeding" substances, such as dry ice, sodium chloride, urea, propane, and water spray, have been used in certain applications. Clouds have also been seeded with metalized plastic chaff in order to dissipate electrical charge build-up and reduce the incidence of lightning.

There may also be some promise in future years of beneficially changing the weather, over both large and small scales of time and space, using technologies that are not in the general category of cloud seeding. Indeed, some such schemes have been proposed and there has been research conducted on a number of these possibilities.

In the following chapter the effects of man's activities and some natural phenomena in changing the weather unintentionally will be discussed. While these inadvertent effects may be of general concern and should be studied in view of potential dangers, they should also be understood inasmuch as they may provide valuable clues on how the atmosphere can be more efficiently modified for beneficial purposes. For example, major heat sources judiciously located might be used to affect weather in ways useful to man.

Solution of problems which overlap considerations of both weather and energy could be investigated and solved in common by scientists and engineers working in both fields. Such research should be underway and some practical applications could be forthcoming during the 1980's. Dissipation of supercooled clouds and fog over large and medium-sized cities, which now appears to be technically feasible, may become desirable when solar energy collectors are more common. Reduction of radiative losses to space could be facilitated by allowing the clouds to reform at night. It is speculated that this diurnal cycle of operation would tend to weaken inversions that are often associated with fog and low stratus and so tend to alleviate problems of air pollution, though there might be some increase of photochemical effects in the daytime with additional sunlight.⁶

Excess heat and moisture from nuclear and other powerplants and from their cooling towers could be usefully employed for generating

⁴ Simpson and Dennis, "Cumulus Clouds and Their Modification," 1974, pp. 274-277.

⁵ See p. 143.

⁶ Dennis and Gagin, "Recommendations for Future Research in Weather Modification," 1977, p. 79.

clouds if the plants are optimally located with regard to water sources and meteorological conditions. The clouds so formed might be used for protection to crops during periods of intense heat or as a shield over a city at night to prevent re-radiation of heat back to space. The clouds might also be seeded subsequently somewhere downwind of the power-plant to enhance precipitation.

Recently, Simpson reviewed and summarized the state of research and development of a number of the nonseeding approaches to weather modification which have been proposed.⁷ She discusses effects of changes to radiation and to sea-air interface processes:

Some expensive, brute force successes have been obtained by burning fuels to clear fogs or even to create clouds. A more ingenious approach is to use solar heat to alter part of the air-surface boundary or a portion of the free atmosphere. Black and Tarmy (1963) proposed ten by ten kilometer asphalt ground coatings to create a "heat mountain" to enhance rain, or to reduce pollution by breaking through an inversion. Recently Gray, et al. (1975) have suggested tapping solar energy with carbon dust over 100-1,000 times larger areas for numerous weather modification objectives ranging from rain enhancement to snow melt, cirrus production, and storm modification. The physical hypotheses have undergone preliminary modelling with promising results, while the logistics appear marginally feasible. Drawbacks are the unknown and uncontrollable transport of the dust and its environmental unattractiveness.

A cleaner way of differentially heating the air appears to be a possible future byproduct of the space program. A Space Solar Power Laboratory is in the planning stages at NASA. Its main purpose is to provide electric power, which will be sent by the space laboratory to the earth's surface. The microwave power will be converted to DC by means of groups of rectifying antennas, which dissipate a fraction of the power into heat. Preliminary calculations * * * indicate that the atmospheric effect of the estimated heating would be comparable to that by a suburban area and thus could impact mesoscale processes. Future systems could dissipate much more heat and could conceivably be a clean way to modify weather processes. It is not too soon to begin numerical simulation of atmospheric modifications that later generation systems of this type might be able to achieve.

Radiation alteration appears to be a hopeful weather modification approach still lacking a developed technology. A cirrus cover has long been welcomed as natural frost protection when it restricts the nocturnal loss of long-wave radiation. More recently, the effect of cirrus in cutting off short-wave daytime radiation has been modelled and measured. * * * Artificial simulation of cirrus effects by minute plastic bubbles impregnated with substances to absorb selected wavelengths received preliminary attention . . . but, to my knowledge has not been pursued.

Alteration of the sea-air interface is also a potentially promising weather modification technique, particularly to suppress convection or to mitigate the destruction by tropical hurricanes. However, the technology in this area may be farther from actual field trials than that in radiation. If methods could be developed to restrict sea-air latent and sensible heat flux, the development from tropical storm to hurricane might be inhibited, while not losing rainfall or other benefits of the system. Presently the monomolecular films which cut down the evaporation from reservoirs do not stay intact in oceanic storm conditions, even if the logistics of their delivery over wide areas ahead of the storm were solved. Logistic obstacles have also impeded implementation of the promising idea of cooling the waters ahead of the hurricane by mixing up the ocean layer above the thermocline.⁸

One possible means of achieving the mixing of ocean layers to cool the sea surface, suggested above by Simpson, might be accomplished,

⁷ Simpson, Joanne, "What Weather Modification Needs," 1977, unpublished, pp. 13-15. (Most of the needs of weather modification identified in this unpublished paper, but not including her summary of nonseeding approaches, were published in another paper with the same title by Dr. Simpson: preprints of "Sixth Conference on Planned and Inadvertent Weather Modification," Champaign, Ill., Oct. 10-13, 1977. Boston, American Meteorological Society, 1977, pp. 304-307.

⁸ *Ibid.*

at least in part, as a beneficial byproduct of another power source under development—the ocean thermal energy conversion (OTEC) concept. The OTEC plants, located in tropical waters where hurricanes are spawned and grow, can provide surface cooling and so assist, at least in localized areas, in the abatement of tropical storms and their attendant damages. This is another area of overlap between energy and weather interests where cooperative research and development ought to be explored.

RESEARCH NEEDS FOR THE DEVELOPMENT OF WEATHER MODIFICATION

In previous sections of this chapter the rationale and the status of development of the various techniques used to modify several kinds of weather phenomena were summarized and discussed in some detail. Applications of these techniques in both operational and research projects were considered and some measures of the current effectiveness were presented. Among these discussions were a variety of statements, some explicit and some implied, on further research necessary to advance weather modification technology. This section addresses research needs more generally and in a more systematic manner. Included are specific requirements and recommendations identified by individual experts and organizations. Recommendations of a policy nature on weather modification research, such as the role of the Federal Government and the organizational structure for managing research, are discussed in chapter 6, which summarizes the recommendations of major policy studies. Current research programs of Federal agencies are discussed in some detail in chapter 5.

Research recommendations summarized in this section are primarily concerned with advancing the technology of advertent weather modification intended for beneficial purposes. Research needs in support of other aspects of planned weather modification and on inadvertent modification are included in other chapters on those subjects. In some cases, however, in the following sets of recommendations, research efforts in these other areas are included with those dealing with technology improvement in order to preserve the completeness of the particular set of recommendations.

GENERAL CONSIDERATIONS

Peter Hobbs identifies four main phases through which most developing technologies such as weather modification must pass—the establishment of scientific feasibility, engineering development, demonstration projects, and full-scale plant operation.⁹ He illustrates these phases in terms of relative expenditures and elapsed time for each in figure 15 and discusses the probable stage of development for weather modification. Noting that some would optimistically place development of the technology as far along as the dashed line YY, he himself would more cautiously place the progress of weather modification in the vicinity of XX, so that the major task ahead remains as the testing of the scientific feasibility to produce significant artificial modification to the weather.¹⁰

⁹ Hobbs, Peter V. "Weather Modification; a Brief Review of the Current Status and Suggestion for Future Research." Background paper prepared for the U.S. Department of Commerce Weather Modification Advisory Board, March 1977, p. 10.

¹⁰ *Ibid.*

This scientific feasibility can best be shown, according to Hobbs, through "mounting comprehensive research programs to investigate the structure and natural processes which dominate a few relatively simple cloud and precipitation systems and to establish the extent and reliability with which they can be artificially modified." He cites as a principal reason for the lack of significant progress in recent years his contention that "most of the effort has been directed at attempts to modify very complicated storm systems about which little is known and good hypotheses for artificial modification are lacking."¹¹

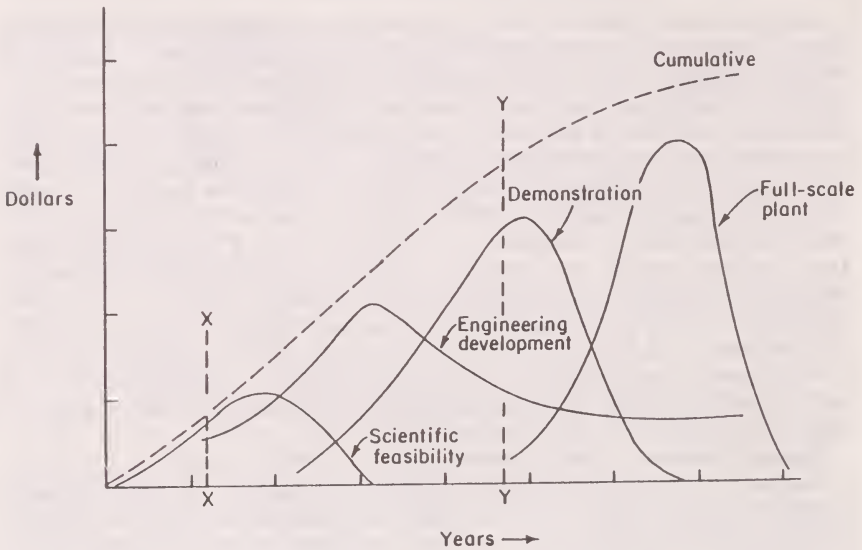


FIGURE 15.—Schematic of the relative costs and time associated with the four phases of development of a new technology. The vertical lines XX and YY indicate two widely differing views on the present stage of development of weather modification technology. (From Hobbs, 1977.)

We have seen that there is some reason to accept weather modification techniques as having some degree of operational capability in possibly two areas—cold fog dispersal and snowfall enhancement from orographic clouds—though there is room for continued research and technique development in these as well as other areas of weather modification. Although supercooled fogs account for only 5 percent of all fog occurrences, their prevalence at airports in northeastern and northwestern North America makes cold fog dispersal a valuable tool. Seeding of wintertime orographic clouds in experiments and operational projects in the western United States has probably resulted in snowfall increases of 10 to 30 percent under certain conditions.

Table 13 is a review and general outlook on weather modification, prepared by Changnon, showing the stage of development, possible economic value or years before operational usefulness, and status of research for 5 areas of weather modification, for the cold-temperature and warm-temperature cases where applicable. The table also shows Changnon's rough estimate of the complexity and difficulty in

¹¹ *Ibid.*, pp. 10–12.

relation to fog dispersal of the development of modification techniques for the other phenomena.¹²

Changnon emphasizes the fact that established techniques do not exist for significant modification of weather phenomena such as rainfall and severe weather over the more populous and major agricultural areas of the eastern United States. He says that:

If measurable economic gains are to be realized in the eastern two-thirds of the United States due to weather modification (largely rain "management", hail suppression, and abatement of severe winter storms), much more research and effort must be extended. This research will concern (1) the thorough study on a regional scale of the complex multicellular convective systems which are the major warm season rain and hail producers, and (2) the study of the cold season cyclonic systems.¹³

TABLE 13.—OUTLOOK FOR PLANNED WEATHER MODIFICATION IN UNITED STATES

[From Changnon, "Present and Future of Weather Modification; Regional Issues," 1975]

	Fog	Orographic precipitation	Convective rainfall	Severe convective storms	Cyclonic scale storms
Cold temperatures (<32° F).	Operational phase; low cost; research declining.	Operational phase (+10 to +30 percent); low cost; research declining.	Research phase; favorable on small clouds; questionable on large clouds and systems; substantial research.	Research phase; 5 to 10 yrs before operational; substantial and increasing research.	Exploratory phase; more than 10 yrs; research on tropical is modest; research on "other" storms is minor.
Warm temperatures (>32° F).	Research phase; 2 to 5 yrs; substantial and increasing research.	Possible phase; little research. ¹	Exploratory phase; modest research. ¹	-----	-----
Degree of complexity (in relation to fog).	1.0-----	10-----	100-----	1,000-----	10,000.

¹ Questionable economic value unless chain reaction is found.

Hobbs discusses in detail some of the kinds of weather modification research projects which he feels would be fruitful:

Some candidate projects for intensive investigation include the dispersal of cold and warm fogs, the enhancement of precipitation from isolated continental-type cumulus clouds, and the targeting of winter orographic snowfalls. Our knowledge of each of these subjects has reached the stage where the mounting of comprehensive projects is likely to yield definitive results. Physical studies have demonstrated that cold fogs can be dissipated by seeding with dry ice, and this technique is now in use operationally at a number of airports; however, a statistical study to quantify the reliability of this technique has not (to my knowledge) been carried out. It could provide the much needed "success story" for weather modification. The dispersal of warm fogs is a much more difficult problem which has not yielded to subtle approaches. The U.S. Air Force has concluded that the best approach to this problem is through direct heat input; this approach appears sufficiently promising that it should be subjected to proper physical and statistical evaluation. The possibility of targeting winter orographic snowfall to specific areas on the ground (e.g., reservoirs) has been investigated. . . . The technique shows sufficient promise that further studies involving both physical and statistical evaluation should be carried out. Attempts at modifying the precipitation from cumulus clouds dates back to the beginning of modern weather modification (the 1940's); however, very few of these projects have involved both physical and statistical evaluation (and many have used neither).

¹² Changnon, Stanley A., Jr., "Present and Future of Weather Modification; Regional Issues," 1975, pp. 172-174.

¹³ *Ibid.*, p. 172.

In view of our growing understanding of the structure and life cycles of individual cumulus clouds, and the advances which have been made in the numerical simulation of these processes, the time is now ripe to mount a substantial investigation to determine whether precipitation from these clouds can be increased.

The primary components of the comprehensive research projects recommended above should be physical, statistical, and theoretical analysis. Physical evaluations should include comprehensive field studies using a wide range of airborne, ground, and remote probing techniques to evaluate the natural systems and the degrees to which they can be artificially modified. Physical testing and evaluation of a proposed weather modification technique is best commenced prior to the establishment of a statistical design, for not only can physical evaluations check the feasibility of a proposed technique, but they can indicate the conditions under which it is most likely to be effective and thereby aid in sharpening or the statistical design. A sound weather modification technique should also be based on, or supported by, the best theoretical models available for describing the weather system under investigation. If the theoretical and physical studies indicate that a particular weather modification technique is effective, a carefully designed randomized statistical experiment should follow. Theoretical and physical evaluations should continue through the statistical experiment. An independent repetition of the experiment in at least one other geographical area will generally be required. The confluence of results from theoretical, physical, and statistical analyses carried out in two areas would permit sound quantitative evaluation of the effectiveness of an artificial modification technique.¹⁴

RECOMMENDATIONS FROM THE 1973 NATIONAL ACADEMY OF SCIENCES STUDY

In the 1973 study published by the National Academy of Sciences¹⁵ three broad research goals for weather modification were recommended along with specific research programs and projects required to achieve those goals. The three goals are:

1. Identification by the year 1980 of the conditions under which precipitation can be increased, decreased, and redistributed in various climatological areas through the addition of artificial ice and condensation nuclei;
2. Development in the next decade of technology directed toward mitigating the effects of the following weather hazards: hurricanes, hailstorms, fogs, and lightning; and
3. Establishment of a coordinated national and international system for investigating the inadvertent effects of manmade pollutants, with a target date of 1980 for the determination of the extent, trend, and magnitude of the effect of various crucial pollutants on local weather conditions and on the climate of the world.¹⁶

Achievement of these national goals would require, according to the National Academy study, implementation of the following research efforts, some in support of all three goals and others as a means to achieving each of the three goals:

A. Recommended research in support of all three goals:

1. More adequate laboratory and experimental field programs are needed to study the microphysical processes associated with the development of clouds, precipitation, and thunderstorm electrification.

¹⁴ Hobbs, "Weather Modification;" a Brief Review of the Current Status and Suggestions for Future Research," 1977, pp. 12-13.

¹⁵ National Academy of Sciences, "Weather and Climate Modification; Problems and Progress," 1973.

¹⁶ *Ibid.*, p. 27.

2. There is a need to develop numerical models to describe the behavior of layer clouds, synoptic storms, orographic clouds, and severe local clouds.

3. There is a need for the standardization of instrumentation in seeding devices and the testing of new seeding agents.

4. There should be established a number of weather modification statistical research groups associated with the major field groups concerned with weather modification and the inadvertent effects of pollutants.

5. There should be created a repository for data on weather modification activities, and, at a reasonable price, such data should be made available for reanalyses of these activities.

B. Recommended research in support of goal 1 above:

1. There is a continuing need for a comprehensive series of randomized experiments to determine the effects of both artificial and natural ice and cloud nuclei on precipitation in the principal meteorological regimes in the United States.

2. Investigations into the feasibility of redistributing winter precipitation should be continued and expanded.

3. Experiments need to be designed so that the effects of seeding on precipitation outside the primary area of interest can be evaluated.

4. Studies of the effects of artificial seeding on cumulus clouds and the numerical modeling of the seeding process should be continued and expanded.

C. Recommended research in support of goal 2 above:

1. Investigations should be made to determine whether the seeding techniques presently used in the study of isolated cumulus clouds and in hurricane modification can be extended to, or new techniques developed for, the amelioration of severe thunderstorms, hailstorms, and even tornadoes.

2. An expanded program is needed to provide continuous birth-to-death observations of hurricanes from above, around, within, and beneath seeded and nonseeded hurricanes and for testing of existing and new techniques for reducing hurricane intensities.

3. Studies on the development of hurricane-modification techniques should include a randomization scheme in the design and conduct of experimental programs.

4. A major national effort in fundamental research on hailstorms and hailstorm modification should be pursued aggressively.

5. A comprehensive program dealing with research on warm fog and its dissipation should be undertaken.

6. A high priority should be given to the development of a variety of research techniques specifically designed for observing severe storms.

D. Recommended research in support of goal 3 above:

1. National and international programs should be developed for monitoring the gaseous and particulate content of the atmosphere, with particular emphasis on modification by man's activities.

2. Satellite programs should be developed to monitor continually, on a global basis, the cloud cover, albedo, and the heat balance of the atmosphere.

3. There should be enlarged programs to measure those parameters that describe the climate of cities and adjoining countryside and to determine the physical mechanisms responsible for these differences.

4. Continued strong support should be provided to the major effort now underway, known as the Global Atmospheric Research Program, to develop properly parameterized mathematical models of the global atmosphere-ocean system, to obtain the observational data to test their efficacy, and to provide the computers that permit simulation of the effects of human activities on a worldwide scale.¹⁷

Some of the recommended research activities discussed above were already underway at the time of the 1973 National Academy study, but continuation or expansion of these efforts were advised. Since that time others have been initiated, and beneficial results from continuation and expansion of earlier efforts have been achieved. The overall decrease in funding of the Federal research program in the past few years has resulted in curtailments of valuable research projects identified to meet the goals above, however, and the current level of research activities can hardly lead to achievement of the goals set by the Academy study. The recent history of Federal funding for weather modification is discussed and summarized in chapter 5, as part of the treatment on Federal activities.¹⁸

RECOMMENDATIONS OF THE ADVANCED PLANNING GROUP OF NOAA

Concerned that its research programs be more responsible to societal needs, the Weather Modification Project Office of the National Oceanic and Atmospheric Administration (NOAA) established a small advanced planning group in 1976. Consisting of one full-time and three part-time members, none of whom were permanent NOAA employees, the advanced planning group was charged with making recommendations and preliminary plans for research projects to be carried out over the following 10 to 15 years. The group set about its task by visiting various user groups to learn opinions about past Federal research and by reviewing available literature and consulting scientists on past and current weather modification field programs.¹⁹

The advanced planning group acknowledged that considerable progress had been made in weather modification in the past few years, but noted that the current research approach has the following shortcomings:

1. Research in the United States on stimulation of precipitation has been concentrated in the semiarid western States and in Florida rather than in the Corn Belt, where the potential economic payoff is much greater.

2. Research on stimulation of rainfall and on suppression of hail and lightning have been carried out in separate projects. A single project dedicated to the concept of precipitation management in large convective clouds would be more likely to solve the problem of changing hailfall and rainfall simultaneously to produce net economic benefits.

¹⁷ *Ibid.*, pp. 27-30.

¹⁸ See p. 242.

¹⁹ Dennis Arnett S. and A. Gaglin, "Recommendations for Future Research in Weather Modification," Weather Modification Program Office, Environmental Research Laboratories, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Boulder, Colo., November 1977, 112 pp.

3. Weather modification has usually been equated with cloud seeding. Other possible means of modifying the weather have been largely ignored.

4. Weather modification is usually considered in isolation, rather than as an integral part of a total response to weather-related problems. There are exceptions: dry ice seeding to improve visibility during cold-fog episodes at airports is normally viewed as a supplement to, rather than a replacement for, good instrument landing systems. However, cloud seeding to increase precipitation is sometimes viewed as an alternative to irrigation or water conservation measures, a situation we think is regrettable. Fortunately, research in inadvertent weather modification is tending to break down the artificial isolation of research related to weather modification from other aspects of atmospheric science.²⁰

Having examined the current weather modification research situation as perceived by user groups and research scientists, the NOAA Advanced Planning Group proceeded to formulate recommendations for future research, using certain general technical, economic and sociological guidelines. Proposed research was evaluated on the basis of answers to the following questions:

1. Will the project advance scientific understanding of atmospheric processes and thereby contribute to an improved capability to modify weather on a predictable basis?

2. Will the operational capability toward which the project is directed provide net economic benefit?

3. Are the proposed research and the possible subsequent applications socially acceptable? ²¹

The group completed its study during 1977 and provided its recommended research program to NOAA's Weather Modification Project Office. The 5 specific recommendations are summarized below:

1. Work should be continued to determine the potential for increasing rainfall from convective clouds in warm, humid air masses by seeding for dynamic effects. Design of a new, comprehensive project to be conducted in the eastern half of the United States should begin immediately. This project should gather information on the effects of seeding upon rainfall, hail, lightning, and thunderstorm winds both within and outside a fixed target area. Additional field studies in Florida to establish the physical mechanisms responsible for the apparent increases in total target rainfall during FACE ²² in 1975-76 should be performed during at least two seasons in parallel with the design of the new project. The results of the additional studies would be valuable input for the design of the new comprehensive experiment.

2. Because of the promising beginnings of the Sierra Cooperative Project on orographic precipitation and the HIPLEX ²³ work on cumulus clouds in the semiarid western States, and because the projects are likely to produce important results of wide applica-

²⁰ *Ibid.*, p. 8.

²¹ *Ibid.*, pp. 8-9.

²² The Florida Area Cumulus Experiment (FACE), an experimental project sponsored by NOAA's discussed under activities of the U.S. Department of Commerce in ch. 5, p. 292.

²³ The Sierra Cooperative Project and the High Plains Cooperative Program (HIPLEX) are projects sponsored under the Division of Atmospheric Water Resources Management of the Bureau of Reclamation in the U.S. Department of the Interior. These projects are discussed in ch. 5, pp. 258 and 263, respectively.

tion, we see no reason for new initiatives in these areas until those projects are completed.

3. In view of the need for more detailed knowledge of hurricane behavior, we recommend that research on hurricane modification be continued with the understanding that the research is a long-term effort with potential payoff 10 to 20 years away. We recommend further that modeling and other theoretical work be intensified to provide a better basis for interpretation of data from seeding trials.

4. Concepts for hail suppression and lightning suppression should be subjected to fundamental reappraisal before the resumption of any field experiments.

5. Long-range planning should be continued toward "futuristic" projects in which problems in deliberate, large-scale weather modification, inadvertent weather modification, forecasting, and agricultural climatology would be treated together rather than separately.²⁴

SUMMARY OF FEDERAL RESEARCH NEEDS EXPRESSED BY STATE OFFICIALS

At the request of NOAA's Advanced Planning Group, whose study was discussed in the previous section, the North American Interstate Weather Modification Council (NAIWMC)²⁵ compiled information on recommended Federal weather modification research, based on the needs of users within NAIWMC member States. Opinions of State officials on needed research were obtained from 16 States through meetings sponsored by California, North Dakota, Pennsylvania, South Dakota, Texas, and Utah and through questionnaires sent out by the NAIWMC during 1976 and 1977.

Table 14 summarizes results of the NAIWMC investigation, showing perceived needs for research for weather modification users, as interpreted by the State officials.²⁶ Keyes notes that the major research area recommended by most State and local governments is in the evaluation of ongoing, long-term operational projects within those States. Other important research needs expressed were for further development of seeding technology and for economic, environmental, and societal studies necessary for eventual public acceptance of weather modification.²⁷

²⁴ *Ibid.*, pp. 11-12.

²⁵ The purposes, organization, and activities of the North American Interstate Weather Modification Council are discussed in some detail in ch. 7, p. 333.

²⁶ Keyes, Conrad G., Jr., "Federal Research Needs and New Law Requirements in Weather Modification: the NAIWMC Viewpoint," testimony before the U.S. Department of Commerce Weather Modification Advisory Board, Champaign, Ill., Oct. 14, 1977.

²⁷ *Ibid.*

TABLE 14.—SUMMARY OF FEDERAL WEATHER MODIFICATION RESEARCH NEEDS, DETERMINED FROM OPINIONS OF STATE OFFICIALS DURING STATE MEETINGS AND THROUGH QUESTIONNAIRES FROM THE NORTH AMERICAN INTERSTATE WEATHER MODIFICATION COUNCIL

[From Keyes, 1977; table format from Dennis and Gagin, 1977]

State	Major categories of research ¹					
	1	2	3	4	5	6
Arizona.....	a, b, c.....	a, b, e.....	a, b, c.....			
California.....	a, b, c.....	a, b.....	a, b, c.....			
Illinois.....	a, b, c.....	a, b, c, d.....	a, b, c.....		Yes	
Indiana.....	b, c.....	a, b, c, e.....	b, c.....		Yes	
Kansas.....	a, b, c.....	b, c.....	a, c.....			
Maryland.....	a, b, c.....	b, c.....			Yes	Yes.....
Michigan.....	a, b, c.....	b, c.....	a.....		Yes	
Missouri.....	a, b.....		a, c.....			
North Carolina ²						
North Dakota.....	a.....	b, c, e.....	c.....			a.....
Pennsylvania.....	c.....		c.....	Yes.....	Yes.....	
South Dakota.....	a, b, c.....	b, c.....	c.....			
Texas.....	a, c.....	a, b, d.....	c.....			a, c.....
Utah.....	a, b.....	b, d.....	a.....			
Vermont.....	a.....	a.....	a.....			a, c.....
Virginia ³						

¹ Categories of Federal research:

1. Evaluation:
 - a. Of operational programs.
 - b. Physical studies.
 - c. Extra-area effects.
2. Seeding technology:
 - a. New seeding agents.
 - b. Transport and diffusion, delivery methods.
 - c. Hail suppression methods.
 - d. New tools, for example, satellites.
 - e. Public education.
3. Economic, ecological, and societal studies:
 - a. Economic benefits.
 - b. Toxicity of agents.
 - c. Societal studies.
4. Detection of clandestine seeding.
5. Inadvertent weather modification.
6. Forecasting:
 - a. Short range.
 - b. Local topographic effects.
 - c. Long range.

² Need a national policy first.

³ Mainly hurricane modification.

RESEARCH RECOMMENDATIONS OF THE AMS COMMITTEE ON WEATHER MODIFICATION

Recently, the chairman of the Committee on Weather Modification of the American Meteorological Society ²⁸ summarized his committee's recommendations on recommended weather modification research needs.²⁹ It was noted that the primary focus of such research should be in the areas of purposeful alteration of patterns of cloud systems and precipitation and in the inadvertent impact of man's activities. In view of critical water problems affecting large portions of the country and the potential for increased demand for application of weather modification techniques by water users, the necessity for improved understanding of underlying physical processes through pursuit of basic research was emphasized. In particular, the "real payoff" to improvements in purposeful weather modification should be seen as coming from increased ability to understand, predict, and

²⁸ Weather modification activities of the American Meteorological Society and purposes and concerns of its Committee on Weather Modification are discussed in ch. 8, p. 395.

²⁹ Silverman, Bernard A., testimony before the U.S. Department of Commerce Weather Modification Advisory Board, Champaign, Ill., Oct. 14, 1977.

control the formation and development of mesoscale³⁰ cloud systems.³¹

Subject areas for recommended research to accomplish basic understanding of atmospheric processes necessary for the development of weather modification technology were presented by the AMS committee in the following outline form:³²

Mesoscale Cloud Dynamics

A. Effect of seeding on convective cloud development and evolution:

1. Growth of convective clouds.
2. Merger of clouds into groups and systems.
3. Organization of inflow (coupling of midtroposphere with the boundary layer).
4. Enhanced moisture budget efficiency.

B. Interaction of clouds with each other and with their environment:

1. Response to mesoscale forcing function.
2. Relationship between low-level convergence and cloud field evolution.
3. Role of outdrafts in development and sustenance of cloud systems.
4. Role of anvils in the evolution of the cloud field.

C. Precipitation "nowcasting":

1. Low-level convergence field as predictor of precipitation intensity.
2. Kinematic and thermodynamic predictors and covariates for statistical evaluation.

D. Need for a multidisciplined mesoscale experiment with strong physical emphasis.

Precipitation Microphysics

A. Evolution of natural ice in cloud:

1. Nucleation processes.
2. Secondary ice production processes:
 - (a) Laboratory studies of causality.
 - (b) Field investigations to define appropriate in-cloud criteria for multiplication of ice.

B. Interaction between microphysics and dynamics to produce and sustain precipitation.

C. Effect of seeding on (A) and (B) above.

D. Distinction between microstructure of clouds developing over land and over water in terms of suitability for seeding.

E. Clarification of microstructure of clouds developing within the hurricane environment in terms of suitability for seeding.

F. Cloud microstructure climatology for selected regions of the United States.

G. Effect of ice generation on charge separation and electrification

³⁰ Mesoscale meteorological phenomena are those with horizontal dimensions ranging from a few tens of kilometers to a few hundred kilometers.

³¹ Silverman, testimony before Weather Modification Advisory Board, 1977.

³² *Ibid.*

Area of Seeding Effect

- A. Induced by dynamic response of environment.
- B. Induced by diffusion of nucleating material:
 1. In orographic regions.
 2. Transport through convective processes.
- C. Insolation pattern resulting from mid- and upper-level outflow.

Turbulence and Diffusion

- A. Targeting of surface-based source(s) of nuclei into desired cloud region.
- B. Entrainment processes related to cloud development.
- C. Spread of nuclei released in cloud (spatial and temporal distribution).

Seeding Agents and Methods

- A. Nucleation efficiency studies.
- B. Particle sizing and composition analyses.
- C. Particle generation systems.
- D. Improvement of technology.

Cloud Climatology for Technology Applicability

- A. National in scope.
- B. Frequency of occurrence of clouds by type.
- C. Cloud base and cloud top heights for selected regions.
- D. Properties of in-cloud microstructure.
- E. Aerosol characteristics.
- F. Radar population studies.
- G. Precipitation statistics.
- H. Model-derived "seedability" assessment.

Inadvertent Impacts

- A. Effect on climatic change.
- B. Effect on air quality.
- C. Effect on meteorology near large urban regions:
 1. Thermal pattern.
 2. Precipitation.
 3. Cloudiness.
- D. Effect on meteorology near deforested areas.

Cloud Modeling

- A. Synthesis of numerical simulation with atmospheric observations on all scales.
- B. Inclusion of cloud interaction and outdraft convergence.
- C. Mesoscale forcing (e.g. sea breeze, topography, etc.).

Improved Methods of Statistical Design and Evaluation

- A. Required to interpret results of new mesoscale experiment.
- B. Required for extraction of physical information from previously-performed nonrandomized experiments.



Study of oak brush as elk forage—part of environmental research conducted as part of Project Skywater. (Courtesy of the Bureau of Reclamation.)

RESEARCH RECOMMENDATIONS RELATED TO EXTENDED AREA AND TIME
EFFECTS

At the 1977 workshop on the extended area and extended time effects of weather modification, participants developed some recommendations for future research into these effects.³³ The following research activities, not necessarily in any order of priority, were recommended to be undertaken immediately with current available tools or over a period of time, as appropriate:

The use of computer simulation and modeling can provide important information on the areal coverage and magnitude of the effects of weather modification. It can also define the types of information and the sensitivity required for future field experiments.

Models developed to detect moisture depletion in natural and seeded cases as an air mass moves over successive mountain ridges should be applied and verified by field measurements in an area with a minimum of complexities caused by the introduction of new moisture sources. In situ measurements of temperature, pressure, liquid water content, ice crystal concentrations, and precipitation on the ground and in the air will be needed as inputs to the model and for model validation.

An intensive study should be initiated on particulate transport, including the transport of both seeding material and ice crystals produced by seeding. Techniques are currently available to measure ice crystal concentrations, nuclei, and silver in precipitation. Special tracers are becoming available and should be developed further. Remote sensing techniques for measuring ice and water need further development.

A re-analysis of some past field programs could be undertaken immediately. (The question of apparent decreases in seeding effectiveness in successive years of the Australian experiment has not been resolved adequately as to whether this effect is real or an analysis artifact. The reported persistence of ice nuclei for days after seeding at Climax and its relationship to the apparent decrease in the seed/no seed ratios with time should be further investigated.)

Continuing monitoring should be initiated of such quantities as ice nuclei concentrations in project areas in order to establish new benchmarks. A modeling effort should also be undertaken to investigate the evaporation and reprecipitation processes.

Studies of wide-area effects from seeding summer convective storm systems may require more preliminary work before mounting a major field effort since less is known about these phenomena. These studies should be directed toward acquiring information about the possible redistribution of convective instability and the microphysical effects including the transport of ice nuclei and/or ice crystals, and the possible interactive effects when these particles are entrained into other cloud systems.

Prior to the design of a major wide-area study program, initial studies should include: cloud population studies, including time

³³ Brown, et al., "Transactions of the Workshop on Extended Space and Time Effects of Weather Modification," 1978, pp. 14-18.

and space distributions and cloud microphysics; hypothesis development, including numerical modeling; reexamination of previous experimental programs; augmentation of ongoing programs to study total-area effects; and development of new capabilities including satellite measurements, rain gage network design, data processing, and management and seeding delivery systems.

The final design of a field program will be dependent on the findings from these preliminary studies. It appears likely that it will be necessary to mount a major effort to determine the total-area effects and mechanics of convective storm seeding. Preliminary estimates call for a 10-year study covering an area of at least a 300-mile radius in the mid-United States. Ideally this study could be operated in conjunction with other mesoscale field studies in cumulus convection and precipitation forecasting.

A national technology assessment on precipitation modification should be conducted with the total-area effect included in both the physical science and social science context.³⁴

³⁴ Ibid.

CHAPTER 4

INADVERTENT WEATHER AND CLIMATE MODIFICATION

(By John R. Justus, Analyst in Earth Science, Science Policy Research Division,
Congressional Research Service)

Out of the total ensemble of environmental factors, the subset which is sensed most immediately and directly by man and which has the greatest integrated impact on human activities is that which is subsumed under the terms of weather and climate.—Earl W. Barrett, 1975, National Oceanic and Atmospheric Administration.

INTRODUCTION

The relationship between man and weather has been basically the one stated succinctly by Charles Dudley Warner: Everybody talked about the weather, but nobody did anything about it. In the 1940's, however, the discovery that clouds could be modified by additions of freezing nuclei created a realization that, at some times and places at least, it might be possible to do something about the weather. This entering wedge into the field of intentional or planned weather modification has since been heavily studied and exploited; it had, as a by-product, the creation of considerable interest in weather modification on the part of both the scientific community and the general population. The science and technology of planned weather modification are discussed in chapter 3. The possibility that man has, in fact, been doing something about the weather without knowing it has become a subject for serious consideration, and chapter 4 reviews a number of processes and mechanisms governing inadvertent weather and climate modification.

TERMINOLOGY

By way of clarification, it is important to appreciate the fact that differences of scale are implied in the terms "weather modification" and "climate modification."

Climate

To most everyone, the term climate usually brings to mind an average regime of weather or the average temperature and precipitation of a locality. This is a rather misleading concept, for the average may be a rare event. Actually, weather from year to year oscillates widely so that climate is a statistical complex of many values and variables, including the temperature of the air, water, ice, and land surfaces; winds and ocean currents; the air's moisture or humidity; the cloudiness and cloud water content, groundwater, lake levels, and the water content of snow and of land and sea ice; the pressure and density of

the atmosphere and ocean; the composition of (dry) air; and the salinity of the ocean. All of these elements encompass climate and are interconnected by the various physical and dynamic processes occurring in the system, such as precipitation and evaporation, radiation, and the transfer of heat and momentum by advection (predominantly horizontal, large-scale motions of the atmosphere), convection (large-scale vertical motions of the atmosphere characterized by rising and sinking air movements), and turbulence (a state of atmospheric flow typified by irregular, random air movements).

Climatic fluctuation and climatic change

Rather than by average value, these elements are best characterized by frequency distributions, which can, in many places, span a wide range for a given element. Within such a range, one notes irregular fluctuations characterized by the occurrence of extreme values for given elements of the climatic system. In such instances, a climatic fluctuation is said to be experienced, not a climatic change. A change denotes that a new equilibrium had been achieved, and with it, a rather different frequency distribution for all climatic elements. Thus, the term change is not to be confused with fluctuation, where trends are frequently reversed, even though some successive values may cluster for a while on one side or the other of the "average."

Weather

Defined as the state of the atmosphere at any given time, the prevalent belief of the public, that wherever the weather goes the climate follows, is fallacious. On the contrary, wherever the climate goes, so goes the weather. Weather is merely a statistic of the physical climatic state.

Weather modification

As used in the context of this chapter and in the text at large, weather modification refers collectively to any number of activities conducted to intentionally or inadvertently modify, through artificial means, the elements of weather and, in turn, the occurrence and behavior of discrete weather events. Intentional or planned weather modification activities may be conducted for a variety of different purposes, including: Increasing or decreasing rain and snow over a particular area; reducing damage to crops and property from hail; reducing the number of forest fires that are started by lightning; removing fog at airports; changing the intensity and direction of hurricanes so they cause less destruction; mitigating the destructiveness of severe thunderstorms and tornadoes.

Climate modification

This encompasses the planned or inadvertent alteration, through artificial means, of the elemental properties comprising the air, sea, ice, land, and biospheric components of the climatic system in order to effect a new equilibrium among the elements of climate and, consequently, a new climate regime. In most instances, the term alludes to mesoscale and macroscale climates, from those of regions to the entire globe. Another common usage is in reference to the microscale climates of cities where persistent, inadvertent effects on weather, in turn, modify the climates of greater metropolitan areas.

Planned climate modification

While the term climate usually brings to mind an "average" regime of weather or, more properly, a frequency distribution of the elements and events of weather, the climatic system itself consists of those elements and processes that are basically the same as those responsible for short-term weather and coordinately for the maintenance of the long-term physical climatic state. It follows, then, that one of the purposes of planned weather modification activities may be to artificially change the climate of a location or region through means including, but not necessarily limited to: Massive and protracted extension of present cloud-seeding operations to influence natural precipitation development cycles; intentional initiation of large heat sources to influence convective circulation or evaporate fog; intentional modification of solar radiation exchange or heat balance of the Earth or clouds through the release of gases, dusts, liquids, or aerosols in the atmosphere; planned modification of the energy transfer characteristics of the Earth's land or water surface by dusting with powders, liquid sprays or dyes, water impoundment, deforestation, etc.

The dramatic idea of some great technological leap toward purposefully altering climate never seems to lose its appeal. The problem with these grand schemes is that, even if feasible, every fix—technological or otherwise—has its toll in side effects. But leaving aside for the moment the question of whether it makes sense to alter or conserve climate, many of the schemes that have been suggested for modifying climate on a hemispheric or global scale have so far been considered to be on the fringe of science fiction. The range of possibilities widens rapidly if one imagines the financial resources of the major world powers available to carry them out. Periodically resurgent are such schemes as darkening, heating, and melting of the Arctic icepack, the damming of the Bering Strait, the transportation of Antarctic icebergs, the diverting southward of North American and Asian rivers that empty into the Arctic, and the modification of tropical storms.¹ These and other perennial suggestions are summarized in Figure 1.

¹ Kellogg, W. W. and S. H. Schneider, "Climate Stabilization: For Better or for Worse?" *Science*, vol. 186, Dec. 27, 1974, pp. 1163-1172.

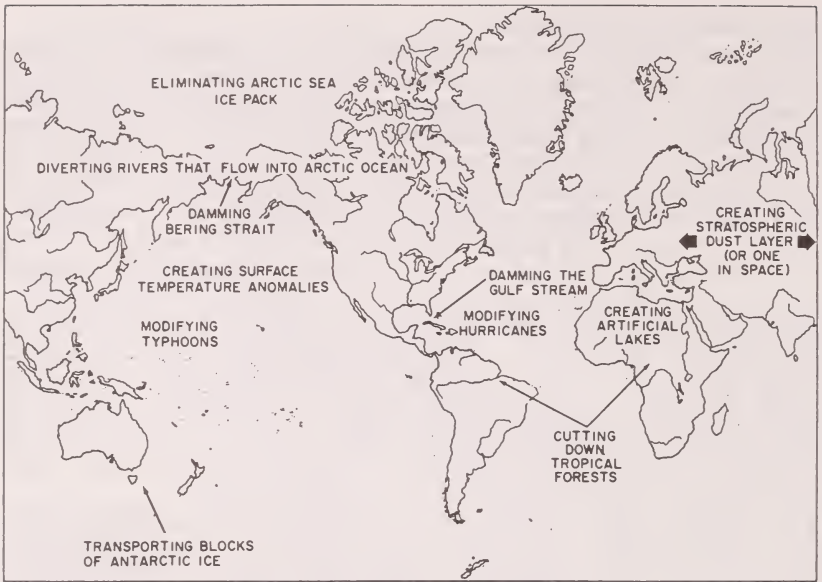


FIGURE 1.—A survey of grandiose schemes that have been proposed to modify or control climate. (From Kellogg and Schneider, 1974.)

Inadvertent climate modification

The modification processes may also be initiated or triggered inadvertently rather than purposefully, and the possibility exists that society may be changing the climate through its own actions by pushing on certain leverage points. Inadvertently, we are already causing measurable variations on the local scale. Artificial climatic effects have been observed and documented on local and regional scales, particularly in and downwind of heavily populated industrial areas where waste heat, particulate pollution and altered ground surface characteristics are primarily responsible for the perceived climate modification. The climate in and near large cities, for example, is warmer, the daily range of temperature is less, and annual precipitation is greater than if the cities had never been built. The climate of the world is governed mainly by the globally averaged effects of the Sun, the location and movement of air masses, and the circulation patterns of the world ocean. It is by no means clear that the interaction of these vast forces can be significantly influenced by human activities. Although not verifiable at present, the time may not be far off when human activities will result in measurable large-scale changes in weather and climate of more than passing significance. It is important to appreciate the fact that the role of man at this global level is still controversial, and existing models of the general circulation are not yet capable of testing the effects in a conclusive manner.

Nevertheless, a growing fraction of current evidence does point to the possibility of unprecedented impact on the global climate by human activities, albeit the effects may be occurring below the threshold where they could be statistically detected relative to the record

of natural fluctuations and, therefore, could be almost imperceptible amid the ubiquitous variability of climate. But while the degree of influence on world climate may as yet be too small to detect against the background of natural variations and although mathematical models of climatic change are still imperfect, significant global effects in the future are inferred if the rates of growth of industry and population persist.

BACKGROUND

HISTORICAL PERSPECTIVE

The possibility of climatic alterations by human activity was alluded to in the scientific literature at the beginning of this century, and again in the late 1930's, but it received little serious attention until the 1950's. The first period of thermonuclear testing, 1954 to 1958, generated a great deal of concern about drastic and widespread effects on weather. It was felt that anything which liberated such great energies must somehow influence the atmosphere. The fact that a device fired at sea level or under the sea did create locally a large convective cloud was cited as evidence.

By about 1960 work had shown that no large-scale or long-term meteorological effects would ensue from nuclear testing at the levels conducted in the 1950's. It had become clear that the inertia of the atmosphere-ocean system was too large to be perturbed seriously by the sudden release of any energy man could generate. Instead of the spectacular and violent, it was realized that one would have to look to the slow and insidious to find evidence of human influences on climate and weather.

Some evidence that manmade carbon dioxide was accumulating in the atmosphere appeared as early as 1938. This, together with some early systematic data from Scandinavia, led to the inclusion of a carbon dioxide (CO₂) measurement program during the International Geophysical Year (IGY), 1957-1958. This CO₂ measurement program, which continues today, was the first serious scientific study of a possible manmade climatic influence on a large scale.

As the reality of the CO₂ effect became established, and as the general mood of increased concern for the environment and the concept of "spaceship Earth" developed during the 1960's, increased scientific efforts began to be focused on inadvertent weather and climate modification. It had been recognized for some time that the climates of cities differed significantly from their rural environs due to the release of heat and pollutants. It was not until the late 1960's that evidence of "urban effect" on the climate at considerable distances downwind began to be noticed. The role of pollution aerosols² as climate modifiers became a topic of great interest, and it remains so today.

In the United States, the attention of the Government to these problems began with the IGY effort. CO₂ and solar radiation measurement programs were started in Antarctica and at the Mauna Loa Observatory in Hawaii, which was established specifically for this program by the U.S. Weather Bureau. This station, located at an elevation of 3,400 meters (11,155 feet) on the north slope of Mauna Loa,

² Dispersions in the atmosphere of particles of matter that remain suspended for a significant length of time.

has been improved over the years and remains the prototype "benchmark" station for climatic change monitoring.

The first major meeting devoted exclusively to the inadvertent modification problem convened in Dallas, Tex., in December 1968.³

The following year, a series of discussions between some faculty members of the Massachusetts Institute of Technology, government officials and scientists gave rise to the first working conference, the Study of Critical Environmental Problems (SCEP). This meeting, held at Williams College, Williamstown, Mass., during July 1970, was devoted to identifying possible global environmental hazards and making recommendations concerning monitoring, abatement, et cetera. The climatic problem areas identified were carbon dioxide and other trace gases that may affect climate; particulate matter in the atmosphere as turbidity and as cloud modifiers; waste heat; changes in the Earth's surface (land-use changes); radioactivity in the atmosphere; and jet aircraft pollution of the high troposphere and stratosphere. The proceedings of this meeting were published by the MIT Press.^{4, 5}

The working group for SCEP was, with one exception, composed of residents of the United States: scientists, representatives of industrial management, and government officials. Some of the participants felt that a more multinational participation would be essential if standardized global programs were to come into existence as a result of such a meeting. Also, it was the opinion that the problems of climate modification were complex enough to occupy the entire attention of a working meeting. As a result, a second such meeting was held, this time in Stockholm, with scientists from 14 countries participating. This working meeting was called Study of Man's Impact on Climate (SMIC). The report prepared by this group⁶ dealt with the substantive scientific questions of inadvertent climate modification, including: previous climatic changes; man's activities influencing climate; theory and models of climatic change; climatic effects of manmade surface changes; modification of the troposphere;⁷ and modification of the stratosphere.⁸ One objective of SMIC was to provide guidelines for the World Meteorological Organization (WMO) and other international agencies to use in establishing monitoring and research programs on a global scale.

In connection with the study of inadvertent climate modification, much was iterated in the early 1970's about the need for global monitoring. Because of the lagtime in planning, financing, and constructing such facilities (which must necessarily be in wilderness areas in order to give representative data not reflecting local effects), the minimum number of benchmark stations (10) considered necessary has not yet been reached. Five stations are currently in operation. Mauna Loa Observatory (MLO), the oldest, was established by the

³ Singer, S. F., "Global Effects of Environmental Pollution," New York, Springer-Verlag, 1970.

⁴ Wilson, Carroll L., editor. *Man's Impact on the Global Environment*, Report of the Study of Critical Environmental Problems (SCEP). Cambridge, MIT Press, 1970, 319 pp.

⁵ Matthews, W. H., W. W. Kellogg, and G. D. Robinson, editors. "Man's Impact on the Climate," Cambridge, MIT Press, 1971, 594 pp.

⁶ Wilson, C. L., and W. H. Matthews, editors. *Inadvertent Climate Modification*, Report of the Study of Man's Impact on Climate (SMIC). Cambridge, the MIT Press, 1971, 308 pp.

⁷ Troposphere—the inner layer of the atmosphere varying in height from 6 to 12 miles. This is the region within which nearly all weather conditions manifest themselves.

⁸ Stratosphere—the region of the atmosphere outside the troposphere, about 10 to 30 miles in height.

U.S. Weather Bureau, then transferred to the supervision of the Atmospheric Physics and Chemistry Laboratory of the Environmental Science Services Administration in 1966 and finally to the Air Resources Laboratory of the National Oceanic and Atmospheric Administration (NOAA) in 1971. In the following year, the NOAA network was officially expanded to four stations: MLO; South Pole; Point Barrow, Alaska; and American Samoa. The other operational station is located at Kislovodsk, North Caucasus, in the U.S.S.R. The Government of Canada has plans for three high latitude northern stations, and some limited monitoring activities are conducted in Australia and New Zealand.

In addition to the long-term monitoring program, two shorter programs have been devoted to the inadvertent modification problem. The first of these, the Metropolitan Meteorological Experiment (Metromex), was directed toward a concentrated investigation of downwind effects of the thermal and particulate emissions from a typical metropolitan area—St. Louis, Mo. The project involved an examination of all available climatological data in a circle around the city, plus an extensive field program in which a number of State and Federal Government agencies and university research groups participated.

The objective of the second program was to prepare an environmental impact statement on the effects of supersonic transport aircraft. The resulting research activity, the Climatic Impact Assessment Program (CIAP), involved 9 agencies and departments of the Federal Government, 7 agencies of other national governments, and over 1,000 individual scientists in the United States and abroad. The program involved data-collecting activities using aircraft and balloons in the stratosphere, development of new techniques for sampling and measuring stratospheric pollutants, laboratory work in the photochemistry of atmospheric trace gases, measurement of pollutant emission by aircraft engines, mathematical modeling of stratospheric transport processes and chemical reactions taking place there.⁹

UNDERSTANDING THE CAUSES OF CLIMATIC CHANGE AND VARIABILITY

It is a human tendency to cling to the belief that the natural environment or climate to which we have become accustomed will remain more or less the same from year to year and from decade to decade. We are surprised and alarmed when an unusually severe winter or an unusually prolonged drought occurs, because our memories tend to be too short to recall past years when things were equally unusual.

—William W. Kellogg, 1978

National Center for Atmospheric Research.

The facts are that climate everywhere does fluctuate quite noticeably from year to year and that there are gradual changes in climate that make one decade or one century different from the one before. These yearly fluctuations and longer term changes have been the result of natural processes or external influences at work on the complex system that determines Earth's climate. It is a system that seems to strive for a balance among atmosphere, oceans, land, and polar ice masses—all

⁹ Barrett, Earl W., "Inadvertent Weather and Climate Modification." Critical Reviews in Environmental Control, vol. 6, No. 1, December 1975, pp. 15-90.

influenced by possible solar and cosmic variations of which climate researchers' knowledge is in some cases nonexistent, or incomplete, and otherwise tenuous at best. Society itself is becoming another significant factor in the climatic balance.

It is no news, for example, that the atmosphere of large midlatitude cities is both warmer and more turbid than the surrounding countryside (particularly in winter) as a result of thermal and chemical pollution and to some extent because of the ability of groups of buildings to trap heat from the Sun. There is also good evidence for increased summertime rainfall downwind from cities such as St. Louis, Chicago, and Paris.¹⁰ Indeed, it is very likely that the industrialization of sizable regions, such as the eastern United States and western Europe, has modified their climates in certain more subtle ways. In any attempt to assess a manmade climatic effect, it is essential to understand and have a measure of the degree of climatic variability which may be expected in the absence of human influence.

The concept of climatic change and variability

The concept of climatic change and variability entails a wide range of complex interactions with a disparity of response times among the air, sea, ice, land, and biotic components of the climate system. Climate is not a fixed element of the natural environment. Indeed, important advances in climate research and the study of former climates confirm that past climates of Earth have changed on virtually all resolvable time scales. This characteristic suggests that there is no reason to assume the favorable climatic regime of the last several decades is permanent and, moreover, that climatic change and variability must be recognized and dealt with as a fundamental property of climate.

In this matter it is important to appreciate the fact that a renewed appreciation of the inherent variability of climate has manifested itself in the public consciousness. Climate has not become suddenly more variable in a way that it has never been variable before, but events of recent years¹¹ have shaken a somewhat false sense of technological invulnerability. Thus, climatic variability is a media item now because society ignored for so long its continued dependence on the ecological/climatic balance achieved, and then failed to plan systematically for the coming unfavorable years, which eventually had to come—and always will, given the nature of the atmosphere. It is more palatable to blame climate for present predicaments than to acquiesce to a lack of preparedness. As F. Kenneth Hare, climatologist with the Science Council of Canada, has noted:

It is paramount that the [climate-related] events of 1972 do not repeat themselves, even if bad weather does. It does not matter whether such events are part of a genuine change in climate or are merely unusually large fluctuations of a basically unchanging system. In fact, I doubt whether such arguments mean anything. It does matter that climatic extremes do occur; that they have recently become rather frequent and have had severe impacts; that we lack the predic-

¹⁰ Dettwiller, J. W. and S. A. Changnon, "Possible Urban Effects on Maximum Daily Rainfall Rates at Paris, St. Louis, and Chicago." *Journal of Applied Meteorology*, vol. 15, May 1976, pp. 517-519.

¹¹ Most of the world's important grain-growing regions experienced unfavorable weather and crop failures in 1972 or 1974, or both. The winter of 1977 was perceived by most Americans as remarkably abnormal, with severe cold in the East (coldest, in fact, since the founding of the Republic), drought in the West, and mild temperatures as far north as Alaska: and the summer of 1977 was one of the two or three hottest in the last 100 years over most of the United States.

tive skill to avoid impacts on food production—and energy consumption; and that we [the atmospheric science community] are insufficiently organized to make maximum use of existing skill.¹²

While scientists concur that climate is not a fixed component of the natural environment, there is less agreement with regard to when and how climatic change occurs. Although in the long term a major natural change to a different climatic regime may be expected, it is unlikely that any trend toward such a change would be perceptible in the near term, as it could be obscured by large amplitude, shorter term climatic variability. Considered from a historical perspective, and judging from the record of past interglacial ages, climatic data indicate that the long-term trend over the next 20,000 or so years is toward a cooling cycle, a cooler climate, and eventually the next glacial age. The onset of that change may be a number of centuries or millennia away; conceivably it may already have begun. In recent years, books and newspaper stories have conditioned us to expect colder weather in the future. In geological perspective, the case for cooling is strong. The modern-day world is experiencing an interglacial period, a relatively warm interlude—lasting many thousands of years—between longer intervals of cold. If this interglacial age lasts no longer than a dozen earlier ones in the past million years, as recorded in deep-sea sediments, we may reasonably suppose that the world is about due to begin a slide into the next ice age. It does seem probable, though, that this transition would be sufficiently gradual so that in the next 100 to 200 years it would be almost imperceptible amid the ubiquitous variability of climate.^{13, 14, 15}

Considering the much more recent past, climatologists point out that the world has been in the throes of a general cooling trend during the last 30 or 40 years. Because this modern-day cooling trend has sometimes been misinterpreted as an early sign of the approach of an ice age (it really is only one of many irregular ups and downs of climate that mankind has witnessed through history), it has reinforced the popular notion that our future is likely to be a cold one. (In point of fact, this cooling trend has been faltering in very recent years, and may already have started to reverse itself.)

Writes research climatologist J. Murray Mitchell, Jr.:

I agree with those climatologists who say that another ice age is inevitable. I strongly disagree, however, with those who suggest that the arrival of the next ice age is imminent, and who speak of this as the proper concern of modern civilization in planning for the next few decades or centuries. Should nature be left to her own devices, without interference from man, I feel confident in predicting that future climate would alternately warm and cool many times before shifting with any real authority toward the next ice age. It would be these alternate warmings and coolings, together with more of the same ubiquitous, year-to-year variability of climate that has always been with us, that would be the appropriate object of our concerns about climate in the foreseeable future.¹⁶

¹² Norwine, Jim, "A Question of Climate," *Environment*, vol. 19, No. 8, November 1977, p. 12.

¹³ National Research Council, U.S. Committee for the Global Atmospheric Research Program. *Understanding Climatic Change: A Program for Action*, Washington, National Academy of Sciences, 1975. 239 pp.

¹⁴ U.S. Federal Council for Science and Technology. Interdepartmental Committee for Atmospheric Sciences, report of the Ad Hoc Panel on the Present Interglacial, Washington, National Science Foundation, 1974. 22 pp. (ICAS 18h-FV75).

¹⁵ United Nations. World Meteorological Organizations (WMO). *WMO Statement on Climatic Change*, pt. B: technical report, p. 9.

¹⁶ Mitchell J. Murray, Jr., "Carbon Dioxide and Future Climate," *EDS [Environmental Data Service] magazine*, March 1977, p. 4.

Because of man's presence on the Earth, however, what will actually happen in future decades and centuries may well follow a different scenario; imperceptibly different at first, but significantly so later on, covering a full spectrum of climatic possibilities ranging from warming to cooling trends. Varying interpretations of this evidence have led, on one hand, to a scientifically valid caution regarding possible instability of present-day climate conditions and, on the other hand, to predictions that the Earth may be on the verge of a new climate regime, which implies a new equilibrium among the elements of the climatic system, involving a somewhat different set of constraints and, almost certainly, noticeable regional shifts of climate. Climate researchers iteratively emphasize the importance of recognizing and appreciating the inherent variability of climate, a fact which may be more significant than the uncertainty of whether recent events portend a trend toward a warmer or cooler climate of the future.

When and how do climatic changes occur?

So far, there is no single comprehensive theory, or even a combination of a small number of theories, that completely explains—much less predicts—climatic fluctuations or change. As yet, there is no deterministic, predictive model of our planet's climate, and, until one is developed, predictions are as valid as the logic producing them. The periods of time involved in climatic predictions cover centuries, and the validity of climate forecasting is not easily tested. Nevertheless, there are some factors and processes that clearly should be taken into account, either in terms of observed correlations in the past or of theoretical assumptions about what should be important. All, in one way or another, effect changes and variability of climate by modifying the natural thermal balance of the atmosphere.

One group of processes responsible for climatic change and variability consists of external mechanisms, including: fluctuations of the Sun's radiative output, variations of Earth's orbital parameters, changes in atmospheric dust content, changes in levels of carbon dioxide and ozone in the atmosphere, and migration of land masses and shifting of continental plates.

In addition to being influenced by external forcing mechanisms, climate is, to a certain degree, regulated by processes internal to the climatic system, involving "feedback" interactions between the atmosphere, the world ocean, the ice masses, the land surface, and the biosphere. If an external variable were to be changed by a certain factor, the response of the climatic system to that change could be modified by the actions of these internal processes which act as feedbacks on the climatic system modifying its evolution. There are some feedbacks which are stabilizing, and some which are destabilizing; that is, they may intensify deviations.

In all likelihood, climatic change is a function of various combinations of interacting physical factors, external processes, internal processes, and synergistic associations (see fig. 2), but it is not yet clear to what extent the observed variability of the climatic system originates from internal mechanisms, and to what extent from external mechanisms. It appears likely that the answer depends upon the time scale of variability, with internal processes probably important on the scale of months and decades, and external mechanisms becoming increasingly important on time scales beyond a century as depicted in figure 3.

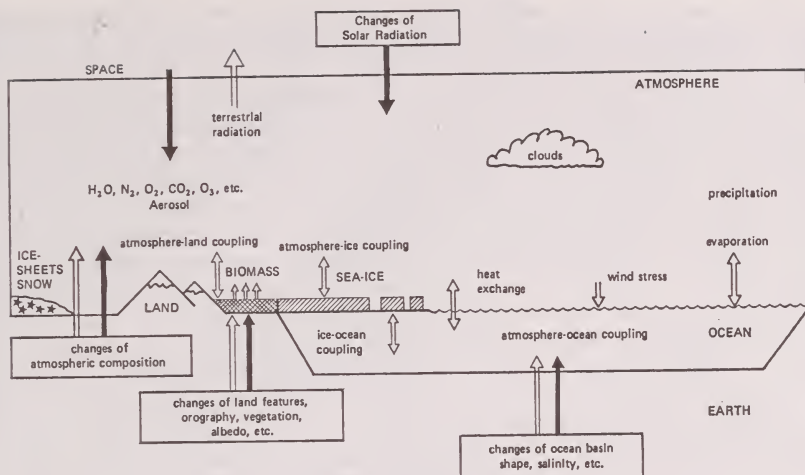


FIGURE 2.—Schematic illustration of the components of the coupled atmosphere-ocean-ice-land surface-biota climatic system. The full arrows are examples of external mechanisms, and the open arrows are examples of internal mechanisms of climatic change.

Source: Living With Climatic Change. Proceedings of a conference/workshop held in Toronto, November 17–22, 1975. Ottawa, Science Council of Canada, 1976, p. 85.

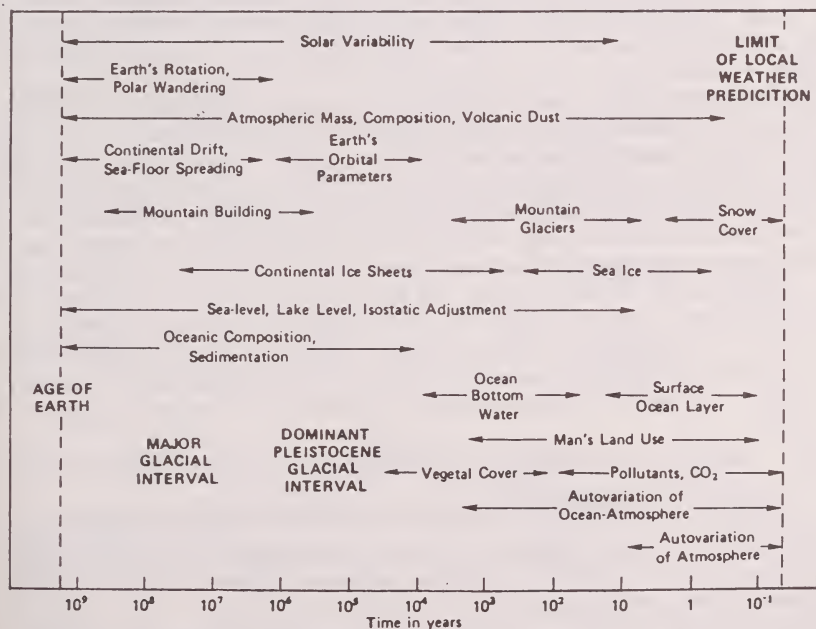


FIGURE 3.—Characteristic climatic events and processes in the atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere and possible causative factors of global climatic change.

Source: National Research Council. U.S. Committee for the Global Atmospheric Research Program. Understanding Climatic Change: A Program for Action. Washington, National Academy of Sciences, 1975, p. 22.

For a comprehensive and detailed discussion of the mechanisms and factors governing climatic change and variability, see "A Primer on Climatic Variation and Change" (1976).¹⁷

The possibility also exists that society may be changing the climate through its own actions by pushing on certain leverage points. Our presence on Earth cannot be assumed to go unnoticed by the atmosphere, and human intervention now presents possibilities that have never existed in the historic or geologic past. At question is whether the effects of civilized existence are yet capable of altering Earth's heat balance and, hence, impacting climate on a global scale to an important extent. Enormous amounts of gaseous and particulate materials have been emitted into the atmosphere through the combustion of fossil fuels (primarily carbon dioxide, sulfur dioxide, and fly ash) and through the manipulation of land for agriculture and commerce (primarily windblown dust, and forest and grass fire smoke). To an increasing extent, waste heat is also entering the atmosphere, both directly and indirectly (via rivers and estuaries) and in both sensible and latent form (as, for example, through evaporation in wet cooling towers). Moreover, large-scale land management programs have been responsible for significant changes in reflective properties, moisture holding capacity, and aerodynamic roughness of the surface (primarily through deforestation, water impoundment by manmade lakes, slash-burn agriculture practices, urbanization, and so forth). In view of the growth of population, industry, food production, and commerce in the years and decades ahead, the time is almost certainly not far off when human effects on large-scale climate would become appreciable in relation to natural phenomena leading to changes and variability of climate.

It does seem likely that industrial man already has started to have an impact on global climate, although this is difficult to prove by direct observation, because the impact is not easily recognizable amid the large natural variability of climate. "If man continues his ever-growing consumption of energy," contends J. Murray Mitchell, "and in the process adds further pollution to the global atmosphere, it may not be very many years or decades before his impact will break through the 'noise level' in the record of natural climatic variability and become clearly recognizable."¹⁸ Furthermore, the most significant impacts that mankind would probably have on the climatic system are apparently all in the same direction as far as global mean temperatures are concerned and are likely to constitute a warming trend.¹⁹

THE FACTS ABOUT INADVERTENT WEATHER AND CLIMATE MODIFICATION

AIRBORNE PARTICULATE MATTER AND ATMOSPHERIC TURBIDITY

Particulate matter in the atmosphere may significantly affect climate by influencing the Earth's radiation balance (figure 4) and/or cloud nucleation and precipitation.

¹⁷ Justus, John R., "Mechanisms and Factors Governing Climatic Variation and Change." In "A Primer on Climatic Variation and Change," prepared by the Congressional Research Service, Library of Congress, for the Subcommittee on the Environment and the Atmosphere of the Committee on Science and Technology, U.S. House of Representatives, 94th Cong., 2d sess. (committee print), Washington, U.S. Government Printing Office, 1976, pp. 77-127.

¹⁸ Mitchell, J. Murray, Jr., "Carbon Dioxide and Future Climate," p. 4.

¹⁹ Kellogg, William W., "Is Mankind Warming the Earth?" Bulletin of the Atomic Scientists, vol. 34, February 1978, pp. 10-19.

Do more particles mean a warming or cooling?

There is a question as to whether more particles mean a warming or cooling of the lower atmosphere. The general cooling trend of the last 30 to 40 years (which some experts feel may have bottomed out and already started to reverse itself) could have been a result of a reduction of solar radiation reaching the surface of the Earth because of particulates that have been scattered into the atmosphere by man's activities, among them: the burning of fossil fuels, mechanized agricultural operations, overgrazing of arid lands, manmade forest fires, and the slash-burn method of clearing land for crops, which is still widely employed in the Tropics. But if man started his polluting processes in the last century, and the decrease of global temperature were due to alteration in the transparency of the atmosphere, then why has a decrease in temperature not been observed earlier? It is possible that instruments were measuring a natural climatic trend that may have been only somewhat augmented by the byproducts of resource development, power generation, and industrial activities.

The situation is such that the net effect of a given particle on Earth's heat balance and hence on climate depends, in large part, upon the nature (number and size) of the particles, where in the atmosphere they are found, and how long they remain suspended. Some aerosols, such as lead from auto exhaust, are rapidly scavenged by precipitation. Others, mostly organic particles such as pesticides, may remain for months or years. While short-term aerosols such as lead may affect weather on a local scale, it is the aerosols that remain and accumulate in the atmosphere that will have long-term effects on climate.

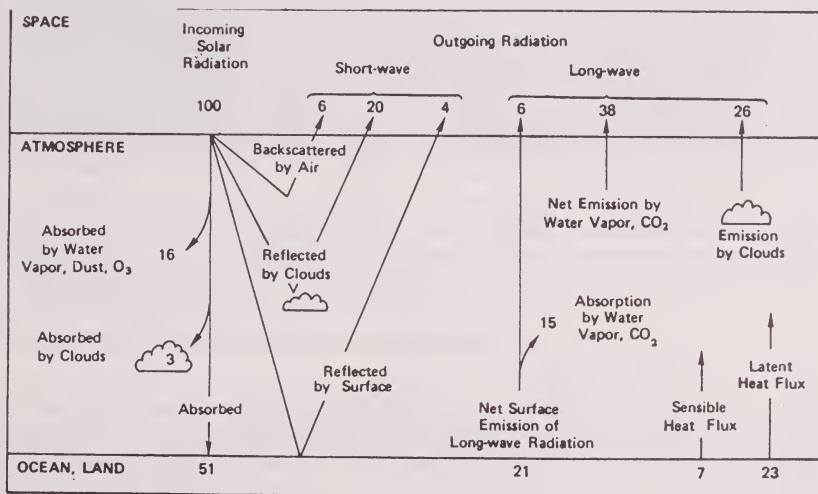


FIGURE 4.—The mean annual radiation and heat balance of the atmosphere, relative to 100 units of incoming solar radiation, based on satellite measurements and conventional observations.

Source: National Research Council, U.S. Committee for the Global Atmospheric Research Program. *Understanding Climatic Change: A Program for Action*, Washington, National Academy of Sciences, 1975, p. 18.

Idso and Brazel reporting on their research results in the November 18, 1977 issue of *Science* magazine found that initial increases in atmospheric dust concentration tend to warm the Earth's surface. After a certain critical concentration has been reached, continued dust buildup reduced this warming effect until, at a second critical dust concentration, a cooling trend begins. But, they explain, this second critical dust concentration is so great that any particulate pollution of the lower atmosphere will have the inexorable tendency to increase surface temperatures. The authors pointed out that if, and when, man-generated, industrial pollution of the atmosphere as a source of particulates ever becomes climatologically significant, the resultant surface temperature trend will definitely be one of warming, not cooling. Thus, whereas many groups assigned to assess the problem have looked on this aspect of intensified industrialization as acting as a "brake" on the warming influence inferred lately of increased carbon dioxide production,²⁰ just the opposite is actually the case—the two phenomena could tend to complement each other.²¹

Sources of atmospheric particulates: natural against manmade

Of course, not all aerosols in the Earth's atmosphere, or even a major proportion, are attributable to human activity. In fact, dust from volcanic eruptions, sea salt from evaporated ocean spray, smoke from lightning-caused forest fires (see fig. 5), debris from meteors which burn up in the atmosphere, windblown dust or sandstorms, and organic compounds emitted by vegetation are much larger sources of atmospheric particulates than human activity. Scientists at Stanford University estimate that natural processes produce about 2,312 million tons of aerosols a year, which amount to 88.5 percent of the total. Man and his activities account for only 296 million tons, the remaining 11.5 percent. At present, it is unlikely that man's activities and man-made aerosols will affect global temperatures. It is important to note, however, that while aerosols from natural sources are distributed fairly evenly across the planet, man, in contrast, contributes high concentrations mostly from industrial centers. Atmospheric scientists at the National Oceanic and Atmospheric Administration's Atmospheric Physics and Chemistry Laboratory found that the 296 million tons of manmade aerosols are produced every year on only about 2.5 percent of the surface of the globe. Within these limited areas, manmade aerosols account for nearly 84 percent of the total. It follows, then, that these aerosols may be expected to have noticeable effects on local weather and urban climates.

²⁰ See, generally, National Research Council, Geophysics Research Board, "Energy and Climate," Washington, National Academy of Sciences, 1977, 231 pp.

²¹ Idso, Sherwood B. and Anthony J. Brazel, "Planetary Radiation Balance as a Function of Atmospheric Dust: Climatological Consequences," *Science*, vol. 198, Nov. 18, 1977, pp. 731-733.



FIGURE 5.—Not all aerosols in the Earth's atmosphere are attributable to human activity. In this Landsat photo, smoke from a fire in the Seney National Forest, upper peninsula of Michigan, serves as a source of atmospheric particulates. Note the extent of the dust veil downwind of the source. (Courtesy of National Aeronautics and Space Administration.)

Atmospheric processes affected by particles

Everyday, particles of soot, smoke, dust, and chemicals from industrial combustion and other activities are emitted into the urban atmosphere. About 80 percent of the solid contaminants are small enough to remain suspended in the air, sometimes for several days.²² Even though these tiny particles reflect and scatter sunlight ostensibly keeping its heat from reaching the ground, they also can act as a lid to prevent the outflow of heat from the land surface to the atmosphere. In a sense, this turbidity acts as an insulator. It reduces the amount of sunlight received at the top of the city in the daytime and cuts down on a source of heat. However, at night urban aerosol pollutants retard the departure of radiant energy from the heated city air, encasing the heat in

²² "Do Cities Change the Weather?" Mosaic, vol. 5, summer 1974, pp. 33, 34.

the city's closed atmospheric system. Certain aerosols may undergo chemical change when they combine with water vapor in the presence of solar radiation. There are many complicated processes that can generate aerosol gas-to-particle conversions, and the particles can then grow by surface chemistry and physical accretion.²³

Perhaps the most sensitive atmospheric processes which can be affected by air pollutants are those involved in the development of clouds and precipitation. The formation and building of clouds over a city can be influenced by the presence of pollutants acting as nuclei upon which water vapor condenses and by the hot dry air with which these aerosols are swept into the base of the clouds (see fig. 6). The structure of clouds with temperatures below 0° C (defined as cold clouds) can be modified, and under certain conditions precipitation from them altered, by particles which are termed ice nuclei.²⁴ The concentrations of natural ice nuclei in the air appear to be very low: Only about one in a billion atmospheric particles which are effective as ice nuclei at temperatures above about -15° C have the potential for modifying the structure of clouds and the development of precipitation. If the concentration of anthropogenic ice nuclei is about 1 in 100 million airborne particles, the result may be an enhancement of precipitation; however, if the concentration is greatly in excess of 1 in 100 million, the result may be a tendency to "overseed" cold clouds and reduce precipitation. Certain steel mills have been identified as sources of ice nuclei. Also of concern is the possibility that emissions from automobiles may combine with trace chemicals in the atmosphere to produce ice nuclei.²⁵

²³ Hobbs, P. V., H. Harrison, E. Robinson, "Atmospheric Effects of Pollutants," *Science*, vol. 183, Mar. 8, 1974, p. 910.

²⁴ National Research Council, Committee on Atmospheric Sciences, "Weather and Climate Modification: Problems and Progress," Washington, National Academy of Sciences, 1973, pp. 41-47.

²⁵ Hobbs, P. V., H. Harrison, E. Robinson, "Atmospheric Effects of Pollutants," p. 910.

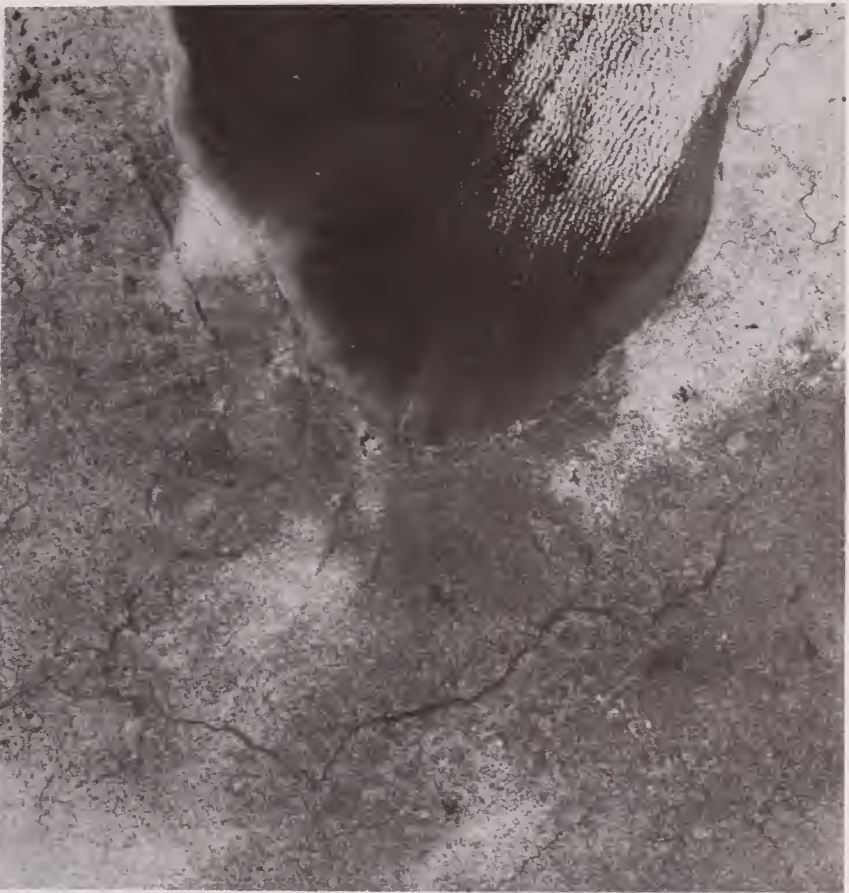


FIGURE 6.—The formation and building of clouds can be influenced by the presence of pollutants acting as nuclei upon which water vapor condenses and by the hot dry air with which these aerosols are swept aloft. In this Landsat photo, excess particles as well as heat and moisture produced by the industries of Gary, Ind., favor the development of clouds downwind. The body of water shown is the southern tip of Lake Michigan. (Courtesy of National Aeronautics and Space Administration.)

Precipitation from clouds that have temperatures above 0°C (warm clouds) may be modified by particles which serve as cloud condensation nuclei (CCN). A source that produces comparatively low concentrations of very efficient CCN will tend to increase precipitation from warm clouds, whereas one that produces large concentrations of somewhat less efficient CCN might decrease precipitation. Modifications in the structure of clouds and precipitation have been observed

many miles downwind of fires and pulp and paper mills. Large wood-waste burners and aluminum smelters have also been identified as major sources of CCN.²⁶

The La Porte weather anomaly: urban climate modification

La Porte, Ind., is located east of major steelmills and other industries south of Chicago. Analysis of La Porte records revealed that, since 1925, La Porte had shown a precipitation increase of between 30 and 40 percent. Between 1951 and 1965, La Porte had 31 percent more precipitation, 38 percent more thunderstorms, and 246 percent more hail days than nearby weather stations in Illinois, Indiana, and Michigan.²⁷ Reporting on this anomaly at a national meeting of the American Meteorological Society in 1968, Stanley Changnon, a climatologist with the Illinois State Water Survey pointed out that the precipitation increase in La Porte closely followed the upward curve of iron and steel production at Chicago and Gary, Ind. Furthermore, La Porte's runs of bad weather correlated closely with periods when Chicago's air pollution was bad. Stated simply, Changnon's theory was that if this effect did not occur by chance, then the increase in precipitation could be caused by the excess particles as well as heat and moisture produced by the industries upwind of La Porte. Pollutants from the industrial sources, it seemed, were serving as nuclei to trigger precipitation, just as silver iodide crystals are used to seed clouds in deliberate efforts of weather modification.²⁸

The discovery of the La Porte anomaly helped usher in considerable scientific and public concern as to whether cities could measurably alter precipitation and severe weather in and downwind of them. A large urban-industrial center is a potential source of many conditions needed to produce rainfall. These include its release of additional heat (through combustion and from "storage" in surfaces and buildings) which lifts the air; the mechanical mixing due to the "mountain effects" of a city existing in flat terrain; additional moisture released through cooling towers and other industrial processes; and the addition of many small particles (aerosols), which could serve as nuclei for the formation of cloud droplets and raindrops.

The interest in whether urban emissions into the atmosphere could trigger changes in weather and climate on a scale much larger than the city itself led to climatological studies of other cities. Historical data for 1901-70 from Chicago, St. Louis, Washington, D.C., Cleveland, New Orleans, Houston, Indianapolis, and Tulsa were studied in an effort to discern whether cities of other sizes, different industrial bases, and varying climatic-physiographic areas also experienced rainfall changes. The six largest cities—Washington, Houston, New Orleans, Chicago, Cleveland, and St. Louis—all altered their summer precipitation in a rather marked fashion: Precipitation increases of 10 to 30 percent in and downwind of their urban locales, plus associated increases in thunderstorm and hailstorm activity were documented.

²⁶ National Research Council, Committee on Atmospheric Sciences, "Weather and Climate Modification: Problems and Progress," p. 50.

²⁷ Lansford, Henry, "We're Changing the Weather by Accident," *Science Digest*, vol. 74, Dec. 1973, p. 21.

²⁸ Changnon, S. A., Jr., "The La Porte Weather Anomaly—Fact or Fiction?" *Bulletin of the American Meteorological Society*, vol. 49, January 1968, pp. 4-11.

Tulsa and Indianapolis, cities of lower population and lesser physiographic irregularities than the others studied, did not reveal any precipitation anomalies.²⁹

The key questions that could not be answered conclusively at the completion of these climatic studies were (1) whether the anomalies found were real (or adequately measured); (2) if real, what was causing the anomalies; and (3) whether and how extensive the anomalies were around other cities. To this end, a major atmospheric program dealing with inadvertent weather modification was initiated by a group of scientists in 1971. The Metropolitan Meteorological Experiment (METROMEX) was designed by four research groups who received support from Federal agencies and one State (Illinois). St. Louis was chosen as the site of extensive field investigations in this first major field program aimed at studying the reality and causes of urban rainfall anomalies suggested in the climatological surveys conducted previously.³⁰

Although data analysis and report preparation continue (summer 1975 was the fifth and final year for field work), METROMEX data thus far portray statistically significant increases in summer rainfall, heavy (more than 2.5 cm) rainstorms, thunderstorms and hail in and just east (downtown) of St. Louis. Examination of the rainfall yield of individual showers, the spatial distribution of rain developments, and areal distribution of afternoon rain clearly point to the urban-industrial complex as the site for the favored initiation of the rain process under certain conditions.³¹

Writes climatologist Stanley Changnon :

The greater frequency of rain initiations over the urban and industrial areas appears to be tied to three urban-related factors including thermodynamic effects leading to more clouds and greater in-cloud instability, mechanical and thermodynamic effects that produce confluence zones where clouds initiate, and enhancement of the [raindrop] coalescence process due to giant nuclei. Case studies reveal that once additional [rainstorm] cells are produced, nature, coupled with the increased likelihood for merger with more storms per unit area, takes over and produces heavier rainfalls. Hence the city is a focal point for both rain initiation and rain enhancement under conditions when rain is likely.³²

Recapitulating, METROMEX researchers have found that rain, thunderstorms and hail can actually maximize within cities and nearby areas, particularly in those downwind. Such locations may have more storms, and they are more intense, last longer and produce more rain and hail than storms in surrounding regions. Apparently, air heated and polluted by a city can move up through the atmosphere high enough to affect clouds. This urban-modified air clearly adds to the strength of convective storms and increases the severity of precipitation. Urban climatic alterations are summarized in table 1.

²⁹ Huff, F. A. and S. A. Changnon, Jr., "Precipitation Modification by Major Urban Areas," *Bulletin of the American Meteorological Society*, vol. 54, December 1973, pp. 1220-1232.

³⁰ Changnon, S. A., F. A. Huff, and R. G. Semonin, "Metromex: An Investigation of Inadvertent Weather Modification," *Bulletin of the American Meteorological Society*, vol. 52, October 1971, pp. 958-967.

³¹ "METROMEX Update," *Bulletin of the American Meteorological Society*, vol. 57, March 1976, pp. 304-308.

³² Changnon, S. A., R. G. Semonin and F. A. Huff, "A Hypothesis for Urban Rainfall Anomalies," *Journal of Applied Meteorology*, vol. 15, June 1976, pp. 544-560.

TABLE 1.—*Some urban climatic alterations*¹

<i>Element</i>	<i>Comparison with rural environs</i>
Radiation:	
Global	10 to 20 percent less.
Ultraviolet:	
Low sun	30 to 50 percent less.
High sun	5 to 10 percent less.
Temperature:	
Annual mean	1 to 2° C higher.
Maximum difference	3 to 10° C higher.
Winter minima	1 to 3° C higher.
Cloudiness:	
General cloud cover	5 to 10 percent more.
Fog:	
Winter	100 percent more.
Summer	20 to 30 percent more.
Precipitation:	
Totals:	
Summer	10 percent more.
Winter	5 percent more.
Relative humidity: Annual mean	4 to 6 percent less.
Evapotranspiration: Total amount	30 to 60 percent less.
Dew: Amounts	50 to 80 percent less.
Wind speed: < 3 m sec ⁻¹	40 percent less.
Speeds:	
3—6 m sec	20 percent less.
> 6 m sec	10 percent less.
Thunderstorms: Number of days	5 to 10 percent more.

¹ After Helmut Landsberg, University of Maryland.

CARBON DIOXIDE AND WATER VAPOR

The constituent gases of the atmosphere that are important variables affecting the distribution of temperature within the atmosphere are carbon dioxide and water vapor. Capable of absorbing important quantities of infrared radiation, they both have a role in modifying the vertical distribution of temperature in the atmosphere by controlling the flux of infrared radiation. The absorption of incoming solar radiation by these gases is so small that their concentration has no appreciable effect on the amount of incoming solar radiation reaching the Earth's surface. Carbon dioxide and water vapor are, however, opaque to major portions of the long-wave radiation emitted by the Earth's surface. The greater the content of these gases the greater the opacity of the atmosphere to infrared radiation and the higher its temperature must be to radiate away the necessary amount of energy to maintain a radiation balance. It is this absorption of long-wave radiation emitted by the Earth, with the subsequent reradiation of additional infrared radiation to the ground and consequent elevation of air temperatures near the surface that is known as the "greenhouse effect."

Increases in atmospheric carbon dioxide concentration: what the record indicates

Man adds carbon dioxide to the atmosphere through the combustion of fossil fuels, and this addition is superimposed on the natural exchanges between the atmosphere, the biosphere, and the world ocean. Since the use of energy has increased exponentially since the beginning

of industrialization around 1860, it is not surprising that the best estimate of carbon dioxide production, which results from fossil fuel combustion and cement manufacture, shows the same exponential trend (see fig. 7).

The concentration of carbon dioxide in the atmosphere has increased steadily from a preindustrial value of about 295 parts per million in 1860 to a current value of 330 parts per million (+ 12 percent). Since the beginning of accurate and regular measurements in 1958, observed atmospheric carbon dioxide concentrations have increased some 5 percent from 315 parts per million to the current yearly average value of 330 parts per million as indicated in figure 8.

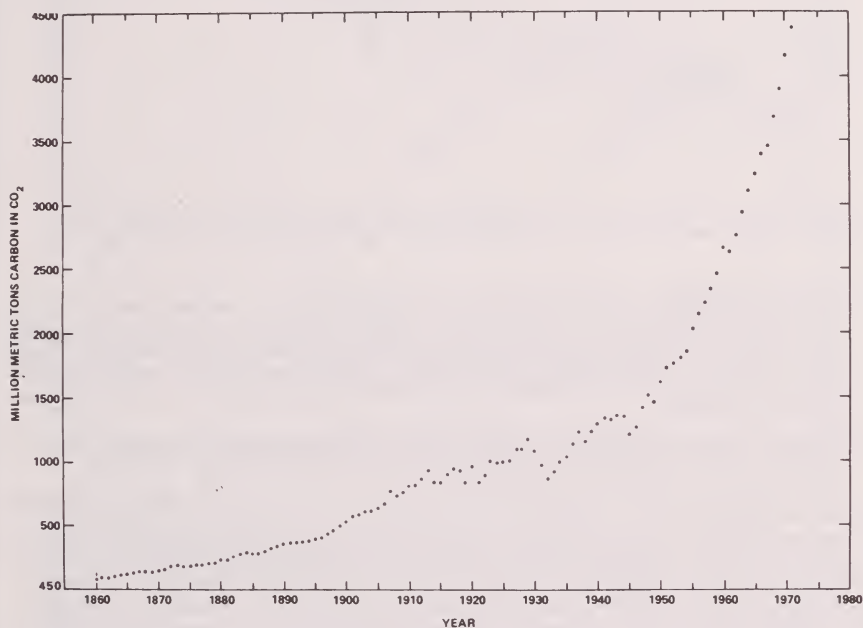


FIGURE 7.—The annual world production of carbon dioxide from fossil fuels (plus a small amount from cement manufacture) is plotted since the beginning of the industrial revolution. Except for brief interruptions during the two world wars and the Great Depression, the release of fossil carbon has increased at a rate of 4.3 percent per year. (Data for 1860-1959 from C. D. Keeling, "Industrial Production of Carbon Dioxide from Fossil Fuels and Limestone," *Tellus*, vol. 25, 1973, p. 174; data for 1960-71 from R. M. Rotty, "Commentary on and Extension of Calculative Procedure for Carbon Dioxide Production," *Tellus*, vol. 25, 1973, p. 508.)

Source: Baes, C. F., et al. "The Global Carbon Dioxide Problem," Oak Ridge National Laboratory, 1976. (ORNL-5194.)

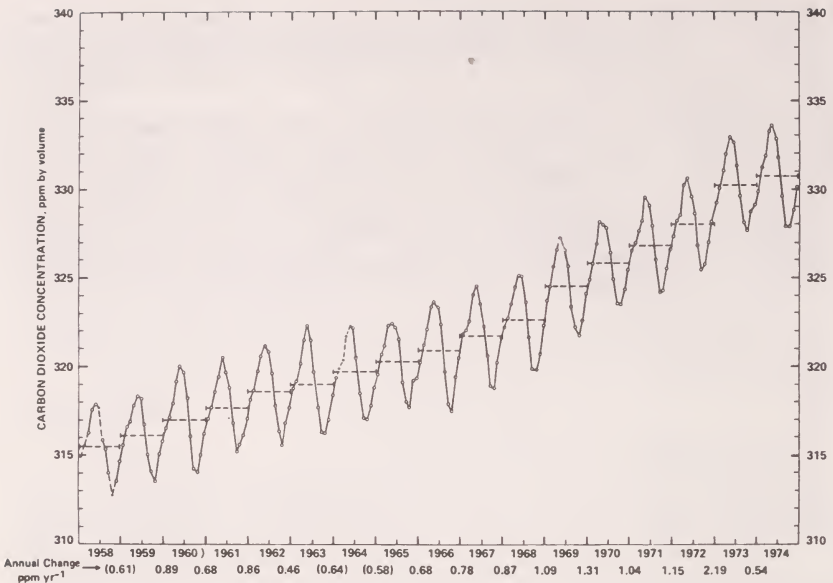


FIGURE 8.—Monthly average values of the concentration of carbon dioxide in the atmosphere at Mauna Loa Observatory, Hawaii, are plotted since the beginning of accurate and regular measurements in 1958. Variations in photosynthesis and other seasonal effects produce the annual cycle. Mean annual concentrations are well above the preindustrial level (290–300 ppm), and the secular increase is quite apparent.

Source: Baes, C. F., et al. "The Global Carbon Dioxide Problem," Oak Ridge National Laboratory, 1978. (ORNL-5194.)

The seasonal variation of the record of carbon dioxide measurements made at Mauna Lao is obvious and regular, showing an October minimum with increases in the later autumn and winter months and a maximum in May. However, of greater importance to possible climatic changes is the continued year-to-year rise. Both the seasonal variation and the annual increase have been confirmed by measurements at other locations around the globe.

Predicting future atmospheric carbon dioxide levels

Projecting the worldwide needs for energy, even with the present problems, indicates a long-term global growth in the consumption of fossil fuels and the associated production of carbon dioxide. Insofar as possible impact on the climate is concerned, it is the amount of carbon dioxide remaining in the atmosphere that is most important. In addition to the atmosphere, the ocean and both land and marine biospheres serve as reservoirs for carbon dioxide. Based on estimates of preindustrial levels of atmospheric carbon dioxide of 290–295 parts per million and the 1958 to present Mauna Loa data, between 58 and 64 percent of the carbon dioxide produced from burning fossil fuels remains in the atmosphere. Cumulative production of carbon dioxide is plotted in figure 9. The upper set of points indicates the increase in the carbon dioxide fraction of the atmosphere that would have occurred if all car-

bon dioxide produced since 1860 from fossil fuels and cement remained airborne. The lower set of points represents the observed increase based on an assumed value of 290–295 parts per million in 1860. The difference between the two sets of points presumably indicates the amount of carbon dioxide being taken up by the world ocean and possibly the biosphere and placed in long-term storage. Nearly half of the carbon dioxide produced from fossil fuels and cement seems to have found its way into reservoirs other than the atmosphere.

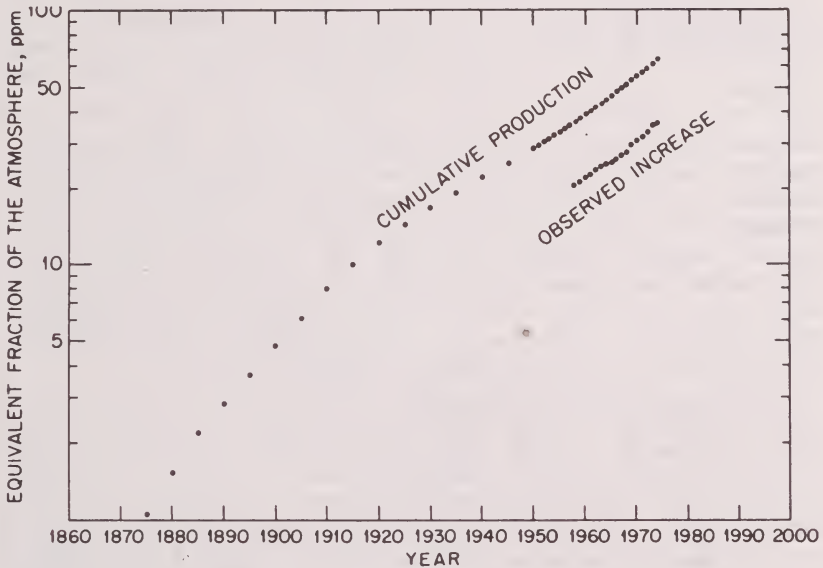


FIGURE 9.—The cumulative production of carbon dioxide since 1860 is compared with the observed increase in the mean annual concentration since that time. The similarity in the rates of increase (about 4 percent per year) produces strong evidence that these two quantities are related. About 50 percent of the fossil carbon flux apparently has been balanced, at least since 1958, by a flow of carbon dioxide to such reservoirs at the world ocean and/or the land biota (assumed 1860 atmospheric concentration equals 295 ppm).

Source: Baes, C. F., et al. "The Global Carbon Dioxide Problem," Oak Ridge National Laboratory, 1976. (ORNL-5194.)

Future levels of atmospheric carbon dioxide will depend primarily on the rate of consumption of fossil fuel and to a lesser extent on land use patterns and practices. With brief interruptions for two world wars and the Great Depression, the production of carbon dioxide from fossil fuels has increased with an annual rate of 4.3 percent.³³ If the use of fossil fuels continues to grow at this present rate, the total carbon dioxide injected into the atmosphere by man since 1860 would reach 300 parts per million by the year 2030, and the total concentration would be equal to 595 parts per million. This assumes, of course, no change in the average uptake by other reservoirs during this time. Those energy scenarios that rely heavily on coal, especially for synthetic oil and gas, yield estimated carbon dioxide concentrations of

³³ 4.3 percent per year provides an excellent fit to the data in figure 7.

600 parts per million about the year 2015 and 1,400 parts per million about 100 years from now. Rotty and Weinberg (1977) discuss a scenario by Niehaus in which nonfossil energy sources dominate soon after 2000. Even in this case the annual emission of carbon dioxide from fossil fuel peaks at about twice the present level in the year 2000 and tapers off thereafter; the atmospheric concentration nevertheless reaches 475 parts per million by 2050.^{34, 35, 36, 37, 38}

Sources and sinks for carbon dioxide

These extrapolations are based on certain assumptions, a critical one being that the ocean and the biosphere will continue to absorb a large fraction of the carbon dioxide in the atmosphere. Some oceanographers see increasing evidence that the upper mixed layer of the ocean, where most of the carbon dioxide is stored, is rapidly becoming saturated, and if this were true, then it tends to reinforce the attainment of relatively high atmospheric carbon dioxide concentrations in the next century. However, this prediction is far from certain, because carbon dioxide absorption in the ocean could turn out to be greater than expected because of mixing between ocean layers or other factors.³⁹ The problem is further complicated by a series of current appraisals that suggest that the terrestrial biomass appears to be a net source of carbon dioxide for the atmosphere. George M. Woodwell of the Marine Biological Laboratory at Woods Hole, Mass., explains:

Over the past seven years several reviews of the world carbon budget have confirmed that there is an annual increase in the carbon dioxide content of [the atmosphere] that is worldwide and is almost certainly man-caused. The source of the carbon dioxide that is accumulating in the atmosphere has been commonly assumed to be the combustion of fossil fuels. Because the amount of carbon dioxide accumulating in the atmosphere is * * * [about] half the total released from fossil fuels, other sinks for carbon dioxide have been sought. The major sink is the ocean, but mixing rates appear to be too low for the oceans to accommodate all the carbon dioxide that is thought to be released in excess of that accumulating in the atmosphere. The question of whether the terrestrial biota could be another sink was raised in 1970 [at SCEP], and the assumption was made that the biota might be a sink, especially in view of the stimulation of photosynthesis under greenhouse conditions by enhanced concentrations of carbon dioxide. More recently, the assumption that increased carbon dioxide in air stimulates photosynthesis worldwide has been questioned. So has the assumption that the biota is a net global sink for carbon dioxide. A series of current appraisals suggests that, quite contrary to the previous estimates, the biota is probably an additional source of carbon dioxide * * * as large as or larger than the fossil fuel source.⁴⁰

Thus, the great puzzle is the basic stability of the global carbon budget. Without better information on the behavior of the terrestrial biosphere, it is difficult to say whether the biosphere is a sink or a net source of carbon dioxide. If the biosphere is supplying more carbon

³⁴ Baes, C. F., Jr., et al. "The Global Carbon Dioxide Problem," Oak Ridge, Tenn., Oak Ridge National Laboratory, 1976, 78 pp. (ORNL-5194.)

³⁵ Lepkowski, Wil. "Carbon Dioxide: A Problem of Producing Usable Data." *Chemical and Engineering News*, vol. 55, Oct. 17, 1977; pp. 26-30.

³⁶ Rotty, Ralph M. "Energy and the Climate." Institute for Energy Analysis, Oak Ridge, Oak Ridge Associated Universities, 1976, 28 pp. (ORAU/IEA(M) 75-3.)

³⁷ Rotty, R. M. and A. M. Weinberg. "How Long is Coal's Future," *Climatic Change*, vol. 1, No. 1, March 1977; pp. 45-57.

³⁸ Rotty, Ralph M. "The Atmospheric Carbon Dioxide Consequences of Heavy Dependence on Coal." Institute for Energy Analysis, Oak Ridge Associated Universities, occasional paper, 32 pp., Nov. 14, 1977.

³⁹ Anthes, Richard A., Hans A. Panofsky, John J. Cahir and Albert Rango, "The Atmosphere." Columbus, Charles E. Merrill Publishing Co., 1975, p. 204.

⁴⁰ Woodwell G. M., et al., "The Biota and the World Carbon Budget." *Science*, vol. 199, Jan. 13, 1978, pp. 141-146.

dioxide than it is absorbing, then the behavior of the ocean must be different from what oceanographers believe, in the sense that it would be an even more effective sink for carbon dioxide than previously surmised. Thus, there is a need for intense examination of the flux of carbon into the ocean. The ability of the world ocean to act as a carbon dioxide sink is large, but the rate of possible sequestering of carbon is the important factor. One possibility is that biotic mechanisms in the ocean are more effective than has been assumed in transferring fixed carbon from the mixed (near-surface) layers of the ocean into deep ocean waters. Before an estimate can be made with confidence of what fraction of the carbon dioxide from fossil fuels remains in the atmosphere, a better understanding of the roles of both the biosphere and the world ocean in the carbon cycle is necessary.^{41, 42, 43}

Atmospheric effects of increased carbon dioxide levels

A change in the carbon dioxide content of the atmosphere upsets the Earth's radiation balance by holding back departing infrared light. All things being equal, if no other change were to occur in the system, the net amount of energy accumulated by the Earth would raise its surface temperature until the enhanced infrared emission reestablished balance between incoming and outgoing radiation. The problem, however, is greatly complicated by the fact that other changes would certainly take place. For example, if the Earth's temperature rises, the water vapor content of the atmosphere is likely to rise. More water will have the same effect as more carbon dioxide creating positive feedback in the system and hence forcing temperatures to climb even higher. A rise in water vapor would quite likely increase the fraction of the globe covered by clouds. Such an increase would cause the amount of primary solar radiation absorbed by the Earth to fall. Some combination of increased temperature and cloudiness will balance the enhanced absorption of infrared radiation by the added carbon dioxide and water vapor.

Implications of increasing atmospheric carbon dioxide concentrations

The possibilities and implications of a continued rise in the atmospheric carbon dioxide concentration were reviewed in a special report entitled "Energy and Climate," released by the National Research Council (NRC) on July 25, 1977.⁴⁴

The most complete, though still imperfect, climate models suggest that a doubling of the amount of carbon dioxide in the atmosphere, relative to its present amount, would increase the average annual temperature of the lower atmosphere at middle latitudes by about 2.4° to 2.9° C (4.3° to 5.2° F), depending on which model is used to derive the estimated temperature change.

Based on one climate model in which the hydrologic cycle is modeled in detail along with other aspects of climate behavior, a doubling of carbon dioxide has been calculated to result in about a 7 percent increase

⁴¹ Bolin, Bert. "Changes of Land Biota and Their Importance for the Carbon Cycle; The Increase of Atmospheric Carbon Dioxide May Partly Be Due to the Expansion of Forestry and Agriculture." *Science*, vol. 196, May 6, 1977, pp. 613-615.

⁴² Siegenthaler, U and H. Oeschger. "Predicting Future Atmospheric Carbon Dioxide Levels." *Science*, vol. 199, Jan. 27, 1978, pp. 388-395.

⁴³ Woodwell, George M., "The Carbon Dioxide Question," *Scientific American*, vol. 238, January 1978, pp. 34-43.

⁴⁴ National Research Council, Geophysics Research Board, "Energy and Climate," Washington, National Academy of Sciences, 1977, 281 pp.

in global average precipitation. Most of this increase would be concentrated in higher latitudes. A general retreat of snow and sea ice cover, by perhaps as much as 10 degrees of latitude, could result in the Arctic regions. The extent of such changes in the Antarctic, however, has not been determined. The temperature rise is greater by a factor of three or four in polar regions than the average temperature change for the world as a whole. For each further doubling of carbon dioxide, an additional 3° C increase in air temperature is inferred. This would mean that should the carbon dioxide concentration approach four to eight times preindustrial levels, and increase in global mean air temperature of more than 6° C (11° F) could be realized—at which time Earth would be experiencing temperatures warmer than those at any time in the last million years.⁴⁵

Implications of a climatic warming

The implications for man-induced climatic warming are particularly far-reaching for agriculture, according to the NRC report. The global picture presented by the report is one dominated by the forementioned gradual increase in mean air temperatures, with a concomitant shifting of agricultural zones, altered rainfall patterns and other major changes. Worldwide average annual precipitation could increase, which, at first glance, would seem to benefit agriculture. The accompanying higher air temperature, however, would raise the rate of evapotranspiration from cultivated lands, and part of the benefits from the additional water supply could be lost. In some regions, evapotranspiration might exceed the increase in precipitation; in others, the reverse might be true. At higher latitudes, there would be a longer frostfree growing season than at present, and the boundaries of cultivation could be extended northward in the Northern Hemisphere. Attendantly, summer temperatures might become too high for full production of middle-latitude crops such as corn and soy beans grown in Iowa, Illinois, Indiana, and Missouri, and it might be necessary to shift the Corn Belt toward the north where less productive soils are encountered. Generally speaking, warmer temperatures would result in a poleward movement of agroclimatic zones. As the authors of the NRC report state :

The most serious effects on agriculture would arise not from changes in global average conditions but from shifts in the location of climatic regions and changes in the relationships of temperature, evapotranspiration, water supply, cloudiness, and radiation balance within regions. Present cropping patterns, crop varieties, and farming technology in different climatic regions are based on cumulative experience over many years in the selection of appropriate crop species and varieties for each region and in adapting both the plants and their physical environment to each other in as nearly an optimal fashion as possible. These adaptations have remained fairly satisfactory over the relatively narrow range of climatic changes that have occurred in the historic past. But large changes in climatic relationships within regions such as might be brought about by a doubling or quadrupling of atmospheric carbon dioxide would almost certainly exceed the adaptive capacity of crop varieties grown at present.⁴⁶

The potential global warming trend associated with increasing concentrations of atmospheric carbon dioxide could increase desertification,⁴⁷ although there is not conclusive evidence for this possibility.

⁴⁵ *Ibid.*, pp. 4, 5.

⁴⁶ *Ibid.*, pp. 13-14.

⁴⁷ The awkward word "desertification" often refers to the process by which existing deserts spread, but the term also may refer to the creation of desertlike conditions such as those which developed during the 1930's dust-bowl years in the North American Great Plains.

The altered pattern of rainfall and temperature resulting from the release of carbon dioxide could change desert conditions in unexpected ways and even increase agricultural potential in some cases. Authors of the NRC report concede the present state of ignorance on the subject:

The most serious effects of possible future climatic changes could be felt along the boundaries of the arid and semiarid regions in both hemispheres. We need to be able to estimate whether these belts of aridity and semiaridity will move toward or away from the poles and whether they will expand or contract in area.⁴⁸

The effect of manmade or of natural climatic alteration of desert areas is not clear. The advancement of desert conditions into agricultural areas in Africa and elsewhere has been documented during the past decade, and although rainfall patterns with associated wet and dry climates are controlled mainly by the general atmospheric circulation, human activities can have a marked effect on local desert conditions, even possibly intensifying the process of desertification and thereby compounding the problem. In particular, excessive ploughing of dry land or overenthusiastic introduction of livestock and expansion of cultivated areas, during wet periods, into marginal lands causes destruction of soil-protecting vegetation. During ensuing dry periods, these marginal lands, with their natural protective cover destroyed by cultivation and overgrazing, suffer loss of, or a decline in, the quality of soil. As this occurs over a large region, the bare dry ground, its reflectivity altered, now acts to intensify the natural climatic conditions which sustain the desert.⁴⁹

Carbon dioxide and future climate: the real climate versus "model climate"

In the final analysis, it is well to remember that it cannot be asserted that a doubling of carbon dioxide in the real world would have the same effects on real climate as a simulated doubling of carbon dioxide in climate models would have on "model climate." This caveat is in order because no climate model is altogether realistic in its description of the real climatic system, and because some of the physical processes that operate in the real climatic system cannot yet be simulated at all in climate models. Comments J. Murray Mitchell, Jr.:

No climate model on which the above conclusions [regarding climatic warming] are based is capable of developing its own cloud systems in a realistic way: most models must be instructed before hand where the clouds are assumed to exist, and the clouds remain there unchanged throughout the computer experiment using the model. We should be wary of this, because if the cloudiness were to change in the real world along with a carbon dioxide change, then the role of clouds in affecting the temperature of the Earth might significantly alter the net temperature effect of the carbon dioxide change as inferred from models that assume fixed cloudiness.⁵⁰

the model is allowed to adjust cloudiness along with other weather variables as the calculation proceeds. Early indications are that

Some preliminary model experiments have been attempted at the National Oceanic and Atmospheric Administration's (NOAA) Geophysical Fluid Dynamics Laboratory in Princeton, N.J., in which

⁴⁸ National Research Council, Geophysics Research Board, op. cit., p. 14.

⁴⁹ Ibid.

⁵⁰ Mitchell, J. Murray, Jr., "Carbon Dioxide and Future Climate," p. 9.

allowance for cloudiness changes does not greatly alter the results of experiments using models with fixed cloudiness.

Altogether, the experience with climate models suggests that their use in evaluating the magnitude of temperature changes associated with changes of atmospheric carbon dioxide leads to results that are likely to approximate reality fairly closely. Models may be overestimating the temperature and other climatic effects of carbon dioxide changes by as much as a factor of two. On the other hand, it is equally likely that they may be underestimating the effects by a factor of two. In balance, the model results to date warrant being taken as an unprejudiced and credibly realistic approximation to reality.⁵¹

OZONE DEPLETION

The concern that man's activities could in some fashion change the stratosphere first emerged as a public issue during the debate on the American SST in 1969. The American SST program was, at that time, almost a decade old and was approaching its final phase when it was challenged by a coalition of more than 30 environmentally oriented organizations. The environmentalists contended that the SST, flying in the stratosphere, would contaminate the stratosphere and alter its characteristics. The dominant concern was that water, created as a product of fuel combustion, would interact with the stratospheric ozone and destroy it.

Concerns regarding ozone destruction

Ozone (O₃) exists everywhere in the atmosphere and reaches a maximum concentration at around 80,000 feet. It is created, as well as destroyed, by the interaction of ultraviolet light from the Sun with oxygen molecules in the upper atmosphere. Most of the ozone is created in the Tropics and is dispersed from there toward both poles. Due to the destructive action of sunlight and to the atmospheric transport systems, the Tropics, where most of the ozone is made, have the least dense coverage of ozone. Ozone density increases in the temperate zones and reaches its maximum density in the polar regions. Ozone density over a given spot on Earth may vary as much as 25 to 30 percent on a given day and as much as 300 percent throughout the year depending on the season. Ozone density measurements have shown that the Northern Hemisphere of the Earth has a slightly denser coverage than the Southern Hemisphere.

The importance of the ozone content of the upper atmosphere centers on the fact that the ultraviolet light that creates ozone is absorbed in the process. These wavelengths of ultraviolet light are damaging to life of all sorts if the intensity is too great. It should be noted that some ultraviolet light is required by animal life to produce vitamin D which gives protection against rickets.

In the debate over the American SST, it became clear that neither side had enough data on the stratosphere to refute the other. Despite this, the debate remained lively for more than a year and was finally terminated by the congressional decision to cancel the SST program and to initiate programs to study the upper atmosphere and in particular, its ozone.

⁵¹ Information gleaned in a session on "climatic futures" at the 1978 annual meeting of the American Association for the Advancement of Science in Washington, D.C., Feb. 17, 1978.

Congress requested and funded a 3-year, \$24 million program, to determine whether or not the stratospheric flight constituted a threat to the Earth's environment. Responsibility for the study was given to the Department of Transportation and was called the "Climatic Impact Assessment Program" (CIAP).⁵² The theoretical mechanisms which indicated that water, created from the combustion of fuel, would mix with and destroy ozone appeared to be reasonable and meritorious of serious study. Early in the CIAP, however, actual measurements of ozone density in the stratosphere in volumes of air which were permeated by the plume from jet engines, were made. These measurements showed that ozone density seemed to increase subsequent to the injection of water vapor. Why this occurs is not yet understood, but the test provided adequate information to conclude that water vapor injected into the stratosphere would not constitute a danger to the ozone.

During the conduct of the CIAP program, other papers began to appear which described a variety of heretofore unconsidered theoretical ways in which man's activities could adversely effect the ozone density in the stratosphere. The atmosphere of the Earth is about 80 percent nitrogen and 20 percent oxygen. The oxygen used in the combustion process is therefore accompanied by a large amount of nitrogen. The heat of combustion causes the formation of several oxides of nitrogen (NO_x). Theoretical mechanisms were proposed which predicted that the NO_x formed in the stratosphere by a jet engine would mix with the ozone and destroy it in a catalytic manner. In other words, during the process in which the NO_x would destroy the ozone, the NO_x would be reformed and released to destroy still more ozone in a continuous manner.⁵³ The mechanisms for this process appeared reasonable and worthy of serious study. However, Dr. John J. McKetta of the CEQ noted that the total NO_x burden produced by combustion processes amounts to only about 2 percent of that produced by dying vegetation in the natural cycle of plant life.⁵⁴ It was then noted that the artificial insertion of nitrogen compounds into the soil for purposes of fertilizing caused the evolution and ultimate release of NO_x in quantities amounting to a sizable fraction of that produced by nature.^{55, 56}

Moreover the bromine compounds used in agriculture as antifungicides were held to be even more potent in destroying ozone than NO_x .⁵⁷ Still more very large sources of NO_x were identified, such as lightning from the some 5,000 storms around the Earth, each day. Also, air bursts of nuclear bombs produce NO_x at the rate of 10,000 tons per megaton of yield.^{58, 59} In the early 1960's, 340 megatons of explosive injected about $3\frac{1}{2}$ million tons of NO_x into the stratosphere.

⁵² "Climatic Impact Assessment Program Development and Accomplishments, 1971-75," J. Mormino, et al. DOT-TST-76-41, December 1975.

⁵³ "Reduction of Stratospheric Ozone by Nitrogen Oxide Catalysts from Supersonic Transport Exhaust," H. Johnston, Science, Aug. 6, 1971.

⁵⁴ "The Eight Surprises," J. J. McKetta, address to the American Trucking Association, Oct. 16, 1974, reprinted in the Congressional Record, Mar. 12, 1975.

⁵⁵ "NOAA Scientist Weighs Possible Fertilizer Effects on Ozone," Paul Crutzen, Department of Commerce News, Apr. 15, 1975.

⁵⁶ "Nitrogen Fertilizer Threatens Ozone," quotes from J. McElroy, Washington Star, Dec. 12, 1974.

⁵⁷ "Weather Warfare" (Bromine), New Scientist, Mar. 27, 1975, p. 762.

⁵⁸ "Ozone Appears Unaltered by Nitric Oxide," Kenneth J. Stein, Aviation Week and Space Technology, Nov. 6, 1972, p. 28.

⁵⁹ "Nitrogen Oxides, Nuclear Weapon Testing, Concorde and Stratospheric Ozone," P. Goldsmith, et al., Nature, Aug. 31, 1973, p. 545.

It had begun to appear to many that, in the Earth's atmosphere, which is about 80 percent nitrogen and 20 percent oxygen, the NO_x is ubiquitous and that there was just no legislative way to save the ozone from the catalytic disintegration hypothesized. The issue endures largely as an academic debate, though its character could change again. One group holds that the destructive mechanisms ascribed to NO_x are real and that ozone density is controlled by the presence of NO_x . An opposing group contends that, while the hypothetical reactions appear to be sound, they just don't seem to occur. The insertion of $3\frac{1}{2}$ million tons of NO_x by nuclear explosions over 1 year's time, for example, was judged by many as an experiment of sufficient magnitude to cause unmistakable perturbations in ozone density, and would prove or disprove the destruction hypothesis. Recordings of ozone density before, during, and following the test were analyzed by numerous people. One investigator detected trends which he associated with the explosions: however, others held that "the conclusion that massive injections of nitrogen oxides into the stratosphere do not upset the ozone layer seems inescapable."⁶⁰

Putting that aside, yet another challenge to the ozone, the manmade fluorocarbons (freon aerosol propellants and refrigerants) has been postulated.⁶¹ The hypothetical mechanisms by which these compounds would migrate into the stratosphere, break down to release odd chlorine molecules which would in turn set up a catalytic destruction of ozone, were examined and found to be plausible and a cause for concern. Subsequent measurements taken in the stratosphere proved the presence of numerous odd chlorine molecules, some of which could indeed be shown to have their origin in freon.⁶²

Although the empirical validity of the destructive interaction of these odd chlorines with ozone is difficult to show and has yet to be shown, their discovery in the stratosphere was enough for several scientists to call for a ban on the fluorocarbons. Other scientists, as well as industry, took an opposing view, calling for empirical proof prior to taking actions to ban or control the manufacture or use of freon propellants.

The argument became partly one of timing with one side claiming that no emergency could be proven and plenty of time was available to test the destruction hypothesis. Opposing this was the view that it may very well be too late already since most of the freons already released have yet to reach the stratosphere.

Unlike the case with NO_x , where changes as vast as banning the use of nitrating fertilizers might be required, the control of freon release was a manageable target for a regulatory control. The resulting studies and actions represent a model of rapid and cooperative action between a large number of highly diverse Government offices and agencies. The decision was made to act without waiting for empirical proof of the destruction hypothesis, but not to institute the total and immediate ban some investigators called for. Instead, propellant application would be labeled as possibly hazardous to the ozone and then

⁶⁰ *Ibid.*

⁶¹ "Stratospheric Ozone Destruction by Man-made Chlorofluoromethanes," R. J. Cicerone, et al., *Science*, Sept. 27, 1974.

⁶² "Atmospheric Halocarbons and Stratospheric Ozone," J. E. Lovelock, *Nature*, Nov. 22, 1974.

banned in stages. Refrigerants would be studied pending their possible regulation at some future time.

Action by the Government on the regulation of fluorocarbons

The Council on Environmental Quality (CEQ) and the Federal Council for Science and Technology (FCST) reviewed theoretical papers on the destructive interaction between fluorocarbons and ozone, the first of which appeared in 1974. They decided that the case was worthy of serious concern. In January 1975, the CEQ and FCST jointly created a large ad hoc task force known as the Federal Inter-agency Task Force on Inadvertent Modification of the Stratosphere (IMOS). IMOS membership included representatives from:

- Interdepartmental Committee for Atmospheric Sciences (ICAS).
- Department of Agriculture.
- Department of Commerce.
- Department of Defense.
- National Institute of Environmental Health Sciences.
- Food and Drug Administration.
- Department of Justice.
- Department of State.
- Department of Transportation.
- Energy Research and Development Administration.
- Environmental Protection Agency.
- Consumer Products Safety Commission.
- National Aeronautics and Space Administration.
- National Science Foundation.
- Council on Environmental Quality.
- Office of Management and Budget (observer only).

The work of IMOS was swift and orderly. A series of studies was completed and published in their report by June 1975.⁶³ IMOS concluded "that fluorocarbons released to the environment are a legitimate cause for concern." The report also referred to a similar study which was then underway at the National Academy of Sciences. IMOS recommended that, should the results of the NAS study agree with their results, then Federal regulatory agencies should initiate rulemaking procedures for implementing regulations to restrict fluorocarbon uses.

The data base for the NAS study was of course the same data base used by IMOS since it was the only one available. The conclusions reached by both studies were therefore the same, and rulemaking was instituted.

If the data base could have contained some empirical proof supporting the validity of the massive ozone destruction hypothesis, the rulemaking procedures would have proceeded without, or at least with much less debate and protest. As it was, the rules were handed down without proof, the justification being that the consequences of higher UV exposure due to ozone thinning were sufficiently severe that precautionary regulations were necessary. Under these circumstances, the rules were models of compromise. A ban was to be issued over the protest of industry, but it would neither be the complete ban nor the immediate one demanded by the environmental groups and some scientists.

⁶³ "Fluorocarbons and the Environment," IMOS, Council on Environmental Quality and the Federal Council for Science and Technology, June 1975.

The proposed rules were formulated jointly by the Department of Health, Education, and Welfare, the Environmental Protection Agency, and the Consumer Product Safety Commission. In brief, they state:

1. By October 15, 1978, no company may manufacture fluorocarbons for use in aerosol products.
2. By December 15, 1978, companies must stop using fluorocarbons as propellants in aerosol products.
3. As of April 15, 1979, no spray product containing a fluorocarbon propellant may be introduced into interstate commerce. Products on store shelves at that time may be sold, however, and there will be no recall.
4. Beginning in October 1978, warning labels will be put on aerosol products which contain fluorocarbons to warn the user that the fluorocarbons are present and may affect the ozone.
5. Certain aerosol products intended for medical purposes are exempt from these regulations.

The rule on labeling has already been put into effect.⁶⁴

Climatic effects of ozone depletion

While the effect of a significant buildup in the concentration of chlorofluorocarbons and chlorocarbons on the chemical balance of the Earth/atmosphere system is currently a subject of concern, their impact and effect on the Earth's overall thermal energy balance must also be considered. The chlorofluorocarbons and chlorocarbons have strong infrared absorption bands, thus allowing these compounds to trap long-wave radiation emitted by the Earth and, in turn, enhance the atmospheric "greenhouse effect." This enhancement may lead to an appreciable increase in global surface and atmospheric temperature if atmospheric concentrations of these compounds reach values of the order of 2 parts per billion (ppb).⁶⁵

Furthermore, ozone itself is important to the Earth's climate because it absorbs some quantities of both solar and terrestrial infrared radiation, thereby affecting the energy balance of the Earth/atmosphere system that determines the Earth's temperature. Exactly how changes in the ozone concentration might affect climate are far more difficult to determine, since changes in surface temperature from variations in ozone depend on such diverse factors as whether the total amount of ozone is increased or decreased, whether the height at which the maximum amount of ozone occurs is altered, or whether the latitudinal distribution of ozone is disturbed. James Coakley of the National Center for Atmospheric Research (NCAR), Boulder, Colo., has found that a uniform reduction in the total amount of atmospheric ozone would lead to a cooling of the Earth's surface, but that a decrease in altitude in the stratosphere where ozone has its maximum concentration can warm the surface. Similarly, an increase in total amount of ozone warms, but an increase in the altitude of maximum ozone concentration can cool the climate. If it were known that an atmospheric

⁶⁴ The previous section on the ozone depletion issue was contributed by George Chatham, Specialist in Aeronautics and Space, Science Policy Research Division, Congressional Research Service.

⁶⁵ Ramanathan, V., "Greenhouse Effect Due to Chlorofluorocarbons: Climatic Implications," *Science*, vol. 190, Oct. 3, 1975, pp. 50, 51.

pollutant, such as chlorofluorocarbons, acted to reduce the amount of ozone in the atmosphere, then before one could conclude that this would lead to a global cooling, it would still also have to be known if the chlorofluorocarbons moved the altitude of maximum ozone concentration up or down. If the maximum moved up, this would enhance the cooling effect of a decrease in ozone, but if the maximum moved down, that situation would oppose the cooling attributable to the decrease in total ozone. Thus, while it is conceivable that a large change in ozone could significantly affect climate, it may be seen that the direction of any potential ozone-climatic effect is difficult to determine.⁶⁶

WASTE HEAT

Another man-generated pollutant that could affect the climate is waste heat generated by combustion, automobiles, home heating, industrial processes, and power generation—all produce heat that eventually is emitted into the atmosphere. In addition to its direct effect on atmospheric temperature, in specific situations waste heat can enhance convection, the vertical motion so important in precipitation processes.

On a regional scale, thermal effects may become important by the turn of the century. However, on a global scale, climatic effects of thermal pollution today and for the near future appear to be insignificant. Some scientists, however, believe this impact may grow with increased energy production and conversion. Research meteorologist James T. Peterson of the Environmental Protection Agency states that a long-term view reveals that continued growth of energy use could lead to a large-scale climatic change in 100 years or more. Of particular concern, says Peterson, are present-day nuclear powerplants, which will produce about 55 percent more waste heat than a fossil fuel plant for a given amount of electricity generated.⁶⁷

To better understand the effects of heat releases on weather and climate, the U.S. Department of Energy is sponsoring a program called *METER*, which stands for "meteorological effects of thermal energy releases." *METER* program scientists are collecting data from several powerplant sites around the United States to aid in predicting the specific environmental effects of releasing large amounts of excess heat and moisture directly into the atmosphere from powerplant operations and cooling towers. The amounts of heat and moisture emitted from the stacks and towers of a large powerplant are small compared with those released by even a moderate-sized thunderstorm. Cooling tower plumes are suspected of acting as a triggering mechanism to create instabilities in the atmosphere, initiating or otherwise modifying rainfall and disrupting storm patterns. A typical cooling tower will produce 5,000 megawatts of heat and evaporate 40,000 to 60,000 gallons of water per minute. Even so, a modest thunderstorm will put out 800 times that much water and 30 times that much heat.⁶⁸

The urban "heat island"

On a local scale, the climatic effects of energy use and heat production are significant and well documented. Obviously, urban areas are

⁶⁶ Schneider, Stephen H., "The Genesis Strategy: Climate and Global Survival." New York: Plenum Press, 1976, p. 183.

⁶⁷ Peterson, James T., "Energy and the Weather," *Environment*, vol. 15, October 1973, pp. 4, 5, 8.

⁶⁸ "Power Plant May Alter Weather," *the Christian Science Monitor*, Mar. 13, 1978, p. 19.

experiencing thermal effects. The most evident feature of city climate is its excess warmth, which is commonly referred to as the urban heat island. Cities are prodigious sources of heat. Factory smokestacks, air-conditioners and heating systems of offices and homes, vehicle engines and exhausts—all contribute waste heat to the outside atmosphere, particularly in winter. Summer temperatures in the city are 0.6°C to 1.1°C higher than in nearby rural areas, and 1.1°C to 2.2°C higher in winter. Also, the building materials of brick, asphalt, mortar, and concrete readily absorb and store more heat from the Sun than the soil and vegetation of a rural area, and give it up more slowly after sundown. While rural areas are rapidly cooling after sunset, the building materials gradually release their stored heat to the urban atmosphere, tending to keep it warmer than the countryside.

Another factor that retains high temperatures and makes the atmosphere dry is the way a city disposes of its rainwater or snow. During any shower or storm, the water is quickly drained from the roofs by gutters and drainpipes, and from the sidewalks and streets by gutters and storm sewers. The winter snows are removed as quickly as possible by shovels and plows, and often hauled away in trucks. These methods of removing precipitation not only take away sources of moisture but also remove the cooling effect of evaporation. In the country, evaporation can cool the area where the rain and melting snow stay on the surface or seep into the ground. A large fraction of the absorbed heat energy is used in evapotranspiration as vegetation transpires water vapor.

An advantage of urban heat emissions is that they decrease the likelihood of surface-based air temperature inversions (air temperature increases rather than decreases with height) and increase the height of the mixed layer near the surface. Inversions inhibit turbulent air motions which diffuse and dilute pollutants. Heat emissions at the city surface create a relative decrease in temperature with height which in turn aids the mixing and dispersion of pollutants. Observations of urban and rural temperature-height profiles have shown this effect of thermal emissions. Thus, urban pollutants emitted near ground level, such as carbon monoxide from auto exhaust, will be diffused through a greater volume of the atmosphere with a consequent reduction in concentration.

Other major features of urban climates that are related to thermal pollution include:

- A longer frost-free growing season.

- Less snowfall because snow melts while falling through the warmer urban atmosphere and less snow accumulation because snow melts on contact with warmer urban surfaces.

- Lower relative humidity.

- Decreased occurrence and density of fog because of the lower relative humidity, a feature which may be offset by more particulate matter which serves as condensation nuclei.

- A slight component of the wind direction toward the city center as a result of the horizontal temperature contrast.

- Apparent enhancement of precipitation downwind of cities, a phenomenon partially due to increased convection (vertical motion).

ALBEDO

The albedo is a numerical indication of the percentage of incoming solar radiation that is reflected by the land, ocean, and atmosphere back into space and, attendantly, how much is absorbed by the climatic system. Another important manner for altering the Earth's heat budget, albedo can be changed by the process of urbanization, agricultural activities, changes in the character of the land surface, and by increasing or decreasing cloudiness.⁶⁹

Most clouds are both excellent absorbers of infrared radiation and reflectors of solar radiation. Therefore, clouds are a major factor in determining the Earth's energy balance. An increase in clouds could warm surface temperatures by tending to reduce the flux of long-wave (that is, infrared) radiation to space, or cool surface temperatures by reflecting incoming solar radiation back to space. The net effect of increased cloudiness is to either warm or cool the surface, depending on cloud type, latitude, and season.⁷⁰ The effect of cloud condensation nuclei (CCN) on the formation of fog and clouds could alter the albedo of a region if the fog or clouds were sufficiently persistent or extensive. P. V. Hobbs and H. Harrison, both professors of atmospheric science at the University of Washington, and E. Robinson of Washington State University's Air Pollution Research Unit, contend that perhaps the most sensitive atmospheric processes which can be affected by air pollutants are those involved in the development of clouds and precipitation.

Apart from effects on precipitation processes, inadvertent modification of the microstructure and distribution of clouds, with attendant consequences for radiative properties, could have profound effects on atmospheric temperature distributions and global climate.⁷¹ Whether a variation in terrain on temperature or other factors would have a negative or positive feedback interaction with clouds is a major question in climate theory that will be answered by extensive analyses of observations and model studies.

The high reflectivity of snow and ice, as compared with water or land surfaces, provides positive feedback if the average year-round temperature decreases and the extent of ice and snow coverage increases and reflects more of the incoming sunlight back to space. The result is to lower the rate of heating still more, particularly in the regions closest to the poles. Columbia University scientists observed from a study of satellite photomaps that snow and icepack cover were more extensive and of longer duration in the early 1970's than in previous years. The result, they reported, was to increase the Earth's albedo, reflect more sunlight back into space, and change the planet's heat balance.⁷² It was pointed out that normally vegetated ground reflects about 15 percent to 20 percent of sunlight and a calm ocean reflects 5 percent to 10 percent, while snow-covered grassland or pack ice reflects about 80 percent.

⁶⁹ Otterman, J., "Anthropogenic Impact on the Albedo of the Earth," *Climatic Change*, vol. 1, No. 2, 1977, pp. 137-155.

⁷⁰ "Living With Climatic Change," proceedings of a conference/workshop held in Toronto, Nov. 17-22, 1975; Ottawa, Science Council of Canada, 1976, p. 88.

⁷¹ Hobbs, P. V., H. Harrison, and E. Robinson, "Atmospheric Effects of Pollutants," pp. 910, 911.

⁷² The atmosphere is principally heated by terrestrial reradiation, thus the reflected incoming light, escaping back into space instead of being transformed into heat, represents a deficit in the Earth's energy balance.

They also found that snow and ice covered twice as much ground in October 1972 as in October 1968 and correlated that situation with a drop in global air temperatures. They warned that the potential for fast changes of climate evidently does exist and should be kept in mind.⁷³

There's yet another contributor to the planet's albedo: airborne particles, particularly the extremely fine dust particles that have been carried too high in the atmosphere to be scavenged and washed out by precipitation processes. Many of these particles remain aloft for months or years. Dust of various kinds may initiate short-term cooling trends with characteristic time spans of decades or centuries. This depends on the optical properties of the particles, which in turn depend on particle composition and size distribution. Furthermore, particles radiate in the infrared, and therefore can alter the outgoing long-wave radiation.

Densely populated regions tend to have higher albedos than do forests or cultivated soils. The deserts of the world have a higher albedo than, for example, grass-covered fields. Urbanization, agriculture, transportation networks—all act to alter the surface albedo. While local changes in albedo have been determined, however, the overall integrated global variation is still unknown. Even local net effects of surface changes may not be fully understood, since changes in the nature of a surface are generally accompanied by changes in surface roughness. Surface roughness alterations can affect the manner and rate of heat and momentum exchanges with the atmosphere through modification of small-scale turbulent processes.⁷⁴

A factor such as roughness of the ocean should not be overlooked in ocean/atmosphere exchange mechanisms. Ocean surface pollution may also figure in the alteration of the albedo as well as the sea surface characteristics: an oil slick forming a surface film on the sea, for example.

LARGE-SCALE IRRIGATION

Beginning in the 1940's, large areas of the Texas Panhandle, western Oklahoma, Kansas, and Nebraska came under widespread irrigation. This large-scale irrigation adds more moisture to the air through evaporation; has made large land surfaces greener (which changes the albedo); and may act to decrease dust in the air. Since the situation is somewhat analogous to a large-area rain modification project, a number of studies have been conducted to ascertain if greater rainfall could occur in the vicinity or downwind of irrigated areas.

Schickedanz (1976) provided strong evidence of irrigation-related anomalies: specifically, increased rainfall during months when irrigation took place in and/or surrounding large irrigated areas of the Great Plains.

The percent rain increase associated with the irrigation effect was found to vary from 14 percent to 26 percent in June, 57 percent to 91 percent in July, 15 percent to 26 percent in August, and 19 percent

⁷³ Kukla, George J., and Helena J. Kukla, "Increased Surface Albedo in the Northern Hemisphere," *Science*, vol. 183, Feb. 22, 1974, pp. 709, 713, 714.

A growing fraction of current evidence seems to suggest, however, that this has not been the case in North America. Analysis of satellite data for the last decade has led scientists with the National Environmental Satellite Service to conclude that North American snow cover showed no significant change during the entire period of record. Rather, the North American total winter snow cover appears to be remarkably similar year to year. Eurasian snow cover on the other hand was reported to be much more variable.

⁷⁴ National Research Council, Committee on Atmospheric Sciences, "Weather and Climate Modification: Problems and Progress," p. 156.

to 35 percent during summer depending on the location and size of the irrigated areas in the States of Kansas, Nebraska, Oklahoma, and Texas.

Acting similarly to the manner in which urban industrial centers affect weather in and downwind of them, irrigated areas may be said to be a focal point for both rain initiation and rain enhancement or redistribution, under conditions when rain is likely.^{75, 76}

Stidd (1975) also found evidence of irrigation-related rainfall anomalies in the Columbia Basin of Washington. Explaining that the increase in rainfall is real, he offered the following explanation:

The moisture added by irrigation is evaporated and must eventually return to the Earth's surface as precipitation. The question is where and when? The [Columbia] basin is nearly surrounded by mountains. The surface layer of air in the basin will eventually be carried over the mountains [at the eastern margin of the basin], and if additional moisture has been added to the air * * * air, we would expect additional precipitation in the foothills. This appears to be what happens during the two months [of July and August] when additional evaporation is greatest.⁷⁷

RECAPITULATION

In review, tables 2, 3, and 4 summarize much of the pertinent information presented in the preceding sections. They are, respectively, "Inadvertent Effects on Ten Weather Phenomena," "Chronic Low-Level Pollutants: Mankind's Leverage Points on Climate," and "Possible Causal Factors in Future Climatic Change to the Year 2000 A.D."

TABLE 2.—INADVERTENT EFFECTS ON 10 WEATHER PHENOMENA¹

Phenomenon	Certainty of inadvertent effect	Scale of inadvertent effect	Importance/significance of inadvertent effect
1. Visibility and haze.....	Certain.....	Meso.....	Major.
	Possible.....	Macro.....	Moderate.
2. Solar radiation and sunshine.....	Certain.....	Meso.....	Do.
3. Cloudiness.....	do.....	Urban.....	Do.
	Probable.....	Meso.....	Do.
4. Precipitation (quantity).....	Certain.....	Urban.....	Major.
	Possible.....	Meso or macro.....	Moderate.
Precipitation (quality).....	Certain.....	Urban.....	Major.
	do.....	Meso.....	Unknown.
	Possible.....	Macro.....	Do.
5. Thunderstorms (hail/heavy rain).....	Certain.....	Urban.....	Major.
	Possible.....	Meso.....	Do.
6. Severe storms (tornados, other).....	Unknown.....	Unknown.....	Unknown.
7. Temperature.....	Certain.....	Urban.....	Moderate.
	Possible.....	Populated meso.....	Minor.
8. Wind/circulation.....	Certain.....	Urban.....	Moderate.
	Unlikely.....	Meso.....	Unknown.
9. Fog.....	Certain.....	Urban/micro.....	Major.
10. Humidity.....	do.....	do.....	Moderate.
	do.....	Meso.....	Do.

¹ From "Final Report to the National Science Foundation on the Third Inadvertent Weather Modification Workshop," Hartford, Conn., May 23-27, 1977. Hartford. The Center for Environment and Man, Inc., 1977.

² Note.—Micro: less than or equal to 1 km; urban: less than or equal to 30 km; meso: 30 to 150 km; macro: greater than 150 km.

⁷⁵ Schickedanz, Paul T. The Effect of Irrigation on Precipitation in the Great Plains. Final report on an investigation of potential alterations in summer rainfall associated with widespread irrigation in the Great Plains, Urbana, Ill., Illinois State Water Survey, 1976. 105 pp.

⁷⁶ Schickedanz, Paul T., "Extra-Area Effects from Inadvertent Weather Modification." In preprints of Sixth Conference on Planned and Inadvertent Weather Modification, Champaign-Urbana, Ill., Oct. 10-13, 1977. Boston, American Meteorological Society, 1977. pp. 134-137.

⁷⁷ Stidd, Charles K., "Irrigation Increases Rainfall?" Science, vol. 188, Apr. 18, 1975, pp. 279-281. In Effect of Large-Scale Irrigation on Climate in the Columbia Basin, Science, vol. 184, Apr. 12, 1974, pp. 121-127. Fowler and Helvey argue that small scale site changes may occur, but the widespread climatic effects of irrigation may well be minimal. Furthermore, they contend that the available precipitation records for the basin do not verify Stidd's conclusion that precipitation increased because of irrigation.

TABLE 3.—CHRONIC LOW-LEVEL POLLUTANTS

Pollutant and source	Observed trend	Potential atmospheric effect	Status of assessment capability	Time scale of importance
Carbon dioxide (CO ₂) from combustion of fossil fuels.	Up more than 20 percent in last 100 yr.	Increased global temperatures leading to melting of polar icecaps, sea level increase, perturbations of marine biology.	Numerical model assessments of the global average effect on temperature differ by about a factor of 2; consequence chains need more study.	Thorough assessment needed in the next 5 yr—may be a problem over next 50 yr.
Fluorocarbons (e.g., freon) from aerosol cans, refrigeration systems, etc. Nitrogen oxides from high flying aircraft (and perhaps from fertilizers).	Fluorocarbons are now detectable throughout the atmosphere. Nitrogen oxides are a natural component. Stratospheric measurement program being established to determine levels and trends.	Reductions of the global stratospheric ozone layer, and perturbation of the atmosphere's radiation balance. Analysis of current trend in ozone is not yet definitive due to natural variability.	Numerical models are capable of assessing the order of magnitude of the various effects, with uncertainties related to lack of basic information on reactants, reactions, and reaction rates; the natural chlorine and nitrogen balance; and the limitations in simulating simultaneously global chemistry, transport, seasonal, and diurnal processes.	Initial assessment in progress by National Academy of Sciences action probably needed within several years.
Krypton-85 from nuclear fuel reprocessing and powerplants.	Building up proportionally with nuclear power generation.	Modification of the atmosphere's electric field, which may cause modification of the hydrologic cycle.	Not adequate.	Thorough assessment needed, may be a problem over next 100 yr with growth of nuclear power industry.
Sulfur compounds from fossil fuel combustion.	Not well-established, but concentrations may already be too high on occasion.	May affect regional precipitation chemistry and acidity on regional to subcontinental scale.	Sulfur balance not well understood.	May presently be a problem which would be aggravated by further coal burning.
Dust from combustion, slash/burn agriculture, and improper land conservation.	Not well-established because of evolution of sources and particle sizes with controls.	Initial response is temperature change (sign dependent on location, and source type), precipitation modification. Problem mainly on subcontinental, but possibly up to global scale.	Theoretical capability is improving, but inadequate knowledge of both trends and consequences exists.	Further evaluation needed as improved data available.
Heat and water releases to the atmosphere from the energy generation process (thermal pollution, cooling towers, etc.).	Increasing with energy generation.	Temperature and precipitation modification on local and regional scale.	Models of atmospheric boundary layer are being developed.	Evaluation needed in regions of concentrated energy generation (e.g., energy parks, etc.).
Oceanic oil slicks from tanker cleaning, etc.	Not known.	By changing the reflectivity and evaporation characteristics of large oceanic areas, the Earth's energy balance might be perturbed in an unknown way.	Further research needed.	Assessment needed as capability for evaluation improves.

TABLE 4.—POSSIBLE CAUSAL FACTORS IN FUTURE CLIMATIC CHANGE TO THE YEAR 2000 A.D.

Origin	Factor	Confidence ¹ that factor will change appreciably	Confidence ¹ that factor would appreciably affect climate	Estimated principal climatic effects ²	Time scale(s) of climatic variation involved			
Solar	1. Total solar output	Low	High	Warming-cooling (not clear)	Months and longer.			
	2. Ultraviolet and other variations	High	Low-moderate	Rainfall/cloudiness changes (1 to 10 percent)	Days and longer.			
	3. Tidal perturbations	do	Moderate	Warming-cooling	2 weeks and longer.			
Lunar/solar	4. Stratospheric particle injections	do	Moderate-high	Cooling (0.1-1°C)	Years and longer.			
	5. Carbon dioxide increase	do	do	Warming (1°C)	Trend.			
	6. Particle increase	Moderate	Low-moderate	Warming-cooling	Days and longer.			
	7. Chlorofluorocarbon (CFC) increase	do ⁴	Moderate	Warming (0.1°C) ³	Temporary trend.			
Anthropogenic	8. Ozone depletion by CFC, NO _x , etc.	do ⁴	do	Ultraviolet radiation increase (10 percent) ³	Do.			
	9. Thermal pollution	High	High (local effects)	Warming; local clouds/storms	Trend.			
	10. Land use changes	Moderate	Moderate (regional effects)	Temperature/precipitation changes	Decades and longer.			
	11. Sea surface temperature variations	High	Moderate-high (regional effects)	Temperature/precipitation changes	Months and longer.			
	12. Sea ice/snow cover variations	High	Moderate (regional effects)	Temperature/precipitation changes	Do.			
	13. Polar ice sheet surges	Low	High	Rise in sea level, possible glaciation	Years and longer.			
	14. Vegetation changes	Moderate	Moderate (regional effects)	Temperature/precipitation changes	Do.			
	Oceans							
		Cryosphere						
			Biota					

¹ Confidence based on intuitive judgment of many atmospheric scientists, considering state-of-the-art knowledge.

² All numerical values are order-of-magnitude estimates for Earth as a whole; regional effects may differ substantially.

³ Cumulative effect by year 2000 A.D.

⁴ Assumes that controls on CFC and other emissions are put into effect by 1980 A.D.

Source: Report of North American Phase I Conference on "Living with Climatic Change," Toronto, November 1975.

ISSUES IN INADVERTENT WEATHER AND CLIMATE MODIFICATION

CLIMATIC BARRIERS TO LONG-TERM ENERGY GROWTH

Revelle and Suess (1957) stated:

Human beings are now carrying out a large scale geophysical experiment of a kind that could not have happened in the past nor be repeated in the future. Within a few centuries we are returning to the atmosphere and ocean the concentrated organic carbon stored in the sedimentary rocks over hundreds of millions of years. This experiment may yield a far-reaching insight into the processes of determining weather and climate.⁷⁸

Thus stated is the case for diligent observation of the consequences of the man-generated flux of carbon dioxide to the atmosphere. Left unstated is perhaps the greater need to anticipate the consequences well enough to keep them within acceptable limits.

Even though carbon dioxide makes up a small fraction (less than one one-thousandth of the total atmospheric mass) of the gases that comprise the atmosphere, it is crucial in determining the Earth's temperature because it traps some of the Earth's heat to produce the so-called greenhouse effect.

Worldwide industrial civilization may face a major decision over the next few decades—whether to continue reliance on fossil fuels as principal sources of energy or to invest the research and engineering effort, and the capital, that will make it possible to substitute other energy sources for fossil fuels within the next 50 years. The second alternative presents many difficulties, but the possible climatic consequences of reliance on fossil fuels for another one or two centuries may be critical enough as to leave no other choice.

The climatic questions center around the increase in atmospheric carbon dioxide that might result from continuing and increasing use of fossil fuels. In 110 years since about 1860 a 12-percent increase in the concentration of carbon dioxide had taken place, but because of the exponential nature of the consumption of energy and the burning of fossil fuels the next 10–12 percent increase would take only about 20 years and the next 10–12 percent increase beyond that only about 10 years. By this time the climatic impact of the carbon dioxide should (according to model calculations) cause a climatic warming of about 1°C (1.8°F). Four questions are crucial:

1. What concentrations of carbon dioxide can be expected in the atmosphere at different times in the future, for given rates of combustion of fossil fuels?
2. What climatic changes might result from increased atmospheric carbon dioxide?
3. What would be the consequences of such climatic changes for human societies and for the natural environment?
4. What, if any, countervailing human actions could diminish the climatic changes or mitigate their consequences?⁷⁹

Whether such a warming would influence the extent of ice and snow at the polar caps or influence the level of the world ocean cannot be

⁷⁸ Revelle, R. and H. E. Suess, "Carbon Dioxide Exchange Between the Atmosphere and Ocean," and the "Question of an Increase in Atmospheric Carbon Dioxide During the Past Decades," *Tellus*, vol. 9, No. 1, 1957, p. 18.

⁷⁹ National Research Council, Geophysics Research Board, "Energy and Climate," p. 1.

said with certainty. Neither can it be said whether such a warming would push the grain belts of the world poleward by several hundred kilometers thereby disrupting the present patterns of agriculture. These are possibilities, but climatic theory is yet too crude to be certain. The only certain proof that the carbon dioxide-greenhouse theory is correct will come when the atmosphere itself "performs the experiment" of proving present estimates too high, or too low. An important point remains, though, and that is: The uncertainty in present scientific estimates of potential climatic consequences of increased energy use is not biased toward optimism.⁸⁰

Carbon dioxide is not the only byproduct of the burning of fossil fuels. Another form of atmospheric pollution results from the introduction of dust and smoke particles, which, when suspended in air, are called atmospheric aerosols. The word "aerosols" is a term used to describe the suspension of any kind of particle in a gas. These particles can be solid like dust, sand, ice, and soot. Or they can be droplets like the water particles in clouds and fog or the liquid chemicals that are dispensed as droplets from aerosol spray cans. The air contains trillions upon trillions of aerosol particles, which, like carbon dioxide, comprise only a minute fraction of the total atmospheric mass.

Despite their relatively small volume, aerosols can affect the climate, primarily by absorbing and scattering back to space some of the sunlight that could have otherwise reached the Earth's surface. Industry is not the only human activity that causes aerosols. They are also produced in great quantities by a variety of agricultural activities and practices, and a significant fraction of the particle loading of the atmosphere is of natural origin.

A consensus among scientists today would not be forthcoming as to whether an increase in aerosols would result in a cooling of the climate or a warming of the climate, because aerosols will cool the climate if they are relatively whiter than the surface over which they lie, or, alternatively, they will warm the Earth if they are relatively darker than the surface over which they are suspended. The dust that exists in the atmosphere today is highly nonuniform in both geographic distribution and relative brightness as compared to the underlying surface. Therefore, one cannot be absolutely certain whether dust contributes to climatic warming or can be implicated in climatic cooling.⁸¹

THOUGHTS AND REFLECTIONS—CAN WE CONTEMPLATE A FOSSIL-FUEL-FREE WORLD?

Putting together the different parts of the story of climate and energy, what picture emerges? How seriously do we respond to the possibility that the present rate of increase of fossil fuel burning is likely to have noticeable consequences for climate by the end of this century, but not become a serious problem until well into the next century? On the longer time scale, the picture that emerges is rather startling in the words of Dr. Wallace Broecker of the Lamont-Doherty Geological Observatory, who explains, "Consumption of the bulk of the world's known fossil fuel reserves would plunge our planet into a

⁸⁰ Schneider, Stephen H., "Climate Change and the World Predicament." *Climatic Change*, vol. 1, No. 1, March 1977, pp. 31-33.

⁸¹ *Ibid.*, pp. 34, 35.

superinterglacial, the likes of which the world has not experienced in the last million years."⁸²

Admittedly, we are talking here of possibilities, not certainties. The climatic consequences of massive fossil fuel consumption may be less severe than assessments project, but they might be more severe. Mankind eventually may discover a new energy source that will obviate the need to use fossil reserves so extensively for that purpose, and yet a fossil-fuel-free world in the relatively near future is so bizarre an idea it is hard even to talk about it seriously. Or perhaps technology could develop a cosmetic, such as the introduction of an artificial dust layer surrounding the Earth to screen some of the incoming sunlight. This could tend to offset the warming effect of the added carbon dioxide.

What would happen if society elected to ignore the problem of carbon dioxide until it manifested itself (perhaps in another 20 years) in the form of a clear signal that a global warming trend had begun that was unmistakably attributable to the further accumulation of carbon dioxide in the atmosphere? Delaying until then a mandated action to phase over the principal energy sources from fossil fuels to other alternative kinds of fuels and taking into account another several decades for the transition to be completed would put us halfway into the next century before the problem could be shut off at its source. But perhaps the most disturbing aspect of the carbon dioxide problem is that the effects of carbon dioxide would endure for hundreds of years, even after the abandonment of the fossil fuel economy, because of the long recovery time associated with the processes that would rid the atmosphere of excess carbon dioxide and establish an equilibrium condition.

This carbon dioxide Sword of Damocles, if indeed it exists, implies development of solar (including wind, ocean, biomass, etc.) fission, fusion, and geothermal at a somewhat more rapid pace than is generally recognized.⁸³

Asserts J. Murray Mitchell, Jr.:

The alternative is clear. Ours is the generation that must come to grips with the carbon dioxide problem and mount a vigorous research effort to allow us to understand all of its ramifications for the future. Ours is the generation that may have to act, and act courageously, to phase out our accustomed reliance on fossil fuels before we have all the knowledge that we would like to have to feel that such action is absolutely necessary. * * * We can scarcely afford to leave the carbon dioxide problem to the next generation.⁸⁴

RESEARCH NEEDS AND DEFICIENCIES

Despite everything that science has learned about the broad characteristics of climate and climatic history, relatively little is known of the major processes of climatic change. Lack of knowledge still is a

⁸² Mitchell, J. Murray, Jr., "Carbon Dioxide and Future Climate," p. 9.

⁸³ Rotty, R. M. and A. M. Weinberg, "How Long Is Coal's Future," pp. 55-57.

⁸⁴ Mitchell, J. Murray, Jr., "Carbon Dioxide and Future Climate," p. 9.

major barrier to accurate forecasting and understanding of potential inadvertent modification of weather and climate. The atmosphere and the ocean make up such a complex and rapidly changing system that even short-range forecasts may often be incorrect. Gathering sufficient information about global climate is of importance if atmospheric scientists are to construct the detailed computerized models capable of rapidly analyzing enormous amounts of data concerning each component of the climatic system, which includes not only the atmosphere but the world ocean, the ice masses, and the exposed land surface.

Observations are essential to the development of an understanding of climatic change. Without them, theories will remain theories and models would be of limited usefulness. Observational records need to be extended in both time and space to facilitate adequate documentation of the climatic events that have occurred in the past and monitoring of the climatically important physical processes occurring now.

Knowledge of the mechanisms of climatic change may be at least as fragmentary as the state of the data. Not only are the basic scientific questions largely unanswered, but in many cases not even enough is known to pose the key questions. What are the most important causes of natural climatic variation, and which are the most important or most sensitive of the many processes involved in the interaction of the air, sea, ice, and land components of the climatic system? There is no doubt that the Earth's climates have changed in the past and will likely change in the future. But will it be possible to recognize the first phases of a truly significant climatic change when it does occur?

In a 1975 report, "Understanding Climate Change: A Program for Action," the U.S. Committee for the Global Atmospheric Research Program of the National Research Council enumerated the principal approaches to these problems emphasizing the interdependence of the major components of a climatic research program and posing a number of key questions. The components included:

Climatic data analysis: What has happened in the past?

Empirical studies: How does the system work?

Monitoring: What is going on now?

Numerical models: What is shown by climatic simulations?

Theoretical studies: How much do we really understand?

Climatic impacts: What does it all mean to man?

Future climates: How and when is the climate going to change?

The various components of the climatic research program are to a great extent interdependent: Data are needed to check general circulation models and to calibrate the simpler models; the models are needed to test hypotheses and to project future climates; monitoring is needed to check the projections; and all are needed to assess the consequences.⁸⁵

⁸⁵ National Research Council, U.S. Committee for the Global Atmospheric Research Program, "Understanding Climatic Change: A Program for Action," Washington, National Academy of Sciences, 1975, pp. 5, 6.

TABLE 5.—SUMMARY OF CLIMATIC INDEX MONITORING PROGRAM

Variable or index	Method	Coverage	Effort required ¹	Frequency required ²
Atmospheric indices:				
Solar constant	Satellite	Global	N	W
Absorbed radiation, albedo	do	do	P	W
Latent heating	do	do	N	W
Surface latent heat flux	do	World ocean	N	W
Surface sensible heat flux	do	Regional	N	W
Cloudiness	do	Global	P	W
Surface wind over ocean	Radar scattering	World ocean	N	W
Oceanic indices:				
Sea-surface temperature	Ships, satellites, buoys	World ocean	E, N	W
Surface-layer heat storage	XBT, AXBT, buoys	Mid-latitude and low-latitude oceans	E, N	W
Heat transport	Moored buoys	Selected sections	N	W
Temperature structure	Ships	do	E	S
Surface salinity	Ships, buoys	High latitudes	E	W
Sea level	Tide gauges	Selected coastal and island sites	E	W
Composition, dissolved gases	Conventional sampling	Selected sections	E	S
Cryospheric indices:				
Floating ice extent	Satellite	Polar seas, lakes	E	M
Ice-sheet budget parameters	do	Greenland, Antarctica	N	Y
Mountain glacier extent	do	Selected sites	E	Y
Snow cover	do	Continents	E	M
Surface and hydrologic indices:				
River discharge	Flow gauges	Selected sites	E, N	W
Soil moisture	Satellite	Land areas	E	W
Lake levels	Gauges	Selected sites	E	W
Precipitation	Satellite, radar, gauges	Global	E	W
Composition and turbidity indices:				
Chemical composition	Sampling	Selected sites	E	S
Aerosols and dust	Satellite	Global	E	W
Anthropogenic indices:				
Thermal pollution	Sampling	Continents and coasts	N	W
Air and water pollution	do	Global	E	W
Land use	Satellite	Continents	E	Y

¹ N, completely new monitoring effort required; E, expansion of present monitoring efforts required; P, present (or slightly expanded) monitoring efforts satisfactory but coordination and further analysis required.

² W, weekly (or possibly daily in some cases); M, monthly; S, seasonally; Y, yearly (or possibly decadal in some cases).

Source: National Research Council, U.S. Committee for the Global Atmospheric Research Program, "Understanding Climatic Change: A Program for Action," Washington, National Academy of Sciences, 1975; pp. 78-79.

The Committee on Atmospheric Sciences, also of the National Research Council, stated in a 1973 report entitled "Weather and Climate Modification: Problems and Progress" that if society is to deal with long-term problems of inadvertent weather modification and climatic changes caused by man and his activities, then urgent attention and action are required at the earliest possible moment. The Committee outlined several courses of action that should be undertaken, each contributing to a part of the necessary work to be accomplished:

1. A worldwide network of ground-based stations is needed to monitor the properties of the atmosphere with particular attention being given to those gases and aerosols affecting radiation and heat transfer. Precipitation collection should be undertaken for the analysis of atmospheric chemical constituents. Surface monitoring efforts should also be augmented by airborne monitoring of particles and gases in the atmosphere. Table 5 summarizes in detail the variables to be monitored, the method of monitoring, coverage, effort required and frequency required.

2. Since influence on climate caused by human factors is a global matter, internationally cooperative plans should be established that will provide long-term and uniform monitoring data.

3. Continuous monitoring of the Earth by satellites should be developed to measure not only cloud cover and cloud types but also the thermal characteristics of the atmosphere and the Earth's surface, as well as related variations in the albedo of the Earth. Satellite measurements should be complemented by a program of ground-based remote sensing of the dynamical, chemical, and particulate properties of the atmosphere.

4. Computer capabilities for simulation of climate and climatic changes should be fully utilized. Climatic models eventually may prove to be quite different from the present general circulation models. However, if we are to reach the capability to assess the consequences of further human intervention, climatic model development must be promptly undertaken.⁸⁶

Many of the efforts envisaged are of an obvious international character, and the degree to which they should be regarded as national versus international activities is not of critical importance. The important point is, however, that there are international efforts now underway of direct relevance to the climatic problem.

The World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) jointly organized a global atmospheric research program (GARP) in 1967. GARP goals include: providing the improved understanding of the global circulation needed to extend the range and accuracy of weather forecasts; understanding the physical basis of climate and climatic fluctuations; and providing a firm foundation for the World Weather Watch (WWW).⁸⁷

Several GARP regional experiments are planned in order to examine specific processes. The GARP Atlantic Tropical Experiment (GATE) followed the Barbados Oceanographic and Meteorological Experiment (BOMEX, 1969) in a succession of experiments designed to gain increased understanding of the atmosphere and the causes of climatic variation and change. The primary objective of GATE was to learn more about the meteorology of the tropical equatorial belt where vast quantities of heat and moisture, carried upward by organized convective systems, are transported and redistributed to higher latitudes, ultimately affecting global atmospheric circulation patterns. Because the tropics are believed to be a key to these circulation patterns, scientists expect data from GATE to help them better understand the global climate machine. Conducted as scheduled from June 15 to September 30, 1974, GATE had the cooperation of some 72 countries. In addition to BOMEX and GATE, experiments designed to contribute to the understanding of specific oceanic-atmospheric processes in selected regions are: the Air Mass Transformation Experiment (AMTEX), the Monsoon Experiment (MONEX), and the Polar Experiment (POLEX). These regional experiments and the knowledge gleaned from them will culminate in a truly international global observing experiment, the First GARP Global Experiment (FGGE) scheduled for the late 1978-79 timeframe.

⁸⁶ National Research Council, Committee on Atmospheric Sciences, "Weather and Climate Modification: Problems and Progress," pp. 160, 161.

⁸⁷ WWW is an operational program of member nations of the WMO for making available the basic meteorological and related environmental information needed by each member nation to supplement and support its meteorological services and research.

The program goals of GARP intersect with the objectives of other international environmental programs. One such program is the Inter-governmental Oceanographic Commission Integrated Global Ocean Station System (IGOSS) being developed jointly with the World Meteorological Organization to provide more extensive and timely information for analysis and prediction of the state of the oceans and for research purposes. This is accomplished through the development of a comprehensive monitoring system for the total physical ocean-atmosphere environment. Another is EARTHWATCH, a major component of the United Nations Environment Program (UNEP) being developed to monitor and assess the state of the oceans, atmosphere, land and human health in order that rational decisions can be made for the management of the environment. EARTHWATCH will also interact with and depend on the monitoring and research capabilities of GARP. A key component of the UNEP/EARTHWATCH global baseline and regional monitoring effort is the Global Environment Monitoring System, which is designed to measure and monitor priority pollutants and related factors of the atmospheric environment, thus permitting quantitative assessment of the global impact of manmade and natural influences on weather and climate.

The Global Observing System provides worldwide meteorological and related environment observation data needed by the World Weather Watch and GARP. The overall system consists of two subsystems: a space-based satellite subsystem, composed of two types of satellites, those in polar orbit and those in geostationary orbit; and a surface-based subsystem composed of basic synoptic surface and upper air networks, other networks of stations on land and sea, and aircraft meteorological observations.

The U.S. Committee for the Global Atmospheric Research Program believes that these observational programs planned in support of GARP offer an unparalleled opportunity to observe the global atmosphere, and furthermore that every effort should be made to use these data for climatic purposes as well as for the purposes of weather prediction. The Committee emphasized however, that the climatic system consists of important nonatmospheric components, including the world's oceans, ice masses, and land surfaces, together with elements of the biosphere. While it is not necessary to measure all of these components in the same detail with which the atmosphere is observed, their roles in climatic variation should not be overlooked.⁸⁸

The Committee's 1975 report, "Understanding Climatic Change: A Program for Action," further stated that:

The problem of climatic variation differs from that of weather forecasting by the nature of the data sets required. The primary data needs of weather prediction are accurate and dense synoptic observations of the atmosphere's present and future states, while the data needed for studies of climatic variation are longer-term statistics of a much wider variety of variables. When climatic variations over long time scales are considered, these variables must be supplied from fields outside of observational meteorology. Thus, an essential characteristic of climate is its involvement of a wide range of nonatmospheric scientific disciplines, for example, oceanography, glaciology, hydrology, astronomy, geology, and paleontology as well as from the biological and social sciences of ecology, geography, archaeology, history, economics, and sociology.

⁸⁸ National Research Council, U.S. Committee for the Global Atmospheric Research Program, "Understanding Climatic Change: A Program for Action," pp. 105, 106.

The types of numerical models needed for climatic research also differ from those of weather prediction. The atmospheric general circulation models do not need a time-dependent ocean for weather-forecasting purposes over periods of a week or two. For climatic change purposes, on the other hand, such numerical models must include the changes of oceanic heat storage. Such a slowly varying feature may be regarded as a boundary or external condition for weather prediction but becomes an internal part of the system for climatic variation.⁸⁹

In view of these characteristics, the Committee suggested that while the GARP concern with climate was a natural one, the problem of climate goes much beyond the present basis and emphasis of GARP. Accordingly, they recommended that the global climate studies that are under way within GARP be viewed as leading to the organization of a new and long-term international program devoted specifically to the study of climate and climatic variation, an international climatic research program (ICRP).

As viewed by the Committee the main thrust of the international climatic program would be the collection and analysis of climatic data during a series of international climatic decades (ICD) designated for the period 1980-2000. During this period, the cooperation of all nations would be sought to participate in an intensive effort to develop and secure as complete a global climatic data base as possible. The Committee urged the creation of an international cooperative program for the monitoring of selected climatic indices and the extraction of historical and proxy climatic data unique to each nation, which would include, but not be limited to, such indices as glaciers, rain forest precipitation, lake levels, local desert history, tree rings, and soil records. This would take the form of an international paleoclimatic data network (IPDN), as a subprogram of the ICRP.

To promote wider international participation in climatic research, it was recommended that programs and activities be developed to encourage international cooperation in climatic research and to facilitate the participation of developing nations that do not yet have adequate training or research facilities. Internationally supported regional climatic studies describing and modeling local climatic anomalies of special interest were also recommended.⁹⁰

The Committee stressed the importance of international cooperative programs to assess the impacts of presently observed climatic changes on the economies of the world's nations, including the effects on water supply, food production, and energy utilization, as well as analyses of the regional impacts of possible future climates.

⁸⁹ *Ibid.*, p. 106.

⁹⁰ The World Meteorological Organization headquarters in Geneva is planning a world conference on climate, tentatively to be held in 1979.

CHAPTER 5

FEDERAL ACTIVITIES IN WEATHER MODIFICATION

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OVERVIEW OF FEDERAL ACTIVITIES

The Federal Government has been involved for over 30 years in a number of aspects of weather modification, through activities of both the Congress and the executive branch. Since 1947, weather modification bills pertaining to research support, operations, policy studies, regulations, liabilities, activity reporting, establishment of panels and committees, and international concerns have been introduced in the Congress. There have been hearings on many of these proposed measures, and oversight hearings have also been conducted on pertinent ongoing programs. A total of six public laws specifically on weather modification have been enacted since 1953, while others have included provisions which in some way are relevant to weather modification. Resolutions dealing with the use of weather modification technology as a weapon by U.S. military forces and promotion of a U.N. treaty prohibiting such activities have been introduced in both houses of the Congress, and one such resolution was passed by the Senate.

Federal legislation has dealt principally with three aspects of weather modification—research program authorization and direction, collection and reporting of weather modification activities, and the commissioning of major studies on recommended Federal policy and the status of technology. In addition to providing direction through authorizing legislation, the Congress has initiated one major Federal program through an appropriations bill write-in, and this program has since regularly received support through additional appropriations beyond its recommended OMB funding level.

Identifiable Federal research and operational weather modification programs can be traced from at least the period of World War II; however, the research programs of most agencies other than the Defense Department were not begun until the 1950's and 1960's. While these research and development programs sponsored at various times by at least eight departments and independent agencies have constituted its major involvement, the executive branch has also performed a wide range of other weather modification activities. Such activities include the conduct of modest operational programs, coordination of Federal research programs, collection and dissemination of U.S. weather modification activities, sponsoring of in-depth studies, publication of a large variety of reports, negotiation for international restrictions barring hostile use of weather modification, and cooperation with other nations in planning of international research projects or assisting in foreign operational programs. The latter two activities,

both essentially international in scope, are only noted here but are discussed more fully in the chapter on international aspects.¹

While some of the numerous studies on weather modification have been undertaken at the direction of the Congress, others have been initiated by one or more Federal agencies or by interagency committees of the executive branch. Published reports have included those which present the findings and recommendations of the special studies undertaken, those which are published periodically by agencies or committees with regular responsibilities for reporting on Federal programs or on operational activities, and the many publications on specific research projects which are prepared by the individual agencies or by contractors and grantees participating in the respective projects. Later in this chapter some of the Federal reports which fall into the first two categories are identified under the discussions of major studies, Federal structure, and coordination of weather modification; reports from the third category are referenced from time to time throughout the report. Some of the Federal reports are included in the selected bibliography in appendix II and many are also listed in the other major bibliographies which are referenced in that appendix.

LEGISLATIVE AND CONGRESSIONAL ACTIVITIES

FEDERAL LEGISLATION ON WEATHER MODIFICATION

Summary

Congressional interest in weather modification has been demonstrated by the fact that legislation on the subject has been introduced in nearly every session of Congress since 1947. Nevertheless, in spite of the apparent interest, a total of six public laws relating specifically and directly to weather modification have been enacted during this period, and two of those passed were mere time extensions of specific provisions in earlier laws.² Briefly, these laws are:

Public Law 83-256 (67 Stat. 559) of August 13, 1953, to create an Advisory Committee on Weather Control, to perform a complete study and evaluation of public and private experiments in weather modification to determine the U.S. role in research, operations, and regulation;

Public Law 84-664 (70 Stat. 509) of July 9, 1956, to extend the authorized life of the Advisory Committee for 2 years through June 30, 1958;

Public Law 85-510 (72 Stat. 353) of July 12, 1958, to authorize and direct the National Science Foundation to initiate a program of study, research, and evaluation in the field of weather modification and to prepare an annual report to the Congress and the President on weather modification;

Public Law 92-205 (85 Stat. 736) of December 18, 1971, to provide for the reporting of weather modification activities to the Federal Government through the Secretary of Commerce and for dissemination of that information by the Secretary of Commerce from time to time;

¹ See ch. 10.

² These six public laws are reproduced in app. I.

Public Law 93-436 (88 Stat. 1212) of October 5, 1974, to extend appropriation authorization for reporting and disseminating weather modification activities through the Secretary of Commerce, as prescribed by Public Law 92-205, through 1977;

Public Law 94-490 (90 Stat. 2359) of October 13, 1976, to authorize and direct the Secretary of Commerce to develop a national policy on weather modification and to extend appropriation authorization for reporting and disseminating weather modification activities, as prescribed by Public Law 92-205, through 1980.

Although not exclusively concerned with weather modification, another act, Public Law 90-407 of July 18, 1968, amended the National Science Foundation Act of 1950. Section 11 of this new act specifically repealed Public Law 85-510, by which the NSF had been directed to initiate and support a program of study, research, and evaluation in weather modification and to report annually on the subject.

Another law of some significance to weather modification, though much broader in its overall purpose, was the fiscal year 1962 public works appropriation, Public Law 87-330 (75 Stat. 722) of September 30, 1961. Through a \$100,000 write-in to this bill, the Congress initiated the atmospheric water resources program (Project Skywater), conducted by the Bureau of Reclamation in the Department of the Interior. Through subsequent public works appropriations the Congress has continued to provide direction to this program almost every year since its inception and has provided frequent funding increases over levels budgeted by the administration.

The Advisory Committee on Weather Control

Between 1951 and 1953 it was disclosed in congressional hearings on several bills introduced by both parties that water users (farmers, ranchers, electric utilities, and municipalities) were spending between \$3 million and \$5 million annually on weather modification and that such activities covered about 10 percent of the country's land area.³ It was the opinion of the Congress in 1953 that "research and development in the field of weather modification have attained the stage at which the application of scientific advances in this field appears to be practical," but also that "the effect of the use of measures for the control of weather phenomena upon the social, economic, and political structures * * * and upon national security cannot now be determined. It is a field in which unknown factors are involved. It is reasonable to anticipate, however, that modification and control of weather, if effective on a large scale, would result in vast and far-reaching benefits to agriculture, industry, commerce, and the general welfare and common defense."⁴

Recognizing possible deleterious consequences which might follow application of weather modification techniques with inadequate safeguards or incomplete understanding, and realizing that weather modification experiments or operations could possibly affect areas extending across State and national boundaries, the Congress considered that such activities "are matters of national and international concern" and accordingly, declared it "to be the policy of the Congress, in order to effect the maximum benefit which may result from experiments and opera-

³ Advisory Committee on Weather Control, final report, Washington, D.C., U.S. Government Printing Office, Dec. 31, 1957, vol. I, p. 8.

⁴ Public Law 83-256 (67 Stat. 559), Aug. 13, 1953, statement of purpose and policy.

tions designed to modify and control weather, to correlate and evaluate the information derived from such activity and to cooperate with the several States and the duly authorized officials thereof with respect to such activity, all to the end of encouraging intelligent experimentation and the beneficial development of weather modification and control, preventing its harmful and indiscriminate exercise, and fostering sound economic conditions in the public interest.”⁵

In order to determine the extent to which the United States should be involved in weather modification research and/or operations and in the regulation of such activities, the Advisory Committee on Weather Control was established by Public Law 83-256, approved August 13, 1953, and was directed by that law to make a complete study and evaluation of public and private experiments in weather control.

The Committee was to be composed of Government and non-Government members in about equal number and, in carrying out its mandate, was given authority to conduct hearings, to acquire pertinent information and records from departments and agencies of the executive branch, and to enlist the services of personnel of any agency of the Federal Government (with the consent of the agency concerned).⁶ The Committee was requested to submit from time to time reports on its findings and recommendations to the President for submission to the Congress and was directed to submit its final report to the President for transmittal to the Congress by June 30, 1956.⁷ It became clear that the study was of such magnitude that additional time would be required for its successful completion, and the Committee requested that its life be extended 2 years, noting that “. . . it has succeeded in establishing some positive and important results which justify the Federal Government continuing its special interest in the field.”⁸ Thereupon, the Congress passed Public Law 84-664 (70 Stat. 509) of July 9, 1956, which extended the date for completion of the report until June 30, 1958. The final report of the Committee was submitted to the President on December 31, 1957.⁹

Direction to the National Science Foundation

The Advisory Committee on Weather Control recognized that the development of weather modification rested on fundamental knowledge obtainable only through scientific research into processes in the atmosphere and recommended that an agency, preferably the National Science Foundation (NSF), be designated to promote and support meteorological research in needed fields, to coordinate research projects, and to constitute a central point for assembly, evaluation, and dissemination of information.¹⁰ Accordingly, when the Congress enacted Public Law 85-510 of July 10, 1958, which amended the National Science Foundation Act of 1950, additional responsibilities were incorporated, directing the Foundation:

To initiate and support a program of study, research, and evaluation in the field of weather modification, giving particular attention to areas that have

⁵ *Ibid.*

⁶ *Ibid.*, sec. 9.

⁷ *Ibid.*, sec. 10.

⁸ Advisory Committee on Weather Control, first interim report, Washington, D.C., February 1956, p. 11.

⁹ Advisory Committee on Weather Control, “Final Report of the U.S. Advisory Committee on Weather Control,” Washington, D.C., U.S. Government Printing Office, March 6, 1958, in two volumes, 32 and 422, pp. (Recommendations of the Committee are found in this chapter, p. 236, and in chapter 6.)

¹⁰ *Ibid.*, vol. I, pp. vii-viii.

experienced floods, drought, hail, lightning, fog, tornadoes, hurricanes, or other weather phenomena, and to report annually to the President and the Congress thereon.¹¹

The NSF was further directed to “. . . consult with meteorologists and scientists in private life and with agencies of Government interested in, or affected by, experimental research in the field of weather control.”¹² Authority was given to NSF to hold hearings, to require the keeping of records and furnishing of information on weather modification research and operations, and to inspect records and premises as appropriate in order to carry out the responsibilities assigned.

In effect, the NSF was assigned the “lead agency” role (a term which was in later years to become the subject of much debate and discussion) among Federal agencies involved in weather modification. A decade later, the Foundation was stripped of these specific responsibilities and of this lead agency role when the Congress again amended the National Science Foundation Act of 1950, by passing Public Law 90-407 of July 18, 1968. Section 11 of the 1968 law struck section 14 and paragraph (9), subsection (a), of section 3 from the National Science Foundation Act, terminating as of September 1, 1968, the responsibilities spelled out in these sections a decade earlier with regard to weather modification.

The Senate report which accompanied the bill subsequently enacted as Public Law 90-407 stated that the NSF was divested of these functions “. . . for a number of reasons :”¹³

One [reason] is that the ramifications of weather modification are so broad as to encompass far more issues than scientific ones. Another is that progress in this area has reached the point where it requires much developmental work as well as continued research. The Departments of Commerce and Interior are assuming much of the responsibility in this area, which the Foundation may continue to back up with appropriate support for some of the research still needed. NSF retains ample authority to continue support for the latter . . . and clearly should do so. The Foundation will in any case continue those research activities necessary to preserve continuity in the program, pending passage of the weather modification legislation now pending. In the latter regard, the committee calls attention to the necessity for legislation to continue elsewhere in the executive branch the development and reporting activities which NSF will not have authority to support after September 1, 1968.

Although legislation was introduced and considered by the Congress which would have reassigned this lead agency role to another agency, no further congressional action was taken on weather modification until 1971.

Reporting of weather modification activities to the Federal Government

Responsibility for maintaining a depository for information on U.S. weather modification activities and for reporting annually on Federal programs and the general status of the field rested with the National Science Foundation for the 10-year period from 1958 through 1968, after which, as has been noted, these and other functions were suspended by Public Law 90-407.

¹¹ National Science Foundation Act of 1950, as amended by Public Law 85-510 (72 Stat. 353) of July 11, 1958, sec. 3, subsec. (a), par. (9).

¹² *Ibid.*, sec. 14.

¹³ U.S. Congress, Senate, Committee on Labor and Public Welfare, “National Science Foundation—Functions—Administration.” report to accompany H.R. 5404. Washington, U.S. Government Printing Office, 1968. (90th Cong., 2d sess. Senate Rept. No. 1137.)

After a lapse of over 3 years, the Congress passed Public Law 92-205 (85 Stat. 736) of December 18, 1971, which directed that “. . . no person may engage or attempt to engage in any weather modification activity in the United States unless he submits to the Secretary of Commerce such reports with respect thereto, in such form and containing such information, as the Secretary may by rule prescribe. The Secretary may require that such reports be submitted to him before, during, and after such activity or attempt.”¹⁴ The act further states that the Secretary of Commerce is charged with responsibility to maintain a record of such weather modification activities in the United States and to publish summaries of the activities “from time to time” as deemed appropriate. Such information received under the provisions of this law, with certain exceptions, is to be made fully available to the public.¹⁵ Authority was provided to the Secretary to obtain the required information by rule, subpoena, or other means and to inspect the records and premises of persons conducting weather modification projects, as necessary, to carry out assigned responsibilities. There is also provision for levying fines up to \$10,000 on any person for non-compliance with the stipulations of the law requiring the reporting of weather modification activities. Public Law 92-205 is concerned with the reporting of weather modification projects, however, not with their regulation, control, or evaluation.

Within the Commerce Department, the weather modification reporting system required by Public Law 92-205 is administered on behalf of the Secretary by the National Oceanic and Atmospheric Administration (NOAA). Upon subsequent advertisement of Commerce Department rules in the Federal Register, the requirement for submitting information on weather modification projects became effective on November 1, 1972. Federal agencies were excluded from the requirement to submit such information under the act; however, upon mutual agreement by the agencies to do so, data on Federal projects have also been collected and disseminated by NOAA as of November 1, 1973.

Appropriations for administering the provisions of Public Law 92-205 were authorized through June 30, 1974, by the original law. Additional authorizations for appropriations, extending the responsibility of the Secretary of Commerce for reporting procedures, were approved by the Congress in two subsequent laws. Public Law 93-436 (88 Stat. 1212) of October 5, 1974, extended reporting requirements through June 30, 1977; while Public Law 94-490 (90 Stat. 2359) of October 13, 1976, contained among other provisions a similar extension of these provisions through June 30, 1980. The major thrust of the latter act, known as the National Weather Modification Policy Act of 1976, is discussed in the next section.

The National Weather Modification Policy Act of 1976

After consideration of a number of bills introduced in the 94th Congress and extensive hearings on weather modification, the Congress passed Public Law 94-490 (90 Stat. 2359), the National Weather Modification Policy Act of 1976, which was signed October 13, 1976. The following particular findings prompted the Congress to take action:

1. weather-related disasters and hazards, including drought, hurricanes, tornadoes, hail, lightning, fog, floods, and frost, result

¹⁴ Public Law 92-205 (85 Stat. 736), sec. 2.

¹⁵ *Ibid.*, sec. 3.

in substantial human suffering and loss of life, billions of dollars of annual economic losses to owners of crops and other property, and substantial loss to the U.S. Treasury;

2. weather modification technology has significant potential for preventing, diverting, moderating, or ameliorating the adverse effects of such disasters and hazards and enhancing crop production and the availability of water;

3. the interstate nature of climatic and related phenomena, the severe economic hardships experienced as the result of occasional drought and other adverse meteorological conditions, and the existing role and responsibilities of the Federal Government with respect to disaster relief, require appropriate Federal action to prevent or alleviate such disasters and hazards; and

4. weather modification programs may have long range and unexpected effects on existing climatic patterns which are not confined by national boundaries.¹⁶

By this act the Congress proposed “* * * to develop a comprehensive and coordinated national weather modification policy and a national program of weather modification research and development—

1. to determine the means by which deliberate weather modification can be used at the present time to decrease the adverse impact of weather on agriculture, economic growth, and the general public welfare, and to determine the potential for weather modification;

2. to conduct research into those scientific areas considered most likely to lead to practical techniques for drought prevention or alleviation and other forms of deliberate weather modification;

3. to develop practical methods and devices for weather modification;

4. to make weather modification research findings available to interested parties;

5. to assess the economic, social, environmental, and legal impact of an operational weather modification program;

6. to develop both national and international mechanisms designed to minimize conflicts which may arise with respect to the peaceful uses of weather modification; and

7. to integrate the results of existing experience and studies in weather modification activities into model codes and agreements for regulation of domestic and international weather modification activities.”¹⁷

The act charges the Secretary of Commerce with responsibility for conducting “a comprehensive investigation and study of the state of scientific knowledge concerning weather modification, the present state of development of weather modification technology, the problems impeding effective implementation of weather modification technology, and other related matters. Such study shall include—

(1) A review and analysis of the present and past research efforts to establish practical weather modification technology, particularly as it relates to reducing loss of life and crop and property destruction;

(2) A review and analysis of research needs in weather modification to establish areas in which more research could be expected

¹⁶ Public Law 94-490 (90 Stat. 2359), sec. 2, declaration of policy.

¹⁷ *Ibid.*

to yield the greatest return in terms of practical weather modification technology;

(3) A review and analysis of existing studies to establish the probable economic importance to the United States in terms of agricultural production, energy, and related economic factors if the present weather modification technology were to be effectively implemented;

(4) An assessment of the legal, social, and ecological implications of expanded and effective research and operational weather modification projects;

(5) Formation of one or more options for a model regulatory code for domestic weather modification activities, such code to be based on a review and analysis of experience and studies in this area, and to be adaptable to State and national needs;

(6) Recommendations concerning legislation desirable at all levels of government to implement a national weather modification policy and program;

(7) A review of the international importance and implications of weather modification activities by the United States;

(8) A review and analysis of present and past funding for weather modification from all sources to determine the sources and adequacy of funding in the light of the needs of the Nation;

(9) A review and analysis of the purpose, policy, methods, and funding of the Federal departments and agencies involved in weather modification and of the existing interagency coordination of weather modification research efforts;

(10) A review and analysis of the necessity and feasibility of negotiating an international agreement concerning the peaceful uses of weather modification; and

(11) Formulation of one or more options for a model international agreement concerning the peaceful uses of weather modification and the regulation of national weather modification activities; and a review and analysis of the necessity and feasibility of negotiating such an agreement.¹⁸

The act directs each department and agency of the Federal Government to furnish pertinent information to the Secretary of Commerce and authorizes the Secretary in conducting the study to "solicit and consider the views of State agencies, private firms, institutions of higher learning, and other interested persons and governmental entities."¹⁹

A final report on the findings, conclusions, and recommendations of the required study is to be prepared by the Secretary of Commerce and submitted to the President and the Congress. The report is to include the following:

(1) A summary of the findings made with respect to each of the areas of investigation delineated above;

(2) Other findings which are pertinent to the determination and implementation of a national policy on weather modification;

(3) A recommended national policy on weather modification and a recommended national weather modification research and development program, consistent with, and likely to contribute to, achieving the objectives of such policy;

¹⁸ *Ibid.*, sec. 4, study.

¹⁹ *Ibid.*, sec. 5, report.

(4) Recommendations for levels of Federal funding sufficient to support adequately a national weather modification research and development program;

(5) Recommendations for any changes in the organization and involvement of Federal departments and agencies in weather modification which may be needed to implement effectively the recommended national policy on weather modification and the recommended research and development program; and

(6) Recommendations for any regulatory and other legislation which may be required to implement such policy and program or for any international agreement which may be appropriate concerning the peaceful uses of weather modification, including recommendations concerning the dissemination, refinement, and possible implementation of the model domestic code and international agreement developed under the specification in the list of investigations above.²⁰

The act stipulated that the report was to be submitted by the Secretary within 1 year after the date of enactment of the law; that is, by October 13, 1977. Following a request by the Secretary in June of 1977 for an extension of this time allotment, a Senate bill was introduced, providing for an extension of the due date of the report through June 13, 1978. No other action on this request was taken, however, during the first session of the 95th Congress. Meanwhile, the study mandated by Public Law 94-490 continues under the auspices of the Secretary of Commerce.²¹

Congressional direction to the Bureau of Reclamation

Of special interest as they have affected the weather modification activities of the Bureau of Reclamation within the Department of the Interior are some laws not specifically concerned with weather modification as are the ones discussed above. The Reclamation Act of June 17, 1902,²² directs the Bureau to develop water resources for reclamation purposes, establishing a "reclamation fund," which may be used, *inter alia*, "in the examination and survey and for the construction and maintenance of irrigation works for the storage, diversion, and development of waters for the reclamation of arid and semiarid lands * * *" throughout the 17 contiguous Western States and Hawaii. The authority of the 1902 act was supplemented by the Fact Finders Act of December 5, 1924, and amendments thereto in the act of April 19, 1945,²³ which enabled the Bureau to conduct "general investigations," not related to specific projects, including research work, for the development of water resources without the necessity of making the costs thereof reimbursable.

Thus, the 1902 Reclamation Act, supplemented by the Fact Finders Act, provides the authority for the Bureau of Reclamation to engage in a program of weather modification research for the purpose of determining practical methods of inducing precipitation and increased runoff that can be stored in surface reservoirs and used for "the rec-

²⁰ *Ibid.*

²¹ This study is underway on behalf of the Secretary of Commerce by a Weather Modification Advisory Board, appointed by the Secretary. See subsequent discussion of activities of the Advisory Board, beginning p. 231.

²² 43 U.S.C. 391 et seq.

²³ 43 U.S.C. 377.

lamation of arid and semiarid lands." Funds appropriated for weather modification research are considered expendable on a nonreimbursable basis.²⁴

In 1961 the Congress specifically directed the Bureau of Reclamation to initiate a program in weather modification through a write-in of \$100,000 to the fiscal year 1962 Public Works Appropriation Act. This first appropriation for the Bureau's weather modification research and development program was added to the Appropriation Act, Public Law 87-330 (75 Stat. 722), approved September 30, 1961, in a congressional committee of conference, under the heading, "General Investigations."²⁵ The specific language which directed the weather modification research appeared in the Senate report on H.R. 9076,²⁶ and the provision was incorporated into the conference report without mentioning weather modification per se. The Senate report included the following item:

Increased rainfall by cloud seeding, \$100,000.—The committee recommends allowance of \$100,000 to be used for research on increasing rainfall by cloud seeding. This amount would be utilized in cooperation with the National Science Foundation and the Weather Bureau, which are expected to contribute funds and participate in this research.²⁷

In accordance with congressional direction in the fiscal year 1962 Public Works appropriation bill, the Bureau of Reclamation established the Atmospheric Water Resources Management Program ("Project Skywater") in 1962. Since the start of this program congressional direction has continued to be almost entirely through provisions in the congressional documents relative to annual Public Works appropriations. Appendix J is a summary of the appropriation language contained in these documents from 1961 through 1977, which provided such direction. It may be noted that by this means the Congress has continued to provide specific direction to this program almost every year since its inception and has provided frequent funding increases, often substantial, over levels budgeted by the administration.

Legislation providing for temporary authorities to the Secretary of the Interior to facilitate emergency actions to mitigate impacts of the 1976-77 drought was enacted by the Congress and signed by President Carter on April 7, 1977. Public Law 95-18 (91 Stat. 36), subsequently amended by Public Law 95-107 (91 Stat. 870), of August 17, 1977, provided authority to appropriate \$100 million for a program including short-term actions to increase water supplies, to improve water supply facilities, and to establish a bank of available water for redistribution. The Bureau of Reclamation published rules in the Federal Register whereby States could apply for nonreimbursable funds for actions designed to augment water supplies.²⁸ Under these provisions, requests for funds to support weather modification activities were received from six States.²⁹

²⁴ Justus, John R. and Robert E. Morrison, legislative authority for atmospheric research by Federal agencies, the Library of Congress, Congressional Research Service, Apr. 1, 1977 (unpublished), p. 12.

²⁵ U.S. Congress, committee of conference, public works appropriation bill, 1962; conference report to accompany H.R. 9076, Washington, D.C., U.S. Government Printing Office, 1961, p. 24. (87th Cong., 1st sess. House Rept. No. 87-1268.)

²⁶ U.S. Congress, Senate, Committee on Appropriations, public works appropriation bill, 1962; report to accompany H.R. 9076, Washington, D.C., U.S. Government Printing Office, 1961, p. 24. (87th Cong., 1st sess. House Rept. No. 87-1268.)

²⁷ *Ibid.*

²⁸ Federal Register, vol. 42, No. 72, Thursday, Apr. 14, 1977, pp. 19609-19613.

²⁹ The States were California, Colorado, Kansas, Nevada, North Dakota, and Utah. See discussion of the Department of the Interior activities in weather modification, p. 267, for amounts of these grants.

PROPOSED FEDERAL LEGISLATION ON WEATHER MODIFICATION

Summary

Since 1947 at least 110 bills and 22 resolutions dealing specifically with one or more aspects of weather modification have been introduced in the Congress. Moreover, many additional pieces of proposed legislation, providing authorization or appropriations for broader agency programs, have given support and/or direction to weather modification activities within Federal agencies, often without mentioning such activities per se.

Table 1 summarizes the legislation and resolutions concerned specifically with weather modification, which were proposed from the first session of the 80th Congress to the first session of the 95th Congress. The table shows, for each session, the numbers of bills and resolutions pertaining to each of several aspects of the subject and the total number of each introduced. The numbers appearing under the several subjects of weather modification legislation will, in general, exceed the total number of measures introduced in a given year because many of the bills were concerned with more than one aspect. It will be noted that a total of six laws were passed during this period, as stated earlier. During the 93d Congress the Senate also passed one resolution, which supported the position that the United States should seek the agreement of other nations to a treaty banning environmental modification as a weapon of war.

TABLE 1.—NUMBERS OF BILLS AND RESOLUTIONS ON WEATHER MODIFICATION WHICH WERE INTRODUCED INTO THE CONGRESS FROM 1947 THROUGH 1977, IN ACCORDANCE WITH MAJOR PROVISIONS OF THE MEASURES

Calendar year/Congress/session	Total number of bills	Total number of resolutions	Directed research or operations	Liability indemnification	Regulation licensing, or control	Directed study and report	Established commission and advisory group	Collection of activity information and report	Establish weather modification office	Drought assistance grants	Prohibit weather modification in the United States	Permit weather modification in wilderness areas	Prohibit U.S. war-related activities	Regulate Foreign activities by U.S. operators	U.S. urge international agreement banning hostile use
1947/80th/1st	1		1												
1948/80th/2d			1												
1949/81st/1st	1		1												
1950/81st/2d	2			2											
1951/82d/1st	2	1	2		1	1									
1952/82d/2d	2	1	8		2	2									
1953/83d/1st	2				1	3									
1954/83d/2d	4		1												
1955/84th/1st															
1956/84th/2d	4		1			3									
1957/85th/1st	9		9					1							
1958/85th/2d	1		1												
1959/86th/1st	13		13												
1960/86th/2d															
1961/87th/1st	3		2				1								
1962/87th/2d															
1963/88th/1st	6		3			1	2				1				
1964/88th/2d		1													
1965/89th/1st	5		2			3									
1966/89th/2d	4		4												
1967/90th/1st	3		3												
1968/90th/2d	2														
1969/91st/1st	7					1	4	1			1				
1970/91st/2d	3					5		2			2				
1971/92d/1st	5		1		1	1			1						
1972/92d/2d	1														
1973/93d/1st	3	5												1	1
1974/93d/2d	8	6			2	1		2	1					5	2
1975/94th/1st	2	2			2	1		1	1					7	1
1976/94th/2d	8	2	4	1	2	1	2	1		2				2	1
1977/95th/1st	3	1			1	1		1						1	1

It can be seen from the table that congressional activity has often evolved in accordance with the emergence of various interests and issues. Thus, in the 1950's and 1960's there were strong attempts to initiate and support Federal research and/or operational programs, usually within one or another of several specified departments or agencies. From time to time emphasis has been given to evaluating weather modification technology and establishing a national policy, usually through mandating an in-depth study; such study was sometimes to be undertaken by a select committee established for that purpose. In the 1970's two thrusts in proposed legislation have dealt with regulating and/or licensing of operations and with reporting weather modification activities to the Federal Government, both reflecting increased concern on the part of large segments of the public about unknown effects of such operations and about legal and economic ramifications of increased or decreased precipitation. Obvious too in the 1970's is the reaction of Congress to public concern about the use of weather modification as a weapon, as 18 resolutions dealing with that subject were introduced in both Houses since 1971.

Specific measures of recent years on weather modification, those introduced in the 94th Congress and the first session of the 95th Congress, are summarized in the following section.

Legislation proposed in the 94th and 95th Congress, 1st session

Proposed legislation and resolutions appearing during the 94th Congress reflected concern over many current problem areas in weather modification coming into focus today, areas over which it is considered by many that the Federal Government should have some jurisdiction. Based upon a number of specific measures introduced during that Congress and the ensuing discussions thereon, there emerged the National Weather Modification Policy Act of 1976 (Public Law 94-490), which could be a landmark, in that studies and decisions pursuant to that act may lead to definition of a clear Federal policy for the first time in recent years. The bills submitted thus far in the 95th Congress address some concerns not dealt with in the recent law and may presage stipulations which could conceivably be incorporated into future Federal policy. Undoubtedly, the 96th Congress will see a greater abundance of proposed legislation dealing with Federal policy on weather modification, following receipt by the Congress of the report from the Secretary of Commerce recommending a national policy and a program of Federal research and development.³⁰ Measures introduced during the 94th Congress and the first session of the 95th Congress are summarized below:

94th Congress, 1st session

S. 2705.—To provide for a study, within the Department of Commerce, by a National Weather Modification Commission, of the research needs for weather modification, the status of current technologies, the extent of coordination, and the appropriate responsibility for operations in the field of weather modification. (Hearing was held Feb. 17, 1976.)

S. 2706.—To authorize and direct the Secretary of Commerce to plan and carry out a 10-year experimental research program to

³⁰ Public Law 94-490 directs the Secretary of Commerce to conduct a study on weather modification and to submit a report to the President and the Congress, recommending a national policy and a program of Federal research and development in weather modification.

determine the feasibility of and the most effective methods for drought prevention by weather modification. Directs the Secretary to appoint an Advisory Board and provides for consultation with State and local governments starting weather modification efforts for drought alleviation. (Hearing was held Feb. 17, 1976.)

S. 2707.—To authorize the Secretary of Commerce to carry out a program of assistance to States in preventing and alleviating drought emergencies. (Hearing was held Feb. 17, 1976.)

H.R. 167.—To prohibit the United States from engaging in weather modification activities, including cloud seeding and fire storms, for military purposes. (No action.)

H.R. 2742.—Directed the Secretaries of Agriculture and Interior to permit the conduct of weather modification activities, including both atmospheric and surface activities and environmental research, which are over, or may affect, areas which are part of the National Wilderness Preservation System or other Federal lands. Authorized the respective Secretaries to prescribe such operating and monitoring conditions as each deems necessary to minimize or avoid long-term and intensive local impact on the wilderness character of the areas affected. (No action.)

H.R. 4325.—Weather Modification and Precipitation Management Act. Authorized the Secretary of the Interior to establish precipitation management projects in order to augment U.S. usable water resources. Authorized the Secretary to engage in operational demonstration projects for potential use in precipitation management programs in certain States and to settle and pay claims against the United States for injury, death, or losses resulting from weather modification pursuant to provisions of this act. (No action.)

H.R. 4338.—Designated specific lands within the Sequoia and Sierra National Forests, Calif., as the "Monarch Wilderness," abolishing the previous classification of the "High Sierra Primitive Area." Directed the Secretary of Agriculture to authorize use of hydrological devices and to provide for weather modification activities within such wilderness. (No action.)

H.R. 10039.—Weather Modification Research, Development, and Control Act of 1975. Directed the Secretary of Commerce to establish a weather modification research and development program to evaluate the specific needs and uses of weather modification and directed the Secretary to establish a weather modification information system. Prohibited individuals from engaging in weather modification activities without obtaining a permit from the Secretary and authorized the President to enter into international agreements to foster establishment of international systems for monitoring and regulation of weather modification activities. (Joint hearings were held on H.R. 10039 and S. 3383, June 15–18, 1976; no further action on H.R. 10039.)

H. Res. 28.—Expressed the sense of the House of Representatives that the U.S. Government should seek agreement with other members of the United Nations on the prohibition of weather

modification as a weapon of war. (Hearing was held July 29, 1975; no further action.)

H. Res. 103.—Same as H. Res. 28. (No action.)

94th Congress, 2d Session

S. 3383.—National Weather Modification Policy Act. Directed the Secretary of Commerce to conduct a comprehensive study of scientific knowledge concerning weather modification and technology of weather modification. Required the Secretary to prepare and submit to the President and the Congress a final report on the findings and conclusions of such study, including a recommended national policy on weather modification. Extended through fiscal year 1980 appropriation authorization for the weather modification activities oversight program of the Department of Commerce. (Reported to Senate, May 13, 1976, in lieu of S. 2705, S. 2706, and S. 2707; considered and passed by Senate, May 21, 1976; hearings held jointly in House subcommittee on S. 3383 and H.R. 10039, June 15–18, 1976; called up under motion to suspend the rules, considered, and passed by the House, amended, Sept. 20, 1976; Senate agreed to House amendments, Sept. 28, 1976; and approved as Public Law 94-490, Oct. 13, 1976.)

H.R. 14544.—Extended through fiscal year 1980 appropriations authorization for the weather modification activities oversight program of the Department of Commerce. (No action.)

95th Congress, 1st Session

S. 1938.—To extend the National Weather Modification Policy Act of 1976 by extending the date for submission of the required report of the Secretary of Commerce to June 13, 1978. (No action.)

H.R. 4069.—Weather Modification Regulation Act of 1977: Requires weather modification licenses and permits, establishes reporting requirements to be administered by the Secretary of Commerce, and requires the Secretary to establish a weather modification information system. Authorizes the President to enter into international agreements to foster establishment of international systems for monitoring and regulation of weather modification activities. (No action.)

H.R. 4461.—Same as H.R. 2742, introduced during 94th Congress, first session. (No action.)

H. Res. 236.—Declares it to be the sense of the House of Representatives that the United States should seek an agreement with other members of the United Nations to prohibit research, experimentation, or the use of weather modification as a weapon. (No action.)³¹

OTHER CONGRESSIONAL ACTIVITIES

Resolutions on weather modification

As noted earlier, some 22 resolutions related to weather modification have been introduced over the past 30 years in both Houses of the Congress. For convenience, data on these resolutions are included along with that on proposed legislation in table 1 and in the discussion

³¹ See ch. 10 for a discussion of the development of such a U.N. convention, opened for signature in Geneva, May 18, 1977.

thereon, and three resolutions are included in the preceding list of summaries of weather modification bills appearing during the 94th and 95th Congresses.

By far, the largest number of weather modification resolutions, 18 in all, have been concerned with barring the use of weather modification as a weapon of war. Introduction of such resolutions began during the 92d Congress in 1971, and, using similar language, they express the sense of either House or of the Congress that the United States should seek an agreement with other U.N. members, prohibiting such use of environmental modification, including weather modification. In 1973, the Senate passed S. Res. 71, which had been introduced by Senator Claiborne Pell. This and other resolutions urging prohibition of environmental modification for purposes of warfare were prompted by a series of hearings and communications between Senator Pell and the Department of Defense on the alleged use of weather modification technology as a weapon in Vietnam by U.S. military forces.³²

Four other weather modification resolutions, introduced in the 1950's and 1960's, pertained to the undertaking of comprehensive studies on the subject, either by special committees to be established by the Congress or by departments and/or agencies of the executive branch.

Hearings

Cognizant subcommittees of both Houses have conducted hearings concerned, at least in part, with Federal weather modification activities, from time to time and annually, in connection with oversight of agency programs, authorizing legislation, and annual appropriations. In addition, more comprehensive hearings on the subject have been important parts of the legislative activities leading to passage of the major public laws on weather modification, which have been enacted since 1953.

Of particular interest in recent years are the extensive hearings conducted during 1976 by the Subcommittee on Oceans and Atmosphere of the Senate Committee on Commerce³³ and by the Subcommittee on the Environment and the Atmosphere of the House Committee on Science and Technology.³⁴ The documents produced from these hearings contain the testimony of a number of expert witnesses on various aspects of weather modification as well as reproductions of numerous pertinent documents which were incorporated into the records of the hearings. References to documents on other weather modification hearings conducted in recent years are contained in the bibliography of congressional publications in appendix H.

On October 26, 1977, the Subcommittee on the Environment and the Atmosphere of the House Committee on Science and Technology conducted a special hearing on the National Weather Modification Policy Act of 1976 (Public Law 94-490). Among other witnesses, Mr. Harlan Cleveland, Chairman of the Commerce Department's Weather Modi-

³² The correspondence and hearings on the use of weather modification as a weapon in Vietnam and of the development of a U.N. treaty barring environmental modification in warfare are discussed among other international aspects of weather modification in ch. 10.

³³ U.S. Congress, Senate, Committee on Commerce, Subcommittee on Oceans and Atmosphere, Atmospheric Research Control Act, hearing, 94th Cong., 2d sess., on S. 2705, S. 2706, and S. 2707, Feb. 17, 1976, Washington, U.S. Government Printing Office, 1976, 297 pp.

³⁴ U.S. Congress, House, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, Weather modification, hearings, 94th Cong., 2d sess., on H.R. 10039 and S. 3383, June 15-18, 1976, Washington, U.S. Government Printing Office, 1976, 524 pp.

fication Advisory Board, briefed the subcommittee on progress of the Board in carrying out for the Secretary of Commerce the comprehensive study required by the act and also reported on findings of the Board to date in a discussion paper which he submitted for the record.³⁵

Studies and reports by congressional support agencies

In addition to the studies and reports of the executive branch which were mandated by the Congress through legislation, studies have also been undertaken on behalf of the Congress by congressional support agencies on at least three occasions. The present report, requested in 1976 by the Senate Committee on Commerce, was preceded by a similar study and report requested a decade earlier by the same committee.³⁶ In 1974, the General Accounting Office (GAO) conducted a critical review of ongoing Federal research programs in weather modification and prepared a report to the Congress on the need for a national program.³⁷ A discussion of the findings and recommendations of this GAO study, along with those of other major Government and non-Government studies, is undertaken in a later chapter of this report.³⁸

ACTIVITIES OF THE EXECUTIVE BRANCH

INTRODUCTION

The executive branch of the Federal Government sponsors nearly all of the weather modification research projects in the United States, under a variety of programs scattered through at least six departments and agencies. The National Atmospheric Sciences Program for 1978³⁹ includes information on specific programs of the Departments of Agriculture, Commerce, Defense, and the Interior and of the Energy Research and Development Administration (now part of the Department of Energy) and the National Science Foundation. In recent years weather modification research programs were also identified by the Department of Transportation and the National Aeronautics and Space Administration.

In addition to specific programs sponsored by Federal agencies, there are other functions relevant to weather modification which are performed in several places in the structure of the executive branch. Various Federal advisory panels and committees and their staffs, which have been established to conduct in-depth studies and prepare comprehensive reports, to provide advice and recommendations, or to coordi-

³⁵ Cleveland, Harlan, "A U.S. Policy To Enhance the Atmospheric Environment." A discussion paper by the Weather Modification Advisory Board, Oct. 21, 1977. Submitted as part of testimony in hearing: U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, "Weather Modification," 95th Cong., 1st sess., Oct. 26, 1977, Washington, D.C., U.S. Government Printing Office, 1977, pp. 2-49.

³⁶ U.S. Library of Congress, Legislative Reference Service, "Weather Modification and Control," a report prepared by Lawton M. Hartman and others for the use of the Committee on Commerce, U.S. Senate, Washington, D.C., U.S. Government Printing Office, Apr. 27, 1966, 181 pp. (89th Cong., 2d sess., Senate Rept. No. 1139.)

³⁷ Comptroller General of the United States, "Need for a National Weather Modification Research Program," report to the Congress, U.S. General Accounting Office, Washington, D.C., Aug. 23, 1974, 71 pp.

³⁸ See ch. 6, p. 324.

³⁹ The National Atmospheric Sciences Program, including the Federal program in weather modification, is published annually in a report of the Interdepartmental Committee for Atmospheric Sciences. The most recent such report, containing a discussion of and funding for the fiscal year 1978 program is the following: Federal Coordinating Council for Science, Engineering, and Technology, Committee on Atmosphere and Oceans, Interdepartmental Committee for Atmospheric Sciences, National Atmospheric Sciences Program, fiscal year 1978, ICAS 21-FY78, September 1977, pp. 87-94.

nate Federal weather modification programs have been housed and supported within executive departments, agencies, or offices. For example, the National Advisory Committee on Oceans and Atmosphere (NACOA) and the Weather Modification Advisory Board are supported through the Department of Commerce. While the membership of the Interdepartmental Committee for Atmospheric Sciences (ICAS) comes from each of the Federal departments and agencies with atmospheric science programs, its staff has been housed in the National Science Foundation.

The program whereby Federal and non-Federal U.S. weather modification activities are reported to the Federal Government is administered by the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce. Under this program a central file is maintained on all such projects in the United States, and summary reports on these projects are published on a nearly annual basis by NOAA.

The United States has been active in at least two areas of international interest in weather modification. One aspect has been the efforts through the United Nations to promote the adoption of a treaty barring weather modification as a military weapon. There is also a U.S. interest in international efforts to modify the environment for beneficial purposes. The State Department is active in negotiating agreements with other countries which might be affected by U.S. experiments and has also arranged for Federal agencies and other U.S. investigators for participation in international meteorological projects, including weather modification, under the World Meteorological Organization (WMO). These activities are discussed in more detail in a subsequent chapter on international aspects of weather modification.⁴⁰

In the next subsection there is an attempt to describe the Federal organizational structure for weather modification, at least to the extent that such a structure exists, has existed, or may exist in the near future. Other subsections address Federal coordination and advisory groups, the weather modification activities reporting program, and the array of Federal studies and reports which have been undertaken by the executive branch, either as required by law or initiated within the branch. A summary of the Federal research program and detailed descriptions of each of the several agencies programs in weather modification are contained in a separate major section at the end of this chapter.⁴¹

INSTITUTIONAL STRUCTURE OF THE FEDERAL WEATHER MODIFICATION PROGRAM

Current status of Federal organization for weather modification

The present Federal structure of weather modification research activities is characterized essentially by the mission-oriented approach, where each of six or seven departments and agencies conducts its own program in accordance with broad agency goals or under specific directions from the Congress or the Executive. The exception to this approach is the program of the National Science Foundation, whose funded weather modification research activities have included a broad

⁴⁰ See ch. 10.

⁴¹ See p. 241 ff.

range of individual fundamental problem investigations, research supporting some aspects of the project of other Federal agencies, and conduct of major projects initiated by the Foundation. The programs of the several agencies have been loosely coordinated with others through various independent arrangements and/or advisory panels and particularly through the Interdepartmental Committee for Atmospheric Sciences (ICAS). The ICAS, established in 1959 by the former Federal Council for Science and Technology, provides advice on matters related to atmospheric science in general and has also been the principal coordinating mechanism for Federal research in the field of weather modification. The following observation on the current Federal weather modification organizational structure was stated recently by the chairman of the ICAS:

Organization[s] doing the research [should] be knowledgeable of the sector of the public that is to be involved with special weather modification techniques. There is no single agency within the Government that knows all of the problems of society vis-a-vis weather modification. As things stand, the individual weather modification programs being carried out by the various ICAS member agencies are being pursued in concert with the missions of those agencies.⁴²

The nature of the present Federal organizational structure for weather modification is related to and results from the prevailing policy, or lack of such policy, currently subscribed to by the Federal Government regarding weather modification. The clearest statement of such a policy came in a reply to a 1975 letter from Congressmen Gilbert Gude and Donald M. Fraser and Senator Claiborne Pell, addressed to the President, urging that a coordinated Federal program in the peaceful uses of weather be initiated.⁴³ In the official response from the executive branch, written by Norman E. Ross, Jr., Assistant Director of the Domestic Council, the current Federal weather modification policy was affirmed:

We believe that the agency which is charged with the responsibility for dealing with a particular national problem should be given the latitude to seek the best approach or solution to the problem. In some instances this may involve a form of weather modification, while in other instances other approaches may be more appropriate.

While we would certainly agree that some level of coordination of weather modification research efforts is logical, we do not believe that a program under the direction of any one single agency's leadership is either necessary or desirable. We have found from our study that the types of scientific research conducted by agencies are substantially different in approach, techniques, and type of equipment employed, depending on the particular weather phenomena being addressed. * * * Each type of weather modification requires a different form of program management and there are few common threads which run along all programs.⁴⁴

Recently, the Chairman of the Commerce Department's Weather Modification Advisory Board, Harlan Cleveland, expressed the Board's opinion of the current Federal policy and structure:

The United States does not now have a weather modification policy. The three main Federal actors in weather modification research are NOAA in the

⁴² Testimony of Dr. Edward P. Todd in U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, "Weather Modification," hearings, 94th Cong., 2d sess., June 15-18, 1976, Washington, D.C., U.S. Government Printing Office, 1976, p. 81.

⁴³ Gude, Gilbert, "Weather Modification," Congressional Record, June 17, 1975, pp. 19201-19203. (The statement in the Congressional Record, including the letter to the President and the official reply, are reproduced in app. A.)

⁴⁴ *Ibid.*

Department of Commerce, the Bureau of Reclamation in the Department of the Interior, and the National Science Foundation. . . . Their combined R and D efforts can only be described as fragmented and famished, living from hand to mouth on each agency's relationship with a different congressional subcommittee, with no sense of a national policy or program. . . . The agencies that are involved, and their university and other contractors and grantees, have developed, despite the fragmentation, remarkably effective informal relationships which make the coordination and mutual assistance better than the division of roles and missions would indicate.⁴⁵

A somewhat different viewpoint, but related in several points to the preceding opinions was expressed in 1976 by Dr. Ronald L. Lavoie, Director of NOAA's Environmental Modification Office, addressing the second meeting of the North American Interstate Weather Modification Council:

Let me address the question of current Federal policies in weather modification—the statement has been made that there aren't any. I think that I must disagree with that statement. There are, in fact, such policies although they are perhaps unobtrusive or low-key. They certainly aren't propounded very loudly, but I think it is safe to say that there is some Federal policy on weather modification. . . . For example, in the area of research and operations the Federal policy, or you may call it strategy, is to leave it to the specialized agencies to fund research and to develop or apply weather modification in carrying out their particular missions. One can argue with this policy; nevertheless, it does exist. . . . One shouldn't get the impression, however, that this is an entirely fragmented effort. . . . There is some coordination or integration, at least in the sense that technocrats responsible for advising the agencies in these matters get together to discuss issues and share problems. . . . Nevertheless, there is no Federal or national commitment to weather modification, and I believe that this is what was implied when it was said that there was no national policy.⁴⁶

Yet another observation on the subject of Federal organization is that expressed in the 1974 report by the U.S. General Accounting Office:

Our review of the Federal weather modification research activities supports the findings of nearly a decade of studies. These studies conducted by scientific panels, committees, and other groups all identified common problems—ineffective coordination, fragmented research, and research efforts that are subcritical (funded below the level necessary to produce timely, effective results). Most studies proposed a common solution. What was needed, in essence, was a national research program under a single Federal agency responsible for establishing plans and priorities, obtaining the needed funds from the Congress, managing research efforts, and accounting for the results its programs achieved.

To date, except for the establishment of several coordinating committees, subcommittees, and advisory panels—none of which have the authority to take action to correct problems already identified—an effective overall national weather modification research program has not been established.⁴⁷

There is some consensus that the apparent fragmentation and lack of a cohesive Federal effort have not only prevented the growth of a strong, adequately funded research program but may have also retarded progress in development of weather modification technology

⁴⁵ Cleveland, Harlan, "A U.S. Policy To Enhance the Atmospheric Environment." A discussion paper by the Weather Modification Advisory Board, Oct. 21, 1977. (Submitted as part of testimony in hearing: U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, "Weather Modification," Oct. 26, 1977, p. 41.)

⁴⁶ Lavoie, Ronald L., "Effects of Legislation on Federal Programs and the Prospect of Federal Involvement." In proceedings of Conference on Weather Modification, Today and Tomorrow: second annual meeting of the North American Interstate Weather Modification Council, Kansas City, Mo., Jan. 15-16, 1976, pub. No. 76-1, pp. 56-57.

⁴⁷ Comptroller General of the United States, "Need for a National Weather Modification Research Program." report to the Congress. U.S. General Accounting Office, B-133202, Washington, D.C., Aug. 23, 1974, p. 3.

itself. Many feel strongly that assignment of a "lead agency" would solidify and strengthen the Federal effort. To others, however, " * * * the present structure for Federal Government activity in weather modification appears to be working satisfactorily,"⁴⁸ and the existence of separate agency programs fosters increased understanding through independent research projects and through the cross-fertilization of ideas and exchange of findings achieved in cooperative projects, in professional meetings, and through program-level coordination.

In a recent Federal study on weather modification, a subcommittee of the Domestic Council could not reach a consensus on the proper institutional structure for planning and management of the national weather modification research effort. Consequently, both of the positions noted above were identified as options for such Federal structure:⁴⁹

Option (1): Continue coordination and planning of the national weather modification effort through the Interdepartmental Committee for Atmospheric Sciences of the Federal Council for Science and Technology, with individual agencies pursuing their mission responsibilities.

Option (2): Establish a lead agency to foster the broad advancement of the science and technology of weather modification as recommended by the National Advisory Committee on Oceans and Atmosphere, the National Academy of Sciences, and other groups to coordinate and plan the national effort with the assistance and participation of other agencies.

Those who espouse the latter position feel that the lead agency responsibility should include the following functions:⁵⁰

The lead agency would assume the leadership for planning the Federal weather modification program, in concert with those other concerned agencies, universities, and the private sector.

The lead agency would present, within the executive branch, a consolidated national weather modification research plan and be available to represent the national plan before the Congress.

The lead agency would, within the framework of the joint planning effort, encourage and assist in justifying programmatic activities in other agencies that might contribute significantly to the national weather modification objectives, especially when those programs can be implemented as supplements to the agencies' ongoing mission-related activities.

The lead agency would take on the responsibility for presenting the budgetary requirements to carry out the national plan to the Office of Management and Budget and, with due consideration of overall priorities of the agency, would seek to provide within its own budget for activities essential to the national plan and not incorporated in the budgets of the other agencies.

The history of the organization of the Federal program in weather modification, to the extent that such a structure has existed, can be

⁴⁸ Testimony of Dr. Alfred J. Eggers, Jr., Assistant Director for Research Applications, National Science Foundation in U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, "Weather Modification," hearings, 94th Cong., 2d sess., June 15-18, 1976, Washington, D.C., U.S. Government Printing Office, 1976, p. 109.

⁴⁹ U.S. Domestic Council, Environmental Resources Committee, Subcommittee on Climate Change, "The Federal Role in Weather Modification," Washington, D.C., December 1975, p. 19.

⁵⁰ *Ibid.*, app. A, pp. A-2 and A-3.

conveniently divided into three periods, each roughly a decade long. These periods and the characteristics of the Federal organization during each are discussed briefly below.

Federal structure; 1946-57

As seen in the earlier historical account of weather modification, in the period from 1946 through 1957 practically all projects in the United States were conducted by private individuals and by industry supported through private funds. What activities the U.S. agencies did support were both mission oriented and mostly uncoordinated. The Defense Department developed an early research program, specifically in seeding technology and hardware. Since World War II, the Air Force had a continuing need to dissipate fog, and the Korean war and SAC missions during this period required airports to be open to permit unrestricted flights. The Navy developed a strong research capability at its China Lake, Calif., laboratory, concentrating on seeding devices and materials. Project Cirrus, a joint project of the Army Signal Corps, the Navy, and the Air Force, was initiated by the Defense Department in 1947 and continued through 1952.

Civilian implications for weather modification were investigated by the U.S. Weather Bureau of the Commerce Department in 1948 as part of its cloud physics program. The Bureau's early position, however, seemed to lack enthusiasm for a research program at the time, largely reflecting agency conservatism and some unwillingness to be caught up in a technology that was fraught with exaggerated claims of commercial rainmakers.⁵¹ This early negative outlook of the Weather Bureau was modified in the late 1960's when its successive parent organizations, the Environmental Science Services Administration (ESSA) and the National Oceanic and Atmospheric Administration (NOAA), inaugurated a fresh interest in a weather modification research program. The Weather Bureau did participate with the Navy in project SCUD in 1953-54 along the east coast, in an attempt to modify the behavior of extratropical cyclones by artificial nucleation.

The third Federal agency conducting weather modification research during this period was the Forest Service of the U.S. Department of Agriculture, which in 1953 initiated Project Skyfire, aimed at suppressing lightning, a major cause of forest fires. This project received joint support later during the 1960's from the National Science Foundation, and, until its demise in 1976, was the longest running single Federal weather modification research project.

Confusion and uncertainty in the state of weather modification, owing to a mixed reaction to achievements and claims of achievement of weather modification operators and to the lack of a cohesive research program in the Federal Government, led to the establishment in 1953 of the Advisory Committee on Weather Control, by Public Law 83-256. During the conduct of the intensive investigation of the subject by the Advisory Committee between 1953 and

⁵¹ Communications from F. W. Reichelderfer, Chief of the U.S. Weather Bureau, in U.S. Congress, Senate, Committees on Interior and Insular Affairs, Interstate and Foreign Commerce, and Agriculture and Forestry, "Weather Control and Augmented Potable Water Supply," joint hearings, 82d Cong., 1st sess., Mar. 14, 15, 16, 19 and Apr. 5, 1951, Washington, D.C., U.S. Government Printing Office, 1951, pp. 37-47.

1957, the committee seems to have provided somewhat of a coordination function and even some modicum of direction to the Federal effort it was studying. There was support in the Congress for both the formulation and the Federal management by the Advisory Committee of a 5-year Federal-State weather modification research program, to be conducted by the committee, the States, universities, and private institutions.⁵² The Advisory Committee favored an existing Federal agency, however, for this proposed management function.

Federal structure; 1958-68

The Advisory Committee, reporting in 1957, provided a setting for progress over the next 10 years, as it presented elements of a national policy and guidelines for future development of a research program. A former NSF program manager for weather modification, Earl G. Droessler, recently praised the work of the Advisory Committee:

The Committee did a remarkable job for weather modification. Perhaps, most importantly, its careful study and reporting in the 1950's gave a measure of respect, cohesion, and momentum for the field of weather modification, and thus provided a setting for progress over the next decade and more. Prior to the work of the committee, the field was plagued with tension and uncertainty.⁵³

Encouraging a wide research program in meteorology as the essential foundation for understanding weather modification, the Advisory Committee named the National Science Foundation as its recommended agency for sponsoring the required research program. Accordingly, the Congress, when it enacted Public Law 85-510, directed the NSF to initiate and support a program in weather modification and effectively named the NSF as lead Federal agency for weather modification.

Weather modification research enjoyed a position of high value and priority among the top leadership of the Foundation.⁵⁴ The NSF promoted a vigorous research program through grants to universities, scientific societies and the National Academy of Sciences, industry, and agencies of the Federal Government and established an Advisory Panel for Weather Modification, which reported to the Foundation. A series of 10 annual reports on weather modification were published by the NSF for fiscal years 1959 through 1968. Recognizing the severe shortage of trained personnel, the NSF established the policy of financing graduate and postgraduate training as part of its grant support program, stating in its second annual report, "In the field of weather modification our greatest deficiency today is skilled manpower."⁵⁵

At the working level, representatives of nine Government agencies were called together by the NSF to form the Interagency Conference on Weather Modification to afford a mechanism for communication on weather modification activities and to plan and develop cooperative

⁵² See, for example, S. 86 and companion House bills, H.R. 3631, H.R. 5232, H.R. 5954, and H.R. 5958, introduced in the 85th Congress during 1957.

⁵³ Droessler, Earl G., "Weather Modification: Federal Policies, Funding from all Sources, Interagency Coordination," background paper prepared for the U.S. Department of Commerce Weather Modification Advisory Board, Raleigh, N.C., Mar. 1, 1977, p. 1.

⁵⁴ *Ibid.*, p. 2.

⁵⁵ National Science Foundation, "Weather Modification; Second Annual Report for Fiscal Year ended June 30, 1960," Washington, D.C., U.S. Government Printing Office, June 16, 1961, p. 1.

projects.⁵⁶ Joint Federal projects were established between the Foundation and the Departments of Agriculture, Commerce, and Interior. During this period the Congress, wanting to support more applied research directed toward a major problem, such as requirements for more precipitation in the West, appropriated funds for what was to become a major weather modification program under the Bureau of Reclamation in the Department of the Interior. The Foundation warmly endorsed the Bureau of Reclamation's "Project Skywater" and has since funded many of the research projects associated with this program.⁵⁷

Federal structure; 1968-77

The lead agency responsibilities and authorities of the National Science Foundation acquired in 1958 under Public Law 85-510 were abrogated by Public Law 90-407, enacted July 18, 1968, which became effective September 1, 1968. A lapse in Federal policy and Federal structure has since occurred as a result of congressional and executive inaction, although after a hiatus of over 3 years, some responsibility was given to NOAA in 1971; namely, that for collecting and disseminating information on weather modification projects in the United States. This requirement, directed by Public Law 92-205, of December 18, 1971, has been the single Federal weather modification function prescribed by law until 1976, when Public Law 94-490 required the Secretary of Commerce to conduct a study to recommend a national policy and a research program in weather modification. The lead agency responsibility has never been reassigned, and Federal leadership for research purposes is dispersed among the several agencies.

The only semblance of weather modification leadership in the Federal structure during this period has been through the coordination mechanism of the Interdepartmental Committee for Atmospheric Sciences (ICAS). The ICAS has established some policy guidelines and has sponsored activities, such as the annual interagency weather modification conferences, intended to foster cooperation among agency programs. It has not assumed a management role nor has it sought to intervene in the budgeting processes by which the several agency programs are supported. The activities of the ICAS are discussed in more detail in a section to follow on coordination of Federal weather modification activities.

Future Federal organization for weather modification

The present intensive study underway within the Department of Commerce, as directed by the National Weather Modification Policy Act of 1976, Public Law 94-490, may be laying the groundwork for a clear Federal policy in weather modification, after a 10-year lapse in Federal leadership and two decades after the first major Federal weather modification study was submitted to the President and the Congress. The new approach will benefit from scientific and technical advances as well as the greater attention which has been given in recent

⁵⁶ Ten annual interagency conferences on weather modification were sponsored by the National Science Foundation through 1968. Since that year, when the lead agency role was taken from the NSF by Public Law 90-407, the annual interagency conference has been sponsored by the Interdepartmental Committee for Atmospheric Sciences (ICAS). The 11th conference, sponsored by ICAS, was conducted by the NSF at the request of ICAS; beginning with the 12th, the annual conference have been conducted by NOAA, at the request of ICAS, the official sponsor.

⁵⁷ Dressler, "Weather Modification: Federal Policies, Funding from all Sources, Interagency Coordination," 1977, p. 4.

years to legal, social, economic, ecological, and international aspects of the subject. Part of the national policy which will presumably be established by the Congress following the study (very likely during the 96th Congress) will be a reorganized or reconstituted Federal structure for leading and managing the Federal activities in weather modification.

Recognizing that most studies of the past decade have proposed solving the apparent fragmentation of Federal projects and responsibilities by redesignating a lead agency, and also observing some of the objections and shortcomings of such a designation, the Commerce Department's Weather Modification Advisory Board has considered various options for structuring the Federal program. One possible option the Board is considering in its study is the creation of a special agency for weather modification, "with a mandate to learn what needs to be learned about weather modification and to insure regulation of its practice."⁵⁸ The new agency would "plan, budget, spur, supervise, and continually evaluate a Federal program of research and development, designed to enhance the atmospheric environment." Under this concept existing agency projects would become part of a coordinated Federal effort, and future projects would be presented to the Congress and to the Executive "as an understandable part of a coherent R and D strategy."⁵⁹

The Advisory Board has had difficulty in deciding where such a new agency should be placed in the executive structure. Presumably it could be made part of an existing structure or it could be established as a "semi-autonomous" agency attached to an existing department for administrative purposes and support. With the creation of a Department of Natural Resources, as has been proposed, a logical departmental home for the suggested weather modification agency would be found. The Board further suggests that such a new agency, regardless of its location in the Federal structure, should work closely with a small (five- to nine-member) Advisory Board, composed of people acquainted with atmospheric sciences, user needs, operational realities, advantages of costs and benefits, and "the broader national and international issues involved."⁶⁰

The current thinking of the Weather Modification Advisory Board also includes a laboratory center as part of the proposed new agency, one newly established or an existing Federal laboratory converted to weather modification research. While some research and development would be conducted "in house" by the agency, portions of the coordinated research effort would be allocated to other Federal agencies or by contract to universities and other non-Federal institutions.⁶¹

Droessler has also observed increased individual support for the concept of a weather modification national laboratory. He suggests that the location of such a center in the Federal structure should be determined by its principal research thrust. If basic scientific research, such as that which "undergirds" weather modification applications, is primary, he suggests that NSF should have the responsibility. If the focus of the new proposed laboratory should be on severe storm amelioration,

⁵⁸ Cleveland, "A U.S. Policy to Enhance the Atmospheric Environment," discussion paper by the Weather Modification Advisory Board, Oct. 21, 1977, pp. 23-24.

⁵⁹ *Ibid.*, p. 24.

⁶⁰ *Ibid.*

⁶¹ *Ibid.*, p. 25.

including hurricane research, NOAA should be the management choice. Finally, if research of the new laboratory is aimed toward the impacts of weather modification on agriculture, the U.S. Department of Agriculture should be directed to establish and manage the facility.⁶²

A number of bills were introduced in the Congress from time to time which would have established within one agency or another a single agency with responsibility for managing a Federal weather modification program. For example, S. 2875 in the 89th Congress would have created in the Department of the Interior a central scientific and engineering facility and regional research and operations centers. In the same Congress, S. 2916, which did pass the Senate, would have provided much the same structure within the Department of Commerce. Both bills permitted weather modification research in support of missions by the other Federal agencies, but established a focal point for research and for other management functions in the Department of the Interior or the Department of Commerce, respectively.⁶³

In addition to management of Federal research programs and coordination of these programs, the Federal weather modification organizational structure must also be concerned with other functions. These could include planning, project review, data collection and monitoring, regulation, licensing, and indemnification. The institutional arrangement within which these activities are handled could be part of the agency with prime research responsibility, or some or all of these functions could be assigned elsewhere. For example, the State Department will presumably continue to exercise appropriate authorities with regard to international programs or U.S. programs with potential impacts on other nations, though responsibility for cooperation on the scientific and technical aspects of such projects would quite naturally be given to one or more research agencies. Assignment of some of these functions might be to other agencies or to special commissions, established as in some States, to deal with regulation, licensing, and indemnification.

Grant argues that "the extensive multidisciplinary nature of and the potential impact on large segments of society by weather modification demands great breadth in the organizational structure to manage the development of weather modification."⁶⁴ He continues:

In view of these complex involvements and interactions, it is clear that the governmental organizational structure needs to be much broader than the mission interests of the respective Federal agencies. Presently, coordination is effected through ICAS. More is required. The present program in weather modification is too fragmented for optimal utilization of resources to concentrate on all aspects of the priority problems. Weather modification has not moved to the stage where research should be concentrated in the respective mission agencies.

Many of the priorities and problems are basic to weather modification itself and must be resolved and tested before emphasis is placed on the respective mis-

⁶² Droessler, "Weather Modification: Federal Policies, Funding From All Sources, Inter-agency Coordination," 1977, pp. 10-11.

⁶³ For analysis of these and other related bills concerned with Federal organization for weather modification see Johnson, Ralph W., "Federal Organization for Control of Weather Modification." In Howard J. Taubenfeld (editor), "Controlling the Weather," New York, Dunellen, 1970, pp. 145-158.

⁶⁴ Grant, Lewis O., testimony in: U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, "Weather Modification," hearings, 94th Cong., 2d sess., June 15-18, 1977, Washington, D.C., U.S. Government Printing Office, 1976, p. 290.

sion users. Present fragmentation of effort, combined with subcritical support levels, retards adequate progress toward the goal of problem resolution and development of application capability.

I suggest that a commission-type approach be considered. This would permit representation of various weather modification missions by researchers, users, and the general public. Such a commission could develop a comprehensive and coordinated national weather modification policy and program of weather modification research. . . . A positive national program and funding levels could be recommended to Congress. I believe that management of the program through this commission for the next five to ten years should also be considered. The highest standards possible and the broadest representation possible should be required for this commission and its staff.

As the technological capability develops and can respond to various uses, the full responsibility for the respective uses could transfer to the mission agencies at that time. Continued involvement by the agencies during the development stages could make a smooth transition possible. If the national research and development program is organized and managed through such a commission, the commission should not have the dual role of regulating weather modification at the same time it has the responsibility for its development.⁶⁵

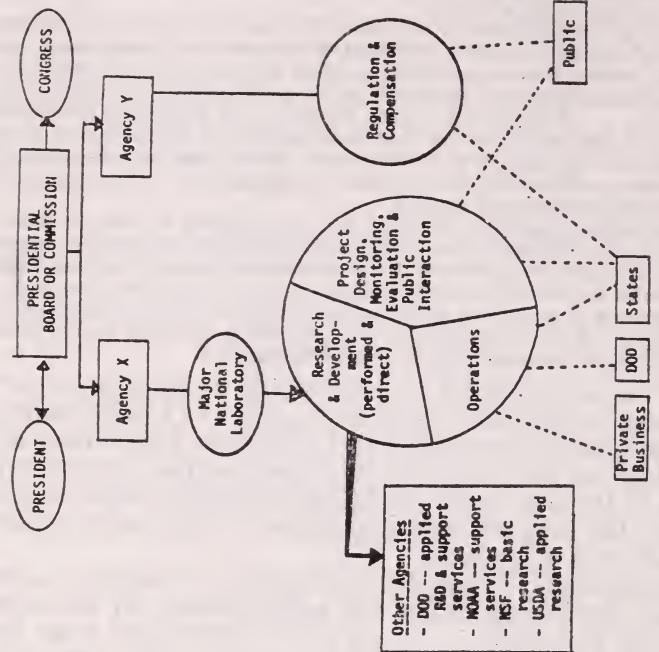
Changnon has recommended an almost total reorganization of the Federal weather modification structure in order to handle better the current major research responsibilities; evaluation efforts needed immediately, which are not being addressed; and readiness to perform responsibilities of the near future, including operations, regulation, and compensation. He suggests two approaches to this reorganization, shown schematically in figure 1.⁶⁶

In his first approach, Changnon would place all weather modification activities, except regulation and compensation, in one agency (Agency X, fig. 1a), either a new agency or a division of one existing. From a weather modification and a user standpoint the likely candidates proposed among existing agencies are the U.S. Department of Agriculture and NOAA. This primary agency would develop a national laboratory which would both conduct research and development and also subcontract such efforts. The agency and its laboratory would be responsible for program design, monitoring, and evaluation of all experimental and operational projects and would report results to the regulatory agency (Agency Y, fig. 1a). The laboratory would also be responsible for Federal operational efforts and for development of guidelines for private operators. Close interaction would be required with the States, private business, and the public within operational regions. Agency Y could be a new agency or an existing one, such as the Environmental Protection Agency or NOAA, provided that NOAA is not also chosen as Agency X. Agency Y would also develop and administer compensatory mechanisms to benefit those identified as losers as a result of weather modification programs. This first approach would also include a Presidential board or commission of appointed non-Federal members with statutory responsibility for reporting annually to the President and the Congress on all weather modification activities performed by Agencies X and Y.⁶⁷

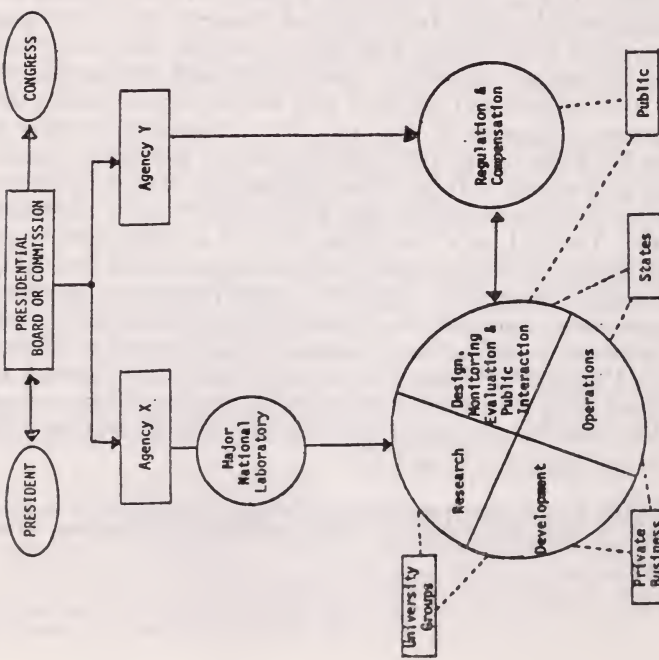
⁶⁵ *Ibid.*, pp. 290-291.

⁶⁶ Changnon, Stanley A., Jr., "The Federal Role in Weather Modification," background paper prepared for the U.S. Department of Commerce Weather Modification Advisory Board, Urbana, Ill., Mar. 9, 1977, pp. 24-27.

⁶⁷ *Ibid.*, pp. 25-26.



(a) First Approach



(b) Second Approach

FIGURE 1.—Two approaches suggested by Changnon, for reorganization of Federal weather modification activities structure. (From Changnon, "The Federal Role in Weather Modification," 1977.)

In Changnon's second organizational approach, there are similarities to the first, but current research activities would be retained with some Federal agencies (see fig. 1b). Agency Y would handle regulatory-compensatory functions as in the first approach, and a Presidential board or commission would make critical annual assessments of the progress and activities in all agencies as well as report annually to the President and the Congress. A major agency, new or existing, would have direct responsibility for its own activities as well as the research programs of other Federal agencies. Thus, existing programs of the Departments of Agriculture, Commerce, and Defense and of the National Science Foundation would continue, but under direction of Agency X, each program directed toward specific agency missions. Other agencies currently involved in weather modification—the Departments of Energy, Interior, and Transportation, and the National Aeronautics and Space Administration—would be stripped of their programs.⁶⁸

In his 1970 paper, Johnson explored some of the more plausible institutional arrangements that could be designed for Federal management of weather modification.⁶⁹ He identified the various functions into which such management responsibilities could be divided and attempted to show the optimum ways that each function might be handled. A major point which Johnson made then, which is still appropriate today, is that the Federal institutional arrangements should depend on the pace of the development of weather modification technology. Thus, establishment of a full-blown structure dealing with all weather modification functions may not yet be advisable, even in 1978.

COORDINATION AND ADVISORY MECHANISMS FOR FEDERAL WEATHER MODIFICATION PROGRAMS

Introduction

There are a number of formal and informal mechanisms by which the Federal research program in weather modification is coordinated, and there exist a variety of panels, committees, and organizations—some governmental and some quasi-governmental—which provide advice and a forum for exchange of information on various aspects of weather modification. Coordination is also achieved through professional society meetings and through workshops on specific problems which are scheduled by Federal agencies from time to time.

Much of the coordination of weather modification projects attempted by agency representatives consists of exchange of information on the scope and the funding of the different agency programs, this exchange accomplished through meetings of committees, conferences, and panels. Through such exchange it is expected that consensus can be approached and coordination achieved.

Various opinions have been expressed on the degree to which Federal weather modification programs are coordinated. According to Droessler, "The weather modification research program probably is as well coordinated as any research effort within the Federal Govern-

⁶⁸ *Ibid.*, p. 26-27.

⁶⁹ Johnson, "Federal Organization or Control of Weather Modification," 1970, pp. 131-180.

ment."⁷⁰ Dr. Alfred J. Eggers, Jr., former Assistant Director for Research Applications at the NSF has recently stated that :

In summary, the current programs in weather modification of the various agencies appear to be sufficiently well coordinated to avoid unknowing duplications of efforts, but not so rigidly coordinated as to unduly narrow the range of scientific approaches being taken to respond to several agency missions. Weather modification is not a well-developed technology. Given the current state of the art, the current mechanisms of coordination appear to be appropriate and adequate.⁷¹

A contrary view was stated in the report by the General Accounting Office (GAO) on the need for a national program in weather modification research :

A national program in weather modification research is necessary to effectively control activities of the agencies involved. Although this need was recognized as early as 1966, the organizations established to coordinate these activities have not developed and implemented an effective overall national program. Although coordinating groups have tried to develop national programs, their implementation has not been successful. The present fragmentation of research efforts has made it extremely difficult for agencies to conduct effective field research which, in the case of weather modification, must precede operational activities.⁷²

In answer to this conclusion of the GAO report that the Federal weather modification research program was not effectively coordinated, the Office of Management and Budget (OMB) replied that :

The point on ineffective coordination of research projects is not supported by fact. Weather modification research is well coordinated by the Interdepartmental Committee on Atmospheric Sciences (ICAS). ICAS meets monthly and provides members and observers the opportunity to exchange information in a timely manner. Interdepartmental coordination of weather modification activities has been, in our opinion, achieved through the efforts of ICAS and the member agencies in an exemplary manner.⁷³

The several means, formal and informal, by which the Federal weather modification research program is coordinated, or by which advice on agency programs is provided, are identified and discussed in the following subsections.

The Interdepartmental Committee for Atmospheric Sciences (ICAS)

The principal mechanism for coordination of Federal weather modification programs has been the ICAS. Weather modification has been a principal concern of the committee since its inception in 1959, and it was recently stated that the ICAS has spent more effort dealing with weather modification than with any other single topic.⁷⁴ This close tie and continued interest by the ICAS on weather modification was instilled from its beginning, when it incorporated functions of an existing interagency weather modification committee.

In 1958, the National Science Foundation recognized the need for a formal interagency coordinating mechanism as part of its newly

⁷⁰ Droessler, "Weather Modification: Federal Policies, Funding From All Sources, Interagency Coordination," 1977, p. 14.

⁷¹ Eggers, testimony before House Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, 1976, pp. 111-112.

⁷² Comptroller of the United States, "Need for a National Weather Modification Research Program," report to the Congress, General Accounting Office, B-133202, Washington, D.C., Aug. 23, 1974, p. 23.

⁷³ Sawhill, John C., Associate Director, Office of Management and Budget, in a letter to Morton E. Henig, Associate Director, Manpower and Welfare Division, General Accounting Office, Sept. 12, 1973.

⁷⁴ Todd, Edward P. (Chairman of the Interdepartmental Committee for Atmospheric Sciences), in testimony at hearings on weather modification before the Subcommittee on the Environment and the Atmosphere, Committee on Science and Technology, U.S. House of Representatives, June 16, 1976, p. 127.

assigned statutory responsibilities as weather modification lead agency and established an Interdepartmental Committee on Weather Modification. A year later the newly established Federal Council for Science and Technology (FCST) considered the need for a committee to cover atmospheric sciences; and, upon agreement between the President's science adviser and the Director of the NSF, the existing Interdepartmental Committee on Weather Modification was formally reconstituted as the FCST's Interdepartmental Committee for Atmospheric Sciences. ICAS held its first meeting September 9, 1959.^{75, 76}

The National Science and Technology Policy, Organization, and Priorities Act of 1976 (Public Law 94-282) was signed May 11, 1976, creating the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). Under the new law, the ICAS, a subcommittee of the former FCST, should have ceased to function, since the parent council was abolished. Prior to the signing of Public Law 94-282, however, the FCST Chairman addressed a letter to all FCST subcommittee chairmen, indicating that these committees should continue their normal activities until such time as a new organizational structure for FCCSET could be established and begin to function. Subsequently, the FCCSET established several supporting subcommittees, one of which is the Committee on Oceans and Atmosphere (CAO). The ICAS was formally adopted by the CAO on a temporary basis, pending creation of its own subcommittee structure. Consequently, the ICAS has continued to hold meetings and published its customary annual report, under authority given by the Chairman of the CAO.⁷⁷ Although the future of the ICAS is uncertain, a recent survey indicated that its members favored continuation of an "ICAS-like" activity. The committee thus intends to meet and conduct business, at a reduced level of activity, until the CAO organization becomes firm and is in full operation.⁷⁸

The coordination activities of the ICAS for the Federal weather modification research program has been particularly valuable, especially since 1968, when the National Science Foundation was relieved of its lead agency role. Prior to that time the NSF had provided leadership to the Federal program in a number of ways. Beginning in 1969 the ICAS has continued the sponsorship of the annual Interagency Conference on Weather Modification, which the NSF had initiated 10 years earlier. This annual conference is a "partial mechanism to promote effective communications and a source of shared responsibility among the Washington program managers and the field program managers."⁷⁹ These conferences provide a forum for exchanging in-

⁷⁵ Special Commission on Weather Modification. "Weather and Climate Modification," report to the National Science Foundation, NSF 66-3, Washington, D.C., Dec. 20, 1965, p. 131.

⁷⁶ A discussion of the history and activities of the Federal Council for Science and Technology is found in the following report: Bates, Dorothy M. (coordinator). Interagency Coordination of Federal Scientific Research and Development; The Federal Council for Science and Technology. Report prepared by the Science Policy Research Division of the Congressional Research Service for the Subcommittee on Domestic and International Scientific Planning and Analysis. Committee on Science and Technology, U.S. House of Representatives. Committee Print, Washington, U.S. Government Printing Office, 1976. 447 pp. Of special interest in this report is a case history of the ICAS: Morrison, Robert E. The Interdepartmental Committee for Atmospheric Sciences: a case history. App. I, pp. 381-396. (Included in the case history is a list of ICAS publications through July 1976.)

⁷⁷ Federal Coordinating Council for Science, Engineering, and Technology. Committee on Oceans and Atmosphere. Interdepartmental Committee for Atmospheric Sciences. National Atmospheric Sciences Program: fiscal year 1978. ICAS 21-FY78. September 1977, 96 pp.

⁷⁸ *Ibid.*, p. iii.

⁷⁹ Droessler. Weather Modification: Federal Policies, Funding From All Sources, Interagency Coordination. p. 14.

formation on progress in past years, plans for the coming year, thoughts on future projects, and suggestions on solutions to various problems encountered. The annual conferences, under ICAS sponsorship, beginning with the 11th in 1969, have been hosted, at the request of the ICAS, by the NSF and by NOAA. The NSF hosted the 11th conference, and NOAA has hosted all of those since, starting with the 12th.

At regular meetings of the ICAS, major weather modification programs of member agencies are frequently reviewed through project briefings by Washington and field program managers. The ICAS has formed standing and ad hoc panels to which are assigned responsibilities for specific facets of the weather modification program. Panels in the past have worked on problems such as legislation on weather modification, a national plan for the Federal weather modification program, and a plan for accelerating progress in weather modification. These panels address topics as requested by the parent committee and make recommendations to the ICAS for actions as required. Two specific ICAS reports have dealt with the subject.^{80, 81}

Besides formal coordination afforded by the annual conferences, discussions at ICAS meetings, and studies undertaken by ICAS panels, there is also included an account of the Federal weather modification program as an appendix to the annual ICAS report.⁸² In the early years of the ICAS member agencies reported their funding for the general support of atmospheric sciences only in two broad categories, meteorology and aeronomy. Beginning with fiscal year 1963 the agencies began to identify specific funds for weather modification, and this information has been included since in the annual ICAS report along with brief descriptions of member agency programs.

It was at the request of the ICAS and with the cooperation of the Secretary of Commerce that Federal agencies began to report their weather modification research activities to NOAA as of November 1, 1973.⁸³ Public Law 92-205 requires such reporting by all nonfederally sponsored weather modification projects in the United States and its territories.⁸⁴ This voluntary reporting by Federal agencies, initiated by the ICAS, thus assured that the central source of information on weather modification projects in the United States is reasonably complete.

In its 1971 annual report, the ICAS identified selected major research projects in weather modification which were designated as national projects.⁸⁵ These national projects were formulated by the ICAS members through combination of agency projects in each of seven categories of weather modification assigning lead agency responsibilities in most cases to that agency with the most significant ongoing

⁸⁰ Newell, Homer E. A recommended national program in weather modification. Federal Council for Science and Technology. Interdepartmental Committee for Atmospheric Sciences ICAS report No. 10a. Washington, D.C., November 1966. 93 pp.

⁸¹ Federal Council for Science and Technology. Interdepartmental Committee for Atmospheric Sciences. ICAS report No. 15a. Washington, D.C., June 1971, 50 pp.

⁸² The most recent account is found in the latest ICAS annual report: Federal Coordinating Council for Science, Engineering, and Technology. Interdepartmental Committee for Atmospheric Sciences. ICAS 21-FY78. Pp. 87-94.

⁸³ Federal Council for Science and Technology. Interdepartmental Committee for Atmospheric Sciences. National Atmospheric Sciences Program: fiscal year 1975. ICAS 18-FY 75. Washington, D.C., May 1974, p. iv.

⁸⁴ See earlier discussions on Public Law 92-205 under congressional activities, p. 197, and under the administration of the reporting program by NOAA, p. 232.

⁸⁵ Federal Council for Science and Technology. Interdepartmental Committee for Atmospheric Sciences. National Atmospheric Sciences Program: fiscal year 1972. ICAS report No. 15, March 1971, pp. 5-6.

project(s) within each category. The proposed national projects and respective lead agencies were:

1. *National Colorado River Basin pilot project.*—Bureau of Reclamation, Department of the Interior: To test the feasibility of applying a cloud seeding technology, proven effective under certain conditions, to a river basin for a winter season to augment the seasonal snowpack.

2. *National hurricane modification project.*—National Oceanic and Atmospheric Administration, Department of Commerce: To develop a seeding technology and associated mathematical models to reduce the maximum surface winds associated with hurricanes.

3. *National lightning suppression project.*—Forest Service, Department of Agriculture: To develop a seeding technology and associated physical and mathematical models to reduce the frequency of forest fire-starting lightning strokes from cumulonimbus clouds.

4. *National cumulus modification project.*—National Oceanic and Atmospheric Administration, Department of Commerce: To develop a seeding technology and associated mathematical models to promote the growth of cumulus clouds in order to increase the resulting natural rainfall in areas where needed.

5. *National hail research experiment.*—National Science Foundation: To develop a seeding technology and associated mathematical models to reduce the incidence of damaging hailfall from cumulonimbus clouds without adversely affecting the associated rainfall.

6. *National Great Lakes snow redistribution project.*—National Oceanic and Atmospheric Administration, Department of Commerce: To develop a seeding technology and associated mathematical models to spread the heavy snowfall of the Great Lakes coastal region farther inland.

7. *National fog modification project.*—Federal Aviation Administration, Department of Transportation: To develop seeding or other technology and associated physical and mathematical models to reduce the visibility restrictions imposed by warm and cold fogs where and to the extent needed.⁸⁶

Although most of these national projects were continued for at least a while, some of them failed to materialize, as hoped, as truly national projects. Few received the expected interagency support and planning effort envisioned; however, in spite of these deficiencies, some were pursued by the lead agencies, largely as major single-agency projects. The National Hail Research Experiment, conducted by the National Science Foundation perhaps came closest to a truly national project and, with assistance from other Federal agencies, continued through 1976.⁸⁷ A critique of the national projects in weather modification was included in the 1974 report of the General Accounting Office on the need for a national program in weather modification research.⁸⁸

In answer to charges that the Federal weather modification research effort has been poorly coordinated, a conclusion of various studies that have been made, the Chairman of the ICAS recently said, "Within the ICAS we have considered coordination as it is defined, namely, har-

⁸⁶ *Ibid.*

⁸⁷ See discussion of the national hail research project under following section on the program of the National Science Foundation, p. 274 ff.

⁸⁸ Comptroller General of the United States. Need for a national weather modification research program. B-133202, 1974. Pp. 16-22.

monious action, communication within Government. I submit that, using that definition, the weather modification research program is probably as well coordinated as any effort within the Government, with the possible exception of programs that are entirely within the purview of a single agency. The critics of the ICAS coordination effort, however, seem to have been interpreting coordination as including management; the ICAS is not a management agent."⁸⁹

The National Academy of Sciences/Committee on Atmospheric Sciences (NAS/CAS)

Advice has been provided to the Federal Government through advisory panels, intensive studies, and published reports on weather modification, by the National Academy of Sciences. The Committee on Atmospheric Sciences (CAS) was organized under the National Research Council of the Academy in 1956, with the stated purpose of addressing "... itself to the task of viewing in broad perspective the present activities in research and education, the exchange of information and related matters as they affect the status of the field and future progress toward a balanced national program in the atmospheric sciences, and participation in international programs."⁹⁰

At the request of, and sponsored by, the National Science Foundation, a conference was organized and conducted by the NAS in 1959, in which meteorologists, mathematicians, and statisticians met to examine needs in weather modification experiments. The report on this Skyline Conference on the Design and Conduct of Experiments in Weather Modification,⁹¹ which had been held in the Shenandoah National Park in Virginia, made a strong plea for careful statistical design of weather modification experiments, pointing out the need for long-term programs, standardization of design, the need for basic research in cloud physics, and the requirement for cooperation between meteorologists and statisticians.

In March 1963, the CAS appointed a Panel on Weather and Climate Modification, "to undertake a deliberate and thoughtful review of the present status and activities in this field and of its potential and limitations in the future."⁹² The Panel was chaired by Dr. Gordon J. F. MacDonald and was comprised of 11 Government and non-Government members. The Academy Panel worked closely with the NSF's Special Commission on Weather Modification, which had been established in 1964. Three reports were subsequently published by the Panel, based on in-depth studies which had been undertaken.

The first of these, "Scientific Problems of Weather Modification," appeared in 1964;⁹³ the second, "Weather and Climate Modification: Problems and Prospects," was published in 1966;⁹⁴ and the third,

⁸⁹ Todd. Testimony before House Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, June 1976, p. 87.

⁹⁰ National Academy of Sciences, National Academy of Engineering, Institute of Medicine, National Research Council. Organization and members: 1975-1976. Washington, D.C., October 1975, p. 81.

⁹¹ National Academy of Sciences, National Research Council. Report of the Skyline Conference on the Design and Conduct of Experiments in Weather Modification. NAS-NRC Publication 742. Washington, D.C., 1959, 24 pp.

⁹² National Academy of Sciences, National Research Council, Committee on Atmospheric Sciences. Weather and Climate Modification: Problems and Prospects. Volume I, summary and recommendations. Final report of the Panel on Weather and Climate Modification. Publication No. 1350, Washington, D.C., 1966, p. vii.

⁹³ National Academy of Sciences, National Research Council, Committee on Atmospheric Sciences. Scientific Problems of Weather Modification: a Report of the Panel on Weather and Climate Modification. NAS-NRC Publication No. 1236, Washington, D.C., 1964, 56 pp.

⁹⁴ National Academy of Sciences. Publication No. 1350, 1966. In two volumes. 40+212 pp.

"Weather Modification: Problems and Progress," came out in 1973.⁹⁵

In addition to the reports produced by the panel, two other National Academy studies were conducted in the 1970's which, in part, addressed aspects of weather modification. The Committee on Atmospheric Sciences surveyed the field in a chapter in its 1971 publication, "The Atmospheric Sciences and Man's Needs; Priorities for the Future."⁹⁶ In 1976 a report was prepared by the Committee on Climate and Weather Fluctuations and Agricultural Production of the Board on Agriculture and Renewable Resources. A full chapter is devoted to weather modification in this report, entitled "Climate and Food; Climatic Fluctuation and U.S. Agricultural Production."⁹⁷

Project Stormfury, a major hurricane modification project of the Commerce Department's National Oceanic and Atmospheric Administration (NOAA),⁹⁸ from its inception has had an advisory panel composed of prominent scientists, primarily meteorologists. Currently, the panel is appointed by and operates under the auspices of the National Academy of Sciences, Committee on Atmospheric Sciences. Members of the Stormfury Advisory Panel all come from either the academic community or from private industry. Not only does the Panel review program results and experimental designs and make recommendations, but it also conducts periodic scientific symposia before larger groups. A recent program review was held in September 1977, and a report on the review is in preparation.

The National Advisory Committee on Oceans and Atmosphere (NACOA)

This advisory committee was created by Public Law 92-125 on August 16, 1971, and was to be advisory to both the President and the Congress on the Nation's atmospheric and marine affairs and to the Secretary of Commerce with respect to the programs of the National Oceanic and Atmospheric Administration (NOAA). Among other duties, the committee was charged with assessing the status of U.S. atmospheric and oceanic activities and with submitting an annual report of its findings and recommendations to the President and the Congress. The Secretary of Commerce was also required, on behalf of the executive branch, to prepare comments on the NACOA recommendations. These comments are appended to each of the annual NACOA reports.

As originally constituted by Public Law 95-125, NACOA included 25 members, all non-Federal, appointed by the President, who also designated one of the members as chairman and one as vice chairman. Each department and agency of the Federal Government concerned with atmospheric and marine matters was to designate a senior policy official to participate as observer and to offer assistance as required. The Secretary of Commerce was to make available such staff, person-

⁹⁵ National Academy of Sciences. National Research Council. Committee on Atmospheric Sciences. *Weather Modification: Problems and Progress*. ISBN 0-309-02121-9. Washington, D.C., 1973. 280 pp.

⁹⁶ National Academy of Sciences. National Research Council. Committee on Atmospheric Sciences. *The Atmospheric Sciences and Man's Needs; Priorities for the Future*. ISBN 0-309-01912-5. Washington, D.C., May 1971, pp. 42-61.

⁹⁷ National Academy of Sciences. National Research Council. Board on Agriculture and Renewable Resources. *Climate and Food; Climatic Fluctuation and U.S. Agricultural Production*. ISBN 0-309-02522-2. Washington, D.C., 1976, pp. 131-162.

⁹⁸ For discussion of Project Stormfury, see p. 296 under weather modification programs of the Department of Commerce.

nel, information, and administrative services as reasonably required to carry out committee activities. The life of NACOA was extended and its appropriation authorization was increased successively by Public Laws 92-657 and 94-69 of October 25, 1972, and August 16, 1975, respectively. The 1971 act was repealed, however, by Public Law 95-63, of July 5, 1977, which effectively disbanded the previous committee and established a new NACOA. Although many of the provisions of the new law were similar to the previous one, the size of the committee was reduced from 25 to 18 members, appointed by the President, with the stipulation that members must be eminently qualified in knowledge and expertise in areas of direct concern to the committee, that is, in atmospheric- and marine-oriented disciplines.

Since its inception, the posture of NACOA has been to concentrate its studies on those important issues where it can make a significant contribution, recognizing that an attempt to review and evaluate every program and issue within its purview of responsibility could result in treating none of them well and could possibly duplicate what others are capable of doing better.⁹⁹ Among other important topics, weather modification has been the subject of examination, deliberation, and comment often throughout the 6 years of NACOA's existence.

Each of the six NACOA annual reports have contained discussion and recommendations on weather modification, which was one of the four major topics covered extensively in the first annual report.¹ NACOA's repeated position has been that there is a need for "a coordinated Federal effort to support the basic research needed to bring weather modification to the point of being an operational tool resting on a sound technical base" but that "major gaps remain, largely because no one agency has the responsibility for identifying and supporting those areas of basic study needed for further progress along a broad front."² Specific recommendations of NACOA on the Federal weather modification program will be discussed in the following chapter of this report on studies and recommendations.³

Other coordination and advisory mechanisms

Although overall coordination of the Federal weather modification programs has been an ICAS responsibility, there are other panels which assist certain agencies in connection with major research projects, and there have been various workshops on particular problem areas through which interagency consensus has been achieved. The NSF Weather Modification Advisory Panel has provided important guidance to the weather modification research activities of the NSF. The presence of representatives from both the Bureau of Reclamation and NOAA, the other agencies with major weather modification programs, was designed to assure a high level of coordination. The National Hail Research Experiment (NHRE) Advisory Panel of the NSF also has had representatives from these two agencies. Research proposals received by the NSF are reviewed by the Bureau

⁹⁹ National Advisory Committee on Oceans and Atmosphere. A report to the President and the Congress. First annual report. June 30, 1972. Washington, D.C., U.S. Government Printing Office, p. iv.

¹ *Ibid.*, pp. 19-29.

² National Advisory Committee on Oceans and Atmosphere, a report to the President and the Congress, sixth annual report. June 30, 1977, Washington, D.C., U.S. Government Printing Office, p. 76.

³ See Ch. 6.

of Reclamation and by NOAA, thus giving a direct input to these agencies in the decision process as to whether individual research proposals are to be funded by the NSF.⁴

The agencies coordinate directly with each other at the working level whenever the respective programs may benefit thereby. A close coordination mechanism was established, for example, between the National Hail Research Experiment (NHRE) of the NSF and the Bureau of Reclamation's High Plains Cooperative Program (HIPLEX), a useful and practical arrangement in view of the geographical proximity of the two projects in northeastern Colorado and northwestern Kansas, respectively.⁵

During the past few years workshops on various aspects and problem areas in weather modification have afforded additional opportunity for coordination. In 1975 the National Science Foundation sponsored a symposium/workshop on the suppression of hail as part of its National Hail Research Experiment.⁶ The NSF also sponsored a major workshop on inadvertent weather modification at Hartford, Conn., in May 1977.⁷ Another recent workshop sponsored by the NSF was held in August 1977 at Fort Collins, Colo., on extended space and time effects of planned weather modification activities.⁸

Since 1967, the Bureau of Reclamation has conducted nine conferences as part of its "Project Skywater," dealing with various special topics of particular concern to the projects and to planned weather modification in general. Some of these Skywater conferences have been jointly sponsored with other agencies, in particular, the National Science Foundation, and more recent conferences have been conducted in a workshop format. Following each conference proceedings have been published. The first conference was held at Denver, Colo., in 1967, on the subject of physics and chemistry of nucleation.⁹ The most recent conference was a workshop, held in November 1976, at Vail, Colo., on environmental aspects of precipitation management.¹⁰ One day of this conference was sponsored jointly with the National Science Foundation. A tenth Skywater Conference is a workshop scheduled for June 1978, at Lake Tahoe, Calif., where the topic will be the Sierra Cooperative Pilot Project of Skywater. This conference will follow a meeting at the same place, sponsored jointly by the American Meteorological Society and the Forest Service of the U.S. Department of Agriculture, on Sierra Nevada mountain meteorology.

Also of interest as a coordination mechanism was the November 1975, Special Regional Weather Modification Conference on Augmen-

⁴ Eggers, testimony before House Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, 1976, p. 110.

⁵ *Ibid.*, p. 111.

⁶ National Center for Atmospheric Research, NHRE symposium/workshop on hail and its suppression, working group reports, Estes Park, Colo., Sept. 21-28, 1976, "National Hail Research Experiment," technical report NCAR/7100-75/2, November 1975, 130 pp.

⁷ Robinson, G. D. (Principal Investigator), inadvertent weather modification workshop, May 23-27, 1977, Hartford, Conn., final report to the National Science Foundation, under grant No. ENV-77-10186, "Hartford, the Center for the Environment and Man, Inc.," November 1977, CEM Report 4215-604, 167 pp.

⁸ Brown, Keith J., Robert D. Elliott, and Max Edelstein (editors), "Transactions of Workshop on Extended Space and Time Effects of Weather Modification," Aug. 8-12, 1977, Fort Collins, Colo. Goleta, Calif., North American weather consultants, February 1978 (draft), 279 pp.

⁹ U.S. Department of the Interior, Bureau of Reclamation, "Physics and Chemistry of Nucleation," proceedings; Skywater Conference I, Denver, Colo., July 10-12, 1967, Denver, July 1967, 419 pp.

¹⁰ U.S. Department of the Interior, Bureau of Reclamation, "Precipitation, Man, and the Environment; an Overview of Skywater IX Conference," second week of November 1976, Vail, Colo., Denver, September 1977, 223 pp.

tation of Winter Orographic Precipitation in the Western United States, sponsored jointly by the American Meteorological Society, the Department of Water Resources of the State of California, the Weather Modification Association, and the Bureau of Reclamation.¹¹

In connection with Project Skywater, the Bureau of Reclamation has established a number of advisory boards and panels from time to time as the need has arisen. These groups have been composed of both Government and non-Government experts. In connection with the High Plains Cooperative Project (HIPLEX), the Bureau of Reclamation has also established citizens' panels to advise on local problems; these groups have included local government officials among other individuals. Similar local advisory groups have been planned for the Sierra Cooperative Pilot Project and are now being organized.

Another means of coordination is provided through the joint sponsorship of some Federal research efforts. For example, the weather modification simulation laboratory at the Colorado State University, funded through the National Science Foundation by three Federal agencies, is a facility used in support of a number of Federal projects. The National Science Foundation has funded a number of research studies which support the major weather modification programs of other agencies, particularly those of the Bureau of Reclamation and the National Oceanic and Atmospheric Administration.

A coordination and advisory role has also been played from time to time by the committees and panels which have been established to conduct major weather modification policy studies. Notable among these groups are the Advisory Committee on Weather Control, established by Congress in 1953, and the Weather Modification Advisory Board, impaneled by the Secretary of Commerce to implement requirements of the National Weather Modification Policy Act of 1976.¹²

Although not officially sponsored by the Federal Government, a forum for coordination and exchange of information on Federal as well as non-Federal programs is provided through the meetings and the journals of professional organizations. The American Meteorological Society (AMS) has sponsored six conferences specifically dealing with weather modification, at which the majority of the papers delivered have been related to Federal research projects and at which nearly all of the papers have been based on federally sponsored research. Exchange of information on Federal projects has also been afforded through the medium of AMS journals, particularly the "Bulletin of the American Meteorology Society" and the "Journal of Applied Meteorology." Among the various specialized AMS committees is the Committee on Weather Modification, concerned with advances and priorities in weather modification research, the greatest portion of which is supported in the United States by the Federal agencies. In addition, specialized conferences on some problem aspects of weather modification have been sponsored by the AMS, sometimes jointly with various Federal agencies.

¹¹ American Meteorological Society, Abstracts of Special Regional Weather Modification Conference: Augmentation of Winter Orographic Precipitation in the Western United States, Nov. 11-13, 1975, San Francisco, Calif. (Cosponsored by the U.S. Department of the Interior, Bureau of Reclamation; State of California, Department of Water Resources; and the Weather Modification Association, Boston (no publication date), 245 pp.

¹² The purpose, formation, activities, and recommendations of these committees are discussed in some detail in various other places in this report.

The Weather Modification Association (WMA) sponsors two professional meetings each year, sometimes jointly with the AMS or other professional organizations, and also published the "Journal of Weather Modification." These WMA mechanisms provide additional opportunities for coordination of Federal projects as information is exchanged among participants, many of whom are employees of Federal agencies or of contractors on Federal projects. The organization, purposes, and activities of the AMS, the WMA, and other nongovernmental organizations concerned with weather modification are discussed under the section on private organizations in chapter 8 of this report.¹³

Weather Modification Advisory Board

The National Weather Modification Policy Act of 1976, Public Law 94-490 of October 13, 1976, requires that the Secretary of Commerce "shall conduct a comprehensive investigation and study of the state of scientific knowledge concerning weather modification, the present state of development of weather modification technology, the problems impeding effective implementation of weather modification technology, and other related matters"; and that "the Secretary shall prepare and submit to the President and the Congress * * * a final report on the findings, conclusions, and recommendations of the study."¹⁴

The Secretary of Commerce responded to these requirements by appointing an 18-member non-Federal Weather Modification Advisory Board to conduct the study and prepare a report recommending a national weather modification policy and a national program of research and action to carry out the policy. Members of the Advisory Board, with their affiliations, and the charter to the Board from the Secretary are included in appendix K. The Board's final draft report is to be submitted to the Secretary for her approval and any necessary modifications, after which it will be transmitted to the President and the Congress.

Owing to the 1976 Presidential election and change of administration in January 1977, and because of procedures required by the Federal Advisory Committee Act, the Advisory Board was not officially appointed until April 1977. Consequently, much of the 1-year allotted time for the study had been lost and it was apparent that the report could not be completed by October 13, 1977, as required by Public Law 94-490. An extension of time, requested by the Secretary, was transmitted to both houses of the Congress, and a bill providing for such an extension was introduced in the Senate,¹⁵ but no action has been taken to date, and formal action by the Congress to extend the time for completion of the study seems unlikely. Meanwhile, the Advisory Board continued its study and report development, planning to deliver its report to the Secretary of Commerce by June 30, 1978. Following public hearings and receipt of comments from other executive branch agencies, it is anticipated that the Secretary will transmit the document to the Congress in the late summer or fall of 1978.¹⁶

¹³ See p. 389.

¹⁴ Public Law 94-490, Secs. 4 and 5. (The complete text of the law is included in app. I.)

¹⁵ S. 1938, introduced July 27, 1977, by Sen. Warren G. Magnuson.

¹⁶ This tentative schedule for completion and transmittal of the report is based on discussions by the Weather Modification Advisory Board at its ninth meeting, Apr. 4, 1978, in Washington, D.C.

The Advisory Board has met formally four times in Washington, D.C., and one time each in North Forks, N. Dak.; Boulder, Colo.; Champaign, Ill.; San Francisco, Calif.; Chicago, Ill.; Tulsa, Okla.; Atlanta, Ga.; and Aspen, Colo.—combining public hearings with working sessions. Subpanels and other ad hoc groups of Board members have also met numerous times to work on specific aspects of the study and to prepare draft sections of the report. At a hearing on October 26, 1977, the Chairman of the Advisory Board, Harlan Cleveland, briefed the Subcommittee on the Environment and the Atmosphere of the House Committee on Science and Technology, relating activities to date of the Board and submitting for the record a discussion paper which summarized the Board's thinking at the time.¹⁷

WEATHER MODIFICATION ACTIVITIES REPORTING PROGRAM

Background and regulations

Public Law 92-205 of December 18, 1971,¹⁸ requires reporting of basic information on all nonfederally sponsored weather modification activities in the United States and its territories to the Secretary of Commerce. The Secretary is further directed to maintain a record of weather modification activities taking place in the United States and to publish summaries of such information "from time to time."

Within the Commerce Department the National Oceanic and Atmospheric Administration (NOAA) has administered this program on behalf of the Secretary. Rules for carrying out the provisions of this legislation, published in the Federal Register,¹⁹ went into effect on November 1, 1972. The rules have since been revised and amended twice—on February 15, 1974,²⁰ to cover safety and environmental aspects of field activities and to consider possible interference with Federal research projects, and again on July 4, 1976,²¹ to modify certain reporting procedures. A copy of the rules and regulations currently in effect appears in appendix L. In the same appendix are copies of the forms and specific reporting instructions to be used for submission of required information to NOAA by weather modification operators.

Reporting requirements include initial, interim, and final reports. It is required that NOAA receive the initial report at least 10 days prior to the commencement of weather modification activities. The rules provide for exceptions whereby this 10-day rule may be waived under certain emergencies and also require filing a supplemental report if the initial report is subsequently found to contain inaccuracies, misstatements, or omissions or if project plans are changed. The interim report is required January 1 of each year (October 1 prior to the 1976 revision of the rules) unless the project has been terminated prior to that date. Upon completion of the project, a final report is due, and,

¹⁷ Weather Modification Advisory Board, "A U.S. Policy To Enhance the Atmospheric Environment," a discussion paper, Oct. 21, 1977, 29 pp. (Also appeared in record of hearing: U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, Weather Modification, 95th Cong., 1st sess., Oct. 21, 1977, pp. 20-49.)

¹⁸ See appendix I for a reproduction of Public Law 92-205 and see earlier section of this chapter under congressional activities for discussion of enactment of this law and those enacted since which have extended appropriations authorization through fiscal year 1980.

¹⁹ Federal Register, vol. 37, No. 208, Friday, Oct. 27, 1972.

²⁰ Federal Register, vol. 39, No. 10, Tuesday, Jan. 15, 1974.

²¹ Federal Register, vol. 41, No. 113, June 10, 1976.

until such final report is received by NOAA, the project is considered active.²²

Reporting of Federal activities

Although not required to do so by Public Law 92-205, as of November 1, 1973, Federal agencies also began reporting to NOAA their experimental activities in weather modification. This procedure resulted from an agreement obtained by the Secretary of Commerce from the responsible agencies at the request of the Interdepartmental Committee for Atmospheric Sciences (ICAS) and the Office of Management and Budget. Reporting guidelines adopted for Federal agencies are similar to those for non-Federal projects, using the same data forms; however, Federal entities and employees thereof are exempted from criminal penalty to which other operators are subject for noncompliance, and no Federal agency is required to furnish information or material whose protection is in the interest of national security. With similar reporting of federally and nonfederally sponsored activities, there now exists a central source of information on all weather modification projects in the United States.²³

Summary reports on U.S. weather modification activities

Since the Secretary of Commerce was given responsibility for collecting information on weather modification activities and for publishing "from time to time" summaries of this information, four such summary reports have been prepared by the Environmental Modification Office of NOAA's Office of Environmental Monitoring and Prediction. The first summary covered reported projects which were active some time between November 1, 1972, and March 22, 1973.²⁴ The second report incorporated information published in the first summary and extended the period of coverage to include activities reported through December 1973.²⁵ Subsequent reports summarized information on ongoing weather modification projects underway during calendar years 1974²⁶ and 1975,²⁷ respectively. The latter two summaries include information on Federal as well as non-Federal projects for the complete calendar years.

An analysis of the weather modification activities conducted in the United States during calendar year 1975 and a preliminary analysis of activities during calendar years 1976 and 1977 are found in chapter 7 of this report. These discussions are based upon the latest weather modification summary report published by NOAA²⁸ and a preliminary report on the latter 2 years prepared by Charak.²⁹

²² Charak, Mason T., "Weather Modification Activity Reports: Calendar Year 1975," National Oceanic and Atmospheric Administration, Office of Environmental Monitoring and Prediction, Rockville, Md., June 1976, pp. 3 and 60.

²³ Charak, Mason T. and Mary T. DiGiulian, "Weather Modification Activity Reports; Nov. 1, 1972, to Dec. 31, 1973," National Oceanic and Atmospheric Administration, Office of Environmental Monitoring and Prediction, Rockville, Md., March 1974, pp. 1 and D-1.

²⁴ Charak, Mason T. and Mary T. DiGiulian, "Weather Modification Activity Reports; November 1, 1972, to March 22, 1973," National Oceanic and Atmospheric Administration, Office of Environmental Monitoring and Prediction, Rockville, Md., March 1973, 23 pp.

²⁵ Charak and DiGiulian, "Weather Modification Activity Reports; Nov. 1, 1972 to Dec. 31, 1973," 1974, 40 pp.

²⁶ Charak, Mason T., "Weather Modification Activity Reports; Calendar Year 1974," National Oceanic and Atmospheric Administration, Office of Environmental Monitoring and Prediction, Rockville, Md., March 1975, 37 pp.

²⁷ Charak, "Weather Modification Activity Reports; Calendar Year 1975," June 1976, 64 pp.

²⁸ *Ibid.*
²⁹ Charak, Mason T., "Preliminary Analysis of Reported Weather Modification Activities in the U.S. for CY 1976 and 1977." (Submitted for publication in the Journal of Weather Modification, 1978.)

It should also be noted that, as part of its responsibilities as lead agency for weather modification under Public Law 85-510, the National Science Foundation (NSF) began collecting reports on weather modification activities on a regular basis in 1966. Two years later, however, Public Law 90-407 repealed the powers of the NSF to require such reporting. During those 2 years, the Foundation published summaries of reported activities for fiscal years 1967 and 1968, which were included in the 9th and 10th annual NSF weather modification reports that were submitted to the President and the Congress.³⁰ From September 1, 1968, until December 18, 1971, when Public Law 92-205 was enacted, no Federal department or agency was authorized to collect reports on weather modification activities. During this interim, pertinent information on weather modification activities of the Federal Government and on the status of weather modification research and technology was published in three weather modification summary reports, published at the request of the ICAS by NOAA.³¹ This brief series ended with the report which covered fiscal year 1973; however, some of the kinds of information contained in these reports will be included in the NOAA summary reports on weather modification activities; such material was first so included in the summary for calendar year 1975.³²

FEDERAL STUDIES AND REPORTS ON WEATHER MODIFICATION

Introduction

In accordance with the mandates of several public laws, or self-initiated by the agencies or interagency committees, the executive branch of the Federal Government has undertaken a number of major studies over the past 25 years on weather modification policy and/or recommended programs for research and development. Some of these studies have been performed under contract, others have been conducted by committees of Federal employees, while a third group were carried out by Federal committees or panels composed of non-Government experts. Each of the completed major studies was followed by a report which included findings and recommendations.

The earliest studies were conducted in the early 1950's, largely at the instigation of the Department of Defense, at that time the agency with the major Federal role in weather modification. The most significant study and report of the 1950's was that of the Advisory Committee on Weather Control, directed by Public Law 83-256. There was an unusually large number of major studies conducted and reports issued during the period from 1965 through 1976. The reports included two from the National Academy of Sciences, two from the Interdepart-

³⁰ National Science Foundation, "Weather Modification: Ninth Annual Report for Fiscal Year Ended June 30, 1967," NSF 68-21, Aug. 28, 1968, Washington, D.C., U.S. Govt. Print. Off., Aug. 28, 1968, pp. 75-77; and ———, "Weather Modification: Tenth Annual Report for Fiscal Year Ended June 30, 1968," NSF 69-18, Washington, D.C., U.S. Govt. Print. Off., Aug. 1969, pp. 111-115.

³¹ U.S. Department of Commerce, National Oceanic and Atmospheric Administration, "Summary Report: Weather Modification; Fiscal Years 1969, 1970, 1971," Office of the Assistant Administrator for Environmental Modification, Rockville, Md., May 1973, 163 pp.; ———, "Summary Report: Weather Modification; Fiscal Year 1972," Office of Environmental Monitoring and Prediction, Rockville, Md., November 1973, 226 pp.; and ———, "Summary Report: Weather Modification; Fiscal Year 1973," Office of Environmental Monitoring and Prediction, Rockville, Md., December 1974, 155 pp.

³² Charak, "Weather Modification Activity Reports; Calendar Year 1975," June 1976, pp. 37-54.

mental Committee for Atmospheric Sciences (ICAS), three from the National Science Foundation, and at least one each from the Department of Agriculture, the Environmental Science Services Administration (predecessor of NOAA), and the Domestic Council's Subcommittee on Climate Change. In 1966 alone, at least five reports on federally sponsored weather modification studies appeared. The National Advisory Committee on Oceans and Atmosphere (NACOA) has also issued policy statements on weather modification in each of its six annual reports to date.

The most recent major study was undertaken in 1977 by the Weather Modification Advisory Board under the auspices of the Department of Commerce, which has been directed to conduct such a policy study and to submit a report to the Congress in accordance with the National Weather Modification Policy Act of 1976 (Public Law 94-490).

The principal weather modification studies and reports, sponsored by the executive branch are discussed very briefly in the following subsections.³³ The conclusions and recommendations of the major policy studies are discussed and summarized in a separate chapter of this report.³⁴

Studies of the early 1950's

In 1950, there were controversies among scientists over the validity of reported results from weather modification experiments, notably Project Cirrus, a Defense Department project, conducted primarily by the General Electric Company under contract.³⁵ It was agreed by those involved that there should be an independent scientific review of the work and the claims of spectacular results. The appointed review committee was organized under the jurisdiction of the Department of Defense, since Project Cirrus was sponsored by that Department, with Dr. Bernard Haurwitz of New York University as chairman. The committee was to investigate results and report to the Defense Department; however, when the report was submitted in the late spring of 1950, it was classified "confidential," to the dismay of committee members, since it had been hoped that the report would explain the real prospects of weather modification to the public.³⁶ According to Byers, the Defense Department finally agreed to let the report be published by the American Meteorological Society, and it appeared "in the guise of a report requested by the president of the Society."^{37, 38} The overall tenor of the report was one of skepticism toward the claims of success for Project Cirrus, and the concluding paragraph of the report stated that:

It is the considered opinion of this committee that the possibility of artificially producing any useful amounts of rain has not been demonstrated so far if the available evidence is interpreted by any acceptable scientific standards.³⁹

In view of the potential value of weather modification techniques and the controversial results obtained thus far, the research agencies of the

³³ Studies and reports of the congressional support agencies have been noted earlier in this chapter under the discussion of congressional weather modification activities. See p. 209.

³⁴ See chap. 6, p. 313 ff.

³⁵ For a discussion of Project Cirrus, see p. 39, under the history of weather modification in chapter 2.

³⁶ Byers, Horace W., "History of Weather Modification," In Wilmot H. Hess (editor), *Weather and Climate Modification*, New York, Wiley, 1974, pp. 33-34.

³⁷ *Ibid.*, p. 34.

³⁸ The report appeared under correspondence, signed by members of the committee, in the *Bulletin of the American Meteorological Society*, vol. 31, No. 9, November 1950, pp. 346-347.

³⁹ *Ibid.*, p. 347.

U.S. Army, Navy, and Air Force, along with the U.S. Weather Bureau, in 1951 appointed an Artificial Cloud Nucleation Advisory Group, chaired by Dr. Sverre Petterssen of the University of Chicago. The Advisory Group was asked to make a survey of the field of weather modification and “. . . to recommend a program for experiments and tests that could be expected to clarify major uncertainties that existed at that time for the operational uses of weather modification techniques.” The Advisory Group found some support for the claims of Langmuir that seeding had affected larger atmospheric systems, but emphasized the need for clarification experiments. The group concluded that there was good evidence to indicate that cold stratus (and presumably cold fog) could be dispelled by nucleation. It had not been possible in any case to predict what results would have occurred if seeding had not been performed, indicating the need for more rigorous control of future tests. The Advisory Group consulted a number of experts in the field and all agreed that there was need for a coordinated program for experiments in order to determine whether or not weather systems can be modified with useful results.⁴⁰

The Advisory Group recommended establishment of six projects to answer these questions and was requested to remain and furnish advice to the projects and their sponsoring agencies, provide for information exchange, and review results. One of these projects was sponsored by the Weather Bureau, and of the five sponsored by the Defense Department, four were conducted by contractors and the fifth by the Army Signal Corps in house. In July 1954 the Advisory Group met with representatives of all the projects and sponsoring agencies, reviewed the results in detail, and recommended that full reports on each project be published. Project results were subsequently reported in a 1957 monograph of the American Meteorological Society.⁴¹

Advisory Committee on Weather Control

The first major comprehensive study of weather modification and its ramifications was undertaken by the Advisory Committee on Weather Control, following the congressional mandate under Public Law 83-256, of August 13, 1953, which established the Committee and directed that the study and evaluation of weather modification be performed. The Committee was comprised of the Secretaries of five departments and the Director of the National Science Foundation, or their designees, and five private members, including the Chairman, who were appointed by the President.⁴² Chaired by Dr. Howard T. Orville, the Committee forwarded its two-volume report⁴³ to President Eisenhower on December 31, 1957, after the June 30, 1956, termination date for the act had been extended by Public Law 84-664 of July 9, 1956. In its final report the committee recommended:⁴⁴

(1) That encouragement be given for the widest possible competent research in meteorology and related fields. Such research should be

⁴⁰ Petterssen, Sverre, “Reports on Experiments with Artificial Cloud Nucleation: Introductory Note.” In Sverre Petterssen, Jerome Spar, Ferguson Hall, Roscoe R. Braham, Jr., Louis J. Battan, Horace R. Byers, H. J. aufm Kampe, J. J. Kelly, and H. K. Welckmann. *Cloud and Weather Modification: a Group of Field Experiments*, Meteorological monographs, vol. 2, No. 11. American Meteorological Society, Boston, July 1957, pp. 2-3.

⁴¹ *Ibid.*, 115 pp.

⁴² Public Law 83-256, sections 4 and 5.

⁴³ Advisory Committee on Weather Control, final report of the Advisory Committee on Weather Control, Washington, D.C., U.S. Government Printing Office, 1958, in two volumes, 32+422 pp.

⁴⁴ *Ibid.*, vol. I, pp. vii-viii.

undertaken by Government agencies, universities, industries, and other organizations.

(2) That the Government sponsor meteorological research more vigorously than at present. Adequate support is particularly needed to maintain continuity and reasonable stability for long-term projects.

(3) That the administration of Government-sponsored research provide freedom and latitude for choosing methods and goals. Emphasis should be put on sponsoring talented men as well as their specific projects.

(4) That an agency be designated to promote and support research in the needed fields, and to coordinate research projects. It should also constitute a central point for the assembly, evaluation, and dissemination of information. This agency should be the National Science Foundation.

(5) That whenever a research project has the endorsement of the National Science Foundation and requires facilities to achieve its purpose, the agency having jurisdiction over such facilities should provide them.

National Academy of Sciences studies

The Committee on Atmospheric Sciences of the National Academy of Sciences (NAS/CAS) produced its report on the first of two major studies on weather modification in 1966. The report, entitled "Weather and Climate Modification: Problems and Prospects,"⁴⁵ was prepared by the Committee's Panel on Weather and Climate Modification, with joint support from the National Science Foundation and the Commerce Department's Environmental Science Services Administration. Volume 1 of the report contains a summary of the study and recommendations, while the second volume presents a general assessment of the subject, on which the panel based its conclusions and recommendations. The report expressed cautious optimism regarding the future of weather modification. Among its recommendations were an increase in Federal support from the 1965 level of \$5 million to at least \$30 million by 1970 and the early establishment of several carefully designed, randomized seeding experiments, planned in such a way as to permit assessment of the seedability of various storm types. The report addressed mostly technical and administrative problems; it did not consider social, legal, and economic aspects of the subject, since these topics were taken up in a concurrent study by the NSF's Special Commission on Weather Modification, which worked closely with the NAS panel.⁴⁶

The second major study was completed by the Panel on Weather and Climate Modification of the NAS Committee on Atmospheric Sciences in 1973.⁴⁷ Sponsored jointly by the National Science Foundation and the Department of Commerce, the panel was given responsibility in the study "(1) to determine the scientific and national progress in weather modification since the earlier study of the field was reported upon in 1966, (2) to consider future activities that would

⁴⁵ National Academy of Sciences, National Research Council, Committee on Atmospheric Sciences, *Weather and Climate Modification: Problems and Prospects*. Publication No. 1350, Washington, D.C., 1966, in 2 volumes, 40 + 212 pp.

⁴⁶ See discussion below on reports by the National Science Foundation, p. 239.

⁴⁷ National Academy of Sciences, National Research Council, Committee on Atmospheric Sciences, *Weather Modification: Problems and Progress*, ISBN 0-309-02121-9, Washington, D.C., 1973, 280 pp.

guide and strengthen work toward further progress, (3) to examine and clarify the statistical design and evaluation of modification activities, and (4) to determine the current circumstances bearing on the increase, decrease, and redistribution of precipitation."⁴⁸ In its report, the panel attempted to fulfill these objectives and further proposed the following three goals for improving the science and technology of weather modification:⁴⁹

1. Completion of research to put precipitation modification on a sound basis by 1980.

2. Development during the next decade of the technology required to move toward mitigation of severe storms.

3. Establishment of a program that will permit determination by 1980 of the extent of inadvertent modification of local weather and global climate as a result of human activities.

Research programs required to achieve these goals were outlined along with basic functions to be performed by the several Federal agencies. These organizational recommendations for the Federal program were: "(1) the identification of a lead agency, (2) the establishment of a laboratory dedicated to the achievement of the proposed national goals, and (3) assignment to the recently established National Advisory Committee on Oceans and Atmosphere of the responsibility for examining the public policy issues of weather modification, as well as the development of organization and legislative proposals."⁵⁰

Studies by the Interdepartmental Committee for Atmospheric Sciences (ICAS)

Another report to appear in 1966 was the first of two by the ICAS on weather modification, which prescribed a recommended national program in the field.⁵¹ Compiled by the chairman of the ICAS Select Panel on Weather Modification, Dr. Homer E. Newell of the National Aeronautics and Space Administration, the report laid out details for such a national program and contained, as appendices, the earlier recommended program of the ICAS Select Panel itself, as well as recommendations from the concurrent studies by the NAS and the NSF Special Commission.

The ICAS completed another interagency study in 1971, when it produced a report which outlines a program for accelerating national progress in weather modification.⁵² The report attempted to identify national weather modification needs and designated research projects for meeting these needs as national projects, each with a responsible lead agency and support from other Federal agencies.⁵³ Some of these projects were already underway or in planning stages by various agencies. Few were ever consummated as truly interagency national projects as envisioned, though there was some degree of cooperation in some, such as the National Hail Research Experiment (NHRE),

⁴⁸ *Ibid.*, p. iii.

⁴⁹ *Ibid.*, p. xv.

⁵⁰ *Ibid.*

⁵¹ Newell, Homer E., "A Recommended National Program in Weather Modification," Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS Rept. No. 10a, November 1966, 93 pp.

⁵² Federal Council for Science and Technology, Interagency Committee for Atmospheric Sciences, "A National Program for Accelerating Progress in Weather Modification," ICAS Rept. No. 15a, June 1971, 50 pp.

⁵³ For a list of the seven national projects identified by the ICAS, see p. 224, under the discussion of the activities of the ICAS.

and others, such as Interior's Colorado River Basin pilot project (CRBPP), continued essentially as large single-agency projects.

Domestic Council study

A weather modification study was undertaken in 1974, following establishment of a Subcommittee on Climate Change by the Environmental Resources Committee of the Domestic Council. Comprised of representatives from the Office of Management and Budget (OMB) and most Federal agencies with atmospheric sciences programs, excepting the Defense Department, the subcommittee attempted to assess the Federal role in weather modification. Drawing upon recent documentation on the progress, status, and problems in the field, and through a 2-day hearing of representatives from various parts of the weather modification community and other interested groups, the subcommittee prepared its report in 1975.⁵⁴ In its executive summary, the Domestic Council report found that:

Weather modification represents a potential tool for exerting a favorable influence over destructive weather events and for augmenting water supplies in some areas where additional water is needed for energy, food, and fiber production;⁵⁵ and the following general recommendation was formulated:

A policy should be adopted to develop, encourage, and maintain a comprehensive and coordinated national program in weather modification research and in the beneficial application of the technology along the lines of the recommendations embodied in this report.⁵⁶

Specific findings and recommendations were also given for each of the three areas of research, operations, and regulation, which the subcommittee examined.⁵⁷

Policy and planning reports produced by Federal agencies

Since the very early studies of the 1950-51 era, instigated primarily by the Department of Defense, other Federal agencies have undertaken major policy and planning studies, either as "in-house" efforts or through contractors or committees established by the agency.

The National Science Foundation has produced the greatest number of agency policy reports, based on studies conducted by its Special Commission on Weather Modification and by contractors. Two reports appearing in 1966 were prepared by or under auspices of the Special Commission, culminating a study authorized in October 1963 by the National Science Board.^{58, 59} The Special Commission, established in June 1964 and chaired by Dr. A. R. Chamberlain of Colorado State University, had been " * * * requested to examine the physical, biological, legal, social, and political aspects of the field and make recommendations concerning future policies and programs."⁶⁰ Physical aspects were studied in cooperative liaison with the NAS panel in its concurrent study;⁶¹ however, the membership of the Special Commission reflected expertise in the other aspects of weather modification not

⁵⁴ Domestic Council, Environmental Resources Committee, Subcommittee on Climate Change, "The Federal Role in Weather Modification," Washington, D.C., December 1975, 39 pp.

⁵⁵ *Ibid.*, p. 1.

⁵⁶ *Ibid.*

⁵⁷ *Ibid.*, pp. 1-iii.

⁵⁸ Special Commission on Weather Modification, NSF 66-3, 1966, 155 pp.

⁵⁹ Taubenfeld, Howard J., "Weather Modification: Law, Controls, Operations," report to the Special Commission on Weather Modification, National Science Foundation, NSF 66-7, Washington, D.C., 1966, 79 pp.

⁶⁰ Special Commission on Weather Modification, NSF 66-3, 1966, p. iii.

⁶¹ See p. 237 above.

previously addressed by the other studies. Much of the background work for the treatment of these other aspects of the problem was supported by NSF grants and subsequently published as separate reports. These included the biological aspects, human dimensions, international relations, and legal aspects. Of these separate studies all were published in various nongovernmental media, except the last one, which appeared in the format of the NSF Special Commission report.⁶² All of these aspects were reviewed and summarized, and recommendations were presented, in the principal Commission report, which sought to answer the following question: "With the physical possibility of modifying the weather and climate already partly demonstrated, how by artificially inducing deliberate changes in the environment may man act to control or develop changes in the atmosphere considered to be desirable by society?"⁶³

A contracted study was undertaken for the NSF by the Rand Corp. in 1962 to establish the framework of a cohesive approach to research on weather modification. Part of the program was to conduct a comprehensive state-of-the-art review of the field; however, the appearance of the 1966 National Academy study⁶⁴ negated the immediate necessity for such a reexamination. Nearly 3 years later Rand did publish such a review, recognizing that there had been "sufficient progress in the overall field of weather modification research to now warrant a new overview."⁶⁵

The authors of the report stressed the following points: "(1) the possibility of inadvertent weather or climate modification is rapidly becoming a probability, as human effects on the atmosphere and the surface of the planet grow at an increasing rate; (2) progress in weather modification research continues to be hampered by the prevalent lack of cohesive effort by both theoreticians and experimenters; (3) computers of advanced design and increased capacity will handle atmospheric models of considerably greater sophistication than in the past; and (4) this is a not-to-be-neglected opportunity for interactive research—constant two-way feedback from theory to experiment to theory, with dynamic atmospheric models facilitating each advance."⁶⁶ General and specific recommendations concerning what they considered to be the most urgently needed research areas and required instrumentation developments were included in the report.

In 1965, following a request from the Chief of the U.S. Weather Bureau, Dr. Robert M. White, the Bureau published an "in-house" report on its role in weather modification research.⁶⁷ In the report it was recognized that research responsibilities extend beyond consideration of scientific and technical problems; however, it dealt primarily with meteorology, leaving to other ongoing studies the treatment of administrative, military, international, and ecological aspects, although some legal and legislative questions were discussed.⁶⁸ It was

⁶² Taubenfeld, NSF 66-7.

⁶³ Special Commission on Weather Modification, NSF 66-3, 1966, pp. 7-8.

⁶⁴ National Academy of Sciences, publication No. 1350, 1966.

⁶⁵ Staff of the Weather Modification Research Project of the Rand Corp., "Weather Modification Progress and the Need for Interactive Research," The Rand Corp., memorandum RM-5835-NSF, Santa Monica, Calif., October 1968, 88 pp.

⁶⁶ *Ibid.*, p. v.

⁶⁷ Gilman, Donald L., James R. Hibbs, and Paul L. Laskin, "Weather and Climate Modification," a report to the Chief, U.S. Weather Bureau, U.S. Department of Commerce, Weather Bureau, Washington, D.C., July 10, 1965, 46 pp.

⁶⁸ *Ibid.*, p. 1.

made clear that the report was not intended to be statement of policy of the Bureau, the Commerce Department, or the Federal Government, but was rather to be considered as a contribution to the national discussion of the future direction of weather modification in the United States.⁶⁹

Another one of the many studies appearing in 1966 was a report by the Commerce Department's Environmental Science Services Administration (ESSA), the organization which preceded the present National Oceanic and Atmospheric Administration (NOAA).⁷⁰ Prepared in response to a request by the ICAS, the report was prepared by an "in-house" task group to define an expanded ESSA program in light of the recommendations of the NAS Committee on Atmospheric Sciences Panel on Weather and Climate Modification and those of the NSF Special Commission on Weather Modification, which appeared in reports that year.^{71, 72} It outlined a 5-year program of research for the fiscal years 1968 through 1972, with projects ranging from large-scale field experiments to those in more basic aspects of atmospheric science pertinent to weather modification.

A report was published in 1968 by the U.S. Department of Agriculture, as part of the continuing joint research planning by the Department and State agricultural experiment stations.⁷³ The recommended program of research and development in weather modification for agriculture and forestry supplemented the national program of research for agriculture. The proposed program addressed direct modification of the weather and the resulting biological, economic, and social consequences of such activity. It was intended to contribute to knowledge and technology needed "in the total enterprise of agriculture and forestry" and to "provide the basis for essential decisionmaking on weather modification programs affecting nearly every aspect of agriculture and forestry."⁷⁴ The report discussed national goals, defined a national research and development program for agencies of the Department of Agriculture and the State agricultural experiment stations, and reviewed the necessary research resources, including manpower, facilities, and organization. For each major phase of the proposed research activity, the report recommended levels of Federal involvement and financial investment for fiscal years 1972 and 1977.⁷⁵

FEDERAL PROGRAMS IN WEATHER MODIFICATION

INTRODUCTION AND FUNDING SUMMARIES

The Federal Government has been involved in weather modification research and development for more than 30 years. As noted earlier, these research programs are scattered throughout a number of Federal departments and agencies. They are not carried out fully independent of one another, however, since they are coordinated by man-

⁶⁹ *Ibid.*, p. iv.

⁷⁰ U.S. Department of Commerce, Environmental Science Services Administration. "An Outline of a Proposed 5-Year Plan in Weather Modification," Rockville, Md., April 1966. 66 pp.

⁷¹ National Academy of Sciences, publication No. 1350.

⁷² Special Commission on Weather Modification, NSF 66-3.

⁷³ Joint Task Force of the U.S. Department of Agriculture and the State universities and land grant colleges. "A National Program of Research for Weather Modification," U.S. Department of Agriculture, Research Program Development and Evaluation Staff, Washington, D.C., January 1968, 38 pp.

⁷⁴ *Ibid.*, p. 1.

⁷⁵ *Ibid.*, pp. 6-8.

agers at the program level, especially through the Interdepartmental Committee for Atmospheric Sciences (ICAS), and by scientists and engineers at the working level through a number of mechanisms including interagency joint projects and the activities of professional organizations.

The Federal weather modification program has been considered to be composed of the several agency programs identified as weather modification by the member agencies of the ICAS and reported as such to the ICAS. According to the latest ICAS annual report,⁷⁶ weather modification programs will be sponsored during fiscal year 1978 by six departments and agencies; these are the Departments of Agriculture, Commerce, Defense, and Interior; the National Science Foundation; and the Energy Research and Development Administration (part of the Department of Energy as of October 1, 1977). As late as fiscal year 1976 the Department of Transportation also reported a program in weather modification, and the National Aeronautics and Space Administration (NASA) identified a research program in warm fog dispersal through fiscal year 1973. The Environmental Protection Agency (EPA) supports research on inadvertent weather change as a joint sponsor of the METROMEX project in St. Louis and vicinity,⁷⁷ but does not choose to report this research as weather modification.

In the early years of the ICAS member agencies reported their funding for support of atmospheric science only in the two broad categories—meteorology and aeronomy. Beginning with fiscal year 1963, however, there has been a discreet identification of funds for weather modification; the total Federal effort amounted to \$2.7 million that fiscal year. Though there have been occasional dips since then, funding for Federal programs has increased steadily to \$20.3 million for fiscal year 1976; however, planned fiscal year 1978 funds have dropped to \$17.1 million.⁷⁸

Table 2 summarizes funding for the Federal weather modification research program by agency and by research category, as reported to the ICAS, for fiscal years 1976 through 1978, data for the latest year being estimated. Figure 2 shows the course of funding from fiscal years 1966 through 1978, from ICAS data assembled by Fleagle, who has recently reviewed the history of Federal weather modification funding since 1946.⁷⁹ From 1946 to 1958 the Federal Government funded several extensive field research programs, the Department of Defense providing the major support through university and industrial contracts. Since expenditures for these programs were not reported under weather modification, Federal funding for this period cannot be determined.⁸⁰

⁷⁶ Interdepartmental Committee for Atmospheric Sciences, "National Atmospheric Sciences Program: Fiscal Year 1978," ICAS 21-FY78, 1977, p. 87.

⁷⁷ See discussion of METROMEX under the program of the National Science Foundation, p. 383 ff.

⁷⁸ Federal Coordinating Council for Science, Engineering, and Technology; Committee on Atmosphere and Oceans; Interdepartmental Committee for Atmospheric Sciences; "National Atmospheric Sciences Program: Fiscal Year 1978," ICAS 21-FY78, August 1977, p. 87.

⁷⁹ Fleagle, Robert G., "An Analysis of Federal Policies in Weather Modification." Background paper prepared for the U.S. Department of Commerce Weather Modification Advisory Board, Seattle, March 1977, pp. 6-14.

⁸⁰ *Ibid.*, p. 6.

TABLE 2.—SUMMARY OF FEDERAL WEATHER MODIFICATION RESEARCH FUNDING FOR FISCAL YEAR 1976 THROUGH FISCAL YEAR 1978 (ESTIMATED), BY AGENCY AND BY RESEARCH CATEGORY, AS REPORTED TO THE INTERDEPARTMENTAL COMMITTEE FOR ATMOSPHERIC SCIENCES. (FROM ICAS 21—FISCAL YEAR 1978).

[In thousands of dollars]

	Fiscal year—			
	1976	1977	1977	1978
Department of Agriculture.....	70	21	55	20
Department of Commerce.....	6,334	1,146	4,577	5,001
Department of Defense:				
Army.....	100	119	268	190
Navy.....	900	175	221	210
Air Force.....	409	112	550	575
Department of Interior.....	4,649	1,632	6,446	7,613
Department of Transportation.....	555			
Energy Research and Development Administration.....	1,096	10	1,155	1,260
National Science Foundation.....	6,216	1,110	5,702	2,250
Total.....	20,329	4,589	18,974	17,119
Precipitation modification.....	3,382	1,057	4,881	5,900
Fog and cloud modification.....	2,164	665	1,906	1,868
Hail suppression.....	3,080	488	2,950	1,180
Lightning modification.....	70	21	55	20
Hurricane and severe storm modification.....	1,961	461	1,911	1,810
Social, economic, legal and ecological studies.....	718	135	687	450
Inadvertent modification of weather and climate.....	4,834	889	3,693	4,158
Support and services.....	4,120	873	2,891	1,733

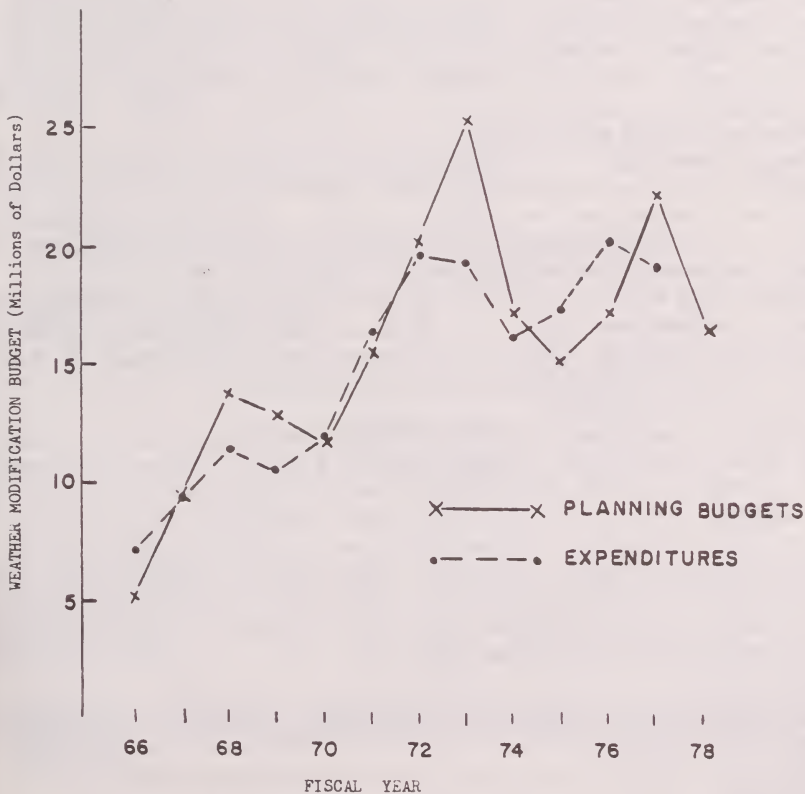


FIGURE 2.—The course of Federal weather modification funding (planning budgets and actual expenditures) from fiscal years 1966 to 1978, as reported by the Interdepartmental Committee for Atmospheric Sciences. (Adapted from Fleagle, 1977, with latest data from ICAS 21—FY78.)

In the period 1958 to 1965 the NSF, as part of its lead agency responsibilities, reported Federal expenditures in weather modification. Reported expenditures reached about \$3 million in fiscal year 1965, although costs of aircraft, radar, and manpower provided by the Defense Department were not identified. Beginning with fiscal year 1966, expenditures have been reported annually by the ICAS under reasonably constant definitions and guidelines.⁸¹

The general growth in Federal funding between fiscal years 1966 and 1972 can be seen in figure 2. Fleagle speculates that the funding drop following 1968 could have been a result of research curtailments brought on by the Vietnam war or of the failure by the Congress to designate a lead agency after that role was taken from the NSF by Public Law 90-407. He feels that the resurgence in 1971 and 1972 could have resulted from a new emphasis on weather modification, evidenced by the endorsement by the Federal Council for Science and Technology of seven national projects identified by the ICAS⁸² and the appearance of a National Academy of Sciences study which emphasized improved management and organization.⁸³ In January 1973 five of the seven national projects were suspended or terminated, owing to the extensive impoundments of appropriated funds by the President. The national projects represented about one-half of the total weather modification budget, exclusive of classified Department of Defense expenditures. The partial recovery through fiscal year 1976 was based on increases in the Department of the Interior's Project Skywater, NOAA's preparation for resumed hurricane modification research, and ERDA's growing research program on the inadvertent effects of increased energy generation.⁸⁴

Fleagle notes that " * * * total funding for weather modification has improved over the period from 1966 to 1977 largely in response to what are perceived as the needs for prompt application of the technology," while "reductions have occurred as results of factors external to weather modification and external to the agencies."⁸⁵

Table 3 is a summary by agency of Federal weather modification research support since fiscal year 1963, excluding inadvertent weather modification research. The data were compiled by Corzine of NOAA from a variety of sources, which are identified in the table, and were accurate as of March 1977.⁸⁶

Changnon compared the Federal weather modification funding data with those of the entire Federal research budget.⁸⁷ From fiscal year 1973 to fiscal year 1974, for example, the total Federal research budget increased 6.5 percent, and federally sponsored civilian research (non-space and nonmilitary) increased 11.8 percent, while weather modification funding dropped 21 percent. Between fiscal years 1969 and 1973, a period of rapid growth for weather modification support, civilian research and development increased 120 percent while weather modification research increased 87 percent.

⁸¹ *Ibid.*, pp. 6-7.

⁸² See p. 225 for a listing of these national projects.

⁸³ National Academy of Sciences, National Research Council, Committee on Atmospheric Sciences, "The Atmospheric Sciences and Man's Needs; Priorities for the Future," Washington, D.C., May 1971, 88 pp.

⁸⁴ Fleagle, "An Analysis of Federal Policies in Weather Modification," 1977, pp. 7-9.

⁸⁵ *Ibid.*, p. 9.

⁸⁶ Corzine, Harold; in Fred D. White (compiler), "Highlights of Solicited Opinions on Weather Modification" (a summary); prepared for use by the Department of Commerce Weather Modification Advisory Board, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Rockville, Md., March 1977, p. 30.

⁸⁷ Changnon, "The Federal Role in Weather Modification," 1977, pp. 17-18.

TABLE 3.—FEDERAL SUPPORT OF WEATHER MODIFICATION RESEARCH, FISCAL YEARS 1963-78. (FROM CORZINE, 1977.)^{1, 2}

[In millions of dollars]

Fiscal year ³	Commerce	Interior	NSF	DOD	Agriculture	Others ⁴	Total
1963	0.19	0.10	1.32	0.96	0.13	0.05	2.75
1964	.18	.18	1.57	1.41	.12	.07	3.53
1965	.11	1.26	2.01	1.45	.14	0	4.97
1966	.65	2.91	2.00	1.27	.14	.07	7.04
1967	1.23	3.73	3.30	1.33	.25	.08	9.92
1968	1.53	4.63	3.39	1.41	.18	.16	11.30
1969	1.14	4.27	2.73	1.63	.29	.18	10.24
1970	1.33	4.77	3.15	1.85	.29	.20	11.59
1971	3.01	6.52	3.79	1.44	.36	.72	15.84
1972	3.94	6.66	5.50	1.82	.36	.40	18.68
1973	3.77	6.37	6.20	1.21	.37	.39	18.31
1974	3.30	3.90	4.70	1.20	.27	.10	13.47
1975	2.49	4.00	4.70	1.14	.09	0	12.42
1976 (estimate)	4.64	4.94	5.60	⁵ 1.12	.07	0	16.37
1977 "	4.58	6.76	4.40	⁵ 2.78	.06	0	18.58
1978 "	3.84	5.70	2.00	⁵ 2.16	.02	-----	13.72

¹ Excludes inadvertent weather and climate modification research funds.² Excludes DOD spending for weather modification operations in Southeast Asia and at military airports.³ Data based on: 1963-68, NSF Annual Reports on Weather Modification, 1969-71, ICAS Annual Reports 14, 15, and 16. 1972-76 material collected for Domestic Council Report (figures for 1975 and 1976 brought up to date). 1977-78, figures submitted to NOAA.⁴ Includes Transportation, EPA, and NASA.⁵ Includes approximately 0.92, 2.18, and 1.56 for thermal modification of warm fog.

Federal research and development funding for fiscal years 1971 through 1976, according to major weather modification research category, is summarized in table 4, which also indicates the agencies under whose programs the funds were expended. Changnon notes that these data show that:⁵⁸

1. The greatest effort has been in precipitation modification, but with a general decrease in this effort with time;

2. There has been a rapid growth of spending on inadvertent modification research;

3. Funding for fog suppression has been decreasing; and

4. In recent years the research categories receiving the major support are precipitation (snow and rain) modification, hail suppression, and inadvertent modification.

TABLE 4.—FEDERAL WEATHER MODIFICATION RESEARCH SUPPORT BY RESEARCH CATEGORY, FOR FISCAL YEARS 1971 THROUGH 1976. (FROM CHANGNON, 1977.)

[In millions of dollars]

Type	Fiscal year—						Supporting agencies ¹
	1971	1972	1973	1974	1975	1976	
Precipitation modification	8.0	6.2	6.0	3.7	4.4	5.0	DOC, DOI, NSF.
Fog and cloud modification	2.9	2.9	2.9	2.4	1.1	1.3	DOD, DOT, NSF.
Hail suppression	2.6	2.9	3.2	3.3	3.5	3.8	NSF.
Lightning modification	.9	.7	.7	.7	.2	.1	DOA, DOD, NSF.
Severe storm modification	.8	1.9	1.7	1.5	1.8	2.0	DOC.
Societal-economic issues	.8	.9	1.1	.8	.6	1.1	NSF, DOI.
Inadvertent	.6	1.7	1.7	2.9	5.2	4.9	NSF, DOT, DOC.

¹ DOC=Commerce; DOD=Defense; NSF=National Science Foundation; DOI=Interior; DOT=Transportation; DOA=Agriculture.⁵⁸ Ibid., p. 18.

There have been minimal Federal efforts in operational weather modification; however, since these activities are usually conducted as parts of other operations not considered weather modification, the expenditures are difficult to identify. These activities have included fog dispersal at airports by the Navy and the Air Force; precipitation augmentation operations by the Defense Department overseas at the request of the Governments of Panama, Portugal, Okinawa, and the Philippines; and 1971 efforts to reduce drought in Texas, Oklahoma, Arizona, and Florida by the Department of the Interior, the Air Force, and NOAA.⁸⁹ Shapley reported in 1974 that estimated expenditures by the Defense Department between 1966 and 1972 in attempts to increase rain during the Southeast Asia war were \$21.6 million.⁹⁰

Federal weather modification programs are summarized, by agency, in the following subsections. Included are discussions of the programs of the departments and agencies listed in table 2; the Department of Transportation has been included since its program was terminated so recently. Discussions contain not only those projects which are underway or planned for fiscal year 1978, but also activities of the recent past, in order to show the continuity and the development or phasing out processes for each of the several programs.

DEPARTMENT OF THE INTERIOR

Introduction

A major weather modification research program has been conducted by the Bureau of Reclamation in the Department of the Interior since 1961. The purpose of this Atmospheric Water Resources Management Program, also called "Project Skywater," has been to develop and verify a practical cloud-seeding technology for increasing water supplies in the Western States. Initiated through a congressional write-in of \$100,000 in the fiscal year 1962 Public Works appropriation, the mission of the project was simply stated as "research on increasing rainfall by cloud seeding."⁹¹ Congressional direction has been almost entirely through provisions in Public Works appropriation documents. A summary of the appropriation language contained in these documents between 1961 and 1977 is found in appendix J.

Since its inception, the program has been characterized by the following three guidelines that were established.⁹²

1. It was to be an applied research program, using "engineering approaches" rather than a basic or pure research program.

2. Scientific expertise was to be used where it existed rather than from an "in-house" effort.

3. Additional water and benefits accruing to local groups from research seeding would not be reimbursed.

⁸⁹ *Ibid.*

⁹⁰ Shapley, Deborah. "Weather Warfare: Pentagon Concedes 7-year Vietnam Effort," *Science*, vol. 184, No. 4141, June 7, 1974, p. 1059.

⁹¹ Bureau of Reclamation, U.S. Department of the Interior. "Atmospheric Water Resources Management Program; Project Skywater, Information Summary," presented before the U.S. Department of Commerce National Weather Modification Advisory Board, May 31, 1977, Washington, D.C., p. 1.

⁹² *Ibid.*

The Bureau of Reclamation, through Project Skywater, has been the principal Federal agency concerned with the operational adaptation of precipitation enhancement research.

Recent legislation in the 95th Congress has also enabled the Bureau to provide grants to States in order to facilitate emergency weather modification activities in hope of mitigating effects of the 1976-77 drought. This program, not part of the Atmospheric Water Resources Management Program, is discussed in a subsequent section.⁹³

Table 5 is a summary of weather modification research funding and projected funding from fiscal year 1976 through fiscal year 1978 for the Bureau of Reclamation. All of the funds shown are associated with Project Skywater and do not include those previously mentioned in connection with emergency grants for drought alleviation.

TABLE 5.—WEATHER MODIFICATION FUNDING FOR FISCAL YEAR 1976 THROUGH FISCAL YEAR 1978 FOR THE DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, UNDER THE ATMOSPHERIC WATER RESOURCES MANAGEMENT PROGRAM (PROJECT SKYWATER)¹

[In thousands of dollars]

	Fiscal year 1976	Transition quarter	Fiscal year 1977	Fiscal year 1978
Precipitation management:				
Snow augmentation (including SCPP).....	375	50	400	1,750
Rain enhancement (HIPLEX).....	2,475	1,007	3,800	4,000
Modeling and comprehensive analysis studies.....	500	100	470	300
Social, economic, legal and environmental.....	300	75	400	300
Support and services.....	2,999	2,400	2,137	2,123
Total.....	4,649	1,632	6,446	7,613

¹ From Federal Coordinating Council for Science, Engineering, and Technology. Interdepartmental Committee for Atmospheric Sciences. National Atmospheric Sciences program: Fiscal Year 1978. ICAS 21—Fiscal year 1978. August 1977, p. 91.

² Includes computer and planning costs.

Project Skywater general discussion

Over the past decade, the Bureau of Reclamation's Atmospheric Water Resources Management Program (Project Skywater) has accounted for about one-third of the total Federal program in all forms of weather modification. All of the Bureau's funding has been directed, however, toward research in precipitation enhancement. Of the funds appropriated, about 83 percent are used for contracted research. Table 6 shows the breakdown of funding for the fiscal years 1962 through 1977 by kinds of contractor and according to in-house or other Federal expenditure. From the table it can be seen that 44 percent has been allocated to universities, 23 percent to private firms, 10 percent to State governments, and 6 percent to other Federal agencies, while 17 percent has been spent by the Bureau for planning, management, and in-house research. Table 7 shows the breakdown of these funds in accordance with functions or major projects. The three major projects in the table will be discussed briefly below.

⁹³ See p. 266 of this section, and also see p. 202 under discussion of congressional activities.

TABLE 6.—ATMOSPHERIC WATER RESOURCES MANAGEMENT PROGRAM; OBLIGATION SUMMARY FISCAL YEAR 1962 THROUGH FISCAL YEAR 1977¹

Fiscal year	Universities	Private	State	USBR ²	Other Federal	Total incurred obligations
1962.....	\$70,000	0	0	\$30,000	0	\$100,000
1963.....	83,747	0	0	16,253	0	100,000
1964.....	133,000	0	0	42,000	0	175,000
1965.....	459,630	\$283,978	\$3,500	151,892	\$201,000	1,100,000
1966.....	1,531,400	637,250	168,700	303,150	339,500	2,980,000
1967.....	1,989,321	779,125	361,300	368,396	251,858	3,750,000
1968.....	2,717,689	859,000	345,000	423,311	286,200	4,631,200
1969.....	2,776,815	860,126	318,549	460,666	273,500	4,689,656
1970.....	2,966,200	873,866	254,885	446,232	268,325	4,809,508
1971.....	3,519,083	1,415,187	570,600	753,436	335,344	6,593,650
1972.....	3,539,323	1,348,203	664,926	784,857	321,597	6,658,906
1973.....	3,312,939	1,105,029	905,200	889,387	173,021	6,385,576
1974.....	899,110	1,498,982	336,104	976,747	189,282	3,600,225
1975.....	768,911	1,318,961	286,227	1,270,634	342,491	3,997,224
1976.....	497,572	1,480,462	617,133	1,677,593	391,156	4,663,956
Transition quarter.....	214,245	609,229	234,528	469,914	96,175	1,624,091
1977 (estimate).....	1,800,000	1,600,000	1,200,000	1,454,481	400,000	6,454,481
Total.....	27,278,985	14,669,398	6,276,652	10,518,949	3,869,489	³ 62,348,381
Percent.....	44	23	10	17	6	100

¹ Bureau of Reclamation. Atmospheric Water Resources Management Program: Project Skywater. Information summary. May 31, 1977, p. 24.

² Includes salaries, equipment, supplies, and computer costs.

³ Official total as corrected for recoveries, underfinancing, and other adjustments.

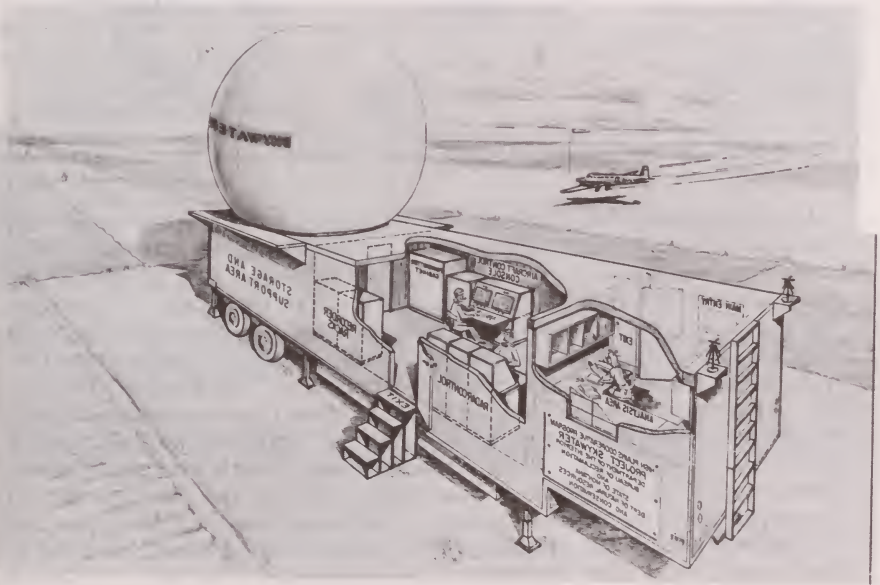
TABLE 7.—Bureau of Reclamation Atmospheric Water Resources Management Program. Allocation of Funding by Function and by Major Projects for Fiscal Years 1962 Through 1977¹

Research and development.....	\$31,749,665
Environmental.....	2,173,676
Associated comprehensive studies.....	3,296,202
Colorado River Basin Pilot Project.....	5,100,792
Sierra Cooperative Pilot Project.....	866,805
HIPL EX.....	10,557,767
Other pilot projects.....	1,980,000
Planning, management, and program support.....	6,623,471
	62,348,381

¹ Bureau of Reclamation, U.S. Department of the Interior. Atmospheric water resources management program: Project Skywater. Information summary, May 31, 1977, p. 23.



Portable radar used in Project Skywater. (Courtesy of the Bureau of Reclamation.)



Artist's rendering of portable radar used in Project Skywater. (Courtesy of the Bureau of Reclamation.)

Skywater has emphasized cooperation, joint participation, and cost sharing with State resource and environmental agencies; and field experiments have included research contracted with universities, State agencies, and private firms. Funds have also been transferred to other Federal agencies, who have cooperated in the various aspects of the program. Table 8 is a listing of the principal contractors and Government activities who have participated. Research contracts have been concerned with winter orographic snowfall augmentation and increases in summer convective cloud rainfall—both of which are principal precipitation mechanisms in the Western United States. The distribution of major field projects underway or planned during fiscal year 1977 as part of Skywater and the locations of contractor institutions and Federal activities involved in various aspects of the program are shown in figure 3.

TABLE 8.—PRINCIPAL CONTRACTORS AND RESEARCH COOPERATORS ASSOCIATED WITH PROJECT SKYWATER 1.

University	Private	Government
University of Arizona.	Amos Eddy, Inc.	U.S. Air Force.
Brigham Young University.	Aeromet, Inc.	U.S. Army (Pueblo Depot).
University of California.	Aerometric Research, Inc.	California Department of Transportation.
University of California at Los Angeles.	Convergence Systems, Inc.	California Highway Partol.
University of Colorado.	Colorado International Corp.	Colorado Department of Natural Resources.
Colorado State University.	E. Bollay Associates.	Colorado River Municipal Water District.
University of Denver.	E. G. & G., Inc.	Forest Service.
Fresno State College.	Electronic Techniques, Inc.	General Services Administration.
Harvard University.	Enterprise Electronics, Inc.	Geological Survey.
University of Michigan.	Environmental Research and Technology, Inc.	Illinois State Water Survey.
Montana State University.	Geophysical Research and Development Corp.	Kansas Water Resources Board.
University of Nevada.	Human Ecology Research Services.	Montana Department of Natural Resources and Conservation.
New Mexico State University.	M. B. Associates, Inc.	National Oceanic and Atmospheric Administration.
New York University.	Meteorology Research, Inc.	National Science Foundation.
University of North Dakota.	North American Weather Consultants.	Navy Weapons Center.
North Dakota State University.	Stanford Research, Inc.	Navy Weather Research Facility.
University of Oklahoma.	T. G. Owe Berg, Inc.	Nebraska Department of Agriculture.
Pennsylvania State University.	Travelers Research Inc.	North Dakota Weather Modification Board.
San Diego State University.	Weather Science, Inc.	Sacramento River Forecast Center.
South Dakota School of Mines and Technology.	Western Scientific Services, Inc.	Soil Conservation Service.
South Dakota State University.		South Dakota Weather Control Commission.
Taff College.		Southwestern Water Conservation District.
Texas A. & M. Research Foundation.		Washington Department of Ecology.
Utah State University.		Texas Water Development Board.
University of Washington.		Utah Department of Water Resources.
University of Wisconsin.		
University of Wyoming.		

¹ Bureau of Reclamation. Atmospheric Water Resources Management Program: Project Skywater. Information summary, May 31, 1977. p. 26.

The widespread field projects of Skywater from 1962 through 1977 are shown in figure 4. In recent years, research experiments and studies have been concentrated on three major projects, one of which has just been completed, while the other two are in relatively early stages. These projects, each of which is discussed below in some detail, are the Colorado River Basin Pilot Project, the High Plains Cooperative Program (HIPLEx), and the Sierra Cooperative Pilot Project. In addition to the concentrated research effort in these three regional projects, the Bureau continues to provide technical planning and equipment assistance to local projects in States such as North Dakota, Kansas, Texas, and Utah. Support is also being given to the development of the application of satellite imagery for cloud seeding decisions and evaluations and to the adaptation of research cloud models for use in local operations. The Skywater Environmental Computer Network

provides real-time data support to both field research and commercial weather modification projects on a cooperative basis. Figure 5 is a schematic of the Data Network, with its central unit in Denver, which also provides access to real time and archived data for a variety of other research projects. Cloud models and other computerized aids are made available for testing by winter and summer operators through the Environmental Data Network in return for practical appraisals of usefulness and recommendations for improvement.

Planning and other preliminary field studies for possible future weather modification cooperative research in the Colorado River Basin are continuing. Recently, the final programmatic environmental impact statement for Project Skywater was completed.⁹⁴ Several site specific environmental impact statements, including one for the Colorado River Basin Pilot Project, were completed earlier. A comprehensive assessment of the entire field of precipitation enhancement is being performed, which includes reviews of both research and operational project results.

Project Skywater = FY 1977

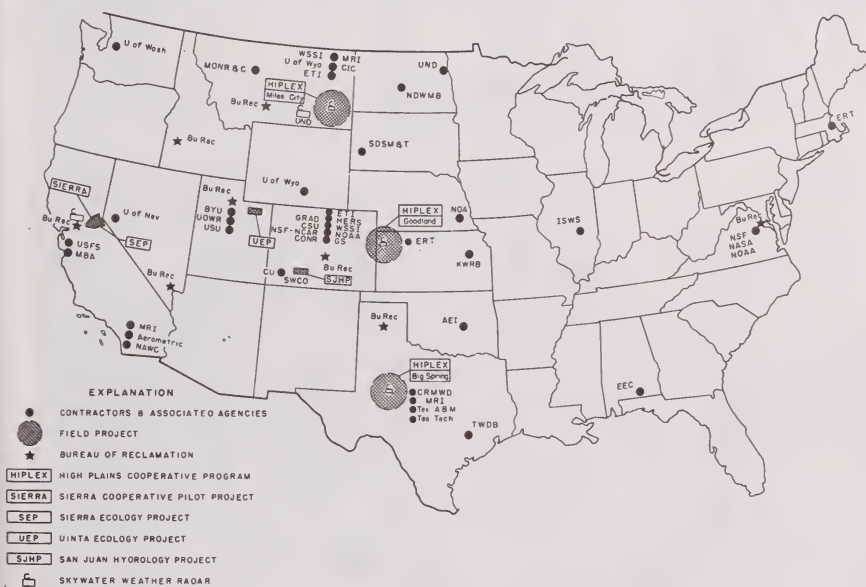


FIGURE 3.—Major Skywater field projects and locations of contractors and Federal institutions during fiscal year 1977. (From Project Skywater information summary, May 31, 1977.)

⁹⁴ U.S. Department of the Interior, Bureau of Reclamation, "Final Environmental Statement for Project Skywater; a Program of Research in Precipitation Management," Division of Atmospheric Water Resources Management, INT FES 77-39, Denver, Oct. 25, 1977. In three volumes. (376 and 316 and 266 pp.)

Skywater Field Projects 1962-1977

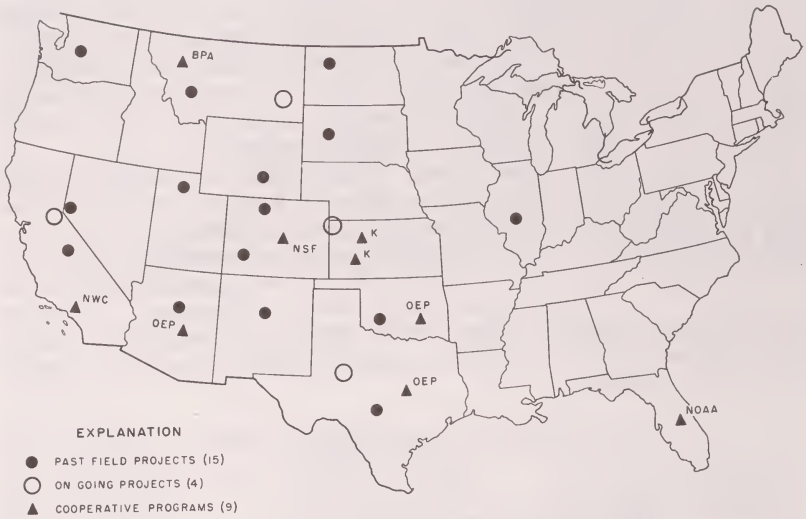


FIGURE 4.—Locations of Skywater field projects from 1962 through 1977. (From Project Skywater information summary, May 31, 1977.)

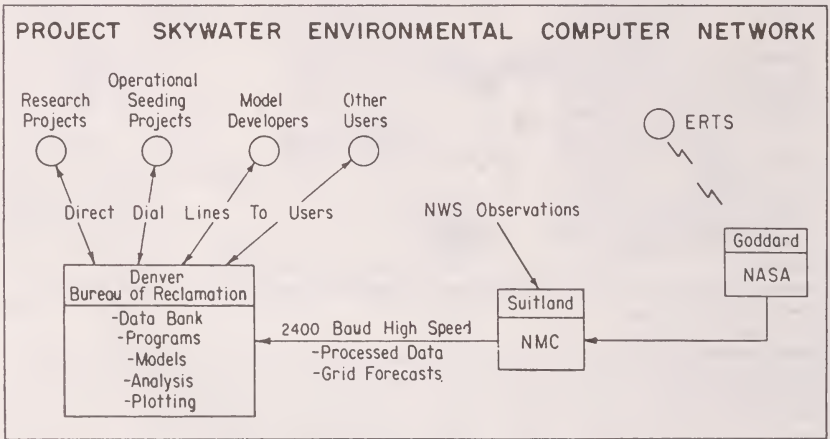


FIGURE 5.—Schematic of the Project Skywater Environmental Computer Network. (From Project Skywater information summary, May 31, 1977.)



Data collection platform and transmitter used by Project Skywater in connection with the Earth Resources Technology Satellite (ERTS). (Courtesy of the Bureau of Reclamation.)

The Colorado River Basin Pilot Project (CRBPP)

This was a large weather modification research project conducted by the Bureau of Reclamation under Project Skywater to determine the feasibility of augmenting high mountain snowpacks in the San Juan Mountains of southwestern Colorado. The seeding and data collection phase of this large project was conducted between 1970 and 1975, although planning for the experiment began in 1967. Project evaluations were prepared in 1976, and further analyses and environmental studies are continuing in 1977. The target area selected for the CRBPP (or the San Juan Project as it is sometimes called) covered nearly 3,400 km² (1,300 mi²) of sparsely populated mountainous terrain east and northeast of Durango, Colo. Elevations extended from above 2,750 meters to 4,200 meters.⁹⁵ Figure 6 shows the locations of target areas and instrumentation arrays in the CRBPP in southwest Colorado.

The Colorado River Basin is one of the most water-short areas in the Nation, and weather modification has been recommended as a practical and immediately available water augmentation technology.⁹⁶ Preliminary results show that a 19-percent augmentation in streamflow may be possible through seeding in this area of headwaters of the Colorado River Basin.⁹⁷

⁹⁵ Aerometric Research, Inc., "Colorado River Basin Pilot Project; Executive Summary of Comprehensive Evaluation," prepared for Department of the Interior, Bureau of Reclamation under contract No. 14-06-D-7332. Goleta, Calif., December 1976, p. 1.

⁹⁶ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, "National Atmospheric Sciences Program: Fiscal Year 1977." ICAS 20-FY 77, May 1976, p. 92.

⁹⁷ Bureau of Reclamation, "Atmospheric Water Resources Management Program; Project Skywater," May 31, 1977, p. 25.

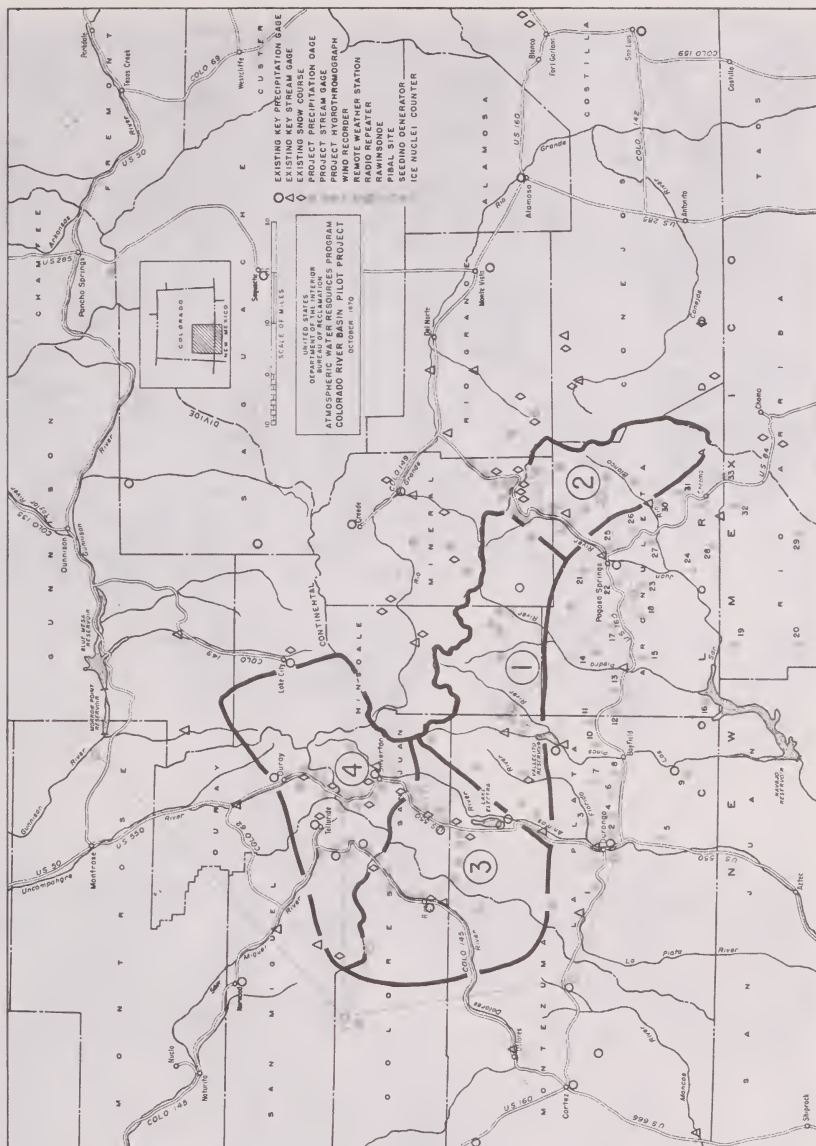


FIGURE 6.—Map showing the locations of target areas and instrumentation arrays in the Colorado River Basin Pilot Project in southwest Colorado. (From Bureau of Reclamation.)

Results of analyses of the San Juan project indicate that winter orographic storms are somewhat more complex than thought originally, but that additional snowpack can be provided through seeding. Characteristics of treatable storms have been identified more clearly.⁹⁸ In a major analysis and evaluation of the project it was determined that many of the clouds actually seeded in the experiment were not of a suitable type, that on some experimental days the weather did not develop as forecast, that in some cases seeding material remained in the area beyond planned experimental seeding periods, and on some days rapid weather changes produced conditions in which precipitation was decreased by seeding.⁹⁹ Consequently, "the total unstratified statistical analysis found no difference between precipitation on seeded experimental days and control days. However, when days of missed forecasts were removed, and data from experimental days were reduced to 6-hour time blocks to improve the correlation between meteorological covariates and precipitation, increases during certain classes of seeded cases were statistically significant."¹ Nevertheless, the evaluation report concludes that, "the overall potential for seeding-produced increases in precipitation during a winter of average snowfall was determined to be about 10 percent. The resulting potential increase in streamflow of about 19 percent is 197 million m³ for the San Juan River."²

⁹⁸ U.S. Department of the Interior, Bureau of Reclamation, "Reclamation in the Seventies," second progress report. A water resources technical publication, research rept. No. 28. Washington, D.C., U.S. Government Printing Office, 1977, p. 2.

⁹⁹ Atmospheric Research, Inc., "Colorado River Basin Pilot Project; Executive Summary of Comprehensive Evaluation," 1976, p. 3.

¹ *Ibid.*

² *Ibid.*



Remotely operated cloud seeding generator similar to those used in the Colorado River Basin Pilot Project. (Courtesy of the Bureau of Reclamation.)

The High Plains Cooperative Program (HIPLEX)

HIPLEX is a comprehensive weather modification research program designed "to develop a practical, scientifically sound, and socially acceptable technology for precipitation management applicable to summer convective cloud systems in the High Plains region of the United States."³ The overall goal of HIPLEX is "to establish a verified, effective cloud seeding technology and a policy and management background for responsibly producing additional rain in the semiarid Plain States. This goal includes improving the current operational cloud seeding methods, transferring the techniques and results to concerned groups; and enhancing public confidence in their use."⁴

Research in HIPLEX is being conducted at three field sites: Miles City, Mont.; Goodland, Kans.; and Big Spring, Tex. (see fig. 3). These cities represent, respectively, the northern, central, and southern High Plains; they were chosen in view of the known or suspected variation of climatic conditions and cloud characteristics over the north-south extent of the High Plains and the obvious implications of such variations on technology transferability.⁵ Examination and understanding of the social, political, and agronomic differences across the High Plains and their implications for effective technology transfer was also instrumental in selecting a variety of field sites.⁶

HIPLEX was initiated in 1973 when the Office of Management and Budget (OMB) assigned to the Bureau of Reclamation the responsibility for mounting an experimental program to test scientific concepts for augmenting precipitation in the High Plains. The \$1 million first appropriated for HIPLEX in fiscal year 1974 has grown to about \$4 million in fiscal year 1977, each recent year's appropriation also including a congressional write-in which has increased OMB's programmed budget.⁷ About 80 percent of the fiscal year 1977 budget has been for contracted research and 20 percent for in-house management and support. Universities received 29 percent of the contracted research funds, private firms were awarded 31 percent, and 20 percent went to State and Federal agencies.⁸ Table 9 is a funding breakdown of fiscal year 1977 HIPLEX funds by function, expressed in percentage of the total HIPLEX budget.

TABLE 9.—Fiscal year 1977 HIPLEX funding breakdown by function

Function :	Percent
Field operations.....	44.1
Analysis	28.7
Management, planning, design, data management.....	22.5
Social, legal, and environmental studies (augmentation to State supported activities).....	4.7
Total	100.0

³ Silverman, Bernard A., "HIPLEX: An Overview." Sixth Conference on Planned and Inadvertent Weather Modification. American Meteorological Society. Champaign-Urbana, Ill., Oct. 10-13, 1977, p. 311.

⁴ U.S. Department of the Interior, Bureau of Reclamation, "High Plains Cooperative Program: Progress and Planning Report No. 2," Denver, March 1976, p. 3.

⁵ Silverman, "HIPLEX: An Overview," 1977, p. 311.

⁶ *Ibid.*

⁷ *Ibid.*

⁸ *Ibid.*, pp. 311-312.



University of North Dakota radar used under contract in the High Plains Cooperative Program (HIPLEX) of Project Skywater. (Courtesy of the Bureau of Reclamation.)

HIPLEX is envisioned as a 5- to 7-year program, running through about 1982. Earliest attention has been given to the site at Miles City, Mont., where seeding was first conducted during 1976, though preliminary studies and measurements of cloud properties have also been underway at the other two sites. The following accomplishments should be noted:⁹

1. Field facilities and research teams have been established at the three field sites: Miles City, Mont.; Goodland, Kans.; and Big Spring, Tex.
2. Active participation and cost-sharing with the States is underway.
3. Major equipment systems have been installed and tested.
4. Agricultural, economic, and environmental assessment studies are underway in all three areas.
5. Experimental designs and data processing and analysis procedures have been developed.

The experimental design for HIPLEX consists of two components—an atmospheric effort and a socioeconomic and environmental effort. Experimental components are divided into three overlapping phases, which are consistent with sequential scientific efforts. In a fourth phase the developed technology is to be transferred to applicable areas in the High Plains region.¹⁰ The details of this four-phase design and tentative dates associated with the overall schedule are shown in figure 7.

⁹ U.S. Department of the Interior, "High Plains Cooperative Program; Progress and Planning Report No. 2," p. 5.

¹⁰ Ackerman, Bernice, G. L. Achtemeier, H. Appleman, Stanley A. Changnon, Jr., F. A. Huff, G. M. Morgan, Paul T. Schickedanz, and Richard G. Semonin, "Design of the High Plains Experiment with Specific Focus on Phase 2, Single Cloud Experiment," Illinois State Water Survey, final report on Hiplex design project to Bureau of Reclamation, contract 14-06-D-7197. Urbana, Ill., June 30, 1976, p. 7.

COMPONENTS OF HIPLEX - RAINFALL ENHANCEMENT

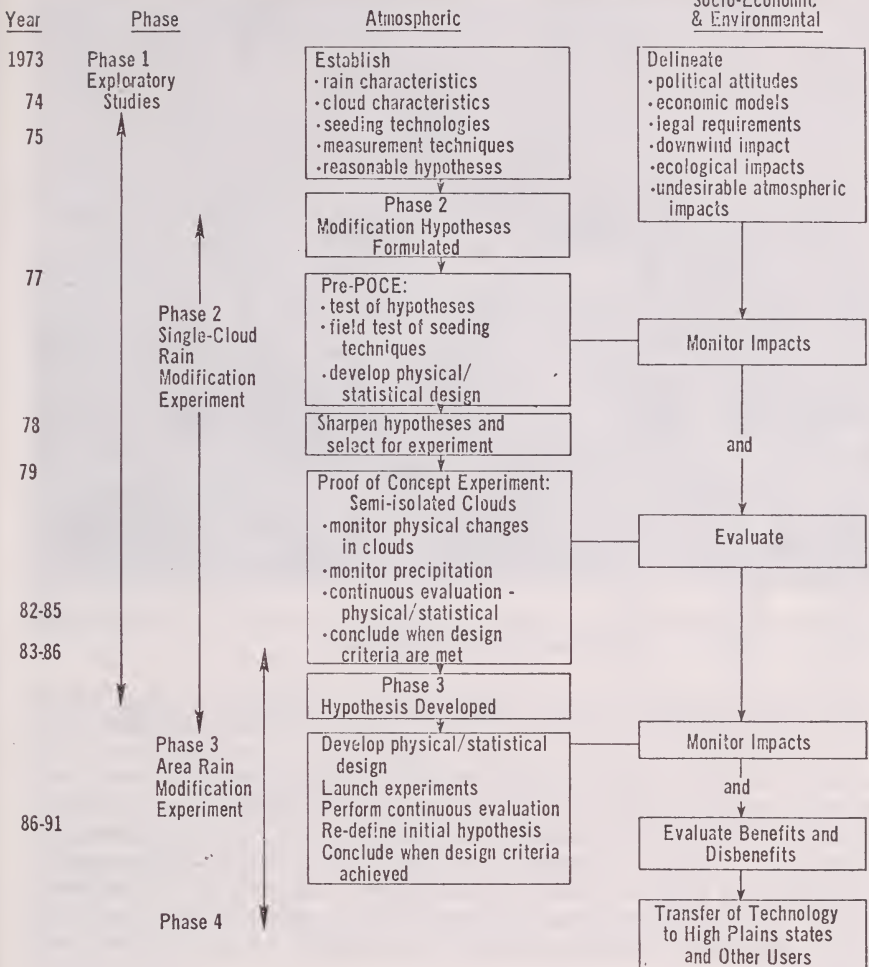


FIGURE 7.—Flow of experimental effort in HIPLEX, showing tentative schedule through 1991. (From Bernard A. Silverman, 1977, private communication.)



University of Wyoming instrumented cloud physics aircraft. (Courtesy of the Bureau of Reclamation.)

HIPLEX is primarily a Skywater activity; however, it also includes the integrated research and supporting efforts of State agencies, local groups, and other Federal agencies. Field research and analyses are to be conducted primarily through contracts with private firms and universities, and the project is closely coordinated with related research sponsored by the National Science Foundation and the Department of Commerce. In order to develop optimum water augmentation potential, pertinent State and local organizations in the High Plains have joined with the Bureau in planning, funding, and implementing this broad research program which is designed to accomplish the following:¹¹

1. Develop and test more productive seeding methods and evaluate results.
2. Resolve the remaining cloud dynamics and precipitation physics uncertainties on seeding effects.
3. Help prepare public weather modification backgrounds and local expertise and establish working relations among concerned non-Federal entities.
4. Assess the actual economic value of cloud seeding and the possible social and ecological impacts.

Anticipated overall costs for State cooperation and cost-sharing in HIPLEX is estimated to be about \$3 million. This contribution amounts to 10 to 15 percent of the total HIPLEX research budget,

¹¹ U.S. Department of the Interior, "High Plains Cooperative Program; Progress and Planning Report No. 2," pp. 3-5.

since the total Federal portion of the project is projected at about \$20 million.¹²

HIPLEX cooperative agreements for cost-sharing and field research support have been negotiated with the States,¹³ as shown in table 10. Funding provided by some of these States and by the Bureau of Reclamation from fiscal year 1974 through fiscal year 1978 (estimated) is shown in table 11.

TABLE 10.—HIPLEX COST-SHARING AND FIELD RESEARCH AGREEMENTS WITH STATES (FROM U.S. DEPARTMENT OF INTERIOR, HIGH PLAINS COOPERATIVE PROGRAM, PROGRESS AND PLANNING REPORT NO. 2.)

Field site	States	Date signed
Miles City, Mont.....	Montana.....	Aug. 25, 1974.
Goodland, Kans.....	Kansas, Colorado, Nebraska.....	May 29, 1974 (tristate).
Big Spring, Tex.....	Texas.....	Oct. 30, 1974.

TABLE 11.—SUMMARY OF HIPLEX FUNDS PROVIDED BY STATES AND BY THE BUREAU OF RECLAMATION, FISCAL YEAR 1974 THROUGH FISCAL YEAR 1978 (ESTIMATED)¹

Fiscal years	State funds			Totals	Bureau of Reclamation funds
	Kansas	Montana	Texas		
1974.....	\$5,000	0	0	\$6,000	\$1,250,000
1975.....	100,000	0	\$25,000	125,000	1,821,000
1976 plus transition quarter.....	100,000	0	81,500	181,500	3,482,000
1977.....	100,000	\$25,000	65,000	190,000	4,110,000
1978 (estimate).....	100,000	25,000	75,000	200,000	4,000,000
Total.....	406,000	50,000	246,500	702,500	14,663,000

¹ Private communication from James L. Kerr, Washington representative, Office of Atmospheric Water Resources, Bureau of Reclamation. November 1977.

The Sierra Cooperative Pilot Project (SCPP)

This cooperative precipitation augmentation research project is being initiated under the auspices of Project Skywater and several State agencies in the northern Sierra Nevada Mountain Range of California and Nevada. Cooperation with commercial cloud seeding operators, whose efforts in this region have been funded for several decades by west coast utility companies, is expected to be a unique part of the project.

The Sierra project began in 1972 with preliminary planning and discussions. Research projects along the crest of the Rocky Mountains and in the Sierra Nevada have shown the possibility of increased snowfall and consequent streamflow enhancement through seeding certain types of weather systems. Commercial projects in the Sierra have reported consistent 5 to 8 percent streamflow increases. The Sierra project is intended to investigate the physical basis for the reported increases and the feasibility of developing a more precise technology for snowfall enhancement for this region.¹⁴

The Bureau of Reclamation and the State of California agreed to pursue a research program in the Sierra Nevada in 1973 and jointly

¹² *Ibid.*, p. 10.

¹³ *Ibid.*, p. 9.

¹⁴ U.S. Department of the Interior, Bureau of Reclamation. "A Status Report: The Sierra Cooperative Pilot Project" (with excerpts from "Weather Modification Design for Streamflow Augmentation in the Northern Sierra Nevada," an initial study by MAB Associates, San Ramon, Calif.), U.S. Government Printing Office, Washington, February 1977, p. 1.

funded a contract for an assessment of potential environmental effects that needed study. Public meetings were held in California and Nevada during 1974 to solicit comments on the proposed project. Another contract, funded in May 1975, led to publication of a project design report in December 1976. In August 1975 the California Department of Water Resources withdrew as a financial partner in the project, owing to re-orientation of priorities and redirection of manpower and funds toward other water projects. The department continues to provide available information needed for development of the project and monitors its progress.

Two studies on likely social and environmental effects of incremental snowpack increases on highways and public transportation were completed in 1976 by two other agencies of the State of California, the California Highway Patrol and the California Department of Transportation. A survey of individual citizens and organizational representatives on attitudes and concerns about seeding by winter cloud seeding was also conducted in 1976.¹⁵

The preliminary experimental design notes that storms in the Sierra cooperative project can be classified into two types and recommends that the project should attempt to modify the storm types with separate objectives.

The orographic (westerly) storms should be seeded to increase the efficiency of the storm, thus augmenting the amount of precipitation resulting from these systems. The procedure would be to seed the storms at light seeding rates to avoid overseeding. Seeding would be done with surface seeding generators and, under certain circumstances, with airborne seeding generators.

It was recommended that the convective storms (southerly) be seeded to increase precipitation at higher, colder elevations, primarily through redistribution, providing a greater total precipitation for storage in the snowpack. These storms will be seeded heavily, with the object of altering the distribution of precipitation with respect to altitude, thus increasing the snowpack. In addition to seeding the general orographic background of these storms by surface generators, the pilot program would seed the updraft areas of the imbedded convective cells heavily with high-output airborne generators.¹⁶

The specific meteorological hypotheses to be tested by the Sierra experiment are that :¹⁷

1. Seeding will increase the average precipitation on treated sample events as compared to the untreated events.
2. Seeding will increase the average elevation of maximum precipitation on treated sample events as compared to untreated events.
3. Seeding will increase the average duration of precipitation and/or the rate of precipitation on treated sample events as compared with the untreated events.

It is intended that the design and evaluation of the SCPP will be a continuing process over a period of 7 years, constituting a major feature in the step-by-step research in the pilot project.¹⁸ The primary hypotheses of the program as well as physical parameters which accompany successful or unsuccessful events, will be tested in the SCPP evaluation. Basic parameters to be tested statistically are :¹⁹

1. The average precipitation accumulation.
2. The elevation of the maximum precipitation band.

¹⁵ *Ibid.*, pp. 1-3.

¹⁶ *Ibid.*, p. 15.

¹⁷ *Ibid.*

¹⁸ U.S. Department of the Interior, Bureau of Reclamation, "SCPP Continuing Design Contract." Sierra Cooperative Pilot Project Newsletter, No. 6, May 1977, Denver, Colo., p. 2.

¹⁹ U.S. Department of the Interior, "A Status Report: The Sierra Cooperative Pilot Project," 1977, p. 27.

3. The average total storm duration, the average duration of precipitation during the first and last days of the storm, and the average rate of precipitation.

The regions that are expected to be affected in the Sierra project are shown in figure 8. Region 1 is the primary area of effect; region 2 is the downwind area recommended for monitoring extra-area effects; and region 3, situated below 1,220 meters (4,000 ft.) elevation in the American River basin, is intended to provide real-time precipitation data as input for the declaration of an experimental unit and to provide better definition of the precipitation distribution within the drainage basin.²⁰

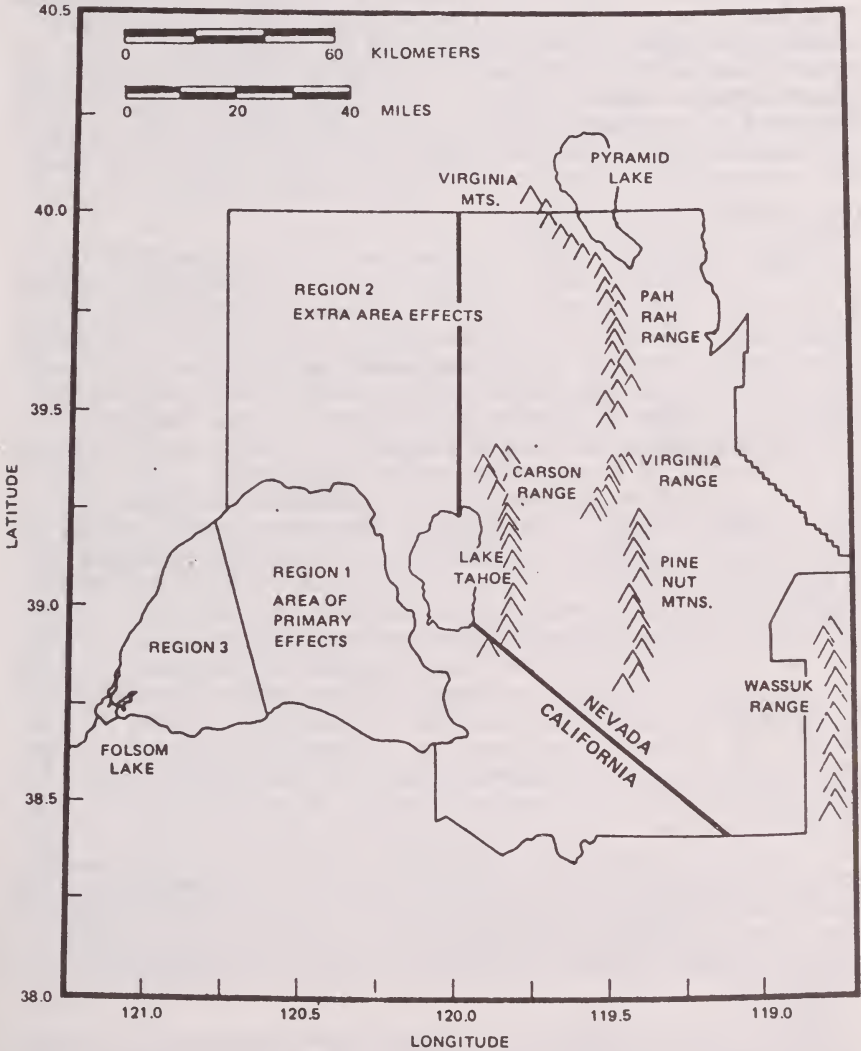


FIGURE 8.—Map of the Sierra Cooperative Pilot Project region, showing the three geographical areas in the project (see text). (From Bureau of Reclamation, Sierra Cooperative Pilot Project, status report, February 1977.)

²⁰ Ibid., pp. 24–25.

The planning and design phase of the Sierra project continues, and during the winter of 1976-77, field tests were conducted that were necessary for design of field operations. During the 1977-78 winter season collection of field data under prerandomized seeding conditions should be completed; operating procedures will be tested and refined; equipment will be installed, tested, and calibrated; concepts for coordinating with operating programs in the area will be developed; transport and diffusion studies will continue; and changes in design will continue as a result of the increased knowledge acquired from the research of the previous year.²¹ If the preceding activities have been accomplished successfully and weather conditions permit, randomized seeding will begin in the 1978-79 season. From historic storm patterns it has been estimated that 5 to 7 years of randomized seeding will be necessary to obtain a data base suitable for confirmation of the expected increases at a significant level. During this period monitoring programs and environmental studies will be designed and implemented. There will be continued dialog with concerned officials and the general public in the project area, and hopefully many answers will be obtained to societal, economic, and environmental questions.²²

Drought mitigation assistance

Drought emergency relief was requested by the Governors of a number of Western States during the summer of 1971. In partial response to this request, the President's Office of Emergency Preparedness directed the Bureau to conduct emergency precipitation stimulation operations in Arizona, Oklahoma, and Texas. Skywater personnel have also provided scientific consulting services for rain augmentation programs in Lebanon, Brazil, India, Tasmania, and Jamaica.²³

A recent program, not part of Project Skywater, was administered by the Bureau of Reclamation, under which grants were given to States to support weather modification activities undertaken to mitigate impacts of the 1976-77 drought. Temporary authorities to the Secretary of the Interior to facilitate various emergency actions were provided by Public Law 95-18, amended by Public Law 95-107, enacted April 7, 1977, and August 17, 1977, respectively. Authority was granted to appropriate \$100 million for a program which included short-term actions to increase water supplies. Funds made available were to be used to repair, replace, or improve affected water-supply facilities and to establish a water bank of available water for rehabilitation. The Bureau implemented the act, publishing rules for emergency loans, grants, and deferrals under the Emergency Drought Act of 1977 in the Federal Register.²⁴ Procedures were established under sections 423.18 and 423.20 of these rules for State water resource agencies to apply for nonreimbursable funds for studies and other actions to augment water supplies. Requests were received during the period of availability from six States for funds to support weather modification activities. Table 12 shows the amount of funds approved for each State for weather modification projects under this provision.²⁵

²¹ *Ibid.*, p. 47.

²² *Ibid.*

²³ Kahan, Archie M., testimony in: U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, "Weather Modification," hearings, 94th Congress, 2d session, June 15-18, 1977. Washington, D.C., U.S. Government Printing Office, 1976, p. 194.

²⁴ Federal Register, vol. 42, No. 72, Thursday, Apr. 14, 1977, pp. 19609-19613.

²⁵ Private communication from James L. Kerr, Washington Representative, Office of Atmospheric Water Resources, Bureau of Reclamation, November 1977.

TABLE 12.—Funds provided for States for weather modification projects by the Bureau of Reclamation, under provisions of the Emergency Drought Act of 1977.

Colorado	\$600,000
California	300,000
Kansas	300,000
Nevada	232,720
North Dakota	186,133
Utah	553,500
Total	2,172,353

NATIONAL SCIENCE FOUNDATION

Introduction and general

Under its Research Applied to National Needs (RANN) program, the National Science Foundation (NSF) has in recent years developed improved capabilities to stimulate research efforts immediately and directly related to problems of society. This program, which dealt primarily with problem-oriented research, focussed scientific and technological resources on selected problems of national importance in an attempt to assist in their solution in a timely and practical manner. RANN's areas of emphasis included the major category of environmental programs, under which most of the NSF-sponsored research in weather modification had until recently been located.²⁶

The NSF program in weather modification supports a broad range of research, extending across the disciplines of economic, social, political, legal, environmental, mathematical, and physical sciences.²⁷ The overall goal of the program is "to establish the concept of weather modification as a tool to help fulfill societal needs," and, to accomplish this goal, the program supports research on the following five program objectives:²⁸

1. To establish the feasibility of, and improve the technology for, mitigating the undesirable effects of selected weather hazards.
2. To delineate the cause, extent, and impact of inadvertent weather modification and to subsequently develop ways to use land and energy resources to achieve more desirable responses in weather and climate.
3. To develop an improved capability to design, perform, and evaluate weather modification experiments.
4. To investigate the impact of weather modification on society.
5. To develop specific applications of weather modification to increase agricultural production.

Table 13 is a summary of weather modification research funding and projected funding from fiscal year 1976 through fiscal year 1978 for the National Science Foundation.

²⁶ In the reorganization of the RANN Directorate in the NSF to the Applied Science and Research Applications (ASRA) Directorate, effective February 1978, the NSF weather modification program was transferred to the basic research Astronomical, Atmospheric, Earth, and Ocean Sciences (AAEO) Directorate, Division of Atmospheric Sciences.

²⁷ Downie, Currie S. and Richard A. Dirks, National Science Foundation weather modification program, papers presented at the second WMO Scientific Conference on Weather Modification, Boulder, Colo., Aug. 2-6, 1976. World Meteorological Organization, Geneva, Switzerland, p. 557.

²⁸ *Ibid.*

TABLE 13.—WEATHER MODIFICATION FUNDING FOR FISCAL YEAR 1976 THROUGH FISCAL YEAR 1978 FOR THE NATIONAL SCIENCE FOUNDATION¹

[In thousands of dollars]

	Fiscal year—			
	1976	1977	1977	1978
Precipitation modification.....	532	0	681	150
Fog and cloud modification.....	0	88	110	0
Hail suppression.....	3,081	488	2,950	1,180
Social, economic, legal, and environmental.....	² 418	60	287	150
Inadvertent modification.....	1,153	101	629	600
Support and services.....	1,032	373	1,045	170
	6,216	1,110	5,702	2,250

¹ From Federal Coordinating Council for Science, Engineering, and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 21—fiscal year 1978, p. 94.

² Includes technology assessment of hail suppression.

The RANN weather modification program dealt with a number of specific, critical research topics and was dedicated to development of improved technology in support of societal needs, transfer of this technology to potential users, and exploration of the impact of weather modification on society; however, the program is not all encompassing. In addition to the RANN-supported research, the NSF supported weather modification through its basic research program in meteorology and through the atmospheric research facilities at the National Center for Atmospheric Research (NCAR) at Boulder, Colo.²⁹

The NSF weather modification program is coordinated with weather modification programs of other Federal agencies through the Interdepartmental Committee for Atmospheric Sciences (ICAS) Panel on Weather Modification and through numerous and frequent contacts with representatives of the other Federal agencies. In 1975 an NSF Weather Modification Advisory Panel was formed, composed of representatives from the Department of the Interior (Bureau of Reclamation), the Department of Commerce (National Oceanic and Atmospheric Administration), the academic community, commercial weather modifiers, and industry. The Panel was formed to provide technical advice to the NSF program manager for weather modification and to assist in coordinating the program with other agencies.³⁰ As part of the concerted effort throughout the executive branch to eliminate advisory panels, the NSF Weather Modification Advisory Panel was recently abolished.

Public Law 85-510 of July 11, 1958, directed the NSF "to initiate and support a program of study, research, and evaluation in the field of weather modification."³¹ The Foundation promptly responded in establishing the new program, then within its broader program for atmospheric sciences, and expended \$1,141,000 for research and evaluation in weather modification in fiscal year 1959.³² In designing the program the advice and assistance of outstanding scientists and engineers were sought, and an Advisory Panel for Weather Modification was ap-

²⁹ Ibid.

³⁰ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20—FY77, p. 95.

³¹ See earlier section of this chapter for discussion of this and other Federal legislation on weather modification.

³² National Science Foundation, "Weather Modification"; first annual report for fiscal year ended June 30, 1959, NSF 60-24, p. 3.

pointed. In an early report to the Director of the NSF, the Chairman of the Advisory Panel, Dr. Reuben G. Gustavson, stated: ³³

Placing this important field of research under the aegis of the National Science Foundation has given rise to a new hope and confidence that the instability factors in regard to size and time of support will be removed. This is already bringing young imaginative workers into the field. The rate of advance will to a large measure depend upon the quality of the trained scientists attracted to the problem. If good scientists are to be attracted into the program, the Foundation must be particularly concerned about the financial stability of the program.

The effect of Public Law 85-510 was to make the NSF the Federal lead agency in weather modification, since there were research programs underway in a number of other agencies. Historically the NSF program has provided the largest measure of Federal support to all aspects of weather modification research over the years since establishment of its program. When Public Law 90-407 of July 18, 1968, amended the National Science Foundation Act of 1950, the specific mandate for NSF to support a weather modification program and the attendant lead agency role were effectively repealed. The further requirements, established earlier by Public Law 85-510, that activities in weather modification in the United States be reported to the NSF and that the Foundation should publish an annual report to the Congress, were also terminated with the passage of Public Law 90-407. During the years when NSF was lead agency for weather modification, 10 annual reports were published, the last one covering fiscal year 1968.³⁴

Following passage of the 1968 law, the NSF continued to support basic and applied research in weather modification under the broad authority of the National Science Foundation Act of 1950 as amended by Public Law 90-407. About one-third of the total Federal support for weather modification has been provided by the NSF.

When the Research Applied to National Needs (RANN) Directorate was established within the Foundation in 1971 "to bring the resources of science and technology to bear on selected important national problems,"³⁵ most of the weather modification research was transferred from the basic atmospheric science program to RANN. While nearly all of this research was managed under RANN by the Division of Advanced Environmental Research and Technology, two major studies were sponsored by RANN's Division of Exploratory Research and Technology Assessment, which "supports research and assessment to provide greater visibility to the longer range social, environmental, and economic impacts of new technology applications and to identify and analyze emerging national problems that may be avoided or ameliorated by science and technology."³⁶

The first of these two technology assessment studies was initiated in 1971 in response to a request from the Interdepartmental Committee for Atmospheric Sciences (ICAS) to explore the feasibility of applying technology assessment concepts to planned weather modification operational projects. ICAS suggested that the first project for such a technology assessment might be the planned project of the Bureau of

³³ *Ib' d.*

³⁴ National Science Foundation. "Weather Modification: Tenth Annual Report for Fiscal Year Ended June 30, 1968." NSF 69-18. U.S. Government Printing Office, Washington, D.C., 1969. 141 pp.

³⁵ National Science Foundation. "Twenty-sixth Annual Report. for Fiscal Year 1976," NSF 77-1. Washington D.C., U.S. Government Printing Office, 1977. p. 85.

³⁶ National Science Foundation. "Guide to Programs: Fiscal Year 1978," Washington D.C., U.S. Government Printing Office, 1977, p. 51.

Reclamation to augment the flow of the Colorado River by seeding orographic clouds to increase snowpack in the Upper Colorado River Basin, since the pilot experiment was already underway in the San Juan Mountain Range and the Secretary of the Interior needed information to make a decision on implementation in the near future.³⁷ The contract for the assessment was funded and monitored by NSF, the Stanford Research Institute being selected to undertake the study, with assistance from the University of California at Davis and a number of consultants. The final report was published in 1974.³⁸

The second major study was an extensive technology assessment of hail suppression in the United States. This project was initiated in August 1975 and became known as the Technology Assessment of the Suppression of Hail (TASH). The NSF grant was to the University of Illinois; however, a number of other institutions and individuals were involved in the study through subcontracts or consulting agreements. Total funding for the 18-month project included \$290,500 from NSF and \$60,000 from the State of Illinois.³⁹ The final report of the TASH study was published in April 1977.⁴⁰

Table 14 is a listing of awards in weather modification research by the Division of Advanced Environmental Research and Technology for fiscal year 1973 through the 1976 transition quarter. The NSF weather modification program has been divided into five major areas under which the numerous research projects have been categorized. These areas, corresponding to the five program objectives stated earlier, are: (1) weather hazard mitigation studies on such phenomena as hail, thunderstorms, lightning, and tornadoes and an attempt to prevent or lessen damage from such storms; (2) weather modification technology development; designed to improve methods for modifying the weather and of evaluating results of weather modification efforts; (3) inadvertent weather modification investigations to delineate the cause, extent, and impact of urban-industrial influences, such as heat, moisture, aerosols, and surface roughness, on the weather; (4) societal utilization activities which relate the impact of weather on man, provide goal orientation, and achieve the societal interface for successful weather modification applications; and (5) an agricultural weather modification program which includes developing techniques for exerting influence on agricultural systems at critical points during the planting, growing, and harvesting seasons in order to expand agricultural production.⁴¹ Each of these major program divisions will be discussed in the following sections.

³⁷ Weisbecker, Leo W. (compiler), "The Impacts of Snow Enhancement; Technology Assessment of Winter Orographic Snowpack Augmentation in the Upper Colorado River Basin," Norman, Okla., University of Oklahoma Press, 1974, p. v.

³⁸ *Ibid.*, 624 pp. (A summary of the report was also published separately: Weisbecker, Leo W., "Snowpack, Cloud Seeding, and the Colorado River; Technology Assessment of Weather Modification," Norman, Okla., University of Oklahoma Press, 1974, 86 pp.)

³⁹ Changnon, Stanley A., Jr., Ray Jay Davis, Barbara C. Farhar, J. Eugene Haas, J. Lorena Ivens, Martin V. Jones, Donald A. Klein, Dean Mann, Griffith M. Morgan, Jr., Steven T. Sonka, Earl R. Swanson, C. Robert Taylor, and Jon Van Blokland "Hail Suppression; Impacts and Issues," Urbana Ill., Illinois State Water Survey, April 1977, pp. i-iii.

⁴⁰ *Ibid.*, 432 pp. (A summary of the report was also published in 1977: Farhar, Barbara C., Stanley A. Changnon, Jr., Earl R. Swanson, Ray J. Davis, and J. Eugene Haas, "Hail Suppression and Society," Urbana, Ill., Illinois State Water Survey, June 1977, 25 pp.)

⁴¹ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20-FY77, p. 95.

Table 14.—Summary of Weather Modification Research Awards by NSF/RANN for Fiscal Year 1973 through 1976 Transitional Quarter. (Data from Annual Summaries of Awards, RANN, Division of Advanced Environmental Research and Technology.)

Principal investigator/ institution	Title	Effective date	Duration (months)	Amount
FISCAL YEAR 1973 AWARDS				
Firor, John W., National Center for Atmospheric Research, Boulder, Colo.	Contract for the management, operation, and maintenance of the National Center for Atmospheric Research (funds for national hail research experiment program).	Aug. 1, 1972.....	12	\$2,700,000
Jayaweera, K.O.L.F., University of Alaska, College, Alaska.	Prevention of ice fog formation by inducing cloud cover—Feasibility study in Fairbanks.	Sept. 1, 1972.....	12	17,600
Sikdar, Dharendra N., University of Wisconsin-Madison, Madison, Wis.	Study of the features and energy budgets of northeastern Colorado hailstones.	Oct. 1, 1972.....	12	96,900
Boone, Larry M., Department of Agriculture, Washington, D.C.	Economic and institutional considerations of suppressing hail.	Oct. 15, 1972.....	12	65,000
Taubenfeld, Howard J., Southern Methodist University, Dallas, Tex.	Study group on the societal consequences of weather modification.	Nov. 1, 1972.....	12	64,400
Haas, J. E., University of Colorado, Boulder, Colo.	A comparative analysis of public support of and resistance to weather modification projects.	Dec. 1, 1972.....	20	60,700
Corrin, Myron L., Colorado State University, Fort Collins, Colo.	Heterogeneous ice nuclei.....do.....	.....do.....	12	49,800
Grant, Lewis O., Colorado State University, Fort Collins, Colo.	Precipitation augmentation from orographically induced clouds and cloud systems.	Jan. 1, 1973.....	12	281,400
Barchet, Wm. Richard, University of Wisconsin-Madison, Madison, Wis.	Precipitation process modification through ice nucleus deactivation.	Feb. 15, 1973.....	12	55,600
McQuigg, James D., University of Missouri-Columbia, Columbia, Mo.	Weather modification management guidelines.	.....do.....	12	42,000
Corrin, Myron L., Colorado State University, Fort Collins, Colo.	Laboratory cloud simulation to support weather modification research and field programs.	Mar. 1, 1973.....	12	112,600
Warburton, Joseph A., Desert Research Institute, Reno, Nev.	Silver iodide seeding rates and snowpack augmentation.	.....do.....	12	80,100
Hobbs, Peter V., University of Washington, Seattle, Wash.	Physical evaluation of cloud seeding techniques for modifying orographic snowfall (the Cascade project).	Apr. 1, 1973.....	15	182,000
Veal, Donald L., University of Wyoming, Laramie, Wyo.	Development of leaf-derived ice nuclei for weather modification.	.....do.....	12	70,000
Changnon, Stanley A., University of Illinois-Urbana, Urbana, Ill.	Design of a hail suppression experiment in Illinois.	.....do.....	12	142,200
Steele, Roger L., Desert Research Institute, Reno, Nev.	Sequence effects of heterogeneous nucleation.	Apr. 15, 1973.....	12	71,000
Plooster, Myron N., University of Denver, Denver, Colo.	M.crophysics—Diffusion interaction in ice nuclei plumes.	.....do.....	12	39,900
Changnon, Stanley A., Jr., University of Illinois-Urbana, Urbana, Ill.	Studies of urban effects on rainfall and severe weather.	.....do.....	12	211,400
Peterson, D. F., Utah State University, Logan, Utah.	Workshop on inadvertent weather modification.	May 1, 1973.....	12	29,900
Weickmann, Helmut K., National Oceanic and Atmospheric Administration, Boulder, Colo.	Installation and maintenance of ground network for national hail research experiment.	May 22, 1973.....	6	39,033
Moore, Charles, B., New Mexico Institute of Mining and Technology, Socorro, N. Mex.	Origin and role of electricity in clouds.	June 1, 1973.....	12	170,800
Braham, Roscoe R., Jr., University of Chicago, Chicago, Ill.	Inadvertent weather modification in the St. Louis area.	.....do.....	12	275,000
Chessin, Henry, State University at Albany, Albany, N.Y.	Development of cloud seeding technology utilizing modified silver iodide structures.	.....do.....	12	33,500
Uthe, Edward E., Stanford Research Institute, Menlo Park, Calif.	Lidar—Radiometric study of urban atmospheric processes related to climatic modification.	.....do.....	12	54,100
Klein, Donald A., Colorado State University, Fort Collins, Colo.	Microbiological impacts of silver iodide used in weather modification.	July 1, 1973.....	12	67,600
Auer, August H., Jr., University of Wyoming, Laramie, Wyo.	Modification of convective cloud activity by an urban area.	.....do.....	12	61,300
Ochs, Harry T., III, University of Illinois-Urbana, Urbana, Ill.	2-dimensional cloud modeling—Application to urban effects on precipitation.	July 1, 1972.....	12	117,700
FISCAL YEAR 1974 AWARDS				
Anderson, C. E., University of Wisconsin.	Study of the features and energy budgets of northeastern Colorado hailstorms.	Oct. 1, 1973.....	12	100,000
Auer, August H., University of Wyoming.	Modification of convective cloud activity.	Apr. 1, 1974.....	12	132,000

Table 14. Summary of Weather Modification Research Awards by NSF/RANN, for Fiscal Year 1973 through 1976 Transitional Quarter, (Data from Annual Summaries of Awards, RANN, Division of Advanced Environmental Research and Technology.)—Continued

Principal investigator/ institution	Title	Effective date	Duration (months)	Amount
FISCAL YEAR 1974 AWARDS—Continued				
Barchet, William R., University of Wisconsin.	Precipitation process modification through ice nucleus deactivation.	Feb. 15, 1973	12	\$55,600
Boone, Larry M., U.S. Department of Agriculture.	Economic and institutional considerations of suppressing hail.	Oct. 1, 1973	15	54,000
Braham, Roscoe R., Jr., University of Chicago.	Inadvertent weather modification in the St. Louis area.	Apr. 1, 1974		243,000
Changnon, Stanley A., Jr., University of Illinois.	Studies of urban effects on rainfall and severe weather.	-----do-----	12	237,500
	Design of a hail suppression experiment in Illinois.	June 1, 1973	12	33,500
Chessin, Henry, State University of N.Y.	Development of cloud seeding technology utilizing modified silver iodide structures.	-----do-----	12	33,500
Chisholm, John P., Sierra Nevada Corp.	An accurate and inexpensive airborne windfinding system.	July 1, 1974	12	44,400
Corrin, Myron L., Colorado State University.	Heterogeneous ice nuclei development.	Oct. 1, 1973	12	49,800
Davis, Briant L., South Dakota School of Mines and Technology.	Chemical complexing of silver iodide-alkali iodide aerosols prepared for cloud seeding purposes.	Sept. 1, 1972	24	103,900
Dennis, Arnett S., South Dakota School of Mines and Technology.	Numerical analysis of proposed hail suppression concepts.	Sept. 1, 1971	24	86,300
Firor, John W., National Center for Atmospheric Research.	National hail research experiment	July 1, 1973	12	2,000,000
Fujita, Theodore T., University of Chicago.	Basic research on tornadoes relevant to their modification.	Sept. 1, 1971	24	55,400
Fukuta, Norihiko, University of Denver.	Development of cloud seeding generators for biodegradable organic ice nuclei.	July 15, 1973	12	106,900
Grant, Lewis O., Colorado State University.	Extended area effects from local weather modification.	Mar. 1, 1974	9	250,000
	Cloud simulation and aerosol laboratory.	Apr. 4, 1974	6	4,000
Haas, J. Eugene, Human Ecology Research Services, Inc.	A comparative analysis of public reaction to weather modification projects.	Aug. 1, 1974	2	22,800
Hobbs, Peter V., University of Washington.	Orographic snowfall in the Cascade project.	Apr. 1, 1973	15	182,000
Klein, Donald A., Colorado State University.	Management of silver iodide used in weather modification: Development in microbial threshold toxicity criteria.	July 1, 1974	3	16,900
Little, Gordon C., National Oceanic and Atmospheric Administration.	Operating two dual-Doppler radars in conjunction with the 1974 summer operations.	June 1, 1974	12	10,000
McQuigg, James D., University of Missouri.	Weather modification guidelines	Feb. 15, 1974	12	42,000
Moore, Charles B., New Mexico Institute of Mining and Technology.	Lightning protection systems and thunderstorm electrification.	May 15, 1974	12	130,000
Mordy, Wendell A., Center for the Future.	A program of social science research coordination and goal evaluation for Metromex.	Oct. 1, 1973	3	15,000
Ochs, Harry T., III, University of Illinois.	Supportive modeling of urban effects on precipitation.	July 1, 1974	9	76,000
Plooster, Myron N., University of Denver.	Microphysics—Diffusion interaction in ice nuclei plumes	Apr. 15, 1974	12	39,500
Schaefer, Vincent J., State University of New York	Second inadvertent weather modification workshop.	April 1, 1974	24	33,000
Schickendanz, Paul T., Illinois State Water Survey.	Climatic alterations in the Great Plains due to widespread irrigation.	June 1, 1974	24	55,500
Simpson, Joanne, University of Virginia.	Evaluation and design of weather modification experiments.	July 1, 1974	12	50,000
Steele, Roger L., University of Nevada	Sequence effects of heterogeneous nucleation.	April 15, 1974	12	71,000
Taubenfeld, Howard J., Southern Methodist University.	Study group on the societal consequences of weather modification.	Oct. 1, 1973	12	60,800
Veal, Donald L., University of Wyoming.	Development of leaf-derived ice nuclei for weather modification.	Apr. 1, 1973	12	70,000
Warburton, Joseph A., University of Nevada.	Silver iodide seeding rates and snowpack augmentation.	Mar. 1, 1973	12	80,100
FISCAL YEAR 1975 AWARDS				
Inadvertent weather modification:				
Auer, August H., University of Wyoming.	Modification of convective cloud activity by an urban area.	Apr. 1, 1975	10	134,300
Braham, Roscoe R., Jr., University of Chicago.	Inadvertent weather modification in the St. Louis area.	-----do-----	12	261,000

Table 14. Summary of Weather Modification Research Awards by NSF/RANN, for Fiscal Year 1973 through 1976 Transitional Quarter. (Data from Annual Summaries of Awards, RANN, Division of Advanced Environmental Research and Technology.)—Continued

Principal investigator/ institution	Title	Effective date	Duration (months)	Amount
FISCAL YEAR 1975 AWARDS—Continued				
Inadvertent weather modification—Continued				
Chagnon, Stanley A., University of Illinois.	Studies of urban effects on rainfall and severe weather.	Apr. 1, 1975.....	12	\$257,200
Gossard, Earl E., National Oceanic and Atmospheric Administration.	Dual-Doppler radar investigation of wind flow patterns in Metromex.	June 15, 1975.....	12	60,000
Ochs, Harry T., University of Illinois.	Numerical cloud modeling.....	Apr. 1, 1975.....	10	63,400
Schickedanz, Paul T., University of Illinois.	Climatic alternations in the Great Plains due to widespread irrigation.	June 1, 1974.....	24	55,500
Societal utilization:				
Boone, Larry M., U.S. Department of Agriculture.	Economic and institutional considerations of suppressing hail.	Oct. 1, 1973.....	15	54,500
Grant, Lewis O., Colorado State University.	Extended area effects from local weather modification.	Dec. 1, 1974.....	12	280,000
Haas, J. Eugene Human Ecology Research Service.	A comparative analysis of public reaction to weather modification projects.	Oct. 1, 1974.....	12	76,000
Klein, Donald A., Colorado State University.	Microbiological impacts of silver iodide used in weather modification.	July 1, 1975.....	12	46,600
McQuigg, James D., University of Missouri.	Weather modification management guidelines.	Aug. 1, 1974.....	14	41,000
Mordy, W. A., Center for the Future.	The importance of climate and weather alterations to mankind.	July 1, 1974.....	15	87,000
Morgan, G. M., University of Illinois.	Design of a hail suppression experiment in Illinois.	Nov. 1, 1974.....	12	67,800
Shafer, Vincent J., State University of New York.	Second inadvertent weather modification workshop.	Apr. 1, 1974.....	12	33,000
Taubenfeld, Howrad J., Southern Methodist University.	Study group on the consequences of weather modification.	November 1974...	6	13,800
Weather hazard mitigation:				
Atlas, David, National Center for Atmospheric Research.	National hail research experiment...	July 1975.....	12	2,130,000
Moore, Charles B., New Mexico Institute of Mining and Technology.	Lightning protection and thunderstorm electrification.	June 1, 1975.....	12	130,000
Weather modification systems:				
Anderson, Charles E., University of Wisconsin.	Studies on the dynamics, microphysics, and forecasting of severe local storms.	Jan. 1, 1975.....	12	96,000
Chisholm, John P., Sierra Nevada Corp.	An accurate and inexpensive airborne windfinding system.	July 1, 1974.....	9	44,400
Davis, Briant L., Institute of Atmospheric Sciences.	Chemical complexing of silver iodide-alkali iodide aerosols prepared for cloud-seeding purposes.	Sept. 1, 1972.....	24	103,900
Fukuta, Norihiko, University of Denver.	Cloud-seeding generators for biodegradable organic ice nuclei.	July 15, 1974.....	12	100,400
Grant, Lewis O., Colorado State University.	Cloud simulation and aerosol laboratory.	Nov. 1, 1974.....	12	18,000
Little, Gordon C., National Oceanic and Atmospheric Administration.	Dual-Doppler radar investigations of wind fields in severe storms.	July 1, 1974.....	12	60,000
Simpson, Joanne, University of Virginia.	Evaluation and design of weather modification experiments.	.....do.....	12	50,000
FISCAL YEAR 1976 AWARDS				
Improved weather modification technology:				
Fukuta, Norihiko, University of Denver.	Development of cloud-seeding generators for biodegradable organic ice nuclei.	Aug. 1, 1975.....	12	133,100
Gossard, Earl E., National Oceanic and Atmospheric Administration.	Collection and processing of multiple Doppler radar data in NHRE.	May 15, 1976.....	14.5	135,000
Grant, Lewis O., Colorado State University.	Testing and calibration program for cloud-seeding materials, seeding generators, and nucleus-observing instruments.	July 1, 1975.....	12	10,800
Simpson, Joanne, University of Virginia.	Evaluation and design of weather modification experiments.	.....do.....	9	73,000
Warburton, Joseph A., Denver Research Institute.	Silver iodide tracing in south Florida	.....do.....	12	15,000
	Silver iodide seeding rates and snowpack augmentation.	.....do.....	6	49,900
Inadvertent weather modification:				
Auer, August H., University of Wyoming.	Lidar, acoustic sounder and radiometer investigation.	July 15, 1975.....	12	52,800
	Modification of convective cloud activity by an urban area.	Feb. 1, 1976.....	14	178,700

Table 14. Summary of Weather Modification Research Awards by NSF/RANN, for Fiscal Year 1973 through 1976 Transitional Quarter. (Data from Annual Summaries of Awards, RANN, Division of Advanced Environmental Research and Technology.)—Continued

Principal investigator/ institution	Title	Effective date	Duration (months)	Amount
FISCAL YEAR 1976 AWARDS—Continued				
Inadvertent weather modification—Continued				
Braham, Roscoe R., University of Chicago.	Inadvertent weather modification in the St. Louis area.	Feb. 1, 1976.....	14	\$301,800
Changnon, Stanley A., University of Illinois.	Studies of urban effects on rainfall and severe weather.	...do.....	14	311,500
Hobbs, Peter, University of Washington.	Inadvertent weather modification by effluents from coal-fired electric powerplants.	June 15, 1976.....	24	181,400
Ochs, Harry T., University of Illinois.	Numerical cloud modeling: Application to urban effects on precipitation.	Feb. 1, 1976.....	14	64,300
Saxena, V. K., University of Denver.	Airborne mapping of urban plume of St. Louis with a cloud condensation nuclei (CCN) spectrometer.	May 15, 1976.....	12	21,700
Social, legal, and economic impact of weather modification:				
Farhar, Barbara, Human Ecology Research Services, Inc.	A comparative analysis of public response to weather modification.	Dec. 1, 1975.....	15	82,000
Grant, Lewis O., Colorado State University.	A field experiment to test hypotheses of the reality, characteristic, and magnitude of extended area effects from weather modification.	...do.....	11	215,709
Klein, Donald A., Colorado State University.	Management of nucleating agents used in weather modification: Development of microbial threshold toxicity criteria.	Oct. 1, 1975.....	15	46,200
Weather hazard mitigation:				
Veal, Donald, National Center for Atmospheric Research.	National hail research experiment...	Aug. 1, 1975.....	12	2,361,000
Weather modification in support of agriculture:				
Grant, Lewis O., Colorado State University.	An assessment of the present and potential role in weather modification in agricultural production.	July 1, 1975.....	9	11,800
Huff, Floyd A., University of Illinois.	Assessment of weather modification in alleviating agricultural water shortages during droughts.	Nov. 1, 1975.....	18	71,000
FISCAL YEAR 1976 TRANSITIONAL QUARTER AWARDS				
Improved weather modification technology:				
Chisholm, John, Sierra Nevada Corp.	An accurate and inexpensive airborne wind measuring system.	August 1976.....	15	61,600
Hallett, John, University of Nevada.	An assessment of synoptic criteria for ice multiplication in convective clouds.	...do.....	12	23,500
Maki, Leroy R., University of Wyoming.	Ice nucleation induced by bacteria...	...do.....	21	64,300
Inadvertent weather modification:				
Uthe, Edward E., Stanford Research Inst.	Lidar and radiometric data analysis of mixing levels, clouds, and precipitation processes.	...do.....	10	45,200
Social, legal, and economic impact of weather modification:				
Lambright, W. Henry, Syracuse Research Corp.	The utilization of weather modification technology: A State government decisionmaking study.	September 1976...	18	60,400
Weather hazard mitigation:				
Auer, August H., University of Wyoming.	The kinematics of thunderstorm gust fronts relating to the mitigation of airport flight hazards.	August 1976.....	12	56,300
Veal, Donald L., National Center for Atmospheric Research.	National hail research experiment...	July 1976.....	4	800,000

Weather hazard mitigation

Research supported by NSF in this category is pointed toward the reduction of undesirable aspects of selected weather hazards. Although the major effort has been in research on the reduction of hail damage, research related to other severe weather phenomena has included investigations on lightning protection, wind shear warning, and fog hazard alleviation. The major project in weather hazard mitigation

in recent years has been the National Hail Research Experiment (NHRE), which was initiated by the Foundation in 1971 "to assess the potential for altering hail . . . by cloud seeding and determine the extent to which beneficial modification can be accomplished effectively on an operational basis."⁴²

The concept of a national hail suppression experiment grew out of interest by U.S. scientists in hail suppression activities in the Soviet Union in the 1960's and also from the 1965 recommendation of the Interdepartmental Committee for Atmospheric Sciences (ICAS) that the Foundation, in collaboration with other Federal agencies, should develop a plan for hail suppression research.⁴³ As a first step in planning such a national effort, the NSF invited the National Center for Atmospheric Research (NCAR) to cooperate in organizing the First National Symposium on Hail Suppression, which was held at Dillon, Colo., on October 14-15, 1965, under the chairmanship of Verner E. Suomi.⁴⁴

Arising from the Dillon conference was an NSF-sponsored Hail Suppression Research Steering Committee, also chaired by Dr. Suomi, which held a number of meetings in the years immediately following and prepared a hail suppression test outline in 1968.⁴⁵ Upon approval of the outline by the ICAS, the NSF requested that a detailed plan for a national experiment be developed by NCAR. A "Plan for the Northeast Colorado Hail Experiment (NECHE)" was prepared by NCAR⁴⁶ and approved by the ICAS in 1969. The NECHE plan called for an intensive investigation into hailstorms and hail suppression to be conducted over a 5-year period. After a few years of preliminary investigations, the project was eventually renamed the National Hail Research Experiment (NHRE) in 1971.

NHRE was one of seven proposed national projects in weather modification identified by the Interdepartmental Committee for Atmospheric Sciences (ICAS) in 1971.⁴⁷ The National Science Foundation, which originally planned the experiment, was recommended as the lead agency for the project, and assistance was to be offered by the Departments of Agriculture, Commerce, Defense, Interior, and Transportation and by the Atomic Energy Commission and the National Aeronautics and Space Administration.⁴⁸

Although there was interagency cooperation in planning the experiment and some support to the project during early years by some of the aforementioned agencies, eventually, most of the other agencies pulled out and NSF had to provide full support on its own. In a 1974 investigation of the Federal weather modification program, the General Accounting Office (GAO) concluded that "even though the ex-

⁴² Downie and Dirks, "National Science Foundation Weather Modification Program," 1976, p. 557.

⁴³ National Science Foundation, "Report of the First National Symposium on Hail Suppression," Dillon, Colo., Oct. 14-15, 1965, p. 1.

⁴⁴ *Ibid.*

⁴⁵ National Science Foundation, Hail Suppression Research Steering Committee, "Outline of a Hail Suppression Test," March 1968, p. 1.

⁴⁶ National Center for Atmospheric Research and Select Planning Group of the Northeast Colorado Hail Experiment, "Plan for the Northeast Colorado Hail Experiment," Boulder, Colo., Mar. 17, 1969.

⁴⁷ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, "A National Program for Accelerating Progress in Weather Modification," ICAS rept. No. 15a, June 1971, p. 21. (The seven national projects are listed in this report, p. 225.)

⁴⁸ *Ibid.*, pp. 35-37.

periment was well planned, requiring extensive interagency participation, * * * for the most part, agencies could not and did not meet all their obligations."⁴⁹ The GAO study observed that, because of the withdrawal of some of the intended support, "important segments of research were lost for 1973" and that each operational season would continue to have problems with commitments from participating agencies.⁵⁰ The other national projects recommended by the ICAS, each with much less coordinated planning than NHRE or with no such coordinated planning at all, failed to materialize as truly national projects, although some were pursued as major single-agency projects.

NHRE was based on the original NECHE plan prepared for the NSF by the National Center for Atmospheric Research (NCAR), and management for conduct of the experiment was assigned to NCAR by NSF. The experiment was a cooperative effort between NCAR and 10 universities, funded by NSF, with additional support from the Department of Commerce (National Oceanic and Atmospheric Administration), the Department of Transportation (Federal Aviation Administration), and the Department of Defense. Figure 9 is a map of the northeastern corner of Colorado, showing the two areas between Sterling, Colo., and Kimball, Nebr., which were target areas for the NHRE. Field headquarters for the experiment were located near Grover, Colo. Figure 10 is a more detailed NHRE map, showing the special use airspace and the protected area as well as the mesonet and rawinsonde site locations during the 1974 season.

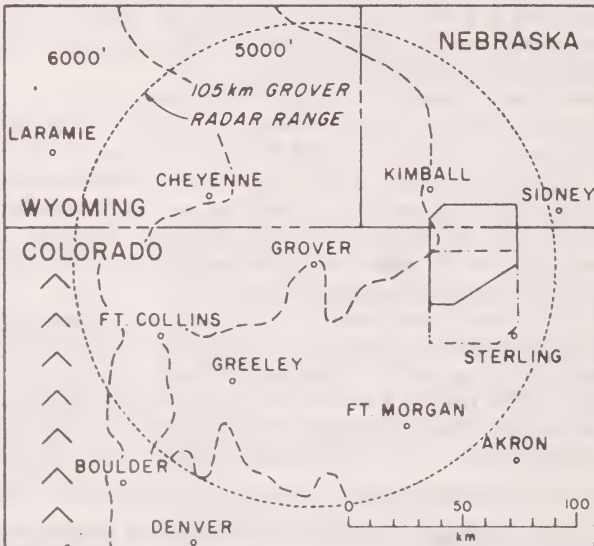


FIGURE 9.—Location map, showing the vicinity of northeastern Colorado where the National Hail Research Experiment (NHRE) was conducted. NHRE field headquarters were located near Grover, Colo. The two areas outlined between Sterling and Kimball were the target areas for the seeding program in 1972 (southern area) and in 1973 and 1974 (northern area). (From Wade, et al., 1977.)

⁴⁹ Comptroller General of the United States. "Need for a National Weather Modification Research Program." report to the Congress, U.S. General Accounting Office, B-133202, Aug. 23, 1974, pp. 19-22.

⁵⁰ *Ibid.*, p. 29.

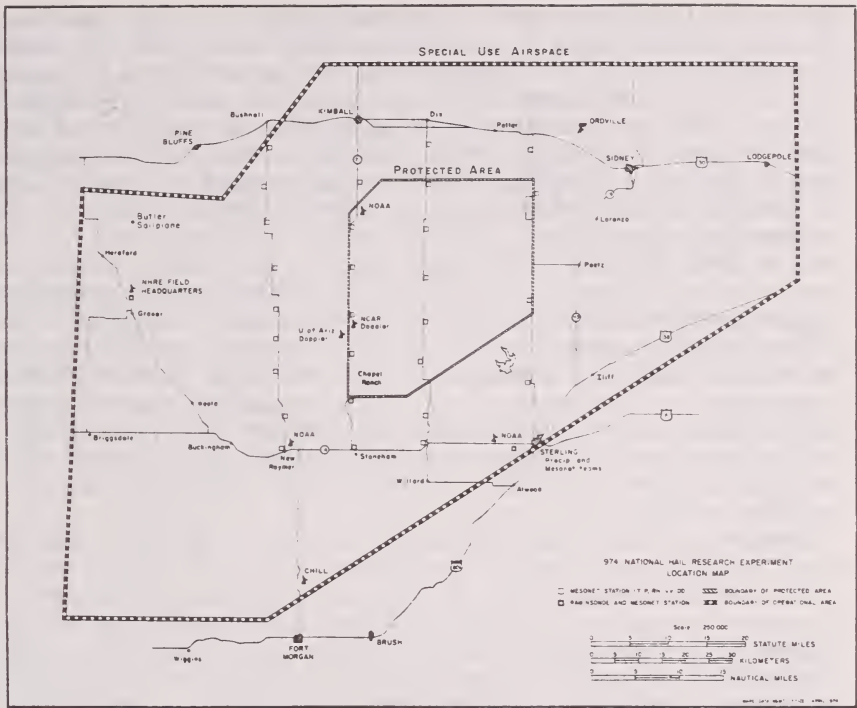


FIGURE 10.—Detailed location map for the National Hail Research Experiment (NHRE), showing the special use airspace and protected area, as well as the mesonet and rawinsonde site locations during the 1974 summer season. (Courtesy of the National Science Foundation.)

Following collaborative studies of northeast Colorado hailstorms by NCAR, Colorado State University, and the U.S. Department of Commerce during the period 1968–70, what was to become the National Hail Research Experiment (NHRE) effectively began in the summer season of 1970 with the following twofold plan:

1. To carry out research into those processes important to the understanding of hail production in severe thunderstorms, and
2. To perform a randomized test of a hail suppression technique modelled in some important respects after the reportedly successful operation in the Soviet Union.

The twofold objective of NHRE has remained throughout the project; however, its statement has varied from year to year in response to changes in emphasis both at NSF and at NCAR. In particular, after transfer of the project to RANN, an important emphasis was given to social, economic, legal, and environmental studies in connection with the potential impact of hail suppression.

A preliminary field program, for instrument testing and field experience, was undertaken during the summer of 1971; and during the summers of 1972, 1973, and 1974 the major randomized hail suppression test was conducted along with other basic research on hail

properties. Instead of continuing the randomized seeding experiment for the planned 5 years, it was curtailed at the close of the 1974 season because research evidence showed strongly that seeding as performed was not likely to suppress hail in northeast Colorado and preliminary analysis indicated that data from 2 more years was unlikely to demonstrate a suppression effect.⁵¹ At a symposium on hail and hail suppression in the fall of 1975,⁵² most of the experts agreed that continuation of the 1972-74 randomized seeding experiment was unwise for the reasons given above.

A revised plan for NHRE followed this symposium, in which it was stated that future research should be directed “* * * to combine applied research, development of techniques, and redesign of a randomized seeding experiment in a manner which will provide the greatest chance of reaching a conclusive answer as to the feasibility of hail suppression in a reasonable time.”⁵³ The revised plan also committed the NHRE staff to completion of a report on the 1972-74 randomized seeding experiment. The five-volume report, the first volume of which is a summary of the analysis and results, has recently been completed and distributed.⁵⁴

A short field season for NHRE was undertaken during 1975 to test new instruments and a new data system aboard the South Dakota School of Mines and Technology armored, penetrating T-28 aircraft. Operated in coordination with the Grover S-band radar, the Grover control center, and the aircraft tracking system, the test was successful and valuable data were obtained. Field measurements were carried out on a larger, more comprehensive scale during the summer of 1976; however, no seeding was done.⁵⁵ Analyses of data from previous years continued in 1976 and 1977. Field research in 1976 and succeeding analyses were intended to assist in an improved design for a randomized seeding experiment.

Highlights of the results obtained by intensive analysis of the data obtained from NHRE through the 1975 summer field season have been summarized by Downie and Dirks as follows:⁵⁶

1. The original techniques employed in NHRE were based on concepts developed in the Soviet Union, which hypothesized that rapid hail growth took place in local regions of liquid water accumulation zones. A variety of observations has led to the rejection of the Soviet model of hail formulation for northeast Colorado storms.

2. Observations within the clouds and examination of thin sections of hailstones indicate that the ice-crystal-riming (graupel) process is dominant rather than the waterdrop-coalescence mode of precipitation formation.

⁵¹ *Ibid.*, pp. 3-4.

⁵² National Center for Atmospheric Research. “NHRE Symposium/Workshop on Hail and Its Suppression,” Estes Park, Colo., Sept. 21-28, 1975. National Hail Research Experiment technical report NCAR/7100-75/2. Boulder, Colo., November 1975. 130 pp.

⁵³ National Hail Research Experiment Staff, revised plan for the National Hail Research Experiment. National Center for Atmospheric Research, Boulder, Colo., February 1976, p. 3.

⁵⁴ Crow, E. L., P. W. Summers, A. B. Long, C. A. Knight, G. B. Foote, and J. E. Dye, final report—“National Hail Research Experiment: Randomized Seeding Experiment: 1972-74, Vol. I. Experimental Results and Overall Summary.” National Center for Atmospheric Research, Boulder, Colo., December 1976. 260 pp. [Vols. II, III, IV, and V deal with precipitation measurements, meteorological summary, radar summary, and hail declaration procedures and seeding operations, respectively.]

⁵⁵ University Corp. for Atmospheric Research. “Fiscal Year 1978 Work Plan for Analysis of Data From the National Hail Research Experiment,” p. 3.

⁵⁶ Downie and Dirks, “National Science Foundation Weather Modification Program,” 1976, pp. 557-558.

3. Much effort was expended in the development of new instrumentation during the NHRE experiment to provide direct measurements of the characteristics of hail-producing storms which were necessary to validate the concepts of hail suppression.

4. Results from the randomized seeding experiment, which was carried out during the period 1972-74, do not permit one to conclude that seeding had any effect on hail or rainfall. However, the data are extremely valuable for determining the required density and extent of surface instruments for a future seeding experiment, as well as estimating the length of time a future experiment would have to be carried out to detect a specified effect.

5. Studies of direct economic costs and benefits have provided estimates of the breakeven point for operational cloud seeding and reiterated the value of hail suppression if reductions in damage of at least 10 percent are attainable.

Referring to the randomized seeding experiment, conducted from 1972 through 1974, the following conclusion was made in the final report: At the outset, the total mass of hail at the ground in the target area was identified as the primary response variable for evaluating seeding effects on hailfall. The major conclusion of the experiment is that no statistically significant effect of seeding is detected. This result is true for the hail mass and all other response variables considered, regardless of the method of analyzing the data.⁵⁷

In a recent paper by Knight, Foote, and Summers it was concluded that "at the present state of knowledge of hail formation in storms, it would appear to be premature to start another major statistical seeding experiment. There is no new, very promising technique in the offing, as the Soviet method appeared to be when NHRE started."⁵⁸ The authors further state that scientific research necessary for a solid foundation for new attempts to modify the precipitation from convective storms is underway and provide the following summary of positive results from NHRE:

The National Hail Research Experiment included a first attempt at mounting a hail suppression test with a strict randomized design and evaluation based upon physical measurement of hail rather than crop damage. The results have been analyzed in detail, with extensive evaluation of data quality and of operational success, facets not generally treated in such detail in previous programs. The outcome was that the seeding may have had a variety of non-zero effects or no effects at all. The one conclusive result was to rule out very large increases or decreases of hail or rain by the seeding. The physical research portion of NHRE led to advances in knowledge of hail and of storms, and contributed substantially to the development of the research tools . . . needed to derive answers to the outstanding, practical problems.⁵⁹

Figure 11 shows the components of the Portable Automated Mesonet (PAM) data network. There were 15 of the remote PAM stations in the NHRE observing network during the 1976 field season. Each PAM station measures pressure, temperature, moisture, precipitation, and wind direction and speed. Data are telemetered to a central collection point, in real time if needed, or they are stored at the PAM station and collected at the central collection point daily.

⁵⁷ Crow, et al., "Final Report—National Hail Research Experiment: Randomized Seeding Experiment: 1972-74," vol. 1, 1976, p. iii.

⁵⁸ Knight, Charles A., G. Brant Foote, and Peter W. Summers, "Physical Research and General Conclusions from the National Hail Research Experiment," preprints from the "Sixth Conference on Planned and Inadvertent Weather Modification," Champaign-Urbana, Ill., Oct. 10-13, 1977. American Meteorological Society, Boston, Mass., p. 165.

⁵⁹ *Ibid.*

PORTABLE AUTOMATED MESONET (PAM)

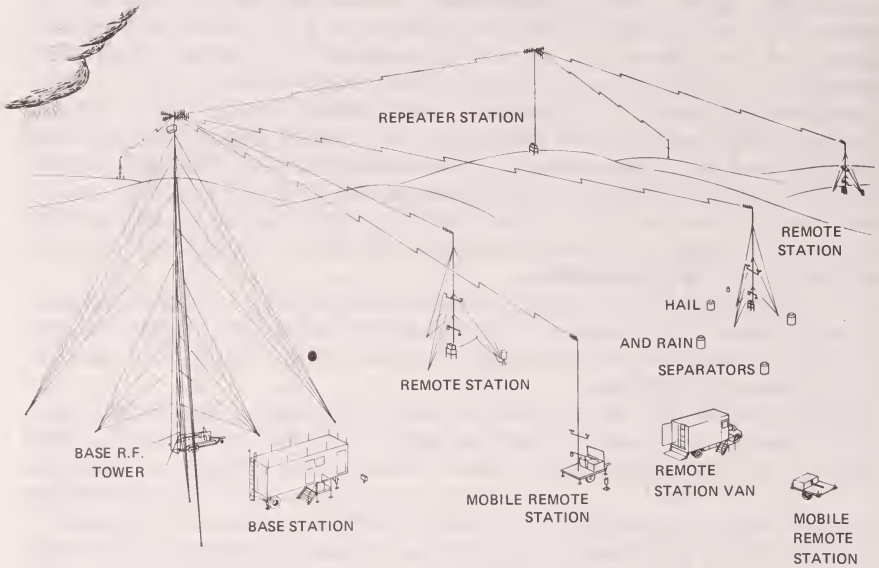
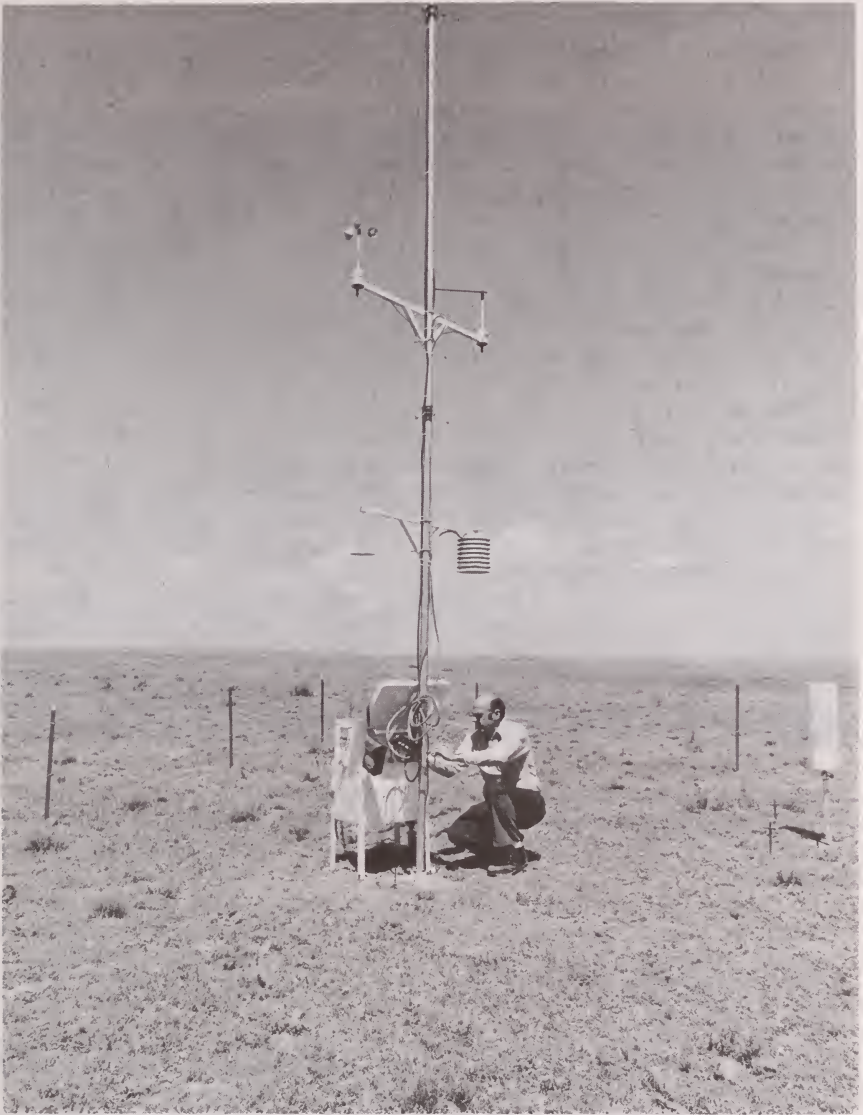


FIGURE 11.—Components of the Portable Automated Mesonet (PAM) data collection system, used in the National Hail Research Experiment (NHRE). Each PAM station measures pressure, temperature, moisture, and wind speed and direction; data are then telemetered to a central collection point. (Courtesy of the National Science Foundation.)



A typical remote field installation of the portable automated mesonet (PAM) system. (Courtesy of the National Science Foundation.)

Weather modification technology development

Research sponsored by the NSF under this category is intended to utilize predictive models, advanced measurement systems, and statistical analyses to improve the experimental design and evaluation of weather modification investigations. Part of the demand for some of the long, costly weather modification experiments is due to the large natural variability of atmospheric processes, which is a major obstacle to successful field tests of weather modification technology. It is expected that improvements achieved through the high priority research incorporating the combined use of the three research tools listed above will not only aid in the logistic design of experiments, but will also reduce the predicted natural variability of weather events, thus reducing the overall time required for conducting a definitive experiment.⁶⁰

The NSF-supported Climax experiments (conducted by Colorado State University from 1960 to 1970) first demonstrated the efficacy of wintertime orographic precipitation enhancement. Results of these experiments have provided the basis for a number of subsequent demonstration experiments.⁶¹ The following examples of weather modification technology development projects have received NSF research support in recent years:⁶²

1. Evaluation of the Florida area cumulus experiment (FACE), where cloud motion has been found to be a significant covariate in the data evaluation.

2. Development of new techniques for the evaluation of convective precipitation in the metropolitan meteorological experiment (Metro-mex).

3. Development and testing of statistical-physical methods for the evaluation of operational cloud-seeding programs.

4. Research on various ice nucleants which might be used instead of silver iodide and on development of delivery systems for organic nucleants.

5. Assessment of Midwest cloud characteristics for weather modification, by compiling and analyzing sample statistics of variables important in cloud development and precipitation processes as well as in their modification as a function of mesoscale and macroscale atmospheric conditions.

6. Exploration of the feasibility of artificially generating cirrus clouds as a weather modification tool and numerical modeling of effects of cirrus clouds on the troposphere and mesoscale weather.

7. Maintenance and operation of a testing and calibration facility for seeding materials, cloud-seeding generators, and ice nucleus measuring instrumentation, for use by research projects of Federal agencies and by the commercial cloud-seeding industry (at Colorado State University).

Other specific research projects designed to improve the technology of weather modification are found in the list of recent RANN awards for weather modification research in table 14. In the past, the NSF program in weather modification has made significant contributions to

⁶⁰ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20-FY77, p. 96.

⁶¹ The Climax experiments are discussed under orographic precipitation enhancement technology, in ch. 3, p. 77.

⁶² Downie and Dirks, "National Science Foundation Weather Modification Program," 1976, p. 560; and Currie S. Downie, personal communication.

the initial phases of major weather modification projects of other Federal agencies, such as Project Stormfury (Department of Commerce) and Project Skyfire (Department of Agriculture).



Instrumented aircraft, operated by the Research Aviation Facility of the National Center for Atmospheric Research (NCAR), whose primary mission in the 1976 summer field season of the National Hail Research Experiment (NHRE), was to assess the feasibility of on-top cloud seeding. (Courtesy of the National Science Foundation.)

Inadvertent weather modification

The objective of this portion of the NSF/RANN weather modification research program is "to delineate the mechanisms whereby, and the extent to which, an agricultural region modifies its own climate and an urban area modifies its surrounding weather, precipitation, and aerosol."⁶³ Most of the NSF research on inadvertent weather modification is concentrated in the metropolitan meteorological experiment (METROMEX) in the neighborhood of St. Louis. The research seeks to provide better definition of the causes for anomalies in precipitation and other atmospheric properties observed as a result of the urban influence. In addition to METROMEX other inadvertent weather modification research in which NSF has interest includes studies on the effects of energy development, expanded agricultural production, and growing urban sprawl.⁶⁴

One current NSF-sponsored project is being conducted by the University of Washington on inadvertent effects induced by coal-fired electric powerplants. The objective of this research is to determine

⁶³ National Science Foundation, "Summary of Awards: 1976," Division of Advanced Environmental Research and Technology, Washington, D.C. (no publication date), NSF-RA-760219, p. 97.

⁶⁴ Federal Council on Science and Technology, Interdepartmental Committee on Atmospheric Sciences, ICAS 20-FY77, pp. 96-97.

the effects on visibility, clouds, and precipitation of the effluents from modern coal powerplants. Such effects may be considerable since the plants emit much heat, moisture, particulates, and gaseous material into the atmosphere. Results from the project are expected to aid in evaluation of environmental effects of these generators and to assist in the siting of new powerplants. Principal users of the results include regional, State, and Federal agencies concerned with energy development, research, ecology, and land development, as well as engineering firms involved with air pollution impact studies and control systems.⁶⁵

The subject of another inadvertent weather modification study is the influence on the climates of the Great Plains by widespread irrigation. The main objective of this research is to determine the effects on precipitation; also of concern are influences on other meteorological parameters. Results show the existence of rainfall anomalies over an area comparable in size to the irrigated area, and the effects are most detectable during wet summer months.⁶⁶

METROMEX is a multi-institutional, multiyear research project sponsored by the NSF and several other Government agencies, attempting to discover causes for, and to assess consequences of, urban-induced weather effects at St. Louis and vicinity. Primary goals of METROMEX are the systematic investigation of:⁶⁷

The effects of a large urban complex on the frequency, amount, intensity, and duration of clouds, precipitation, and related severe weather; and

The conditions whereby the urban complex modifies the precipitation process.

Application related goals of the experiment are investigation and activities:⁶⁸

To study and develop techniques for translating the results of the scientific goals to other urban areas so as to predict the urban-related changes in other cities;

To translate relevant results to a wide variety of users in the scientific, government, and business communities;

To provide the basis for studies of the potential changes in climate relating to megalopolis and to major land use changes.

A wide variety of potential users of the information from METROMEX include urban and regional planners, meteorologists, hydrologists, airport planners and operators, and air quality scientists. The study is relevant to impacts of increased use of coal, large concentrations of electrical energy generators in power parks, and long range consequences of air pollution on climate.⁶⁹

METROMEX is the world's first major field program planned to link urban land use with modification of the surrounding weather. The selection of St. Louis as the site for the experiments was based on the relatively simple topography of the city and its surroundings, the existence of farmlands downwind to the east in the "shadow" of the

⁶⁵ National Science Foundation, Division of Advanced Environmental Research and Technology, "Summary of Awards: 1976," p. 99.

⁶⁶ Downie and Dirks, "National Science Foundation Weather Modification Program," 1976, p. 559.

⁶⁷ "Principal Investigators of Project Metromex. Metromex Update." Bulletin of the American Meteorological Society, vol. 57, No. 3, Mar. 1976, p. 304.

⁶⁸ Ibid.

⁶⁹ Downie and Dirks, "National Science Foundation Weather Modification Program," 1976, p. 559.

city on which urban influences can be studied, the relatively uncluttered airspace above the city which permitted research flights and atmospheric experiments, and the patterns of urbanization which are typical of other areas in midlatitude North America.⁷⁰

Most of the METROMEX field activities were conducted during the summer months in a 2,000-square-mile area about 56 miles in diameter which includes St. Louis and the Alton-Wood River industrialized area to the northeast. A larger 3,800-square-mile area which includes St. Louis and extends downward contained the world's largest rain-gage network.⁷¹ These two areas are shown in figure 12.

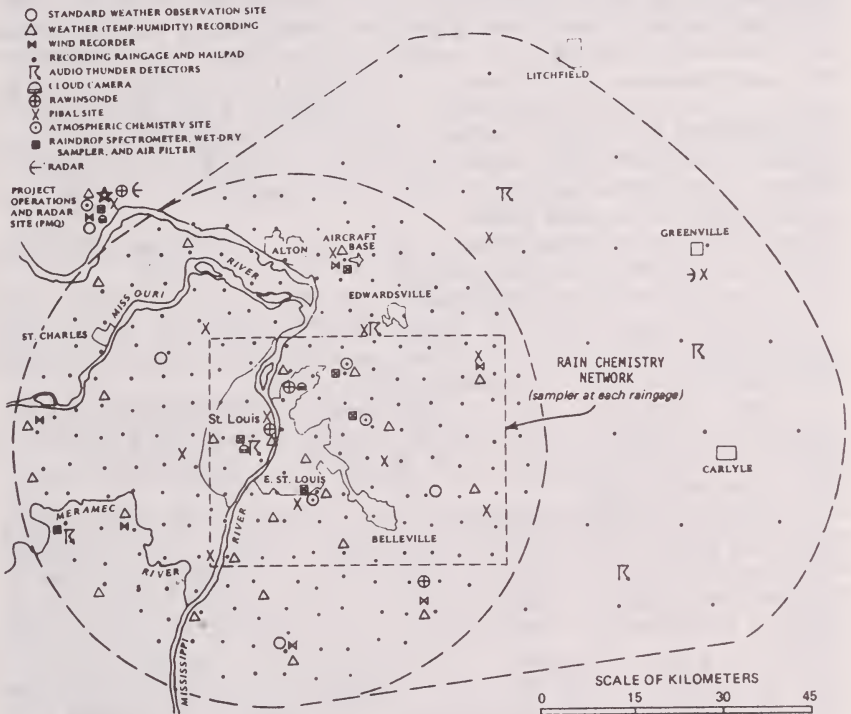


FIGURE 12.—METROMEX field experiment area, centered in St. Louis, and extended “downwind” area containing network of rain gages and other instrumentation. (From Changnon and Simonin, *Studies of selected precipitation cases from METROMEX*, Illinois State Water Survey, Urbana, 1975.)

⁷⁰ National Science Foundation, “Do Cities Change the Weather?” *Mosaic*, vol. 5, No. 3, summer 1974, p. 30.

⁷¹ *Ibid.*

Within the research and data collection areas, measurements have been made of the speeds and direction of winds at different heights and locations, of temperatures, cloud dynamics, precipitation, the nature and intensity of pollutants, number and sizes of storms, and the quality and quantity of ground water under different weather conditions.⁷²

Planning for METROMEX was initiated in 1969-70 by scientists from the Illinois State Water Survey, the University of Chicago, the University of Wyoming, and Argonne National Laboratory. The experimental field program was launched in 1971, supported in part by the Atomic Energy Commission, the Department of Health, Education, and Welfare, and the State of Illinois, as well as the National Science Foundation. Other research groups which later participated in the project include Stanford Research Institute, Battelle Pacific Northwest Laboratories, the University of Missouri, Sierra Nevada Corp., and the University of California at San Diego.⁷³ Field measurements in METROMEX were essentially completed during 1976; although the final METROMEX project report is expected to be published in the near future, the analysis of the large amount of collected data should continue for some years.

In a 1976 review of project accomplishments, the following findings from METROMEX were summarized:⁷⁴

1. There is a summer precipitation anomaly at St. Louis, varying between a 10 and 30 percent excess above background, the location and intensity of which vary with the prevailing seasonal storm motions and general character of summer weather.

2. Some individual rain intensity centers of showers or thunderstorms that develop or pass over St. Louis and over the Alton-Wood River industrial area appear to be enhanced significantly (94 and 73 percent, respectively).

3. The major precipitation changes in and east of the urban industrial area seem to occur during squall line or squall zone conditions when nature is capable of producing moderate to heavy rains, resulting in a 60 percent or greater increase in heavy rain (greater than or equal to 3 cm.) days, a 25 percent increase in thunderstorm activity, and an 80 percent increase in hailstorms and hail intensities in and just east of the city. Radar shows a region of maximum development of large thunderstorms extending to 100 kilometers northeast from the city.

4. Like most large cities, St. Louis has a marked heat island and an identifiable minimum in specific humidity. These effects are most marked at the surface, but often show height-averaged temperature excesses of 1 degree K and moisture deficits of 1 gram of water vapor per kilogram of air, relative to nearby rural areas, extending through the mixing layer to cloud bases.

5. The low-level air flow under light wind conditions is markedly perturbed by the city and often results in distinct convergence over and just downwind of the city center.

6. The pattern of production of Aitken condensation nuclei (ACN) and cloud condensation nuclei (CCN) has been developed for the area. Elemental emission rates have been measured.

⁷² Ibid.

⁷³ Principal Investigators of Project Metromex. Metromex update, 1976, p. 304.

⁷⁴ Ibid., pp. 304-305.

7. Convective storms in the St. Louis area are significant mechanisms for removal and deposition of urban pollutants.

Mechanisms which, in varying degrees, may be responsible for observed downwind increases in summer precipitation, heavy rain occurrences, and hail activity include the large quantities of particulate and gaseous matter injected by industries and motor vehicles into the atmosphere, the heat added and heat island effects of the urban area, the anomalous moisture patterns over the city, and the increased turbulence and wind perturbation caused by the roughness of the city's surface and the heat island.⁷⁵ It has further been observed that the 10 to 30 percent increase in summer rainfall over the 2,000-square-mile area east of St. Louis produces a 15-percent average increase in streamflow and increased infiltration of ground water.⁷⁶

Societal utilization activities

The purposes of this portion of the NSF/RANN program, concerned with social, legal, environmental, and economic impacts of weather modification, are "to evaluate societal reaction to weather modification, to determine societal expectations, and to identify the needs for the scientific base necessary to bring about successful application of weather modification." This research "extends across the disciplines of political, social, legal, economic, ecological, and physical sciences in an effort to investigate the impact of weather modification technology on man."⁷⁷ A number of studies have been supported by the Foundation in this category, in which these aspects of weather modification are examined.

A study group on the societal consequences of weather modification was formed in 1973 at the request of the Interdepartmental Committee for Atmospheric Sciences (ICAS). This study, sponsored by the NSF, was designed to examine needs of the Nation for a weather modification capability and to determine if the present Federal weather modification program is directed toward meeting those needs. Results of this investigation, now nearing completion, should be useful in identifying the alterations or redirections of the Federal program required to meet societal goals.⁷⁸

Studies in social, legal, economic, and ecological aspects of weather modification that are currently underway or have recently been completed include the following:

1. Preparation of a compendium on economic impacts of weather variability, by the University of Missouri. This report was designed to present quantified relations between weather and certain basic human activities, such as agriculture and energy use.⁷⁹

2. A comparative analysis of public response to weather modification, by Human Ecology Research Services, Inc. Building on results of 6 years of sociological study of public response to weather modification, this research will examine social response to weather modification in South Dakota and test preliminary hypotheses on acceptance and rejection processes. Validation of the preliminary hypotheses and

⁷⁵ Downie and Dirks, "National Science Foundation Weather Modification Program," 1976, p. 559.

⁷⁶ *Ibid.*

⁷⁷ National Science Foundation, Division of Advanced Environmental Research and Technology, "Summary of Awards: 1976," p. 101.

⁷⁸ Downie and Dirks, "National Science Foundation Weather Modification Program," 1976, p. 560.

⁷⁹ *Ibid.*

response, patterns will provide the framework for development of a causal model of the acceptance/rejection process.⁸⁰

3. Field experiment to test a hypothesis of the reality, characteristic, and magnitude of extended area effects from weather modification, by Colorado State University. With increasing evidence that planned weather modification projects may have effects that extend over broad geographic areas, this research is an investigation of "downwind" effects of past experiments in the Rocky Mountains and the Great Plains of the United States and in Israel, extending an earlier 3-year study of such effects. Physical and statistical analyses are combined to determine such extended area effects and to develop hypotheses describing processes which produce the effects. The project also includes design of a field experiment based on results of these post hoc analyses and on current results from modeling studies and physical experiments. This research is intended to provide a basis for evaluating extended-area effects on societal activities and should be valuable in formulation of policies on public issues in weather modification.⁸¹

4. Management of nucleating agents used in weather modification and development of microbial threshold toxicity criteria, by Colorado State University. The purpose of this research is to provide information on possible long-term effects of weather modification nucleating agents on microbial ecosystems, concentrating on soil and aquatic ecosystems, which are the most critical areas for accumulation of the agents. Results of this study will be used to prepare environmental impact statements for silver iodide seeding in various experimental and operational cloud seeding programs.⁸² In the final phase of this study, a workshop on the environmental impacts of cloud seeding materials was conducted in Vail, Colo., in November 1976. The proceedings of the workshop are expected to be published during 1978.

5. Utilization of weather modification technology: A State government decisionmaking study, by Syracuse University. State governments have taken the lead in developing regulatory policies affecting the present use of weather modification technology; however, such policies cover a wide spectrum, some being highly restrictive while others are more permissive. This study, focusing on decisionmaking processes in five States—South Dakota, Colorado, Illinois, Pennsylvania, and California—will develop case histories and analyses of policymaking, the availability of which should help Federal and State officials in making decisions on emerging weather modification technology.⁸³

Agricultural weather modification

This relatively new portion of the NSF/RANN weather modification program is evolving in response to a need "to develop a better understanding of weather variability and its significance to food production and to develop specific applications of weather modification technology as it relates to agricultural needs."⁸⁴ For such applications, weather modification is considered in a broad context, including all identifiable modifications of the atmospheric environment.

⁸⁰ National Science Foundation, Division of Advanced Environmental Research and Technology, "Summary of Awards: 1976," p. 101.

⁸¹ *Ibid.*, p. 102.

⁸² *Ibid.*, pp. 102-103.

⁸³ National Science Foundation, Division of Advanced Environmental Research and Technology, "Summary of Awards: Transition Quarter 1976," NSF 77-S. Washington, D.C. (no publication date), p. 48.

⁸⁴ National Science Foundation, Division of Advanced Environmental Research and Technology, "Summary of Awards: 1976," p. 105.

A major study, which included an assessment of the potential of weather modification in support of agriculture, was recently completed by the National Academy of Sciences (NAS)/National Research Council. The investigation dealt with changing weather and climate patterns and their effects on agricultural and renewable resources productivity.⁸⁵ These implications were examined by the committee in climate and weather fluctuations and agricultural production, which was established by the NAS in June of 1975 at the request and with the support of the National Science Foundation. Among other considerations, a chapter of the committee's report was devoted to weather modification, covering such topics as the feasibility of weather modification, crop-weather relationship and weather modification, impact variability, and societal and environmental issues. The committee made the following recommendations:⁸⁶

Intensive efforts should be made to apply existing basic knowledge of atmospheric and cloud processes in specific applied research programs to benefit agriculture. Methods of applying the benefits of demonstrated or nearly demonstrated weather modification techniques to specific crop needs, incorporating water storage, and other water management procedures, should be developed. Proper recognition of societal concerns must be included.

Gaps in basic knowledge of agriculturally oriented weather modification should be identified, and research initiated to fill them. Results of this research should be applied on an interactive basis with ongoing research and application projects. Important segments of the basic research should address the exploration of new ideas and approaches.

Government organizational structures and policies should insure an integrated approach to weather modification research so that related problems such as rain and hail from convective systems can be treated in the same experimental framework. Research programs should be interdisciplinary, should draw on the expertise available from Government agencies and from the academic and private sectors, and should incorporate a productive mix of big science—permitting large, pooled facilities—and small science—encouraging small group initiatives. The growing collaboration between scientifically and operationally oriented weather modification experts should be focused on key crops and agricultural regions.

Two other recent NSF-sponsored research projects on weather modification in support of agriculture are:

1. An assessment of the present and potential role of weather modification in agricultural production, conducted by Colorado State University. This research was intended to identify potential capabilities of weather modification in terms of agricultural productivity and to focus priorities for weather modification research in terms of maximum benefits to agriculture. The research plan included a workshop of experts in agriculture and weather modification in order to develop an authoritative document on the role of weather modification in increasing world agricultural production.⁸⁷

⁸⁵ National Academy of Sciences, National Research Council, "Climate and Food; Climate Fluctuation and U.S. Agricultural Production," a report of the Committee on Climate and Weather Fluctuations and Agricultural Production, ISBN 0-309-02522-2, Washington, D.C., 1976, 212 pp.

⁸⁶ *Ibid.*, p. 131.

⁸⁷ National Science Foundation, Division of Advanced Environmental Research and Technology, "Summary of Awards: 1976," p. 105.

2. Assessment of weather modification in alleviating agricultural water shortages during drought, conducted by the Illinois State water survey. The purpose of this study was to provide information needed in decisionmaking processes regarding use of weather modification for mitigation of agricultural droughts in the Midwest and other similar areas. This research was intended to contribute to man's knowledge of the limitations of weather modification to planned precipitation augmentation for agricultural applications and to assist in determining the scope and duration of future weather modification research in similar climatic regions of the world.⁸⁸

DEPARTMENT OF COMMERCE

Introduction and general discussion

Within the Department of Commerce the research program in weather modification is conducted by the Environmental Research Laboratories of the National Oceanic and Atmospheric Administration (NOAA). Through NOAA's predecessor organizations, the U.S. Weather Bureau and the Environmental Science Services Administration (ESSA), the Commerce Department has been active in weather modification since 1946, with research programs directed at modifying severe storms such as hurricanes, increasing rainfall from tropical cloud systems, and suppressing lightning in thunderstorms. The two major ongoing research projects are the Florida Area Cumulus Experiment (FACE), a project to demonstrate the possibility of increasing precipitation from convective cloud systems through dynamic seeding, and Project Stormfury, intended to mitigate the severe impacts of hurricanes.

The NOAA Research Facilities Center (RFC), is an operational and technical organization, with the mission of providing instrumented aircraft for research programs of NOAA and other Government agencies, including weather modification projects. Part of NOAA's overall weather modification effort is its program of Global Monitoring for Climatic Change (GMCC), under which measurements are made of natural and manmade atmospheric trace constituents in order to determine their increases or decreases and possible influences on climatic change. Other research in recent years has been concerned with modification of extratropical severe storms and in suppression of lightning, the latter in cooperation with the National Aeronautics and Space Administration (NASA) in connection with protection of launch vehicles.

In addition to these activities intended to explore weather modification and develop techniques for controlling the weather, NOAA also conducts background research in a variety of areas of atmospheric science that is essential to the future of weather modification development. Included are modeling and theoretical work on the structure, dynamics, and energy processes of severe storms such as hurricanes, tornadoes, and thunderstorms. Also pertinent is the development of instrumentation for direct measurement of atmospheric properties and for remote probing of the atmosphere.⁸⁹

A summary of the funding for the NOAA weather modification program for fiscal year 1976 through fiscal year 1978 (estimated) is contained in table 15.

⁸⁸ *Ibid.*, pp. 105-106.

⁸⁹ Townsend, John W., testimony in: U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, "Weather Modification," hearings, 94th Congress, 2d session, June 15-18, 1977, Washington, D.C., U.S. Government Printing Office, 1976, p. 171.

TABLE 15.—WEATHER MODIFICATION FUNDING FOR FISCAL YEAR 1976 THROUGH FISCAL YEAR 1978 FOR THE DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION ¹

[In thousands of dollars]

	Fiscal year—			
	1976	1977	1977	1978
Hurricane modification.....	870	180	735	810
Modification of convective clouds.....	755	171	757	893
Modification of extratropical severe storms.....	1,091	281	1,176	1,000
Research facilities center (prorated).....	1,589	0	0	0
Subtotal.....	4,304	632	2,668	2,703
Global monitoring for climatic change:				
Air quality observations.....	1,717	438	1,563	2,138
Air quality analysis.....	313	76	346	160
Subtotal.....	2,030	514	1,909	2,298
Total weather modification program.....	6,334	1,146	4,577	5,001

¹ From Federal Coordinating Council for Science, Engineering, and Technology, Interdepartmental Committee for Atmospheric Sciences. National Atmospheric Sciences Program: Fiscal Year 1978. ICAS 21-FY 78, August 1977, p. 89.



NOAA 1 X-band Doppler radar operated by the Wave Propagation Laboratory of the National Oceanic and Atmospheric Administration. (Courtesy of the U.S. Department of Commerce.)

The Florida Area Cumulus Experiment (FACE)

The FACE program is conducted by the cumulus group of NOAA's National Hurricane and Experimental Meteorology Laboratory

(NHEML) and is an outgrowth of a series of experiments in which individual clouds were seeded in Florida. These experiments demonstrated that dynamic seeding⁹⁰ is effective in increasing the sizes and lifetimes of individual cumulus clouds and the rainfall resulting from them. FACE is designed to determine whether dynamic seeding can be used to augment convective precipitation over a large area in south Florida by promoting the development of larger, better organized convective systems. Cloud merger, the joining of two formerly independent cloud entities, appears to be the important natural process leading to heavy and extensive rainfall in Florida.⁹¹

The design of FACE was intended to investigate two sequential questions. The first question was whether dynamic seeding can be used systematically to induce cloud merger and increase rainfall from the groups of subject clouds, and the second was to determine whether dynamic seeding can be used to produce a net increase in rainfall over a fixed target area. An affirmative answer to the first question, while necessary, may not be a sufficient condition to verify the second.⁹² FACE has been an exploratory experiment intended to answer these questions; hence, its design has been evolutionary. It cannot, therefore, be regarded as a conclusive experiment, in spite of strong indications of a positive seeding effect, it must be replicated with a predetermined design to confirm results achieved to date. It is planned that such a confirmatory FACE effort will begin in Florida during the summer of 1978.⁹³

The experimental design for FACE is a random design, where the days over a single target are randomized into seeded and nonseeded days, with nonseeded days as the control. Experiments began on a limited basis in 1970 and were continued in 1971, 1973, 1975, and 1976. Design features included:⁹⁴

1. A fixed target area with the experiments randomized by day.
2. Surveillance of the clouds in the target by 10-centimeter radars, with radar estimation of the rainfall (rain estimates were adjusted using rain gages).
3. Determination of suitable experimentation days on the basis of a daily suitability criterion, based on predicted cloud heights for seeded and nonseeded conditions, using a one-dimensional cloud model. A factor was also introduced to bias the decision for suitability against natural rainy days.
4. Flights by seeder aircraft on days that satisfy the suitability criterion. The decision to seed was randomly determined in the air, with only the randomizer knowing the decision. Suitable convective clouds were seeded near their tops.
5. Final acceptance of a day for inclusion in the analysis only if 60 flares were ejected or six clouds were seeded, or both.

⁹⁰ For a discussion of dynamic seeding of cumulus clouds see ch. 3, p. 68.

⁹¹ Woodley, William L., Joanne Simpson, Ronald Blondini, and Joyce Berkeley, "Rainfall Results, 1970-75: Florida Area Cumulus Experiment," *Science*, vol. 195, No. 4280, Feb. 25, 1977, p. 735.

⁹² *Ibid.*

⁹³ Woodley, William L., J. A. Jordan, Joanne Simpson, Ronald Blondini, and John A. Flueck, "NOAA's Florida Area Cumulus Experiment, Rainfall Results; 1970-76" (Submitted for publication to the *Journal of Applied Meteorology*.) 1978.

⁹⁴ Woodley, Simpson, Blondini, and Berkeley, "Rainfall Results, 1970-75: Florida Area Cumulus Experiment," 1977, pp. 735-736.

In the analysis of the FACE experimental days, floating target and total target calculations were made for the 6 hours following the initial seeding. The floating target is composed of the radar echoes of all experimental clouds and those with which they merge. The total target is made up of the floating target echoes plus the echoes of nonexperimental clouds.⁹⁵

Figure 13 is a map of the field design for FACE, showing the

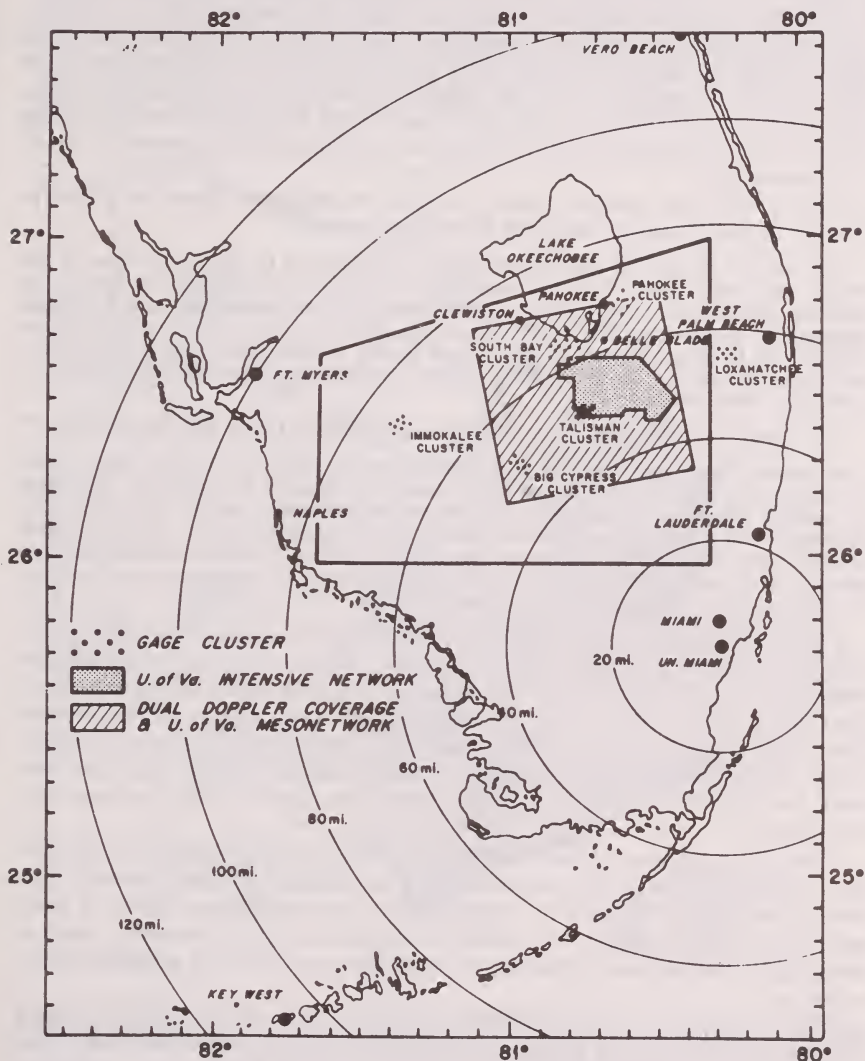


FIGURE 13.—Field design for the Florida Area Cumulus Experiment (FACE). The largest quadrilateral is total target area, within which are areas covered by the dual Doppler radars, the mesonet intensive network and the clusters of rainuages. (From Woodley and Sax, NOAA Technical Report ERL 354-WMPO 6, January 1976.)

⁹⁵ Woodley, William L. and Robert I. Sax, "The Florida Area Cumulus Experiment: Rationale, Design, Procedures, Results, and Future Course," NOAA technical report ERL 354-WMPO 6, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Boulder, Colo., January 1976, p. xiv.

13,000 km² target area and several smaller areas of radar and rain gage coverage, as configured in the period 1972-73. Although the basic target area remained the same, the networks of intensive coverage by radar and rain gages were modified somewhat in later years.

Data from 75 experimental days have been accrued in FACE since 1970; these have represented 39 seed days and 36 control days. Analyses have shown that dynamic seeding under appropriate atmospheric conditions is effective in increasing the growth and rain production of individual cumulus clouds, in inducing cloud merger, and in producing increases in rainfall from groups of convective clouds as they pass through the target area. When rainfall over the total target area (i.e., that from the floating target plus that from nonexperimental clouds within the target area) is averaged, a net increase also seems to result from seeding.⁹⁶

The following specific results of the experiment from analyses to date have been summarized by Woodley, et al.:⁹⁷

The many overall and specialized analyses presented in this paper lead to the strong indication that dynamic seeding increased areal rainfall in FACE, by altering convective processes on the mesoscale and promoting cloud merger. Rainfall in the floating and total targets was greater in the mean (about 50 percent in the floating target and 25 percent in the total target), and the standard deviation (50 percent in the floating target and 40 percent in the total target) on seed days than on control days.

The authors continue, discussing the physical basis for confidence:⁹⁸

Although FACE has been an exploratory effort with an evolving design, one can have considerable confidence in the interpretation of the outcome. Increases of seeding effect based on rain gage measurements agree with those based on gage-adjusted radar. The microphysical measurements within seeded clouds provide clear evidence for anomalous glaciation relative to their unseeded counterparts. * * * The time-dependence of the seeding effect and its dependence upon the number of flares expended are consistent with an effect of seeding.

In fiscal year 1977, FACE activities have included a thorough analysis of available experimental data and additional research in order to establish the physical basis for FACE rainfall results. During fiscal year 1978 there will be further analysis of data and results obtained from field programs in order to solidify, both physically and statistically, the encouraging preliminary results, showing a rainfall increase over the entire 13,000 km² experimental area on seed days versus non-seed days.⁹⁹

The implications of this work to the needs of hydrology and agriculture demand that it be continued and expanded. A confirmatory dynamic seeding effort will be conducted in an area where there is both need and a favorable meteorological and societal climate for such a program.¹ Preliminary studies are underway to identify possible addi-

⁹⁶ Woodley, William L., Joanne Simpson, Ronald Biondini, and Jill Jordan, "NOAA's Florida Area Cumulus Experiment: Rainfall Results, 1970-76." in preprints from Sixth Conference on Planned and Inadvertent Weather Modification, Champaign-Urbana, Ill., Oct. 10-13, 1977. American Meteorological Society, Boston, 1977, p. 209.

⁹⁷ Woodley, Jordan, Simpson, Biondini, and Flueck, "NOAA's Florida Area Cumulus Experiment; Rainfall Results: 1970-1976." 1978.

⁹⁸ *Ibid.*, p. 58.

⁹⁹ Federal Coordinating Council for Science, Engineering, and Technology, Interdepartmental Committee for Atmospheric Sciences, "National Atmospheric Sciences Program: Fiscal Year 1978," ICAS 21-FY 78, September 1977, p. 88.

¹ Woodley, Simpson, Biondini, and Jordan, "NOAA's Florida Area Cumulus Experiment; Rainfall Results, 1970-76," 1977, p. 209.

tional sites for field experiments during fiscal year 1979. The long-range objective of the program is to make the technology developed in Florida available to other areas in the United States which are characterized by periods when most of the rainfall is provided by convective showers.

Preliminary plans have been developed to conduct a summer cumulus experiment, along the lines of FACE, in the cornbelt of the Midwest, in an attempt to determine the transferability of the FACE results. A very suitable region for such a field experiment appears to be in central Illinois, and plans for the proposed Precipitation Augmentation for Crops Experiment (PACE) have been concentrated on this area, whose location is shown in figure 14.² Initial plans for the

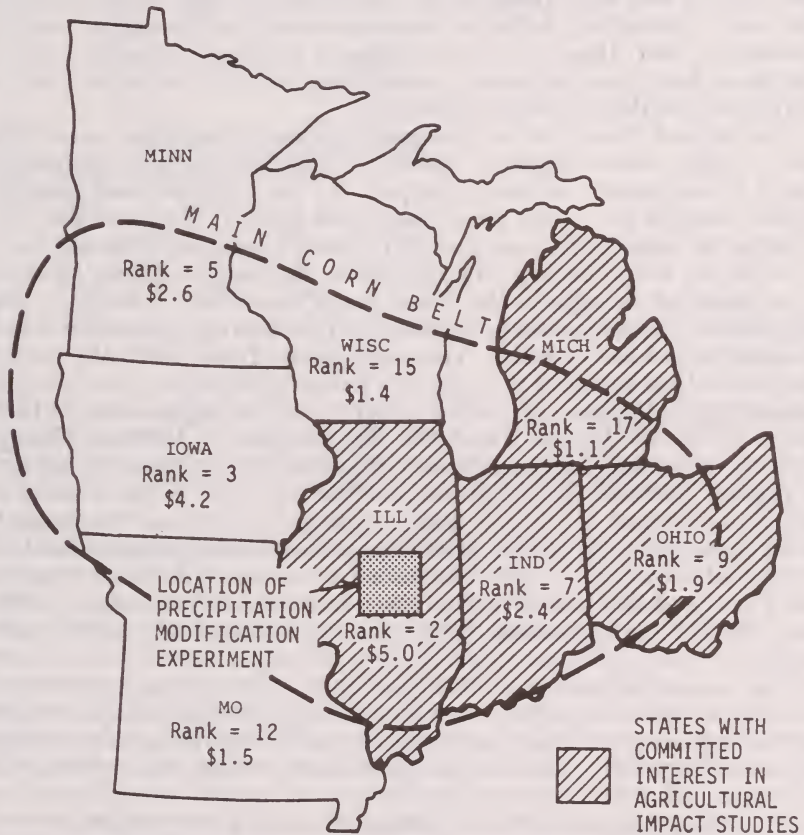


FIGURE 14.—Map showing the location of the target area for the proposed precipitation Augmentation for Crops Experiment (PACE) (from Ackerman and Sax, 1977).

NOTE.—Shown for each State is its 1975 value of farm products in billions of dollars, and its resulting national rank.

² Ackerman, Bernice, and Robert I. Sax, precipitation augmentation for crops experiment (PACE), presentation to the U.S. Department of Commerce Weather Modification Advisory Board, Champaign, Ill., Oct. 13, 1977.

meteorological program are being developed by the Illinois State Water Survey and NOAA's NHEML, and interest in the program has been indicated by scientists from four midwestern universities, the University of Virginia, and the NHEML. A four-stage experiment is now contemplated, which could extend over a 9- to 13-year span, with costs ranging from \$8.5 to \$10.5 million.³

Project Stormfury

NOAA's largest effort in weather modification has been Project Stormfury, conducted by the National Hurricane and Experimental Meteorology Laboratory (NHEML) and aimed at developing methods for moderating the most destructive peak winds in hurricanes. The project is designed to investigate the structure and dynamics of tropical cyclones and their potential for modification. The range of activities under Stormfury includes development of mathematical models; theoretical and diagnostic investigations and calculations; field research on hurricane structure, variability, and dynamics; and actual hurricane modification experiments.⁴

The earliest known hurricane modification attempt occurred October 13, 1947, when General Electric Co. scientists and technicians, under Government contract, dropped dry ice into the thin, stratified clouds outside the walls of a hurricane east of Jacksonville, Fla. Equipment suitable for monitoring the structure, intensity, and movement of the storm during this operation was not available; however, some localized changes in the thin-layered cloud were noted by visual observation. Subsequent studies indicate that this operation could have had little effect on the storm. The experiments from which the present project evolved began in 1961, though Project Stormfury was formally established in 1962 as a combined program of the Department of Commerce (Weather Bureau) and the Department of Defense (Navy). Over the years the National Science Foundation has provided support to various parts of the program, and the U.S. Air Force became an active participant in the late 1960's. Since the Defense Department's decision to discontinue joint sponsorship in 1973, the program has been conducted primarily by the Commerce Department.⁵ Aircraft from the Air Force and from the National Aeronautics and Space Administration (NASA) are available for future experiments and storm monitoring.

The concept behind Stormfury seeding is that dynamic seeding of cumulus cloud towers just outside of the eyewall of the hurricane causes these clouds to develop vertically until they replace the original eyewall. The effect is to increase the diameter of the eye, reducing the maximum winds in the new eyewall.

Under this program, four storms have actually been seeded between 1961 and 1971; the tracks of these storms are shown in figure 15. In the first storm, Hurricane Esther, clouds near the eyewall were seeded with relatively small amounts of silver iodide on September 16 and 17, 1961. After the experiment of September 16 there was an apparent 10-percent recorded reduction in maximum wind speed, but little change was observed on September 17, owing perhaps to seeding in a

³ Ibid.

⁴ Sheets, Robert C., "Project Stormfury: Questions and Answers." U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, National Hurricane and Experimental Meteorology Laboratory, Coral Gables, Fla., 1977, p. 1.

⁵ Ibid.

cloud-free zone. Similar single-seeding experiments were conducted on August 23 and 24, 1963, in Hurricane Beulah, with similar results; that is, an apparent 10- to 14-percent reduction in wind speed on August 24, but little change on August 23. Errors in delivery of the seeding agent were subsequently attributed to the poor radar systems used at the time.⁶

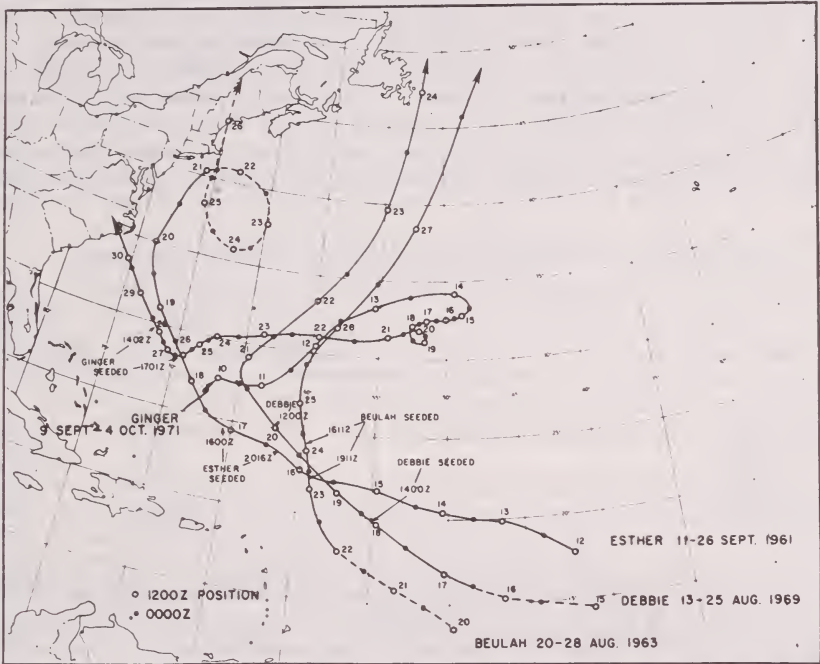


FIGURE 15.—Tracks of all hurricanes which have been seeded from 1961 to 1971. Times and locations of seedings are indicated. (From Sheets, 1977.)

The greatest apparent success was achieved in experiments on Hurricane Debbie on August 18 and 20, 1969, when maximum wind speed reductions of 30 and 15 percent, respectively, were observed. The reduction on August 18 followed five seeding events at 2-hour intervals over an 8-hour period. Debbie was not seeded on August 19 and regained strength; and the observed reduction on August 20 followed the same seeding procedure used on August 18. Although the results were exciting, an evaluation problem is that the observed changes following seeding are within the natural hurricane variability. Such occurrences are statistically unlikely, however, since a 15-percent reduction would occur less than 10 percent of the time naturally, and a 30-percent reduction is less than 5 percent likely to occur.⁷

The last storm to have been seeded under Stormfury was in 1971 on Hurricane Ginger, a storm which did not have suitable structure for eye modification experiments. Clouds were seeded well away from the storm center, and only local effects were detected. Consequently, the experiment on Ginger ought not to be included with the Esther, Be-

⁶ *Ibid.*, pp. 1-2.

⁷ *Ibid.*, p. 2.

lah, and Debbie cases.⁸ Results of all known hurricane seeding experiments are summarized in table 16. The 1947 storm and Hurricane Ginger in 1971, results from which are much less definitive than those of the other cases, are discussed in footnotes to the table.

To minimize the possibility that a populated region might experience adverse effects from a hurricane seeding experiment, many safeguards have been built into Stormfury. Although all results to date have been either positive or neutral, strict guidelines are maintained in selection of storms to be seeded.⁹ To be eligible for seeding, a hurricane must be predicted to be within 700 nautical miles (1,100 kilometers) of the operating base—Miami or San Juan—for at least 12 hours and have maximum winds of at least 65 knots. There will be no seeding if the predicted track of the hurricane has more than a 10-percent chance of approaching within 50 miles of a populated land area within 24 hours after the seeding.¹⁰ Consequently, few opportunities have

TABLE 16.—RESULTS OF EXPERIMENTS IN SEEDING HURRICANE CLOUDS NEAR THE EYEWALL^{1,2}

Name and date	Number of seedings	Silver iodide used ³ (number, kilogram)	Approximate maximum wind speed change (percent)
Hurricane Esther:			
Sept. 16, 1961-----	1	8/35.13	-10
Sept. 17, 1961-----	1	8/35.13	+0
Hurricane Beulah:			
Aug. 23, 1963-----	1	55/219.96	+0
Aug. 24, 1963-----	1	67/235.03	-14
Hurricane Debbie:			
Aug. 18, 1969-----	5	976/185.44	-30
Aug. 20, 1969-----	5	978/185.82	-15

¹ In addition, a hurricane was seeded Oct. 13, 1947, and Hurricane Ginger was seeded Sept. 26 and 28, 1971. The clouds seeded in these storms were far different and the seedings were done in a different fashion than for the storms listed above.

² From sheets. Project Stormfury: (Questions and Answers, 1977.)

³ Values in column are for total number of units and total kilograms of silver iodide used each day (based on records kept by Sheldon D. Elliot, Jr.). Test results indicate the smaller seeding pyrotechnic units make more efficient use of the silver iodide.

⁴ Pyrotechnics dropped outside seedable clouds.

been afforded by nature for these experiments. Furthermore, analyses of past cases, particularly the Debbie experiments, have shown the need for more sophisticated aircraft and instrumentation, so that actual field experiments were discontinued in 1972, while state-of-the-art aircraft and instrumentation were procured.

Several alternatives have been considered for increasing the number of suitable experimental situations over a given time period. One approach would be to move the project to an area where nature provides more opportunities statistically, such as the western Pacific Ocean. Or, operations could be combined for a number of areas, such as the North Atlantic and the eastern North Pacific or the North Atlantic and Australian storm areas. Another possibility is to relax selection criteria, but this does not seem to be a desirable choice for the near future.¹¹

⁸ *Ibid.*, p. 3.

⁹ *Ibid.*, p. 4.

¹⁰ U.S. Department of Commerce News, "Stormfury—1977 to Seed One Atlantic Hurricane," news release, NOAA 77-248, Rockville, Md., Sept. 20, 1977, p. 1.

¹¹ Sheets, "Project Stormfury: Questions and Answers," 1977, p. 5.

Tentative plans were formulated to conduct seeding experiments on typhoons of the western Pacific in view of the greater frequency of suitable storms in that region. These plans were canceled, however, when protests were received from the Governments of Japan and mainland China, although the Philippines had been favorable to such experiments. Meteorological satellite observations have shown that hurricanes and tropical storms in the eastern North Pacific (to the west of Central America) occur more frequently than thought previously, the number in that region exceeding those in the western North Atlantic in recent years. Hence, a significant increase in opportunities for hurricane research can be achieved by including eastern Pacific storms.¹² This would require a formal agreement with Mexico, with whose officials bilateral consultations have begun, and with other countries that may be directly affected by the hurricanes which are eligible for seeding.¹³

In the interim since 1972, new instrumentation has been developed, especially in the field of cloud physics, and NOAA's instrumented aircraft has been updated and augmented in preparation for research experiments in 1977 if suitable storms become available. During the 1976 hurricane season, NHEML personnel utilized two new aircraft for the first time in research hurricane reconnaissance. The complement of five aircraft now available for Stormfury include three from the NOAA Research Facilities Center and one each from the Air Force and NASA.

Since 1972 Stormfury research has concentrated on special observational programs to provide data on hurricane structure and microphysical processes and on analytical and theoretical studies to improve their description and understanding. There has been a major emphasis on development of mathematical models to simulate the development, structure, and behavior of hurricanes in the natural state and when seeded. A more explicit seeding hypothesis has been defined from the results of this research, which will also benefit evaluation of future seeding experiments.¹⁴

Plans were formulated for one hurricane seeding experiment in the Atlantic in 1977, if conditions were suitable, as a rehearsal for full-scale resumption of multiple experiments during 1978, using the five newly instrumented aircraft. For hurricanes not suitable or eligible for such experiments, emphasis will be on acquisition of further information on the structure and natural variability of hurricanes on the 24- to 36-hour timescale characteristic of the seeding experiments.¹⁵

The purpose of Stormfury is the establishment of a modification hypothesis at a confidence level high enough that the techniques can be taken from the experimental stage and used operationally.¹⁶ It is

¹² Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, "National Atmospheric Sciences Program: Fiscal Year 1977." ICAS 20-FY77, May 1976, p. 89.

¹³ Epstein, Edward S., in testimony before the Subcommittee on the Environment and the Atmosphere, House Committee on Science and Technology, U.S. House of Representatives, on NOAA's atmospheric and oceanic environmental research and development, May 18, 1977.

¹⁴ *Ibid.*

¹⁵ Federal Coordinating Council for Science, Engineering, and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 21-FY78, 1977, p. 88.

¹⁶ Sheets, "Project Stormfury: Questions and Answers." 1977, p. 10.

felt that 10 to 12 seeding experiments are required to verify the Stormfury hypothesis, taking at least two or three full hurricane seasons to realize sufficient seeding opportunities.¹⁷

Research Facilities Center (RFC)

The NOAA Research Facilities Center, formerly the Research Flight Facility, is an operational and technical support organization whose mission is to provide instrumented aircraft to meet the cloud-seeding and airborne measurements needs of NOAA and other governmentally sponsored research programs.¹⁸

A program of modernization for this facility was begun in fiscal year 1973 and completed in fiscal year 1977. In fiscal year 1973 three of the then existing NOAA aircraft (an RB-57 and two DC-6's) were deactivated, but the C-130 was retained. Two new P-3 aircraft were acquired in the following years and, with the C-130, were instrumented with the most modern and sophisticated meteorological and oceanographic research measurement systems available.¹⁹ Instrumentation includes inertial/omega/doppler navigation systems, data recording/processing/display systems, dropwindsonde systems, cloud physics measurement devices, radar systems, cloud-seeding equipment, gust probes, and photographic systems.²⁰

Global Monitoring for Climatic Change (GMCC)

This program, considered as part of NOAA's total weather modification research effort, is designed to provide quantitative data needed to understand and predict climatic changes. Data are derived from measurements of existing amounts of natural and manmade trace constituents in the atmosphere, from which are determined the rates of increase or decrease in these trace amounts and their possible effects on climate change.²¹

Measurements are made at a network of baseline observations at four stations—Point Barrow, Alaska; Mauna Loa, Hawaii; American Samoa; and South Pole, Antarctica. Measurements at these baseline observatories include determination of concentrations of carbon dioxide, carbon monoxide, and surface and total ozone; of solar-terrestrial radiation; of atmospheric aerosols; of precipitation chemistry; and of standard meteorological variables—wind, temperature, humidity, precipitation, and pressure. The program also includes the development of new and improved measurement systems for atmospheric trace constituents for observatory use, data reduction and quality control of observations, and analysis of the data in terms of climatic variations.²²

¹⁷ Epstein, testimony before the Subcommittee on the Environment and the Atmosphere, House Committee on Science and Technology, U.S. House of Representatives, May 18, 1977.

¹⁸ Federal Coordinating Council for Science, Engineering, and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 21-FY78, 1977, p. 88.

¹⁹ *Ibid.*

²⁰ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20-FY77, 1976, pp. 89-90.

²¹ Federal Coordinating Council for Science, Engineering, and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 21-FY78, 1977, pp. 88-89.

²² Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, "National Atmospheric Sciences Program: Fiscal Year 1975," ICAS 18-FY75, May 1974, p. 79.

In the past there have been cooperative projects with the University of Rhode Island and for the U.S. Environmental Protection Agency and the U.S. Energy Research and Development Administration.

The program also includes a seven station network in the continuous United States for measuring total atmospheric ozone. An eighth station is planned for installation in California during fiscal year 1978. The world standard ozone spectrophotometer is maintained by the GMCC program, and during fiscal year 1977 an intercomparison of seven secondary standards of various countries with the NOAA standard was conducted at Boulder, Colo.²³

During fiscal year 1978 the GMCC program plans are as follows:²⁴

A careful analysis of a number of atmospheric parameters important in climatic assessment will be continued and expanded. Global surface and tropospheric temperature records will be updated and interpreted in terms of possible causes for the observed variability. Total ozone, and the vertical distribution of ozone, and stratospheric water vapor measurements will be analyzed to detect trends and further understand the causes for their fluctuations. The duration of sunshine, probably reflecting cloudiness over the United States will be studied with updated information. The size of the 300-millibar (ten-kilometer altitude) circumpolar vortex will be followed; this quantity shows some promise of being a monthly or seasonal climatic predictive tool. Fluorocarbon-11 and -12 measurements at Adrigole, Ireland, will be analyzed in the light of the source of the air mass reaching that location. Finally, work will continue on the use of tetroons to delineate boundary layer air trajectories in urban areas and elsewhere. This research is of use in certain air pollution problems.

Lighting suppression

In recent years NOAA has conducted a small experimental effort in lightning suppression, using fine metalized nylon fibers—or chaff—as a seeding agent. Based on a theoretical model, a field program was initiated in 1972 to test the chaff seeding concept and to determine the effect of such seeding on the electric fields of thunderstorms. Storms are seeded from below, and, based on data from 10 seeded storms and 18 unseeded control storms, the number of lightning occurrences was about 25 percent of those observed in the control storms. The experiments were not strictly randomized; however, the observed differences between seeded and control storms was statistically significant.²⁵

During the 1975 Apollo-Soyuz launch, aircraft were on standby for possible lightning-suppression flights at Cape Canaveral. Research on thunderstorm electrofication at the Kennedy Space Center is a cooperative program with NOAA, NASA, the Department of Defense, and several universities.²⁶

Modification of extratropical severe storms

Research has been conducted by NOAA on the possibilities of moderating and modifying mesoscale cloud systems associated with severe storms, including thunderstorms, tornadoes, and cyclonic storm sys-

²³ Federal Coordinating Council for Science, Engineering, and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 21-FY78, 1977, p. 89.

²⁴ *Ibid.*

²⁵ Townsend, John W., Jr., in U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, "Weather Modification," hearings, 94th Cong., 2d sess., June 15-18, 1976. Washington, D.C., U.S. Government Printing Office, 1976, p. 171.

²⁶ *Ibid.*, p. 172.

tems. Critical to this research are studies in atmospheric physics and atmospheric chemistry that are aimed at understanding the role of particular materials as condensation and ice-freezing nuclei and in influencing the dynamics and structures of clouds.²⁷ Research objectives of this program of NOAA's Atmospheric Physics and Chemistry Laboratory (APCL) include:²⁸

1. Expanding current knowledge and documenting descriptions of the behavior of extratropical weather systems;
2. Improving the accuracy and detail in short-range predictions—24 hours or less—of both natural and modified severe weather systems through development, verification, and refinement of numerical mesoscale models;
3. Identifying and testing, through numerical experiments using the recently mesoscale model, modification hypotheses, and procedures that appear to inhibit or suppress severe attending extratropical weather systems;
4. Establishing data requirements for field programs including observations needed for developing an understanding and a prediction capability through numerical modelling; and
5. Designing field modification experiments to test the most promising hypotheses.

Research at APCL includes efforts to measure and define relationships between numbers and chemical composition of natural and man-made nuclei and aerosols and to determine their impact on cloud and precipitation mechanisms. Nuclei inventories are made prior to, during, and after cloud-seeding experiments to permit evaluation of the efficiency of artificial nuclei generating techniques, their efficiency in cloud glaciation, and atmospheric residence times. Research is also directed toward optimization of cloud-seeding techniques and existing analysis methods.²⁹

DEPARTMENT OF DEFENSE

Introduction

The weather modification research, development, and operations carried on by the Department of Defense are intended primarily to protect men and materials from environmental hazards and to be aware of current and developing weather modification technologies in order to avoid technological surprise by potential adversaries.^{30 31} Recent and planned expenditures by Defense for both operational and research efforts in weather modification for fiscal year 1977 through fiscal year 1979 are shown in table 17.

Air Force fog dispersal operations

The U.S. Air Force conducts the only operational weather modification activities in the Department of Defense and the only regular

²⁷ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 18-FY75, 1974, pp. 77-78.

²⁸ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20-FY77, 1976, p. 89.

²⁹ *Ibid.*

³⁰ Ruggles, Kenneth W., briefing on Department of Defense weather modification programs for the Weather Modification Advisory Board, Washington, D.C., May 31, 1977, p. 1.

³¹ See app. B for a statement of the current official position of the Department of Defense on weather modification.

identifiable federally sponsored operational program. This Air Force program provides a capability to dissipate cold fogs at two Air Force bases—Fairchild AFB, Washington, and Elmendorf AFB, Alaska—permitting use of these airfields and improvement of flight safety during cold fog conditions. At these installations a ground-based dispersion system is used for spraying liquid propane into the atmosphere upwind of the target area to be cleared. Vaporization of the propane induces local cooling, with attendant formation and growth of ice crystals at the expense of water droplets, dissipating the fog.³²

A capability is also maintained by the Air Force for dispersal of crushed dry ice from WC-130 weather reconnaissance aircraft if the need should arise for dissipation of cold fog at locations not equipped with ground-based systems.

TABLE 17.—DEPARTMENT OF DEFENSE PLANNED EXPENDITURES FOR WEATHER MODIFICATION OPERATIONS AND RESEARCH, FISCAL YEAR 1977 THROUGH FISCAL YEAR 1979

(In thousands of dollars)

	Fiscal year—		
	1977	1978	1979
Operations: Air Force ¹	53	82	70
Research and development: ²			
Army: Cold fog dispersal.....	237		
Navy: Cold fog dispersal.....	226	210	
Air Force:			
Cold fog and stratus dispersal.....	550	778	714
Warm fog dispersal ³	1,400	2,200	1,200
Total, research and development.....	2,413	3,188	1,914

¹ Estimates of pro rated costs for operational cold fog dispersal at Air Force bases, from Capt. Kenneth W. Ruggles in briefing on Department of Defense weather modification programs for the Weather Modification Advisory Board, May 31, 1977.

² Data for basic research on weather modification differs from entries in table 2, based on 1977 inputs to ICAS; data above on research and development were received Apr. 27, 1978, from Col. Elbert W. Friday, Office of the Under Secretary of Defense for Research and Engineering.

³ Includes costs for engineering development of a warm fog dispersal system as well as expenditures for basic research on warm fog dispersal.

The dry ice particles falling through the fog sublimate, causing a large temperature decrease in their vicinity, so that the resulting ice particles which form and grow at the expense of supercooled fog droplets will fall out as snow. This capability has not been used since fiscal year 1976, and the dry ice crushers are currently stored at Keesler AFB, Miss. The Air Force plans continued use of these techniques, however, to reduce adverse weather effects due to fog on airfield operations and flight safety.³³

Army research and development

Research and development efforts in weather modification are conducted by all three services in the Department of Defense to some extent. Although the Army has terminated its technical base program, one equipment item, a mobile cold fog dissipator, is in the engineering

³² Ruggles, briefing on Department of Defense weather modification programs for the Weather Modification Advisory Board, 1977, p. 1.

³³ *Ibid.*, p. 2.

development phase.³⁴ This gear, intended to provide a capability for dissipating supercooled fog at Army airfields, helipads, and artillery sites, employs the propane dispenser technology to remove fog in local areas. The system is to be field tested in Alaska during 1978.³⁵ Army research on warm fogs, now terminated, had been directed toward dispersal through a variety of possible techniques, including helicopter downwash, use of hygroscopic materials, and application of heat.

Navy research and development

The research weather modification effort of the Navy is now concerned with evaluation of weather modification experimental data and of state-of-the-art techniques in order to avoid technological surprise. Instruments and methods have been developed to study fog, clouds, and natural weather processes, utilizing measurements of dewpoint, liquid water distribution, cloud and fog droplet and ice particle sizes, and number of cloud condensation nuclei. Recent investigations have been directed toward generation, characterization, and evaluation of active agents to inhibit or enhance the formation, growth, coalescence, removal, and frequency of cloud and fog water droplets and toward understanding the mechanisms and theories applicable to these processes. Numerical modeling of the fog or cloud system has been used to design experiments and to define and evaluate the physical processes which occur in field experiments.³⁶

The principal ongoing Navy research program in weather modification has been a statistical analysis to evaluate data from the Santa Barbara cold cloud modification experiments.³⁷ While not a large effort, it is an important attempt to examine alternatives for reducing uncertainty in evaluating weather modification experiments. No further field experiments are currently planned by the Navy.³⁸

In the recent past, the Navy has also sponsored major projects related to warm fog modification. Field experiments were conducted by the Naval Weapons Center, China Lake, Calif.; computer simulation studies have been underway at the Navy Environmental Prediction Research Facility, Monterey, Calif.; the Naval Research Laboratory, Washington, D.C., has been developing instrumentation and conducting studies related to cloud particle and cloud nuclei properties; a standard evaluation site near Macon, Ga., was under development; and the Office of Naval Research has provided support for a variety of investigations.³⁹

Air Force research and development

Air Force research projects in weather modification are currently directed toward dispersal of warm fog and stratiform clouds. Devel-

³⁴ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20-FY77, 1976, p. 91.

³⁵ Ruggles, briefing on Department of Defense weather modification programs for the Weather Modification Advisory Board, 1977, p. 2.

³⁶ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20-FY77, 1976, p. 91.

³⁷ Ruggles, "Briefing on Department of Defense Weather Modification Programs for the Weather Modification Advisory Board," 1977, p. 2. (The second Santa Barbara randomized seeding project was conducted by North American Weather Consultants from 1967 through 1970, under contract to the Naval Weapons Center, China Lake, Calif.)

³⁸ *Ibid.*

³⁹ Moschandreas, Demetrios J., "Present Capabilities To Modify Warm Fog and Stratus," Geomet, Inc., technical report for the Office of Naval Research and the Naval Air Systems Command, contract No. N00014-71-C-0271, Geomet report No. EF-300, Jan. 18, 1974, p. 5.

opment of a prototype warm fog dispersal system planned for eventual installation at an Air Force base is underway. The system development tests will be conducted at Otis AFB, Mass., and the field program will be supplemented with modeling studies in order to develop relationships between windspeed and the heat and thrust requirements of the dispersal system.⁴⁰

The system includes a number of combustors positioned along a runway and its approaches. The burn rate of the combustors is to be controlled precisely by a computer which monitors meteorological instruments in the runway area.⁴¹ Such a system, using both heat and thrust, is termed a thermokinetic system. The expected warming of the air over runway and approaches by 2° to 3° C above ambient temperature should result in lowering the relative humidity and evaporation of the fog droplets. Figure 16 shows the expected clearing geometry for the system. Upon successful completion of the field tests in 1979, it is expected that an operational warm fog dispersal system will be designed and installed at an Air Force base by 1982.⁴² The bulk of the Air Force research funding shown in table 17 covers development and testing of this system at Otis Air Force Base.⁴³

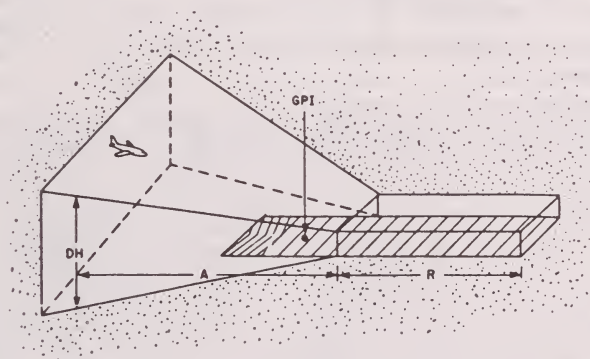


FIGURE 16. Clearing Geometry of the Warm Fog Dispersal System, Under Development by the U.S. Air Force. (From Kunkel. *The Design of a Warm Fog Dispersal System*. 1977.)

Another Air Force project is directed toward development of an operational technique for dispersal of supercooled stratus clouds. Field

⁴⁰ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20-FY77, 1976, p. 91.

⁴¹ Ruggles, "Briefing on Department of Defense Weather Modification Programs for the Weather Modification Advisory Board," 1977, p. 3.

⁴² Kunkel, Bruce A., "The Design of a Warm Fog Dispersal System," Sixth Conference on Planned and Inadvertent Weather Modification, American Meteorological Society, Campaign-Urbana, Ill., Oct. 10-13, 1977, pp. 174-176.

⁴³ Ruggles, "Briefing on the Department of Defense Weather Modification Programs for the Weather Modification Advisory Board, 1977, p. 3.

experiments and numerical modeling will be used to estimate quantities and types of seeding materials suitable for dispersal under a wide range of meteorological conditions.⁴⁴ Under the auspices of the Air Force Geophysics Laboratory, field tests on supercooled stratus dispersal were conducted during February 1977 in Michigan, using a dispensing system which deployed silver iodide. The objective of these tests was to produce clearing over a predetermined ground target. In all cases, except when the minimum cloud temperature was greater than -6°C , clearings were effected. The tests demonstrated that such clearings can be produced with a small lightweight delivery system adaptable for use on tactical aircraft and that targeting is not a serious problem. At a steep elevation angle ground targets were clearly visible after clearing, but they were obscured by residual glaciated clouds in the clearings when the look angle was more shallow. It is considered possible that some of the residual might have been due to overseeding. In another planned series of tests, attempts will be made to optimize the seeding rate to improve visibilities in the cleared area. Other seeding materials such as formaldehyde and propane, which are active in the 0°C to -6°C temperature range, will also be tested, since silver iodide is not active above -6°C . A theoretical study is also planned to determine the effects various forms of radiant energy could have on dispersal of warm stratus clouds.⁴⁵

Overseas operations

In recent years there had been much concern on the part of the Congress and the American public over the use of weather modification as a weapon of war in the war in Vietnam. A full disclosure of these activities and a discussion of their effectiveness were provided by the Defense Department in hearings before the Senate Committee on Foreign Relations in 1974.⁴⁶ In a recent briefing before the U.S. Commerce Department's National Weather Modification Advisory Board, it was stated that the current weather modification activities of the Department of Defense "are in accord with the provisions of the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, signed at Geneva on May 18, 1977."^{47, 48}

⁴⁴ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20-FY77, 1976, p. 91.

⁴⁵ Ruggles, "Briefing on Department of Defense Weather Modification Programs for the Weather Modification Advisory Board," 1977, pp. 3-4.

⁴⁶ U.S. Congress, Senate, Committee on Foreign Relations, Subcommittee on Oceans and International Environment, "The Need for an International Agreement Prohibiting the Use of Environmental and Geophysical Modification as Weapons of War and Briefing on Department of Defense Weather Modification Activity," hearing, 93d Cong., 2d sess., Jan. 25 and Mar. 20, 1974. Washington, U.S. Government Printing Office, 1974, 123 pp. (Contains the top secret hearing held on Mar. 20, 1974, which was made public on May 19, 1974.)

⁴⁷ Ruggles, "Briefing on Department of Defense Weather Modification Programs for the Weather Modification Advisory Board," 1977, p. 4.

⁴⁸ A full discussion of the developments leading to the signing of this convention is contained in ch. 10 of the report, entitled "International Aspects of Weather Modification." The full text of the draft treaty is in app. C.

Perhaps less well known than the use of weather modification in Vietnam were the attempts at precipitation enhancement for beneficial purposes carried out by the U.S. Air Force in the Philippine Islands at the request of the Philippine Government. This rain enhancement project, named GROMET II, was conducted from April through June of 1969, using airborne pyrotechnic seeding devices. The Air Force had operational responsibility for the project, while the Naval Weapons Center provided technical direction, and cooperation was also provided by Philippine agencies. Although precise determination of increased rainfall resulting from seeding was not possible, it was concluded, nevertheless, that rainfall augmentation from tropical cumulus clouds was accomplished in a simple operational manner. Benefits derived from the project included improvement in the agriculture, increased sugar production, and augmented crops of rice and corn. In addition, local personnel were trained in seeding operations, and, owing to the success of GROMET II, the Government of the Philippines conducted similar operations in subsequent years.⁴⁹ Other operational attempts to assist in drought mitigation were conducted by the Air Force in Panama, Portugal, and Okinawa.

DEPARTMENT OF TRANSPORTATION

The weather modification research and development activities of the Department of Transportation have been conducted by the Federal Aviation Agency (FAA), whose interest has been focused on warm fog dispersal and the development of systems for the removal of such fogs from airport runways. The current modest effort by the FAA is concerned with monitoring the U.S. Air Force development program for a warm fog dispersal system⁵⁰ and with considerations of implementing recommendations of a major FAA-sponsored warm fog dispersal systems study which was completed recently.⁵¹

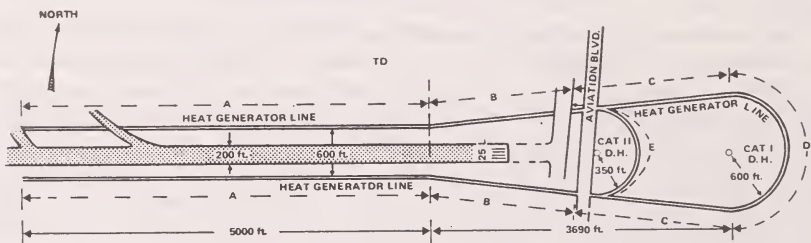
The FAA engineering report was completed in November 1975, following a 2-year study by an in-house task force that was charged with determining the feasibility of a ground-based warm fog dispersal system for a selected U.S. airport. The study included preparation of a conceptual design and cost estimates for the proposed system. Given that the actual mechanisms to be used for fog clearings had to be both theoretically and operationally sound, the task force eliminated a number of more exotic schemes and concentrated on design and cost estimates for two candidate fog dispersal approaches—(1) a modified passive thermal fog dispersal system and (2) a thermokinetic fog dis-

⁴⁹ St. Amand, Pierre, D. W. Reed, T. L. Wright, and S.D. Elliott, "GROMET II: Rainfall Augmentation in the Philippine Islands," Naval Weapons Center, NWC TP 5097, China Lake, Calif., May 1971, 110 pp.

⁵⁰ See discussion of weather modification research and development activities of the Department of Defense, beginning on p. 303.

⁵¹ FAA Systems Research and Development Service, fog dispersal task team, "Ground-based Warm Fog Dispersal Systems: Technique Selection and Feasibility Determination with Cost Estimates," Federal Aviation Administration, report No. FAA-RD-75-126. Final report, Washington, D.C., November 1975, 67 pp.

persal system. Both systems depend on evaporation of the fog as a result of a small temperature rise; however, whereas in the one case the natural convective forces of the heated atmosphere and the winds are relied upon to mix and transport the heat energy throughout the fog, the thermokinetic technique uses jet engines to transport the heated air into the fog by thrust. The latter technique produces some turbulence but not to a disqualifying degree.⁵² In selecting an airport it was thought important that there be a high annual occurrence of fog and a high air traffic density during the hours of fog for the system to be cost-effective. From 38 U.S. airports that were screened as potential candidates, Los Angeles International Airport (LAX) was selected as the airport which, in 1981, would gain the highest potential benefit from a fog dispersal system located along one of its runways.⁵³ Figure 17 shows the preliminary configuration of a single line of burners for a fog dispersal system installed along runway 25L at LAX. Costs for such an installation are of the order of \$10 million, but would vary, depending on the kind of system selected and the category of landing clearance for which the system is designed. Cost-to-benefit ratios vary accordingly, but the study showed that 15 U.S. airports turned out to have at least a 1:1 cost/benefit ratio.



LAX - RUNWAY 25L

LINE SECTION	HEAT GENERATOR OUTPUT (Therms/Yd. Hr.)
A - 5000 ft.	5 to 30
B - 1847 ft.	9 to 55
C - 1847 ft.	17 to 100
D - 1856 ft.	20 to 120
E - 814 ft.	13 to 80

D.H. = Decision Height

TOTAL HEAT GENERATOR LINE LENGTH - 19274 ft. for CAT I, line sections A, B, C, D.
14504 ft. for CAT II, line sections A, B, E.

FIGURE 17.—Preliminary configuration of proposed single line of burners for warm fog dispersal system for runway 25L at Los Angeles International Airport. (From Department of Transportation report FAA-RD-75-136, by FAA Fog Dispersal System Task Team, 1975.)

The FAA has contemplated participation in a joint warm fog dispersal demonstration project with Los Angeles International Airport and the U.S. Air Force; however, such a project has not yet been

⁵² *Ibid.*, p. 6.

⁵³ *Ibid.*, pp. 10-13.

agreed upon. In discussions with the Air Transport Association on this program, the FAA has learned about the concern of the association about increased landing fees to finance the system.⁵⁴

DEPARTMENT OF AGRICULTURE

The Forest Service within the Department of Agriculture has carried on weather modification research aimed at development of methods for suppressing cloud-to-ground lightning activity as a means of reducing forest fires in the intermountain west. Forest protection agencies developed early interest in possible application of weather modification to the forest-fire problem, first by considering the possibility of increasing moisture through rainfall on dry forests or on the fires directly and, later, by examining the potential for reducing directly the fire-starting capabilities of lightning itself.

The Forest Service established in 1953 a long-range program of lightning research, called Project Skyfire, as part of its overall fire research program. Project Skyfire has been the oldest continuously performed weather modification program in the United States until its recent demise.⁵⁵ Two broad objectives of the project were (1) to obtain a better understanding of the occurrence and characteristics of lightning storms and lightning fires in the northern Rocky Mountain region and (2) to investigate the possibility of preventing or reducing the number of lightning fires by applying techniques of weather modification.⁵⁶

After several years of gaining basic information about mountain thunderstorms, the first cloud seeding experiments were conducted under Skyfire in 1956 in the San Francisco peaks area of Arizona.⁵⁷ Beginning in 1960 field programs were conducted for a number of summer seasons in the mountainous areas of western Montana. These programs included both experiments designed to test the effects of seeding on lightning frequency and the development of techniques for observation and careful measurement of the characteristics of lightning strokes. A portion of the research during the 1960's was jointly sponsored by the Forest Service and the National Science Foundation.⁵⁸ Other participants in Skyfire have included the National Weather Service, the National Park Service, the Bureau of Land Management, several universities, and commercial contractors. Results of these experiments were encouraging but have not been conclusive. Field and laboratory experiments have shown the relationship of ice crystals to the lightning process. Skyfire field experiments seemed to show about one-third fewer cloud-to-ground lightning strokes for

⁵⁴ Bromley, Edmond, briefing on the Department of Transportation weather modification program before the Department of Commerce National Weather Modification Advisory Board, May 31, 1977.

⁵⁵ Barrows, J. S., "Preventing Fire From the Sky." Yearbook Separate No. 3589 (reprinted from the 1968 Yearbook of Agriculture), U.S. Department of Agriculture, Washington, U.S. Government Printing Office, 1968, p. 219.

⁵⁶ Fuquay, Donald M. and Robert G. Baughman, "Project Skyfire Lightning Research," U.S. Department of Agriculture, Forest Service, final report to National Science Foundation, Missoula, Mont., December 1969, p. 3.

⁵⁷ Barrows, "Preventing Fire From the Sky," 1968, p. 221.

⁵⁸ Fuquay and Baughman, "Project Skyfire Lightning Research," 1969, p. 3.

seeded clouds. Later experiments were carried out in Alaska in 1973 in cooperation with the Bureau of Land Management. While efforts in Montana had been concentrated on the long continuing current lightning stroke which seemed to be the most destructive, results in Alaska indicated that fires could be started there with shorter strokes because the ground cover was more combustible. Thus, the Montana results were not transferable.⁵⁹

All field experiments in weather modification under Project Skyfire were terminated in 1973, since they were not considered to be cost-effective, and work subsequent to that time has been concentrated on analysis of data from previous experiments and on reporting to fire protection agencies on the prospects for lightning suppression. With conclusion of this wrap-up work during 1977, the Forest Service proposes no further research in weather modification in the immediate future.⁶⁰

DEPARTMENT OF ENERGY

Weather modification research in this Department is concerned only with inadvertent changes to weather and climate as a result of man's activities related to energy development and consumption. Reporting of this research through the Interdepartmental Committee for Atmospheric Sciences (ICAS) as weather modification was begun with fiscal year 1975 funding by the former Energy Research and Development Administration (ERDA), recognizing that a significant amount of research on inadvertent modification of weather and climate had been part of their agency effort.⁶¹

Within the former agency's atmospheric science program, pertinent studies address atmospheric chemistry of energy production pollutants, removal processes, interactions with atmospheric processes, radioactive properties of the atmosphere, and the effects of waste heat and moisture from energy production. As part of the METROMEX field studies in the St. Louis area,⁶² research on urban aerosols and precipitation composition was conducted under ERDA support by the Illinois State Water Survey and the Battelle Pacific Northern Laboratories. The ERDA Divisions of Biomedical and Environmental Research and of Nuclear Research and Applications developed a program during fiscal year 1976 to investigate the atmospheric impacts of waste heat and moisture rejection from proposed energy centers containing both nuclear and fossil fuel generating units. The Biomedical and Environmental Research Division is also developing a program to learn the effects on atmospheric processes in the Western States resulting from

⁵⁹ Roberts, Charles F., briefing on the Department of Agriculture weather modification program before the Department of Commerce National Weather Modification Advisory Board, May 31, 1977.

⁶⁰ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20-FY77, 1976, p. 88.

⁶¹ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20-FY77, 1976, p. 94.

⁶² See earlier discussion of the weather modification activities of the National Science Foundation for a more complete account of METROMEX, p. 283f.

increased stack emissions and resuspended aerosols during extraction of coal and oil shale processing.⁶³

The Division of Biomedical and Environmental Research has also established a carbon dioxide effects research program to provide a national focus for research and assessment of the potential for possible problems relating to carbon dioxide accumulation rates. This comprehensive research program is being developed to determine the physical, environmental, and social implications of inadvertent weather and climate modification resulting from increased carbon dioxide in the atmosphere.⁶⁴

⁶³ Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 20-FY77, p. 94.

⁶⁴ Federal Coordinating Council for Science, Engineering, and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS 21-FY78, 1976, p. 92.

CHAPTER 6

REVIEW OF RECOMMENDATIONS FOR A NATIONAL PROGRAM IN WEATHER MODIFICATION

(By James E. Mielke, Analyst in Marine and Earth Sciences, Science Policy Research Division, Congressional Research Service)

INTRODUCTION

A number of major studies have been undertaken over the past 25 years in an effort to determine and review the status of the Federal role in weather modification. Eight of these studies which resulted in reports presenting findings and recommendations for actions have been selected for review and the recommendations summarized. Some of the studies were mandated by Congress through passage of public laws. Others were initiated by agencies or interagency committees of the executive branch, two of these were prepared by the National Academy of Sciences. One study was conducted by the General Accounting Office. In chronological order, the selected major reports containing weather modification recommendations are as follows:

1. U.S. Advisory Committee on Weather Control, "Final Report of the Advisory Committee on Weather Control," Washington, D.C., U.S. Government Printing Office, December 31, 1957. In two volumes, 32 and 422 pages.

2. Special Commission on Weather Modification. "Weather and Climate Modification," report of the Special Commission on Weather Modification, Washington, D.C., National Science Foundation, 1966, NSF 66-7, 79 pages.

3. National Academy of Sciences, National Research Council, Committee on Atmospheric Sciences, "Weather and Climate Modification: Problems and Prospects," publication No. 1350, Washington, D.C., 1966, in two volumes, 40 and 212 pages.

4. Newell, Homer E., "A Recommended National Program in Weather Modification," Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, ICAS report No. 10a, Washington, D.C., November 1966, 93 pages.

5. Federal Council for Science and Technology, Interdepartmental Committee for Atmospheric Sciences, "A National Program for Accelerating Progress in Weather Modification," ICAS report No. 15a, Washington, D.C., June 1971, 50 pages.

6. National Academy of Sciences, National Research Council, Committee on Atmospheric Sciences, "Weather Modification: Problems and Progress," ISBN 0-309-02121-9, Washington, D.C., 1973, 280 pages.

7. Comptroller General of the United States, "Need for a National Weather Modification Research Program," Report to the Congress,

B-133202, Washington, D.C., General Accounting Office, August 23, 1974, 64 pages.

8. U.S. Domestic Council, Environmental Resources Committee, Subcommittee on Climate Change, "The Federal Role in Weather Modification," Washington, D.C., 1975, 39 pages.

In addition to the above reports, the annual reports of the National Advisory Committee on Oceans and Atmosphere (NACOA) frequently contain recommendations on weather modification. These recommendations are summarized and the second annual NACOA report is cited in particular:

National Advisory Committee on Oceans and Atmosphere, "Second Annual Report to the President and Congress," Washington, D.C., U.S. Government Printing Office, June 29, 1973, 47 pages.

SUMMARIES OF MAJOR WEATHER MODIFICATION REPORTS

The purpose of this section is to trace the evolution of recommendations for Federal action as expressed in a number of major weather modification reports. The reports summarized in this section are not intended to be inclusive of all major weather modification studies. Only those reports primarily containing recommendations directing Federal activities have been selected. Other policy orientated reports, such as some of those sponsored by the American Meteorological Society, are available but, in general, these are focused less strongly on recommendations for the Federal role. Quotations contained in the report summaries of the following sections are from the respective report under consideration in that section.¹

FINAL REPORT OF THE ADVISORY COMMITTEE ON WEATHER CONTROL

The Advisory Committee on Weather Control was established by act of Congress in 1953. The Committee was directed to make "a complete study and evaluation of public and private experiments in weather control for the purpose of determining the extent to which the United States should experiment with, engage in, or regulate activities designed to control weather conditions." The final report of this Committee, submitted in 1957, contained the following findings and recommendations:

(1) That encouragement be given for the widest possible competent research in meteorology and related fields. Such research should be undertaken by Government agencies, universities, industries, and other organizations.

(2) That the Government sponsor meteorological research more vigorously than at present. Adequate support is particularly needed to maintain continuity and reasonable stability for long-term projects.

(3) That the administration of Government-sponsored research provide freedom and latitude for choosing methods and goals. Emphasis should be put on sponsoring talented men as well as their specific projects.

(4) That an agency be designated to promote and support research in the needed fields, and to coordinate research projects. It should also constitute a central point for the assembly, evaluation, and dissemination of information. This agency should be the National Science Foundation.

(5) That whenever a research project has the endorsement of the National Science Foundation and requires facilities to achieve its purpose, the agency having jurisdiction over such facilities should provide them.

¹ See preceding list of reports for complete references.

In addition the Committee recommended the initiation of a general meteorological research program to develop large numbers of highly qualified research scientists working along the following lines:

- (1) The effect of solar disturbances on weather.
- (2) The factors which control our global atmospheric circulation.
- (3) The factors which govern the genesis and movement of large-scale storms.
- (4) The dynamics of cloud motions.
- (5) The processes of rain and snow formation, and the relative importance of the physical phenomena which govern these processes.
- (6) The electrification process in clouds, and the role electricity plays in meteorological phenomena.
- (7) The natural sources of condensation and ice-forming nuclei, and their role.
- (8) The methods, materials, and equipment employed in weather modification.

As a result of these recommendations, the National Science Foundation (NSF) was directed by Public Law 85-510 of July 10, 1958, to initiate and support a program of study, research, and evaluation in the field of weather modification. The NSF established a research program as directed and, in effect, served as lead agency for weather modification until 1968, when this specific role was removed from the NSF by Public Law 90-407.

WEATHER AND CLIMATE MODIFICATION ; REPORT OF THE SPECIAL
COMMISSION ON WEATHER MODIFICATION

In 1964 the Director of the National Science Foundation appointed the Special Commission on Weather Modification. The Commission was assigned to "fulfill the need of the National Science Foundation for a review of the state of knowledge on weather and climate modification, make recommendations concerning future policies and programs and examine the adequacy of the Foundation's program." The Commission's assignment included consideration of not only the scientific aspects but also the legal, social and political problems in the field. The Commission's report was released in 1966.

In general the report concluded that there were four basic research needs to be met in weather modification:

1. Assessment and development of an understanding of natural climatic change.
2. Assessment of the extent and development of the understanding of inadvertent modifications of weather and climate.
3. Improvement of the process of weather prediction.
4. Development of means for deliberate intervention in atmospheric processes for weather and climate control and evaluation of their consequences.

As steps toward attaining these pursuits the Commission recommended that the following enterprises be fostered:

1. Examination of the routes, rates and reservoirs of water substance and energy exchanges in all aspects of the hydrologic cycle.
2. Investigation by numerical laboratory and field experiments of the dynamics of climate as a basic study for weather modification technology.
3. Advancement of weather prediction as a proof of understanding, including support of this effort by the establishment of a global weather observation network.
4. Broadening of the knowledge of cloud physics and dynamics in the laboratory and field, with attention to wave phenomena and an evaluation of electrical influences.
5. Study of the effects of large scale surface modification by numerical and laboratory models of the oceanic and atmospheric general circulation, and of practical means for surface modification of the land and sea.
6. Study of the radiative effects of changes in the atmospheric composition and alteration of its transparency that urban growth and new forms of industry transportation or land use may evoke.

With regard to biological implications of weather modification, the Commission stated that there should be a strong effort to bring the field of biological forecasting up to a higher level of usefulness. In order to improve biological forecasting, several approaches should be brought to bear on the problem including growth chamber simulation, computer modeling, study of the fine structure in the fossil record of the recent past, and examination and monitoring of areas biologically and climatically analogous to the changed and unchanged situations.

The Commission also recommended that greater use be made of statisticians in analyzing Government-sponsored research in weather modification and that statistics be given greater emphasis in related academic programs for meteorologists. In addition, there is a need to assess more fully the social and economic implications of weather modification experimentation, and all agencies engaged in weather modification attempts should give attention to the social implications.

With regard to the legal system, the Commission recommended that the Federal Government be empowered by appropriate legislation to: (a) delay or halt all activities—public or private—in actual or potential conflict with weather and climate modification programs of the Federal Government; (b) immunize Federal agents, grantees, and contractors engaged in weather and climate modification activities from State and local government interference; and (c) provide to Federal grantees and contractors indemnification or other protection against liability to the public for damages caused by Federal programs of weather and climate modification.

In the area of international relations, the Commission recommended the enunciation of a national policy embodying two main points: (1) that it is the purpose of the United States, with normal and due regard to its own basic interests, to pursue its efforts in weather and climate modification for peaceful ends and for the constructive improvement of conditions of human life throughout the world; and (2) the United States, recognizing the interests and concerns of other countries, welcomes and solicits their cooperation, directly and through international arrangements, for the achievement of that objective.

In light of the above program, the Commission considered that Federal funding for weather modification should be increased substantially from approximately \$7.2 million in fiscal year 1966 to a total of \$40 million or \$50 million per year by 1970. This would include substantially increased support for basic research and development in weather and climate modification, large field experiments of both a basic and an applied nature, and development of a strong centralized group, such as could be provided by a national laboratory, to serve as a focal point for research and development.

The Commission further determined that no single agency in the Federal Government has the responsibility for developing the technology of weather and climate modification and that the need for such designation was becoming evident. The Commission took the position that the mission of developing and testing techniques for modifying weather and climate should be assigned to an agency such as the Environmental Science Services Administration (ESSA), now part of the National Oceanic and Atmospheric Administration (NOAA), or to a completely new agency organized for the purpose. In addition the

National Science Foundation should continue and expand its support of research in the atmospheric sciences, including weather modification. Furthermore, other Federal agencies should remain free to conduct and support such research and development as may be required in the discharge of their missions. Finally, the Commission recommended that the Office of Science and Technology establish a mechanism for resolving conflicts between agencies with regard to weather modification activities and that an advisory committee on weather modification be established within the National Academy of Sciences.

WEATHER AND CLIMATE MODIFICATION: PROBLEMS AND PROSPECTS

In November 1963, the Committee on Atmospheric Sciences of the National Academy of Sciences appointed a panel on weather and climate modification "to undertake a deliberate and thoughtful review of the present status and activities in this field, and of its potential and limitations for the future." Volume I of the panel's final report contains a summary of the status of weather and climate modification, suggestions for essential research, and recommendations for actions to insure orderly and rapid future progress. While legal, social, and economic questions were considered important, they were not within the area of responsibility of the Academy panel.

The panel concluded that the present fragmentation of effort in weather modification research and development is unusual for the environmental sciences in that many of the fragments were below critical size or quality needed for effective work, and that major responsibility for weather modification should be centered in a single agency; at the same time, however, a degree of delegated responsibility should be maintained that will allow other agencies to meet their mission requirements for work in this field. A sixfold increase in Federal support from \$5 million in 1965 to \$30 million in 1970 was recommended. The panel considered a number of possible administrative arrangements for the support of weather modification research including (1) a national laboratory for weather modification; (2) a lead agency, either existing or new, with prime responsibility for weather modification; or (3) multiagency sharing of mission responsibility. However, the panel declined to make a firm statement as to the most desirable administrative means of achieving the goals set out in the report.

A number of projects in precipitation stimulation were recommended including: (1) Early establishment of several carefully designed seeding experiments, planned in such a way as to permit assessment of the seedability of a variety of storm types, (2) develop better means than are currently available to evaluate operational programs, and (3) give immediate attention to careful monitoring and regulation of operational programs for weather modification.

Other field investigations were recommended including: (1) A comprehensive exploration of hurricane dynamics leading to a hypothesis for hurricane modification, (2) measurement of tropical convection and other aspects of energy exchange in the tropics, (3) a comprehensive investigation of hailstorms, and (4) a study of the water budgets of a variety of precipitating storm types.

The specific research areas of greatest promise that the panel recommended should receive the highest priority were: (1) Studies of atmospheric water budgets and vapor transport over those areas of the United States where the potential for cloud seeding is important, (2) studies of boundary-layer energy exchange processes, (3) development of theoretical models of condensation and precipitation, and (4) studies of the meteorological effects of atmospheric pollution, including carbon dioxide and urbanization.

The need for enhancement or establishment of certain support systems and research facilities was also noted. In particular the panel noted that the best computer just then becoming available had only one-fiftieth of the effective speed needed to meet the growing computational requirements of meteorological research, and, consequently, the panel recommended that all necessary steps be taken to encourage the computer industry to respond to these requirements. In addition, the panel recommended that civil research aircraft facilities be enlarged to include diversified types of aircraft and supporting data-gathering systems to meet the requirements placed upon them by large field research programs in atmospheric sciences and weather modification.

The panel also recommended that full U.S. support and leadership be given in establishing an advanced global-observational system, and that the Federal agency assigned major administrative responsibilities in weather and climate modification also be empowered to deal with the complex international issues arising from weather modification projects.

A RECOMMENDED NATIONAL PROGRAM IN WEATHER MODIFICATION

ICAS (Interdepartmental Committee for Atmospheric Sciences) report No. 10a was prepared by Dr. Homer E. Newell in response to a request to formulate a national weather modification program along the lines delineated in the report of the ICAS Select Panel on Weather Modification titled "President and Future Plans of Federal Agencies in Weather-Climate Modification" (included as app. III in ICAS Rept. No. 10a). The weather modification program developed was based on analysis of existing agency programs and needed expansion of activities including budget support. The following principles were among those developed which underlie the program recommendations:

1. There is sufficient potential payoff indicated by the results of past research to justify continuing basic and applied research in the area of weather modification.
2. The potential dollar savings in lessening the destructive effects of weather, and the potential gains in enhancing the beneficial effects, are so great that expenditures of appreciable dollars on weather modification research and application can be justified.
3. There is a need for a single agency to assume responsibility for taking the lead in developing a well-rounded national program of research on weather modification.
4. It is desirable to maintain a multiple-agency approach to weather modification, and each agency's basic mission should determine its role in weather modification, but not to the exclusion of basic research.
5. Interagency cooperation and support is essential.

6. A formal procedure must be developed to achieve continuing visibility and coordination of the total weather modification program.

7. There must be regulation and control of weather modification activities, especially as these become of greater magnitude and international in scope.

ICAS report 10a recommended that the major thrust of the national program in weather modification for the immediate future be in the direction of understanding the physics and dynamics of weather systems to provide a sound basis for experimentation in, and application of, weather modification. The report also found that the budget figures and program expansion plans developed by the ICAS select panel to be about twice as high as might be realistic. (The ICAS select panel had envisioned growth in Federal funding for weather modification programs from \$9.3 million in 1967 to \$146.8 million in 1970.)

Report 10a recommended that weather modification be coordinated (in the sense of providing all concerned with a continuing visibility of the whole national weather modification effort) by the Office of the Federal Coordinator for Meteorological Services and Supporting Research. However, it was not intended to give the Federal Coordinator responsibility for program planning and control, which would remain the responsibility of the operating agencies and under the review of ICAS. A body for regulating weather modification activities was deemed necessary, but no recommendation was made as to a specific organization. The view was expressed that it should not be one of the operating agencies participating in the national weather modification program, nor should it be the Office of the Federal Coordinator because of the ambivalent relationship existing between that office and ESSA. In addition, ICAS would not have the means to perform the regulatory function.

The report recognized that international impacts may arise through weather modification activities and suggested that a practical and constructive approach to reducing possible conflicts would be through bilateral or multilateral agreements. In these, the United States should seek to establish mutual interest in large-scale experiments.

The report concentrated on four agencies—the Department of Agriculture, ESSA (now part of the National Oceanic and Atmospheric Administration), the Interior Department's Bureau of Reclamation, and the National Science Foundation (NSF)—which together would represent over 98 percent of the total national weather modification activity in 1970.

With regard to the program developed for the Department of Agriculture, there were two major categories: (1) Direct modification of weather, and (2) ecological and supporting research. These relate primarily to the suppression of specific harmful effects of weather phenomena, and a study of the effects of weather modification upon farm and forest crops, and on land management in general.

The single objective of the Department of Interior's atmospheric water resources program was to ascertain the technical and economic feasibility of increasing the water supply for Bureau of Reclamation projects through weather modification. Research results showed sufficient promise that the ICAS report recommended the program should be reoriented to reflect the eventual goal of the effective, beneficial utilization of the Nation's atmospheric water resources.

The report recommended that ESSA pursue a broad research and development effort which is essential to a viable national weather modification program, supplementing and integrating the research programs of the mission-orientated agencies. In particular, the ESSA program should focus on such areas as severe storm suppression, hurricane modification, and large-scale atmospheric modeling.

The ICAS report supported the proposition that NSF should increase the support of basic and closely associated applied research, which is appropriate and fundamental to any program of weather modification. The NSF program should be directed toward three objectives: (1) The establishment of a sound scientific foundation for an intensified program of weather modification, (2) the substantial involvement of universities in this area of research, and (3) the production of substantial numbers of highly trained people for this work.

A NATIONAL PROGRAM FOR ACCELERATING PROGRESS IN WEATHER MODIFICATION

ICAS report No. 15a, prepared in 1971, proposed a program for accelerating national progress in the modification of weather through consolidation of a number of prime Government weather modification efforts into seven key projects. A lead agency was designated for each of the proposed national projects. The national projects were defined as multiagency efforts of major national significance, which were considered to have near-term potential for meeting identified national needs. Each had as a base an ongoing weather modification program with a potential for making a vital contribution to the solution of a national problem.

The national projects were designed to learn about physical mechanisms and to test scientific concepts, except for one with the special designation of pilot project. The pilot project was concerned with the development of efficient operational techniques and the process of decisionmaking. These national projects were designed so that different departments with differing missions would advance their own as well as broader national interests by formal collaboration with one another.

The proposed national projects and lead agencies were:

1. National Colorado River Basin pilot project, Bureau of Reclamation, to test the feasibility of applying a cloud-seeding technology, proven effective under certain conditions, to a river basin for a winter season to augment the seasonal snowpack.

2. National hurricane modification project, National Oceanic and Atmospheric Administration, to develop a seeding technology and associated mathematical models to reduce the maximum surface winds associated with hurricanes.

3. National lightning suppression project, Forest Service, to develop a seeding technology and associated physical and mathematical models to reduce the frequency of forest fire-starting lightning strokes from cumulonimbus clouds.

4. National cumulus modification project, National Oceanic and Atmospheric Administration, to develop a seeding technology and associated mathematical models to promote the growth of cumulus clouds in order to increase the resulting natural rainfall in areas where needed.

5. National hail research experiment, National Science Foundation, to develop a seeding technology and associated mathematical models to reduce the incidence of damaging hailfall from cumulonimbus clouds without adversely affecting the associated rainfall.

6. National Great Lakes snow redistribution project, National Oceanic and Atmospheric Administration, to develop a seeding technology and associated mathematical models to spread the heavy snowfall of the Great Lakes coastal region farther inland.

7. National fog modification project, Federal Aviation Administration, to develop seeding or other technology and associated physical and mathematical models to improve the visibility in warm and cold fogs where and to the extent needed.

In addition to the special support needed for these national projects, a significant increase in relevant broad background research and development support would be needed. In this regard, the areas of nuclei counting and efficiency assessment, the physical chemistry of nucleating agents, the microphysics and dynamics of mesoscale systems, mesoscale mathematical models, and cloud physics instrumentation, such as doppler radars and microwave sensors, were singled out in particular.

Specific recommendations were also made to establish a national depository for weather modification data, for the study of and effective handling of the socioeconomic legal aspects for the future, and for certain ecological and hydrological studies to be performed.

WEATHER AND CLIMATE MODIFICATIONS : PROBLEMS AND PROGRESS

In 1973 the National Academy of Sciences (NAS) published a second report on weather and climate modification which reviewed progress since the 1966 report and made further recommendations for a Federal program. Three definite research goals were recommended to form the principal objective of the Nation's weather modification program :

1. Identification by the year 1980 of the conditions under which precipitation can be increased, decreased, and redistributed in various climatological areas through the addition of artificial ice and condensation nuclei ;

2. Development in the next decade of technology directed toward mitigating the effects of the following weather hazards: hurricanes, hailstorms, fogs, and lightning ;

3. Establishment of a coordinated national and international system for investigating the inadvertent effects of manmade pollutants, with a target date of 1980 for the determination of the extent, trend, and magnitude of the effect of various crucial pollutants on local weather conditions and on the climate of the world.

A program to achieve these goals would contain many elements. In this regard, several recommendations were presented in the NAS report. These included :

1. More adequate laboratory and experimental field programs would be needed to study the microphysical processes associated with the development of clouds, precipitation, and thunderstorm electrification.

2. There was a need to develop numerical models to describe the behavior of cloud systems. Existing work had dealt mainly with isolated cumulus clouds.

3. A need was identified for the standardization of instrumentation in seeding devices and the testing of new seeding agents.

4. There should be established a number of weather modification statistical research groups associated with the major field groups concerned with weather modification and the inadvertent effects of pollutants.

5. NOAA should create a repository for data on weather modification activities and, at a suitable price, make available for reanalysis complete data on these activities.

6. A continuing need was identified for a comprehensive series of randomized experiments to determine the effects of both artificial and natural ice and cloud condensation nuclei on precipitation in the principal meteorological regimes of the United States.

7. Further investigations into the feasibility of redistributing winter precipitation were needed.

8. Evaluation of the effects of seeding on precipitation outside the area of seeding was needed.

9. Studies of the effects of artificial seeding on cumulus clouds and the numerical modeling of the seeding process should be continued and expanded.

10. Investigations should be made to determine whether the seeding techniques presently used in the study of isolated cumulus clouds and in hurricane modification can be extended to the amelioration of severe thunderstorms, hailstorms, and even tornadoes.

11. An expanded program was needed to provide continuous formation-to-decay observations of hurricanes from above, around, within, and beneath seeded and nonseeded hurricanes and for testing new techniques for reducing hurricane intensities.

12. A major national effort in fundamental research on hailstorms and hailstorm modification should be pursued aggressively.

13. A research program dealing with fog dissipation should be undertaken.

14. There was a need to develop a variety of research techniques for observing severe storms.

15. National and international programs should be developed for monitoring atmospheric changes and pollutants resulting from man's activities.

16. Satellite programs should be developed to monitor on a global basis, the cloud cover, albedo, and the heat balance of the atmosphere.

17. Enlarged programs were needed to measure climatic differences between cities and adjoining countrysides and to determine the mechanisms responsible.

18. Continued strong support should be provided for the global atmospheric research program now underway to model properly the global atmosphere-ocean system.

The NAS report recognized that three major functions must be provided within the Federal organizational structure to achieve these goals. First, at this stage in the development of the field, there must be support for many basic studies at universities in the relevant aspects of the atmospheric sciences, biological sciences, social sciences, engineering, and public policy. Second, the mission oriented agencies must maintain their weather modification programs. Finally, an agency that has the scientific and management competence, the dedication, and the resources to make the national weather modification program part of its basic mission needs to be designated; the absence of an

agency with this ability and role has been the reason that progress has not been more rapid. The report went on to recommend that the National Oceanic and Atmospheric Administration (NOAA) be assigned principal administrative responsibility for a national program in weather modification. Several considerations were presented in support of this recommendation.

The NAS report also suggested that it is unlikely that the current ad hoc method of carrying out large field programs would be satisfactory over the long term and that a national laboratory should be assigned primary responsibility for carrying out large weather modification experiments involving theoretical, laboratory, and field programs. This laboratory would have the advantage of being of sufficient size to comprise the "critical mass" needed to mount a meaningful and effective research and development program directed specifically toward weather modification.

In addition, the NAS report recommended that the newly created National Advisory Committee on Oceans and Atmosphere (NACOA) undertake a major study of the public policy issues of weather modification and of the Federal organization and legislation necessary. While the report did not present a detailed budget for the various program elements, it estimated that no less than \$50 million per year would be needed. This would have required at least a doubling of current efforts at the time.

ANNUAL REPORTS TO THE PRESIDENT AND CONGRESS BY NACOA

The first annual report of the National Advisory Committee on Oceans and Atmosphere in 1972 discusses the background and present state-of-the-art in weather modification and recommended action it believed desirable in: "legislation to define rights, responsibilities, and a sense of purpose; research to hasten and extend our abilities to reduce risks; and international agreement to promote peaceful uses of weather modification and to eschew its hostile uses." This report also found that a central focus was lacking in Federal weather modification activities and suggested that NOAA might be the appropriate agency for the lead role.

The second annual NACOA report (1973) repeated the basic weather modification findings of the previous year, only this time highlighted them more clearly in the form of recommendations. The report recommended that: "The many small programs in weather modification now scattered widely through the Federal agencies be focused and coordinated under NOAA's lead; basic cloud physics and dynamics be given higher priority; and that the legal, social, and economic impact of weather modification be thoroughly examined and appropriate regulatory and licensing legislation be sought."

NACOA's third annual report again put forward the weather modification recommendations of the previous years, calling for designation of NOAA as lead agency, greater research emphasis on the physics of cloud formation and rainfall augmentation, and examination of legislative and public policy issues including U.S. initiatives to establish international agreement to insure that weather modification efforts are devoted to mutually beneficial purposes.

The fourth annual NACOA report (1975) amplified the previous weather modification recommendations and added a recommendation that the Department of Agriculture, in conjunction with NOAA, develop a crop assessment and planning system which will recognize the national implications of simultaneous climatic variation upon agricultural production worldwide.

In 1976 NACOA reported that the fragmented Federal effort in weather modification placed too much emphasis on operations, with insufficient attention to the basic research which is needed to make weather modification a reliable operational tool. Finding that enough studies have been conducted to permit a decision as to how to proceed, NACOA recommended that action be taken now, by the executive branch or by the Congress to give NOAA the responsibility for coordinating and managing a coherent Federal program of weather modification research and experimentation.

Subsequent to passage of the National Weather Modification Policy Act of 1976 (P.L. 94-490) the sixth annual NACOA report in 1977 did not include recommendations specific to weather modification. However, the report stated that "NACOA has repeatedly urged a coordinated Federal effort to support the basic research needed to bring weather modification to the point of being an operational tool resting on a sound technical base. * * * Major gaps remain—largely because no one agency has the responsibility for identifying and supporting those areas of basic study needed for further progress along a broad front."

Public Law 94-490 directed the Secretary of Commerce to conduct a 1-year study and on the basis of this to recommend to the President and to the Congress a national policy on weather modification, a Federal program to implement this policy, and organizational and legislative actions needed to put this program into effect. Because of administrative delays this study, being conducted by the 17-member weather modification advisory board appointed in 1977, was not completed within the year specified by the act, but will be completed during 1978.

NEED FOR A NATIONAL WEATHER MODIFICATION RESEARCH PROGRAM

Because of the multiagency participation and the increased Federal funding, in 1974 the General Accounting Office (GAO) undertook a review of the administration of weather modification research. The GAO report found that several administrative problems existed which had been identified by previous studies during the past decade. These problems were: (1) No central authority to direct Federal departments efforts, (2) ineffective coordination, and (3) insufficient resources to achieve timely, effective results. Although most previous studies proposed the formation of a national program for weather modification, previous recommendations that a single agency be responsible for developing a national weather modification program had not been implemented.

The GAO report also examined the ongoing national hail research experiment which was planned as a coordinated effort with the National Science Foundation as lead agency. GAO found "even though the experiment was well planned, requiring extensive interagency

participation, in comparing planned efforts with actual efforts that, for the most part, agencies could not and did not meet all their obligations."

Consequently, the GAO report recommended that "the Office of Management and Budget should, in cooperation with the Federal departments and agencies involved in weather modification research: (1) Develop a national program with goals, objectives, priorities, and milestones, designating one of the agencies, which would have a major program responsibility, to administer and maintain the national program; (2) develop a plan to define and reassign, if appropriate, the responsibilities of Federal departments and agencies providing support or conducting weather modification research; and (3) develop a plan to allocate resources to the national program elements. The GAO report went on to state that while proposed legislation to establish a Department of Natural Resources would transfer three agencies' weather modification activities to the proposed department, in GAO's opinion, problems of administration and management would continue because weather modification activities would still be fragmented.

THE FEDERAL ROLE IN WEATHER MODIFICATION

In 1975 the Domestic Council, Subcommittee on Climatic Change, published a report containing findings and recommendations for the Federal role in weather modification. The principal recommendation of the report was that a policy should be adopted to develop, encourage, and maintain a comprehensive and coordinated national program in weather modification research. The recommended Federal role was divided into three areas; research, operations, and regulation.

Among the recommendations for research, the report stated that the Federal Government should recognize weather modification as having significant potential for ameliorating important weather related problems and foster a broad-based effort to research and experimentation in weather modification during the next decade. The Domestic Council report offered two options for carrying out this Federal research role: (1) Continued coordination and planning through ICAS, with each agency following its mission-directed role, and (2) establishing a lead agency. An appendix to the report stated that the Departments of Commerce, State, and Transportation and the National Aeronautics and Space Administration subscribe to the lead agency option and recommend that NOAA be assigned this lead agency responsibility.

Other research recommendations included: (1) Increased funding for weather modification; (2) a more vigorous research program in basic cloud physics; (3) greater emphasis on assessment of socioeconomic and environmental impacts of weather modification; and, (4) greater emphasis on developing improved methodologies to evaluate the effects of weather modification.

These recommendations were based on findings that the present strategy for Federal research in weather modification has largely been mission orientated, which does not allow development of weather modification as a broad based national goal. Furthermore, although some progress has been made over the past two decades, the scientific and

technological complexity of even modest weather modification experiments requires greater staffing and funding than has generally been available.

The report went on to note that few operational weather modification techniques have been thoroughly proven, although several are sufficiently close to the stage when they could become operational. Consequently, the Domestic Council report made several recommendations for the Federal versus State and private roles regarding weather modification operations. The report stated that the Federal Government should reserve for itself responsibility for: (1) precipitation modification related to multiple State water resources or Federal projects, (2) weather modification over airports or related facilities, (3) mitigation of large-scale drought, and (4) mitigation of hurricanes or extensive storm systems.

The States and private sector should be encouraged to conduct weather modification operations in all other areas. The Council recommended that the private sector be utilized to conduct Federal weather modification operations where feasible or desirable.

In the area of regulation, the Council report found that additional Federal regulatory legislation was not needed at that time as present reporting procedures were adequate. However, given the importance and expected development of the field, continued examination of the need for Federal regulation and international treaties to govern weather modification activities would be prudent. In response to that finding, the Domestic Council report recommended that a formal procedure be established to periodically review regulatory needs. In addition, the report recommended that future U.S. domestic and foreign weather modification activities should include prior assessment of the potential international implications.

TRENDS AND ANALYSIS

In the studies and reports reviewed, a number of problems hindering progress in weather modification have been identified and recommendations have been made to resolve these problems. Two areas of concern generally arose: (1) Federal organization or administration of weather modification research and (2) specific program elements or research needs. The recommendations are listed in table 1 in the form of a matrix in which the recommendations are related to the reports in which they are found. This format facilitates recognition of trends such as recommendations made in early reports which are still being made or, in some cases, may have been acted upon. Administrative recommendations are grouped first.

TABLE 1.—SUMMARY OF RECOMMENDATIONS

Recommendations/report	Advisory Committee, 1957	Special Commission, 1966	National Academy, 1966	ICAS, 1966	ICAS, 1971	National Academy, 1973	NACOA, 1972→	GAO, 1974	Domestic Council, 1975
1. Designate lead agency	X	X	X	X		X	X	X	(1) X
2. Improve support and cooperation from agencies	X	X		X		X		X	
3. Establish standing committee in NAS		X				X			
4. Establish coordinating mechanism in OST ²		X				X			
5. Further study administration of weather modification					(c) X	X			
6. Establish national laboratory		X		X		X			
7. Improve logistics support for field experiments		X		X		X			X
8. Increase basic meteorological research		X		X		X			
9. Develop scientific manpower		X		X		X			
10. Assess legal impacts			(c) X	X		X			
11. Assess socioeconomic impacts			(c) X	X		X			XX
12. Assess environmental impacts			X	X		X			XX
13. Study inadvertent modification		X	X	X		X			
14. Improve weather prediction through global study	X	X	X	X		X			X
15. Seek international accord		X	X	X		X			
16. Improve numerical modeling		X	X	X		X			
17. Improve evaluation of programs		X	X	X		X			XX
18. Need greater regulation		X	X	X		X		X	
19. Establish national depository for weather modification data					X	X			
20. Establish large field experiments or national projects in general		X				X			
(a) General study of variety of storm types			X	X		X			
(b) Specific projects:									
(1) Cumulus cloud seeding			X	X		X	X		
(2) Study hurricanes			X	X		X	X		
(3) Lightning suppression			X	X		X	X		
(4) Snow redistribution			X	X		X	X		
(5) Fog dissipation			X	X		X	X		
(6) Study hailstorms			X	X		X	X		
(7) Study tropics			X	X		X	X		
(8) Colorado basin snowpack augmentation			X	X		X	X		
(9) Study areas adjacent to seeding			X	X		X	X		
(10) Study areas adjacent to cities			X	X		X	X		
(11) Study violent storms and tornadoes			X	X		X	X		

¹ Recommended as 1 of 2 options (see text).

² ICAS has responsibility in this area.

³ Incorporated into recommended national projects.

⁴ Considered important but not within report's area of responsibility.

The most common administrative recommendation is to designate a lead agency to provide overall coordination of a Federal weather modification program. Other than the advisory committee report of 1957, which recommended NSF for this role, the lead agency recommended was NOAA or its predecessor ESSA. In the case of the Domestic Council's report, a lead agency role was presented as one of two options, the other being continued coordination through ICAS, but an appendix supported by four agencies recommended that NOAA be designated the lead agency. The recommendation for a lead agency was frequently coupled with the recommendation that mission oriented agencies support more fully the national weather modification efforts as they relate to their particular mission.

In some cases recommendations of an administrative nature have been acted upon or lead to a solution to the problem along other lines. For example, the report of the Special Commission on Weather Modification in 1966 recommended that a standing committee on weather modification be established in the National Academy of Sciences. While a standing committee has not been established in NAS, panels on weather and climate modification have been assembled as needed by the Committee on Atmospheric Sciences. Additionally, in 1972 NACOA was established which, although not within the National Academy, serves in the role of a standing advisory committee. Another recommendation of the special commission was that the Office of Science and Technology should establish a mechanism for the coordination of weather modification policies and programs. To some extent, ICAS has responsibility in this area, but it lacks authority to initiate action within any agency.

With regard to specific research recommendations or program elements, some reports are more general than others. For example, the special commission report recommended that the Federal Government conduct large field experiments without discussing these in detail. Subsequent reports often detailed specific field projects.

Some perspective can be gained by comparing early reports to more recent ones. Early reports identified the limitations on numerical modeling imposed by the existing state-of-the-art in computer technology. While these limitations still exist to some extent, the significant progress that has occurred in this field has served to reduce the apparent magnitude of the problem. Early reports also identified research and numerical modeling on isolated cumulus clouds as a primary focus (the wisdom of dealing with simpler problems before attacking more complex ones), but later reports noted progress in this area and pointed to the need for research and numerical modeling on a variety of cloud systems. Early reports were also somewhat caught up in the general enthusiasm for, and expectation of, being able to modify the weather on an operational basis in the near future. Consequently, a general feeling was that problems may arise in the absence of regulatory direction at the Federal level. However, as progress in weather modification was not as rapid as expected (perhaps as a result of lower levels of funding than expected or perhaps because of unanticipated complexities with weather modification projects), it has since become apparent to many authorities that new regulatory measures are not needed at this time. In this regard, the Domestic Council's report recommended periodic review to assess regulatory needs.

Almost invariably the reports pointed out that considerably greater progress could be made if funding were increased. Although funding for weather modification activities has increased over the years, most recommendations for funding have been for considerably higher levels than have actually been provided.²

² See ch. 5 for funding data on Federal weather modification research programs. In particular, fig. 2 shows the course of Federal funding (planning budgets and actual expenditures) from fiscal year 1966 to fiscal year 1978.

CHAPTER 7

STATE AND LOCAL ACTIVITIES IN WEATHER MODIFICATION

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OVERVIEW OF STATE WEATHER MODIFICATION ACTIVITIES

INTRODUCTION

A majority of the States in the United States have some official interest in weather modification. Twenty-nine States have some form of law which relates to such activities, usually concerned with the various facets of regulation or control of operations within the State and sometimes pertaining to authorization for funding research and/or operations at the State or local level. The statutes dealing with weather modification for these 29 States are reproduced in appendix D. Two other States, Maryland and Massachusetts, had also enacted legislation on the subject; however, the laws in these two States have since been repealed. The general policy toward weather modification in each State is usually reflected in the weather modification law of that State; the laws of some States tend to encourage development and use of the technology, while others discourage such activities.

The current legal regime regulating weather modification has been developed by the States rather than the Federal Government, except in the areas of research support, commissioning studies, and requiring reporting of activities. The various regulatory management functions which the States perform are embodied in the collection of State laws on weather modification. These functions include such activities as (1) issuance, renewal, suspension, and revocation of licenses and permits; (2) monitoring and collection of information on activities through requirements to maintain records, the submission of periodic activity reports, and the inspection of premises and equipment; (3) funding and managing of State or locally organized operational and/or research programs; (4) evaluation and advisory services to locally organized public and private operational programs within the State; and (5) other miscellaneous administrative activities, including the organization and operation of State agencies and boards which are charged with carrying out the statutory responsibilities.

Both the kinds of weather modification functions performed and the diversity of the functions performed by the several States can be gleaned from table 1, in which are identified the chief elements of the weather modification laws for the respective States having such laws. (The information in the table was provided by Davis and reflects the

content of State laws in force at the end of 1975.)¹ Hawaii's law merely mentions atmospheric waters and is not included in the table.

In order to administer the various regulatory and managerial responsibilities pertaining to weather modification within the States, an assortment of institutional structures has been established. These include State departments of water or natural resources, commissions, and special governing or advisory boards. Often there is a combination of two or more of these types of agencies or groups, separating the responsibility functions of pure administration from those of appeals, permitting, or advisory services. In the cases of particular State activities contained in the latter part of this chapter, some examples of State institutional structure for weather modification are discussed.²

TABLE 1.—ELEMENTS OF STATE WEATHER MODIFICATION LAWS IN FORCE AS OF THE END OF 1975

State	Administrative	Funding	Licensing	Permit	Records and report	Water rights	Liability
Arizona.....	X			X	X		
California.....	X	X		X	X		
Colorado.....	X		X	X	X	X	
Connecticut.....	X	X					
Florida.....	X			X	X		
Idaho.....	X	X		X	X		
Illinois.....	X		X	X	X		X
Iowa.....		X					
Kansas.....	X	X	X	X	X		
Louisiana.....	X		X	X	X		
Minnesota.....		X					
Montana.....	X		X	X	X		
Nebraska.....	X	X					
Nevada.....	X		X	X	X		
New Hampshire.....		X					
New Mexico.....	X			X	X		
New York.....		X				X	
North Dakota.....	X		X	X	X	X	X
Oklahoma.....	X		X	X	X		
Oregon.....	X				X		
Pennsylvania.....	X			X	X	X	X
South Dakota.....	X	X	X	X			
Texas.....	X	X	X	X	X	X	X
Utah.....	X		X	X	X	X	X
Washington.....	X	X	X	X	X		
West Virginia.....	X			X	X		X
Wisconsin.....	X			X	X		
Wyoming.....	X	X		X	X		

¹ From Davis. Testimony in hearings, House Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, June 1976.

It is clear that the State weather modification laws and their attendant administration are concerned especially in a variety of ways with the regulation or control of activities within the State. This regulation often includes licensing and/or the granting of permits, and it may also include monitoring, evaluation, and reporting of operations. The various means by which weather modification is controlled are discussed in some detail in a section of the chapter of this report on legal aspects.³ Specific laws of the States, found in full in appendix D are also summarized in table 1 of that appendix, where they are compared in terms of their being reasonably comprehensive, their providing for licensing only, or their containing some other miscellaneous provision.⁴

¹ Davis, Ray J., testimony in: U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, "Weather Modification," hearings, 94th Cong., 2d sess., on H.R. 10039 and S. 3383, June 15-18, 1976, Washington, D.C., U.S. Government Printing Office, 1976, pp. 250-252.

² See p. 351 ff.

³ See ch. 11, p. 449 ff.

⁴ See p. 514 ff.

Since regulation cannot be effective without sufficient information about ongoing activities, most States which do regulate weather modification provide authority which enables officials to inspect the premises of operators and to require them to maintain daily logs and report on their activities regularly. Daily reporting is not required, however, by any State, and copies of reports filed with the Department of Commerce are also accepted in some cases as satisfactory compliance with reporting requirements. If properly analyzed by responsible State agencies, the information contained in these reports should indicate appropriate changes or cessations to cloud-seeding operations, if any, that should be made in the public interest.⁵

The extent of involvement in research and operations varies considerably from State to State. Some States support research only, while others fund and operate both operational and research programs. In some cases funding only is provided to those localities, usually at the county level, which have established operational programs. In other States, counties and/or groups of individuals within local regions operate programs funded entirely by local citizens, but with approval and/or advisory services from State agencies. The recent 1976-77 drought conditions led some Western States to initiate emergency cloud-seeding programs as one means of augmenting dwindling water supplies. Among such measures taken on a short time basis are the emergency operations in California, Kansas, and Washington; programs in these States are discussed briefly in the sections at the end of this chapter dealing with the cases of individual States.

Within many of the States, particularly in the West, there is a broad range of weather modification research activity. Usually this research is performed by atmospheric and other scientists at the State universities or other State research agencies. Such research is frequently funded through one of the Federal agencies with major weather modification research programs, such as the National Science Foundation or the Bureau of Reclamation, or it may be supported at least in part with State funds. A few States contribute funds to a Federal research project which is conducted jointly with those States partly within their boundaries.⁶

NORTH AMERICAN INTERSTATE WEATHER MODIFICATION COUNCIL

On January 17, 1975, the North American Interstate Weather Modification Council (NAIWMC) was organized to coordinate intrastate, interstate, and possible international weather modification activities. Its main purpose was to achieve and maintain local and State control of such activities while attempting to attain a high degree of uniformity in legislation and an effective mechanism for information exchange.⁷ The origin of the NAIWMC had its roots in a conference in June 1974, in Sioux Falls, S. Dak., to which Gov. Richard K. Kneip of South Dakota invited the Governors of the United States.⁸ The program for this Interstate Conference on Weather Modification was developed at Gov-

⁵ Davis, testimony before House Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, June 1976 hearings, 94th Cong., 2d sess., p. 245.

⁶ See discussion of the High Plains project (HIPLEX), under "Project Skywater," sponsored by the Bureau of Reclamation, ch. 5, p. 258 ff.

⁷ North American Interstate Weather Modification Council: Its Purposes and Activities, Las Cruces, N. Mex., office of the NAIWMC, September 1976, Pub. No. 76-2, p. 1.

⁸ Conference on Weather Modification in the United States: Potential and Problems for Interstate Action, State of South Dakota, Sioux Falls, S. Dak., June 10-12, 1974, 248 pp.

ernor Kneip's direction by the South Dakota Weather Modification Commission, which was then responsible for the operation of the statewide South Dakota weather modification program.⁹ Representatives of 23 States and the Canadian Province of Alberta attended the conference and reported on weather modification activities within their States.

Recognizing the need for the prudent design and critical analysis of all weather modification efforts, Governor Kneip stressed the fact that interstate cooperation was "particularly needed in view of the growing importance of agricultural production to the economy and well-being of the people of all States and the tendency to develop individual State weather modification programs."¹⁰ At the end of the conference representatives were selected from California, New Mexico, North Dakota, South Dakota, Texas, Washington, and the Province of Alberta to serve on an ad hoc committee which was to:

1. Investigate possible organizational needs;
2. Plan a second conference on interstate weather modification cooperation and coordination within 1 year; and
3. Study the Sioux Falls conference working committee reports and develop suggestions into recommendations.¹¹

The conference in June 1974 showed an expanding awareness of the role of the States in weather modification activities, so that the main mission of the ad hoc committee was to establish a forum for interchange and coordination of information of primary interest to State officials in the operational or regulatory aspects of weather modification.¹² Meeting in October 1974, the ad hoc committee summarized the following bases of concern:

- (1) Substantial but fragmental local, State, and Federal activity in deliberate and inadvertent weather modification.
- (2) Weather modification effects do not respect internal or national boundaries and no compacts or agreements exist regarding the effects.
- (3) States require a measure of control over weather modification.
- (4) No effective mechanism existed for interstate cooperation in weather modification and the States did not have a coordinated approach for atmospheric resources decisionmaking.
- (5) Minimal public involvement in whether modification decisionmaking had been solicited in the past.
- (6) Lack of uniformity existed in most State statutes.
- (7) Little exchange of information among States had taken place.
- (8) Weather modification decisionmaking must be responsive to local, State, and interstate concerns.
- (9) Weather modification activities in response to emergency drought conditions would be most effective through an interstate organization of State representatives.¹³

The ad hoc committee suggested that the overall objectives of the proposed Interstate Council must be to serve as the focal point and

⁹ The South Dakota program has since been curtailed, owing to action of the State Legislature. See discussion of the weather modification activities in South Dakota, p. 376.

¹⁰ Kneip, Richard F., letter of invitation to Governors of the United States to the Interstate Conference on Weather Modification, June 10-12, 1974, Sioux City, S. Dak., Pierre, S. Dak., February 19, 1974.

¹¹ Keyes, Conrad G., Jr., "North American Interstate Weather Modification Council: Need, Goals, Purpose, and Activities," *Water Resources Bulletin*, vol. 13, No. 5, October 1977, p. 918.

¹² *Ibid.*

¹³ *Ibid.*

clearinghouse for interstate weather modification activities and outlined the following specific objectives:

- (1) Serve as the official spokesman for States' needs and views.
- (2) Provide the organization through which funding of multi-State assistance programs can be accomplished.
- (3) Provide a forum for developing interstate agreements.
- (4) Develop and promote the adoption of compatible State regulatory activities.
- (5) Develop and provide information for public use.
- (6) Exchange information and provide assistance in environmental and societal relations.¹⁴

The NAIWMC called its first business meeting in Denver, Colo., on January 17, 1975, following the second interstate conference on weather modification.¹⁵ During this first meeting the Council adopted bylaws, elected an executive committee and a board of directors, and adopted several resolutions.¹⁶ Membership was made available to all of the States of the United States, to the Government of Mexico, and to all the Provinces of Canada. Each of these jurisdictions electing to become a member was to affirm its decision through informing the Council of its support, appointment of a Council delegate and alternate, and payment of dues. Affiliate membership was also made available to national agencies, political subdivisions within States or Provinces, and professional organizations. Ten geographical areas were formed as shown in table 2; areas 2 and 4 were Canada and Mexico, respectively, while the other 8 areas were comprised of regional groupings of the 50 U.S. States. Figure 1 shows the membership within these 10 areas as of October 1977, according to the several membership categories. (At its November 1977 meeting, the NAIWMC was reorganized into six districts—four in the United States; one each in Canada and Mexico.)

TABLE 2.—Areas of the North American Interstate Weather Modification Council, through October 1977¹

Area 1-----	Washington, Oregon, Idaho, Montana, Wyoming, Alaska.
Area 2-----	Canada.
Area 3-----	California, Nevada, Utah, Arizona, Colorado, New Mexico, Hawaii.
Area 4-----	Mexico.
Area 5-----	North Dakota, South Dakota, Nebraska, Minnesota, Iowa, Wisconsin.
Area 6-----	Kansas, Oklahoma, Texas.
Area 7-----	Michigan, Illinois, Indiana, Ohio, Kentucky.
Area 8-----	Tennessee, North Carolina, South Carolina, Alabama, Georgia, Florida, Mississippi.
Area 9-----	West Virginia, Virginia, Maryland, Delaware, New Jersey, Pennsylvania.
Area 10-----	New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, Maine.

¹ At its annual meeting, November 3-4, 1977, the NAIWMC reorganized into six areas, consisting of four in the United States (Western, Midwestern, Eastern, and Southeastern), one in Canada (northern), and one in Mexico (southern).

¹⁴ *Ibid.*, p. 919.

¹⁵ North American Interstate Weather Modification Council, "Conference on Weather Modification—a Usable Technology; Its Potential Impact on the World Food Crisis," Denver, Col., Jan. 16-17, 1975, 150 pp.

¹⁶ Keyes, Conrad G., Jr., "NAIWMC—Formation and Its Activities Through 1975," the *Journal of Weather Modification*, vol. 8, No. 1, April 1976, pp. 158-159.

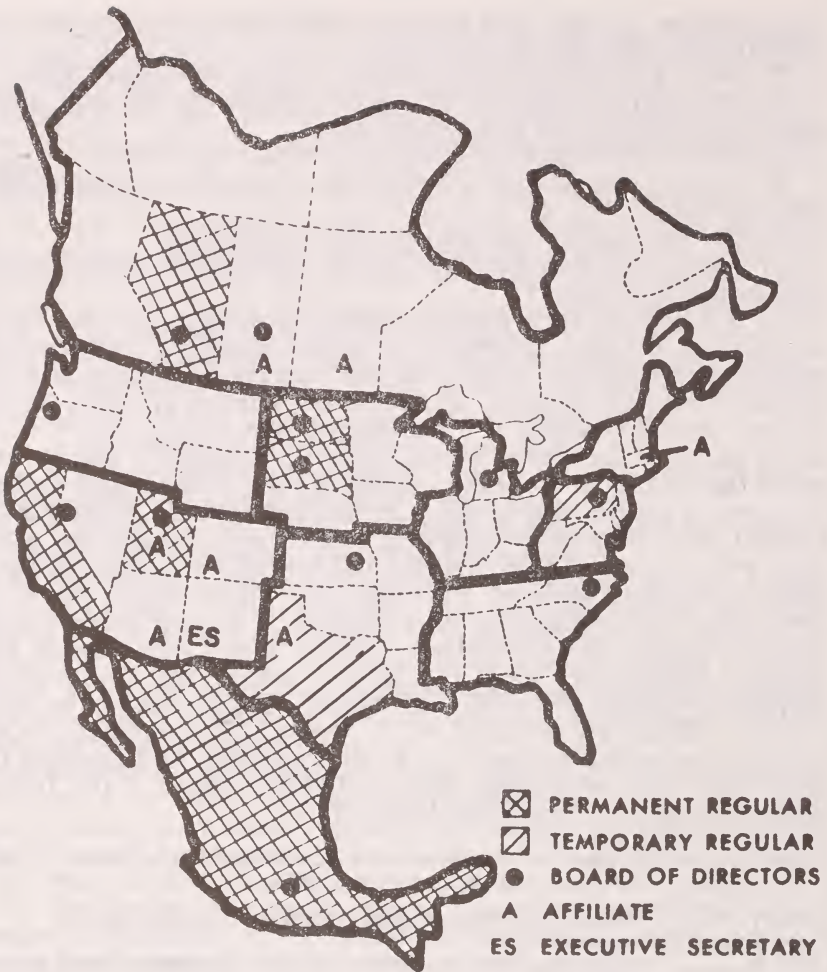


FIGURE 1.—Map showing the location of 1976 members and geographical distribution of board of directors of the North American Interstate Weather Modification Council (from Keyes, 1977). (At its November 1977 annual meeting, the NAIWMC reorganized into six areas—see footnote 1, table 2, p. 335.)

The purpose of the NAIWMC, as stated in the adopted bylaws, is divided into the following six categories:

Operations.—The Council shall assist governmental and private organizations in planning, design, implementation, coordination, and assessment of ongoing, temporary, and emergency weather modification operations which are planned with the intent or conducted with the effect of causing international, national, interstate, or intrastate consequences. The Council shall promote effective partnerships among various agencies conducting weather modification operations, and shall assist in integrating weather modification operations with water resources development and other activities affected by weather modification activities.

Research and development.—The Council shall assist governmental and private organizations in planning, design, implementation, coordination, and assessment of weather modification research and development. It shall promote common research concerning weather modification activities and their environmental and societal consequences. The Council shall provide a forum for the exchange of experience, data, and information about weather modification.

Public involvement.—The Council shall seek to provide information for and engage the discussions with (a) public officials, (b) persons involved in weather modification activities or who demonstrate an interest in the effects of weather modification, and (c) the general public. It shall serve as spokesman for the needs and views of the member jurisdictions, and it shall develop public education programs.

Legislation.—The Council shall assist national governments, State or Provincial governments, and groups of State or Provincial governments in preparation, review, and alternation of treaties, statutes, compacts, and administrative rules and regulations. It shall seek to obtain legislation which is responsive to local, State, interstate, national, and international concerns.

Regulations.—The Council shall assist regulatory agencies in maintaining a high level of integrity and professional competency among weather modifiers. It shall assist regulatory agencies in coordination of their professional licensing and operational permit issuing functions. It shall serve as a clearinghouse for environmental impact statements relating to weather modification and for such other data as will assist regulatory agencies.

Miscellaneous.—The Council shall serve such other purposes relating to the development, operation, and control of weather modification as are consistent with those purposes expressly named in this article. Such purposes shall be stated by resolution adopted at annual, regular, or special meetings of the Council.¹⁷

Counting the January 1975 conference in Denver as the first meeting of the Council, there have been a total of five NAIWMC conferences through 1977. The second annual meeting was held in January 1976 at Kansas City, Mo.¹⁸ Two subsequent conferences were also held during 1976, both in Denver, in August and December, respectively. The first of these was a special meeting on legal uncertainties of weather modification, and the December conference was the third annual meeting of the Council.¹⁹ At both of these conferences, the Council held business meetings. The 1977 regular meeting of the NAIWMC was held November 3–4 in Canada at Calgary, Alberta. Proceedings of the 1977 conference will be published during 1978.

The annual meetings of the NAIWMC provide opportunities to exchange information on weather modification activities within the several Council areas and to discuss and act upon resolutions and position statements pertaining to matters of State, regional, national, and international concern. Five resolutions were passed at the first meeting in January 1975, on the following subjects:

1. Federal and State legislative actions affecting weather modifica-

¹⁷ Keyes. "North American Interstate Weather Modification Council: Need, Goals, Purpose, and Activities," 1977, pp. 919–920.

¹⁸ North American Interstate Weather Modification Council. "Conference on Weather Modification. Today and Tomorrow," January 15–16, 1976, Kansas City, Mo., publication No. 76–1. NAIWMC, Las Cruces, N. Mex., 119 pp.

¹⁹ North American Interstate Weather Modification Council. "Legal Uncertainties and Legislation in Weather Modification: Special and Third Annual Meeting of the Council," NAIWMC publication No. 77–1, September 1977, 172 pp.

tion: The unanimous decision of the NAIWMC was to inform all Federal legislators of the existence of the Council and of the interest and willingness of the organization to assist in the preparation and review of existing and proposed Federal legislation. Further, since some of the States have successful legislation in effect and have had considerable experience in implementing their laws, the Council felt it appropriate to offer the expertise of its members to assist other States in preparation and development of weather modification legislation.

2. U.S. Forest Service control of weather modification activities: Based upon the Organic Administration Act of 1897 (30 Stat. 34, 35, 36; 16 U.S.C. 475), regional supervisors of the Forest Service have recently required land and water use permits for weather modification projects possibly impacting national forest or national grassland areas. The NAIWMC unanimously opposed this action of some Forest Service personnel and strongly recommended that both Federal and State officials and agencies address this problem, since its ramifications could well reach beyond the question of weather modification regulation and control.

3. Planning and operation of weather modification programs in drought emergency situations: Because of existing and continuing drought conditions over much of the Great Plains and the Corn Belt, it was anticipated that Federal governments may implement weather modification activities as a drought relief tool. It was noted, however, that the feasibility of such relief was limited to decisionmaking totally within Federal agencies, without consultation with officials of potentially affected States. The NAIWMC recommended that State agencies be consulted and included in the planning, developing, and implementing of emergency weather modification programs during drought situations.

4. Assistance in reviewing, assessing, and furthering the field of weather modification by the Weather Modification Association: In this resolution the NAIWMC requested that the Weather Modification Association consider supporting the concept of the Council and agree to provide a ready and willing reservoir of talent and expertise to the Council and/or the various States.²⁰

5. Emergency drought assistance bill, S. 4028, 93d Congress: The NAIWMC strongly supported the concept of utilizing weather modification as proposed in the bill, but further suggested that these concepts be expanded to specifically include a strong organizational structure at the State level, advanced technical planning, the mechanisms for quick-reacting financial response, and a strong local input to subsequent field operations. The Council furthermore recommended that such a bill ought to specify a mechanism for recognizing and anticipating the conditions under which its provisions would come to play so that relief could be given before a drought becomes advanced and critical.²¹

At the January 1976 meeting, the Council adopted position statements on bills then before the 94th Congress of the United States. The

²⁰ The purposes and activities of the Weather Modification Association are discussed under Private Activities in ch. 8, p. 390.

²¹ Keyes, "NAIWMC—Formation and Its Activities Through 1975," 1976, pp. 160-162.

first of three bills introduced by Senator Henry Bellmon, S. 2705, to establish a National Weather Modification Commission, was strongly supported by the Council, which pledged to work with such a commission if established. No position was adopted, however, on the other two "Bellmon bills," and an opposing position was taken on H.R. 10039 (the "Evans bill").²²

The NAIWMC has established close coordination with the Council of State governments and the National Conference of State Legislatures, recommending that input be made on weather modification at future meetings of both groups. Suggested issues to be discussed at such meetings include interstate arrangements for research, operations, and evaluation; provision of institutional framework for handling funding and tradeoffs between various societal segments; and provision of better information to State decisionmakers in both the executive and legislative branches.²³ In January 1976 the Council adopted a resolution to support the draft of the proposed model law on weather modification, prepared by Prof. Ray Davis of the University of Arizona. Copies of this draft law have been provided to the Model Law Committee of the Council of State Governments. The NAIWMC also supported the concept of and sponsored four participants to the conference on "Legal and Scientific Uncertainties of Weather Modification," conducted by the American Bar Foundation and the American Association for the Advancement of Science at Duke University on March 12-13, 1976. State governments have requested and received testimony from members of the Council; and, in particular, such testimony was provided at meetings of the Minnesota Task Force on Weather Modification and the Minnesota State Senate prior to adoption of the new Minnesota weather modification statute.²⁴

The Council has also participated with Federal agencies in planning future weather modification projects affecting various regions of the country. A cooperative planning session on the Bureau of Reclamation's proposed Colorado River weather modification demonstration program was sponsored by the NAIWMC in Denver in August 1976. Invited to the session were the seven States on the Colorado River Basin, the Bureau of Reclamation, the Upper Colorado River Commission, and State commissions from the lower river basin. The Council has also been requested by the Advanced Planning Group on NOAA's Weather Modification Project Office in Boulder to provide input to planning of future weather modification research projects.²⁵

In order to learn about the State weather modification activities, laws, institutional structure, research recommendations, and potential interest in participation on the Council, the NAIWMC circulated a number of questionnaires among the officials and agencies of State governments during 1976 and 1977. Information from these surveys has been summarized in tabulated form and conclusions formulated

²² See ch. 5, p. 205, for a synopsis of these bills introduced in the 94th Congress.

²³ Keyes, "North American Interstate Weather Modification Council: Need, Goals, Purpose, and Activities," 1977, p. 922.

²⁴ *Ibid.*

²⁵ *Ibid.*

by the executive secretary of the Council. This information is presented elsewhere in this report in discussions of State weather modification activities²⁶ and recommended research activities for Federal agencies.²⁷

Questionnaires and regional meetings of the NAIWMC have defined potential users of weather modification technology throughout the North American Continent. Views on legislation have also been presented in testimony at 1976 weather modification hearings in both Houses of the U.S. Congress and before Appropriation Committees in 1977. Testimony was also provided by the NAIWMC to the U.S. Department of Commerce Weather Modification Advisory Board at its fifth meeting in October 1977 in Champaign, Ill. Recommendation by the States, presented through the Council in such testimony, has generally supported a Federal law which would include establishment of a national weather modification policy in research and development, a coordinated effort of Federal activities (possibly by regions or major water basins), and a common licensing and permit system administered by the States.²⁸

Results of a survey of State interests in weather modification, conducted by the NAIWMC, are included in the following section.

SURVEY AND SUMMARY OF STATE INTERESTS AND ACTIVITIES IN WEATHER MODIFICATION

During 1977, the North American Interstate Weather Modification Council (NAIWMC) surveyed weather modification interests in all 50 States, posing the following questions to appropriate State agencies or officials:

1. Which organizations in your State have the mission of licensing, monitoring, controlling, or operating weather modification activities?
2. Does your State presently support weather modification programs?
3. What weather modification regulation does your State have?
4. What positions on weather modification does your State have?²⁹

The responses received in reply to the NAIWMC questionnaire have since been revised and updated. The data in table 3 were obtained from officials in the respective States and have been updated through January 1978.³⁰ In the table the States are arranged according to the 10 areas to which they had been assigned by the NAIWMC prior to the reorganization into six areas at the November 1977 annual meeting.³¹ (Areas 2 and 4 were comprised of the Canadian Provinces and the Mexican States, respectively, and are not included in the results of the survey.)

²⁶ See p. 341 in this chapter.

²⁷ See ch. 3, p. 138.

²⁸ Keyes, Conrad G., Jr., "Federal Research Needs and New Law Requirements in Weather Modification: the NAIWMC Viewpoint," testimony before the U.S. Department of Commerce Weather Modification Advisory Board, Champaign, Ill., Oct. 14, 1977.

²⁹ Keyes, "North American Interstate Weather Modification Council: Need, Goals, Purpose, and Activities," 1977, p. 924. (In addition to these four questions, the States were also queried about their interests and potential participation in the Council; since these latter questions and responses to them are not germane to the general survey of State activities, they are not included in the list above or in the assemblage of responses in table 3.)

³⁰ Keyes, Conrad G., Jr., Private communication, January 1978.

³¹ See preceding section, p. 333, for a discussion of the North American Interstate Weather Modification Council.

TABLE 3.—SUMMARY OF WEATHER MODIFICATION INVOLVEMENT BY THE STATES, AS DETERMINED FROM SURVEY BY THE NORTH AMERICAN INTERSTATE WEATHER MODIFICATION COUNCIL (NAIWMC)¹

[Areas are those to which the States are assigned by the NAIWMC]

State	Control organization	Involvement in programs	Support of programs	Statutes	Position on technology
AREA 1					
Alaska	None	Federal research	Unknown	None	None
Idaho	Reporting to Department of Agriculture	Districts by county tax in Bear River Basin	Citizens in southeast counties	Code 22-3201 through 3202, Code 22-4301 through 4302	Interest in technology by water resources.
Montana	Department of Natural Resources	HIPILEX	Research only	Rev. Code 89-310 through 89-331	Research at this time.
Oregon	State Department of Agriculture	Commercial operations	Power companies	Rev. Stat. 558.010 through 558.990	None at this time.
Washington	Department of Ecology	Hydroelectric, universities, airlines, farmers	Active support by state (1977)	Rev. Code 43.37.010 through 43.37.910	None at this time (1976).
Wyoming	Weather Modification Board	University research	Private	Stat. 9-267 through 9-276	None.
AREA 3					
Arizona	Water Commission	Licensing only and NAIWMC	Research efforts	Ch. 45-2401 through 45-2407	Funding for demonstration.
California	Department of Water Resources	Observer and planning	Not as a participant	Secs. 400-115, and 235 of Water Code	Supports Colorado River demonstration.
Colorado	Department of Natural Resources	Research and operations	HIPILEX and emergency	1973 Col. Rev. Stat. secs. 36-20-101 to 126	None.
Hawaii	Department of Regulatory Agencies	None	Technology must improve	State Law, sec. 174-5 (8)	None.
Nevada	Department of Conservation and Natural Resources	Desert Research Institute	Research and operation	Secs. 544.010 to 544.240	Use Desert Research Institute.
New Mexico	Weather Control and Cloud Modification Commission	None	Research	Secs. 75-37-1 to 15	Applicants have burden of proof.
Utah	Division of Water Resources	Research and operations	Funding	Secs. 73-15-3 to 8	Supports Colorado River demonstration.
AREA 5					
Iowa	County Board of Supervisors	Very limited	None	Code Ann. 361.1 through 361.7	Went against a 1977 project.
Minnesota	Department of Agriculture	Counties in operation	Research mainly	Ch. 42.01 through 42.14	Against ground-based seeding.
Nebraska	Department of Agriculture	Very limited	HIPILEX	Rev. Stat. 2-2401 through 2-2449	None.
North Dakota	Weather Modification Board	Research and operations	Funding	Cent. Code 2-07-01 through 2-07-13	Supports operation and research.
South Dakota	Weather Modification Commission	Operations by counties	Regulation only	Comp. Laws 46-3A-1 through 46-3A-31	Supports operation and research.
Wisconsin	Department of Agriculture	Planning for research	Regulation only	Chapter 87, Laws of 1977	None.
AREA 6					
Arkansas	None	None	None	None	None
Kansas	Water Resources Board	Groundwater districts in operations	Contributions and HIPILEX	Stat. Ann. 82a-1401 through 82a-1495	Mainly research.
Louisiana	Department of Agriculture and Immigration	None	None	Rev. Stat. 37:2201 through 37:2208	None.

TABLE 3.—SUMMARY OF WEATHER MODIFICATION INVOLVEMENT BY THE STATES, AS DETERMINED FROM SURVEY BY THE NORTH AMERICAN INTERSTATE WEATHER MODIFICATION COUNCIL (NAIWMC) 1.—Continued
 [Areas are those to which the States are assigned by the NAIWMC]

State	Control organization	Involvement in programs	Support of programs	Statutes	Position on technology
Missouri.....	None.....	None.....	None.....	None.....	Not enthused.
Oklahoma.....	Water Resources Board.....	Operations by counties.....	None.....	Stat Ann. 1401 through 1432.....	None.....
Texas.....	Texas Water Development Board.....	Operations by counties, State in research.....	State in HIPLEX.....	Water code 14.001 through 14.112.....	Up to the counties.
AREA 7					
Illinois.....	Department of Registration and Education.....	Licensing, interest in research.....	Research only.....	Stat. Ann. ch. 146 3/4, arts. 1-32.....	None, other than the law.
Indiana.....	None.....	Interest in research.....	Project proposals on research.....	None.....	None.
Kentucky.....	None.....	Low priority.....	None.....	None.....	None.
Michigan.....	None.....	Interest in legislation.....	Department of Agriculture.....	None.....	Involved in proposed research.
Ohio.....	None.....	None.....	Possible research.....	None.....	None.
AREA 8					
Alabama.....	None.....	None.....	None.....	None.....	None.
Georgia.....	None.....	None.....	None.....	None.....	None.
Florida.....	Department of Environmental Regulation.....	Minimal.....	None.....	Ch. 75-22.....	None.
Mississippi.....	None.....	None.....	None.....	None.....	None.
North Carolina.....	None.....	Low.....	None.....	None.....	None.
South Carolina.....	None.....	None.....	None.....	None.....	None.
Tennessee.....	None.....	None.....	None.....	None.....	None.
AREA 9					
Delaware.....	None.....	County programs.....	Consulting to private sectors.....	None.....	None.
Maryland.....	None.....	None.....	None.....	None—repealed 66C.....	None.
New Jersey.....	None.....	Educational.....	Department of Agriculture.....	None.....	None.
Pennsylvania.....	Department of Agriculture Penn State.....	Regulatory.....	Some citizens against.....	Stat. Ann. title 3, arts. 1101-1118.....	Testimony—Hill.
Virginia.....	None.....	Research.....	Some citizens against.....	None.....	Testimony—Hoster.
West Virginia.....	Aeronautics Commission.....	None.....	None.....	Code Ann. 29-2B-1 through 29-2B-15.....	None.
AREA 10					
Connecticut.....	Weather Control Board.....	None.....	None.....	Gen. Stat. Ann. 24-5 through 24-8.....	None.
Maine.....	None.....	None.....	None.....	None.....	None.
Massachusetts.....	Weather Amend. Board.....	None.....	None.....	Ann. Laws ch. 6, art. 72.....	None.
New Hampshire.....	None.....	None.....	None.....	Rev. Stat. Ann. art. 432:1.....	None.
New York.....	None.....	Low priority.....	None.....	Gen. Munic. 119-p.....	None.
Rhode Island.....	None.....	None.....	None.....	None.....	None.
Vermont.....	None.....	None.....	None.....	None.....	None.

¹ From Keyes, North American Interstate Weather Modification Council: Need, Goals, Purpose, and Activities, 1977. Revised September 1977 and January 1978.

In his analysis of the responses to the NAIWMC questionnaire Keyes has made the following observations:³²

1. Few States have weather modification regulation outside a department of water or natural resources.
2. Only a few States have direct involvement in on-going weather modification programs.
3. Several States support the concept of funding further research in weather modification.
4. Twenty-nine States have a law that deals directly or indirectly with weather modification.
5. Very few States have positions concerning weather modification programs.

STATE CONTACTS FOR INFORMATION ON WEATHER MODIFICATION ACTIVITIES

The diversity of weather modification activities within the States and the frequent changes in State laws and procedures for executing the provisions of the laws point to the need for obtaining current information on a given State through responsible State officials. Also, further information on the statute's official activities, and policy toward weather modification in the several States can be obtained through contacting appropriate individuals within the governmental structure of each State. A list of such persons, found in appendix E, has been assembled from names and addresses of persons within the States, collected by the North American Interstate Weather Modification Council (NAIWMC), who have some interest and/or responsibility for weather modification.³³

The list in appendix E is intended to provide a single point of contact within each State and is believed to be current as of January 1978. The individuals listed are cognizant of official State activities and current State laws; however, they can also serve as starting points within each State, leading to subsequent contacts for additional information for which they may not have direct responsibility. Such information might relate to local operations and activities of citizens groups, commercial operators incorporated and based within the State (whose sphere of operations includes other States and countries), university research projects, and Federal research projects conducted within the State.

The list of individuals in appendix E is complete in that all 50 States are represented, including those without weather modification laws. In the latter cases, the names or offices appearing are those qualified to respond to queries on private or local activities within the State or on current and future State interest on the subject. The entries in the list are alphabetically ordered according to State name.

NONFEDERAL U.S. WEATHER MODIFICATION ACTIVITIES

The mechanism for reporting of U.S. weather modification activities to the Secretary of Commerce through the National Oceanic and Atmospheric Administration (NOAA), as required by Public Law 92-205 and its amendments, has been discussed under activities of the executive branch of the Federal Government.³⁴ In accordance with the

³² Keyes, "North American Interstate Weather Modification Council: Need, Goals, Purpose, and Activities," 1977, pp. 924-925.

³³ Keyes, Conrad G., Jr. (executive secretary of the North American Interstate Weather Modification Council), private communication.

³⁴ See chapter 5, p. 232.

requirement for publishing summary reports on these activities "from time to time." NOAA has prepared four such summary reports, the last of which covers projects which were actively in progress at some time during calendar year 1975.³⁵ (A summary report incorporating similar activities for calendar years 1976 and 1977 is in preparation by NOAA.) For convenience, the NOAA summary reports include data on Federal research projects as well as all U.S. non-Federal projects although the law requires only reporting of the latter category of activities.

Analysis of calendar year 1975 projects

The total listing of both non-Federal and Federal U.S. weather modification projects conducted during 1975 and appearing in the latest NOAA summary report³⁶ appears in appendix G. Of the 85 projects reported in 1975, 12 were completed early in the year, but 12 similar projects were reinstated later the same year at the same locations. Furthermore, two U.S. Air Force operational projects in Alaska were replaced during the same year by a single project. Of the 72 non-duplicative projects in as many separate locations, 58 were nonfederally sponsored and the Federal Government sponsored 14. This division and the breakdown of the 72 projects by numbers in various categories of initiation, completion, and continuation during 1975 are shown in table 4. Tables 5 and 6 give numbers of projects carried out according to various types of operators and according to kinds of sponsors, respectively. Some activities, such as fog dispersal projects at airports, have multiple sponsors, as several airlines, for example, may enter into joint funding arrangements. Of the 80 distinct sponsors in table 6, at least 13 are public at the State and local level if the four categories—municipal districts, States, cities, and counties—are combined. At least 23 non-Federal public projects during 1975 can be counted, however, from the listing in appendix G, since some of the sponsors enumerated in table 6 funded more than one project; some of the sponsors counted in the category of "airlines/airports" were also public agencies.

The purposes for the reported activities are identified, with the corresponding numbers of each, in table 7. The total in this table (88) is larger than the number of nonduplicative projects (72) because some projects were conducted for two purposes.³⁷

TABLE 4.—*Active, nonduplicative weather modification projects in the United States in calendar year 1975 (from Charak, 1976)*

Non-Federal projects.....	58
Federally sponsored projects.....	14
Projects active on Jan. 1, 1975.....	35
Projects active on Dec. 31, 1975.....	26
Projects active on Jan. 1 and Dec. 31, 1975.....	10
Projects initiated in calendar year 1975.....	37
Projects completed in calendar year 1975.....	46

³⁵ Charak, Mason T., "Weather Modification Activity Reports: Calendar Year 1975." National Oceanic and Atmospheric Administration, Office of Environmental Monitoring and Prediction, Rockville, Md., June 1976. 64 pp.

³⁶ *Ibid.*, pp. 19-35.

³⁷ *Ibid.*, pp. 3-7.

TABLE 5.—OPERATORS OF WEATHER MODIFICATION ACTIVITIES (FROM CHARAK, 1976)

Type	Operators	Activities
Commercial weather modifiers.....	15	47
Universities.....	5	6
Federal.....	5	8
Municipal districts.....	5	5
Community associations.....	2	2
Power companies.....	1	2
Individuals.....	2	2
Total.....	35	72

TABLE 6.—SPONSORS OF WEATHER MODIFICATION ACTIVITIES (FROM CHARAK, 1976)

Type	Sponsors	Activities
Community associations.....	22	22
Federal.....	6	14
Airlines/airports.....	32	10
Municipal districts.....	8	8
States.....	2	7
Power companies.....	3	4
Private sector.....	4	4
Cities.....	2	2
Counties.....	1	1
Total.....	80	72

TABLE 7.—PURPOSE AND SPONSORSHIP OF WEATHER MODIFICATION ACTIVITIES (FROM CHARAK, 1976)

Sponsors	Increase		Precipitation	Disperse fog		Decrease hail	Research
	Rain	Snow		Cold	Warm		
Community associations.....	5		16			6	
Airlines/airports.....				9	1		
Federal agencies.....				2			12
Municipal districts.....	4	3	2			1	
States.....	6			1		6	1
Power companies.....		2	2				
Private sector.....	1		1				2
Cities.....			1	1	1		
Counties.....	1					1	
Total.....	17	5	22	13	2	14	15

Table 8 summarizes weather modification statistics by State and by total target area covered for 1975. Seventy-five activities in 25 States are shown, duplications appearing over the 72 basic project locations because three projects extended into adjoining States—from Michigan into Indiana, from Delaware into Maryland, and from California into Nevada. The geographical distribution of all reported projects is shown in figure 2. Numbers on the map indicate the order in which initial project reports were received by NOAA, missing numbers corresponding to projects reported in earlier years but now terminated. An "F" adjacent to a number indicates a federally sponsored project.³⁸

Eighty percent of U.S. weather modification projects were carried out west of Kansas City during 1975, with the largest projects in California, Oklahoma, South Dakota, and Colorado, in that order of size. South Dakota, Utah, North Dakota, Kansas, and California, in order, had the largest area coverage from these projects. In the East, Michi-

³⁸ Ibid., pp. 8-10.

gan led in the number of projects, while Florida had the most area covered. The total target area comprised about 5 percent of the total area of the United States, Federal activities accounting for about 7 percent and commercial operators for 93 percent of this area. Sixty-five percent of the area of South Dakota was specified as target area, while in Utah, Delaware, and North Dakota corresponding percentages were 49, 36, and 26, respectively.³⁹

TABLE 8.—LOCATION AND SIZE OF TARGET AREAS (FROM CHARAK, 1976)

Location	Activities	Target area (square miles)
Alaska	2	51
California	11	5,183
Colorado	6	3,315
Delaware	1	750
Florida	2	4,878
Idaho	1	198
Illinois	1	2
Indiana	1	204
Iowa	2	4
Kansas	1	9,000
Maryland	1	750
Michigan	6	3,507
Montana	1	5
Nebraska	1	2
Nevada	2	755
New Hampshire	1	4
North Dakota	5	18,629
Oklahoma	9	7,885
Oregon	3	7,841
Pennsylvania	1	200
South Dakota	7	50,085
Texas	3	7,200
Utah	3	41,510
Washington	3	56
Wyoming	1	180
Total	75	163,194

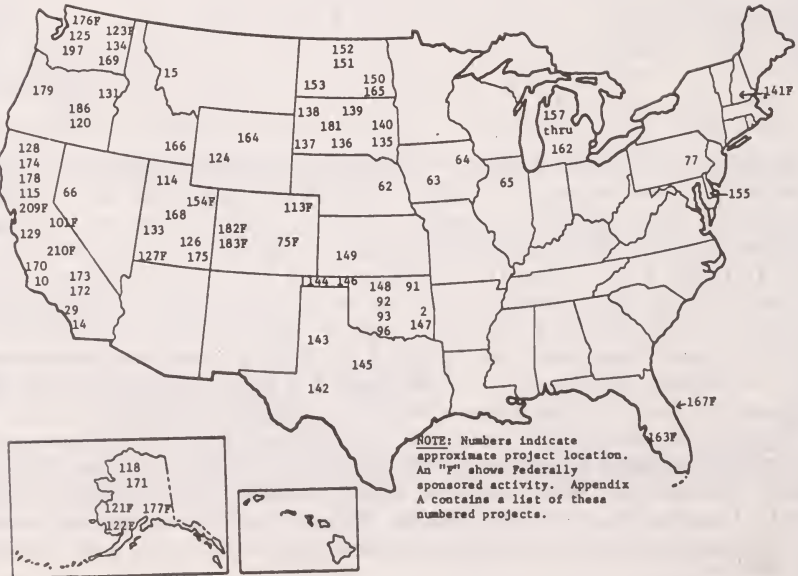


FIGURE 2.—Federal and non-Federal weather modification activities in the United States, calendar year 1975. (From Charak, 1976.)

³⁹ Ibid., p. 10.

Preliminary analysis of projects for calendar years 1976-77

Prior to publication of the next NOAA summary of U.S. weather modification projects, to be completed during 1978, Charak has completed a preliminary analysis of reported projects for the calendar years 1976-77.⁴⁰ Table 9 provides information on numbers of projects, operators, and sponsors for the 2 years. An increase of 44 percent in total activities is seen from 1976 to 1977, although Federal projects decreased 33 percent while non-Federal ones increased 60 percent. The number of non-Federal weather modifiers remained constant for the 2 years; however, there was an approximate 40-percent increase in the number of community sponsoring groups from 1976 to 1977. Further analysis of the operators in 1977 shows that six commercial firms conducted 60 percent of the activities, and three of these companies operated 50 percent of the projects. The increase in projects in 1977 reflects the efforts to combat or forestall drought conditions in the United States on the part of various States, local farm groups, and municipal water districts. Charak feels that this increase may also indicate that the belief in the potential of cloud seeding for precipitation enhancement is shared by more and more governmental officials and other people affected by water shortages.⁴¹

TABLE 9.—OPERATORS AND SPONSORS OF WEATHER MODIFICATION ACTIVITIES IN THE UNITED STATES
(FROM CHARAK, 1978)

	Calendar year—	
	1976	1977
Total activities/locations.....	61	88
Non-Federal.....	52	82
Federal.....	9	6
Operators.....	31	29
Federal.....	4	2
Non-Federal.....	27	27
Commercial.....	16	16
Water districts.....	7	7
Universities.....	2	2
Community associations.....	1	1
Utilities.....	1	1
Sponsors.....	59	68
Community associations.....	18	25
Airlines.....	10	10
Municipal districts.....	10	12
Federal organizations.....	6	3
States.....	5	6
Utilities.....	4	3
Private.....	5	6
Cities.....	1	3

Table 10 shows the distribution of reported activities by State and by total target area size within the States for the 2 years. California led in the number of activities for both years and also had the largest target area increase from 1976 to 1977. However, the total target area in Utah in 1977 was the largest for any State for the 2 years. Because some projects crossed State boundaries, the total numbers in table 10 exceed the numbers in table 9. The purposes and the seeding agents for

⁴⁰ Charak, Mason T. "Preliminary Analysis of Reported Weather Modification Activities in the United States for Calendar Year 1976-77." Submitted for publication in *The Journal of Weather Modification*, 1978.

⁴¹ *Ibid.*

the various weather modification activities are given in table 11. Increase of precipitation continues to be the major purpose of the projects. The number of projects directed to hail suppression was reduced by 50 percent over the previous year in 1977, and in all hail projects there was the additional intended goal of increasing precipitation. The most used seeding agent continues to be silver iodide, although there is increased use of dry ice for precipitation enhancement as well as for cold fog dispersal.⁴²

TABLE 10.—ACTIVITIES AND SIZE OF TARGET AREAS, BY STATE (FROM CHARAK, 1978)

	Calendar year 1976		Calendar year 1977	
	Activities	Area (square miles)	Activities	Area (square miles)
Alaska.....	2	3	3	7
California.....	11	11,993	20	59,403
Colorado.....	3	2,915	6	31,300
Delaware.....	1	1,000	0	0
Florida.....	1	4,800	0	0
Georgia.....	0	0	3	9,000
Idaho.....	1	8,600	1	600
Illinois.....	2	2,502	3	3,700
Iowa.....	2	4	1	3,600
Kansas.....	1	9,000	1	10,400
Louisiana.....	0	0	2	1,350
Maryland.....	1	1,100	0	0
Michigan.....	1	530	3	7,524
Minnesota.....	2	15,381	1	240
Montana.....	2	20,005	2	20,005
Nebraska.....	1	2	0	0
Nevada.....	1	5	7	16,326
New Hampshire.....	1	4	1	4
North Dakota.....	4	23,068	3	16,288
Oklahoma.....	7	6,948	2	719
Oregon.....	2	7,821	3	836
South Dakota.....	3	11,821	1	2,500
Texas.....	5	11,226	5	11,826
Utah.....	4	59,410	9	92,135
Washington.....	3	56	10	25,379
Wisconsin.....	0	0	1	1,100
Wyoming.....	2	196	4	1,446
	63	198,390	92	315,689

TABLE 11.—WEATHER MODIFICATION PURPOSE AND AGENT (FROM CHARAK, 1978)

	Calendar year—	
	1976	1977
Purpose:		
To increase precipitation.....	41	76
To decrease hail.....	12	6
To disperse fog.....	11	8
For research.....	5	4
Agent:		
Silver iodide.....	45	74
Dry ice.....	11	17
Liquid propane.....	2	4
Polyelectrolyte.....	2	1
Water spray.....	2	0

GENERAL DISCUSSION OF LOCAL WEATHER MODIFICATION POLICY AND ACTIVITIES

In most instances, the principal beneficiaries of weather modification are the local or regional users who include agricultural interests,

⁴² Ibid.

weather-related industries, municipalities, airports, utilities, and ordinary citizens—those individuals and groups whose economic well-being and whose lives and property are subject directly to adverse consequences of insufficient water supplies or the extreme effects of severe weather. It is at the local level where the need to engage in weather modification is most keenly perceived. Most evident at this same level are the interests of those who may be affected negatively by the real or perceived results of weather modification. It follows that both the greatest support and the strongest opposition to weather modification projects are focused at the local level, where expressions of differing positions are most vocal.

The popularity of a particular weather modification project and the degree of controversy surrounding a project are frequently determined in large measure by the extent to which local citizens and organizations have a voice in whether a project shall be conducted, how it can be controlled and curtailed if necessary, and how it shall be funded. When, as in some States, counties or municipalities are authorized to raise and expend tax moneys to support weather modification, the importance of this voice becomes even more evident. At the local level, the decision to implement or withdraw from a project can be most often made with minimum social stress. Table 12 summarizes the results of a study by Haas, in which citizens in Colorado and South Dakota were polled on their sentiments on the level of government or other groups by which decisions ought to be and likely will be made on local cloud-seeding projects.⁴³ More than half of the respondents in the survey who expressed an opinion felt that local residents or local government officials should make such decisions, and the greatest plurality held that the decision should be solely that of local residents.

TABLE 12.—CITIZEN VIEWS OF WHO SHOULD AND WHO WILL MAKE THE DECISION REGARDING A LOCAL CLOUD-SEEDING PROJECT (PRIOR TO START OF LOCAL PROGRAM) (FROM HAAS, 1974)

[In percent]

Response	Colorado (N=168)		South Dakota (N=182)	
	Should	Will	Should	Will
Local residents.....	58	16	36	7
Local government.....	4	2	7	13
County and State government.....	(1)	(1)	9	15
State government.....	8	14	7	21
State and Federal Government.....	7	15	6	8
Federal Government.....	7	18	1	8
Scientists.....	7	13	7	1
Other, including combinations ²	5	8	24	7
Don't know.....	4	14	3	20

¹ Not included in Colorado survey.

² Includes 6 percent who said, "farmers and ranchers" without specifying area of residence.

Counties and other local governmental jurisdictions exercise the greatest control over weather modification through their willingness or reluctance to support with tax dollars either the projects initiated by States or by districts within the States. In their appraisal of the

⁴³ Haas, J. Eugene, "Sociological Aspects of Weather Modification," in Wilmot N. Hess (editor), "Weather and Climate Modification," New York, Wiley, 1974, p. 805.

relevance which local government policy at various levels has to weather modification, Lambright and Dorsey conclude that:

The jurisdictional powers of local government bear no direct, and little indirect, relationship to weather modifications activities. Only in an area where tax levies are authorized for the support of weather modification (e.g., a county) can the local government exercise "control" (positive or negative) over weather modification by its willingness, or reluctance, to sponsor the activity. Where multicounty, cooperative areas are involved, the actions of several counties can provide a substantial substate base of support for weather modification within a State. Acting under State law, these substate regions can become the principal structure for day-to-day decisions governing the technology.^{44, 45}

In both North and South Dakota, counties have been given authority by the State legislatures to levy taxes for the specific purpose of supporting local weather modification projects. In North Dakota, county weather modification authorities are created to provide user control over projects and to stabilize local social problems arising from controversies over the projects. A North Dakota statute provision allows county residents to withdraw from a joint State-county project and to abolish a county authority through circulation of petitions or countywide elections.

A California statute, enacted in 1955 and providing authority to various local governmental units to support and conduct weather modification operations, states that:

Any county, city, city and county, district, authority or other public corporation or agency which has the power to produce, conserve, control or supply water for beneficial purposes shall have the power to engage in practices designed to produce, induce, increase or control rainfall or other precipitation for the general benefit of the territory within it.⁴⁶

Regulation of weather modification in California is essentially a function of the State and not local governments. This division of authority follows from the fundamental role of the State to allocate water, even though the California constitution gives authority to counties and cities to enact regulatory measures so long as they do not conflict with the general laws. On the other hand, special districts are not given this authority nor can the legislature delegate such authority to these districts. Since the State has already enacted minimal weather modification regulations, local regulatory power is somewhat limited as it may not conflict with the State provisions.⁴⁷

In other States local regulation of weather modification is more in evidence, both through formal and informal arrangements. For example, in Pennsylvania, where the State law does permit weather modification projects under very strict regulations, some townships in the south-central part of the State have passed ordinances prohibiting all such activities.⁴⁸

⁴⁴ Lambright, W. Henry and Thomas A. Dorsey, "An Issue Paper: Some Notes on Inter-governmental Relations in a National Weather Modification Policy," background paper prepared for the U.S. Department of Commerce Weather Modification Advisory Board, February 1977, pp. 9-10.

⁴⁵ In the context of this quotation, "local" refers to governments at the subcounty level; whereas the term "local" means any jurisdiction, including counties, at the substate level elsewhere throughout this chapter.

⁴⁶ California Government Code, sec. 53063. (The entire body of California State law pertaining to weather modifications is reproduced in app. D, p. 516).

⁴⁷ Sato, Sho, "The Role of Local Governmental Units in Weather Modification: California," in Howard J. Taubenfeld (editor), "Controlling the Weather: a Study of Law and Regulatory Processes," New York, Dunellen, 1970, pp. 229-231 and pp. 242-248.

⁴⁸ In Pennsylvania, townships are local administrative units within counties, mostly rural in complexion, which, along with cities and boroughs, make up the total area of each county.

In Colorado, the Department of Natural Resources has sole authority to grant or revoke a permit. Nevertheless, strongly negative sentiments expressed in a preference vote in five counties of the San Luis Valley were instrumental in the decision of the department to deny a summer cloud-seeding permit in 1973. Winter cloud seeding has been initiated in the region subsequently and continues only with the unofficial yet very effective approval and local control of a citizens group. This group was formed as the result of an agreement by, and includes members from, both local proponents and opponents of cloud seeding, and the group holds veto power to suspend operations by majority vote.

Local projects have typically been sponsored by groups of farmers or ranchers, public utility companies, air lines and airports, water districts, and municipalities. Often they have been sponsored and/or controlled at the county, city or special district level and have been funded at least in part through local tax levies, depending on the authorities granted these jurisdictions in particular States. In some States, counties and States have jointly funded local projects in accordance with some cost-sharing formula established by statute or agreed upon between the State and local jurisdictions.

Tables 6 and 9 in an earlier section of this chapter⁴⁹ summarize information on sponsors of U.S. weather modification projects for 1975 through 1977. From these data the numbers of local public sponsors are seen to be 33, 29, and 38, respectively, for calendar years 1975, 1976, and 1977, when the sponsor categories of community associations, municipal districts, cities, and counties are combined. "State" projects usually include joint efforts with counties or groups of counties within the States, so that the sponsors so identified as States in the tables could be further broken down in some cases into additional local sponsors, increasing the previous totals. The category "community associations" consists of groups of local citizens within a county or group of counties, supported by local taxes and/or voluntary contributions.

Specific examples of local projects and sponsors are included in discussions of weather modification activities within particular States in the latter part of this chapter. In particular, table 13, listing individual projects for the water year 1977 (October 1, 1976 through September 30, 1977) in California shows the variety of sponsors, public and private, found in that State, which has both the greatest number of sponsors and projects in the country. Tables 16 and 17 provide similar information for calendar years 1975 and 1976 for projects in the three-State area of North and South Dakota and Minnesota in the upper Middle West.

WEATHER MODIFICATION ACTIVITIES IN PARTICULAR STATES

Since each of the States is somewhat different from the others in the extent and the diversity of involvement in weather modification, it is difficult to give a full account of activities by the several States. The list of individuals in the respective States, referred to in a previous section and found in appendix E, can be used to acquire detailed, cur-

⁴⁹ See pp. 345 and 347.

rent information on activities within a particular State. In addition, however, in order to provide further insight into the kinds of organizational structures, regulatory activities, and operational and research programs within States, some case examples of particular States are discussed in the following sections. The cases were selected on the basis of both availability of information and the variety of State activities. The States discussed are California, Illinois, Kansas, North Dakota, South Dakota, Utah, and Washington.

CALIFORNIA

State weather modification law and regulations

The California statute both encourages the development of weather modification technology and recognizes the need to regulate its practice. Chapter four of the State water code, entitled "Regulation of Rain-making and Rain-prevention," passed in 1953, states that:

The public interest, health, safety, welfare, and necessity require that scientific experimentation in the field of artificial nucleation, and that scientific efforts to develop, increase, and regulate natural precipitation be encouraged, and that means be provided for the regulation and control of interference by artificial means with natural precipitation of rain, snow, moisture, or water in any form contained in the atmosphere, within the State, in order to develop, conserve, and protect the natural water resources of the State and to safeguard life and property.⁵⁰

The California Department of Water Resources is the agency responsible for carrying out the provisions of the water code related to weather modification. The law itself expresses in some detail the means by which the regulations are to be administered. Licenses are required and must be obtained from the department of water resources, each application requiring specific information on the education, experience, and other qualifications of the individual or persons in control of and charged with the operations. Data required with each application includes:

The previous education, experience, and qualifications of the applicant, or, if the applicant is other than an individual, the previous education, experience, and qualifications of the persons who will be in control of and charged with the operations of the applicant;

A general description of the operations which the applicant intends to conduct and the method and type of equipment the applicant proposes to use; and

Such other information as the department may require.⁵¹

Licenses are effective for a calendar year unless revoked or suspended and may be renewed annually. Prior to undertaking any operation authorized by the license, under normal circumstances a notice of intention to perform a weather modification project must be filed with the Department of Water Resources and shall be published in a newspaper having a general circulation and published within the county, or in each of the counties, in which the operations are to be

⁵⁰ California Water Code, sec. 400. (The California weather modification law is reproduced in entirety in app. D, p. 516.)

⁵¹ Ibid., sec. 403.

conducted. If no newspaper is published within a particular county, publication shall be in a newspaper with a general circulation within that county. Published notices must include information on the nature and object of intended operations, the person or persons on whose behalf the project is to be performed, the area and approximate times for conduct of the operations, and the area which may be affected by the project to the extent that such area can be determined in advance.⁵²

The requirement for published advance notification may be waived in an emergency situation if the operations appear to the department to be desirable in aiding extinguishment of fires. Furthermore, at the request of the board of supervisors of a county or of the governing body of a city or a public district in the State, the department may also grant a licensee permission to undertake seeding to alleviate a drought emergency, without prior compliance with the need for publication of intent; however, the licensee must publish such notice as soon as practicable after the granting of permission for emergency seeding.

Licensees are required to maintain records of all operations, showing the method and equipment used, times and places of operations, and the names and addresses of all persons participating and assisting in the operations. Immediately following completion of each operation a report is to be filed. An evaluation statement for each operation, including estimated precipitation gain or loss occurring from the seeding activities and other supporting data, is to be prepared and maintained by the operator, and it is to be submitted to the department upon request.⁵³

Weather modification projects

Cloud-seeding projects have been underway in California since the late 1940's, and some projects sponsored by utility companies have been continuous since the 1950's. Some operations are carried out during the winter season to increase winter snowpack, whose runoff is used for hydroelectric power generation and to augment water supplies. Other projects are designed to increase summer rainfall for a variety of water needs and for fighting forest fires.

Fifteen weather modification licenses were issued in California during calendar year 1977, and 14 projects were conducted within the 1977 water year, October 1, 1976 through September 30, 1977.⁵⁴ Table 13 shows the projects active in the State during this period along with licensed operators who were inactive during that year. Projects in the table with an "E" following the project number were emergency programs, which nearly doubled the customary number of annual projects. The variety of public and private clients sponsoring operational projects in the State is seen in the fourth column. Note that, while most of the licensees in the third column are commercial cloud-seeding firms, other licenses are granted to some clients who provide their own services and one license was given to a university research group for participation in a research project of a U.S. Federal agency.

⁵² *Ibid.*, secs. 402-410.

⁵³ *Ibid.*, secs. 411-412.

⁵⁴ State of California, the Resources Agency, Department of Water Resources, *Weather Modification Activities in California*; Oct. 1, 1976 to Sept. 30, 1977.

TABLE 13.—WEATHER MODIFICATION PROJECTS IN CALIFORNIA: 1977 WATER YEAR

[From California Department of Water Resources, 1977]

Project No.	License No.	Licensee	Client	Target area
1-77-1.....	1	North American Weather Consultants, Santa Barbara Municipal Airport, Goleta, Calif.	Southern California Edison Co.	Upper San Joaquin River watershed.
1-77-2(E)....	1	North American Weather Consultants.	Nevada Irrigation District in cooperation with Pacific Gas & Electric Co.	Upper Middle Yuba River and north side South Yuba River above Spaulding Dam.
21-77-1.....	21	Atmospherics, Inc., Fresno, Calif.	Kings River Conservation District.	Upper Kings River watershed.
21-77-2.....	21	do.....	Kaweah Delta Water Conservation District.	Kaweah River watershed.
21-77-3(E)...	21	do.....	Yolo County Flood Control and Water Conservation District, Lake County, Sonoma County, Mendocino County, and Pacific Gas & Electric Co., Yolo County, Solano County Flood Control and Water Conservation District.	Clear Lake, Indian Valley Reservoir watersheds in Lake County and added later portions of Mendocino County and that portion of the Eel River drainage in Lake County to all of that county. Portions of Yolo County and the watershed above Lake Berryessa in Napa County.
21-77-4(E)...	21	do.....	Los Angeles Department of Water and Power.	East slopes of the Sierra from southwest of Lone Pine to the southern portions of Mono Basin.
21-77-5(E)....	21	do.....	Kern County.....	Kern River above Isabella Dam.
21-77-6(E)....	21	do.....	Desert Research Institute, University of Nevada.	Higher elevations of Tahoe Basin and the Walker River drainage basin.
22-77-1.....	22	San Bernardino Valley Municipal Water District, San Bernardino, Calif.	San Bernardino Valley Municipal Water District.	Upper Santa Ana watershed.
23-77-1.....	23	Pacific Gas & Electric Co., San Francisco, Calif.	Pacific Gas & Electric Co.....	Lake Almanor drainage basin.
23-77-2.....	23	do.....	do.....	Upper Mokelumne River watershed.
26-77-1.....	26	Santa Clara Valley Water District, San Jose, Calif.	Santa Clara Valley Water District.	Santa Clara County.
	29	Envaids Inc., Stockton, Calif.	Licensee inactive this year....	None.
	32	Desert Research Institute Energy and Atmospheric Environmental Center, University of Nevada System, Reno, Nev.	do.....	Do.
34-77-1.....	34	Sacramento Municipal Utility District, Sacramento, Calif.	Sacramento Municipal Utility District.	Upper American River.
	40	Joe Warburton, Desert Research Institute, Reno, Nev.	Licensee inactive this year [see 21-77-6(E)].	[See 21-77-6(E).]
	41	Marin Municipal Water District, Corte Madera, Calif.	Licensee inactive this year....	None.
	42	Institute of Earth, Planetary and Life Sciences, Los Angeles, Calif.	do.....	Do.
	43	University of Washington, Department of Atmospheric Science, Seattle, Wash.	Transport and diffusion studies for U.S. Bureau of Reclamation.	American River Basin.
44-77-1(E)...	44	Weather Modification, Inc., Bowman, N. Dak.	California Department of Water Resources.	Summer cumulus program in the mountains and uplands of Mendocino County and Mariposa County northward. For a short period operations were also carried out over the Kern River drainage.
	45	Mr. Jack VanZandt, Tehachapi, Calif.	Licensee inactive this year....	None.
	46	Weather Consultants, Inc., Santa Barbara, Calif.	do.....	Do.

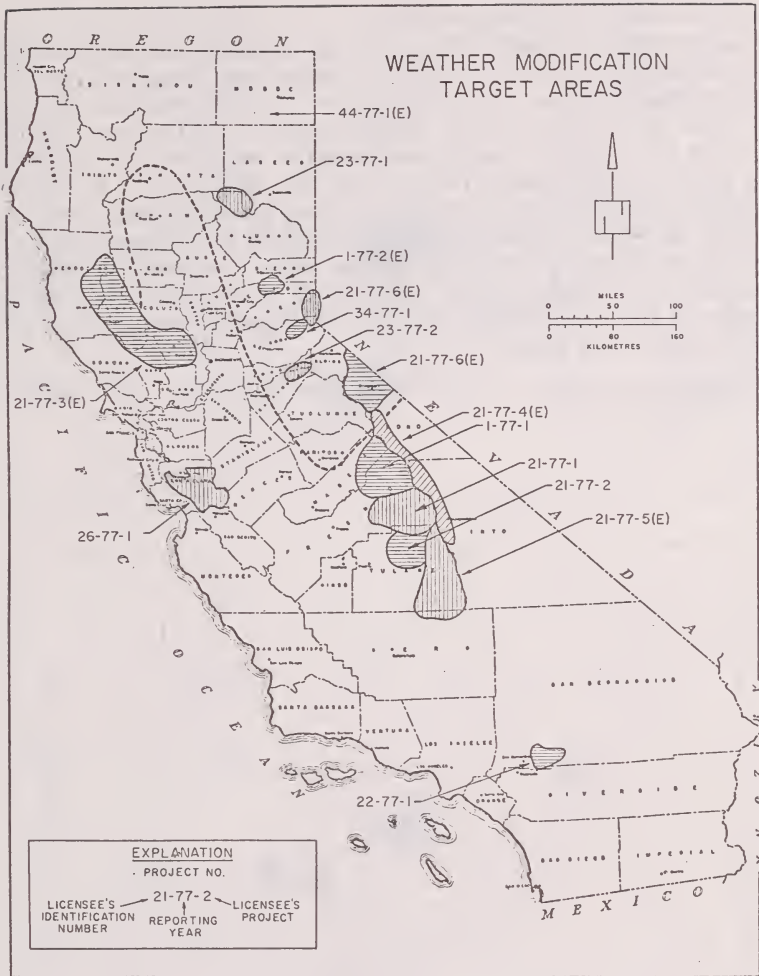


FIGURE 3.—California weather modification target areas, Oct. 1, 1976, through Sept. 30, 1977. "E" following project number indicates emergency project. (From California Department of Water Resources, 1977.)

The target areas, showing the area of the State covered by weather modification projects during the 1977 water year, are shown on the map in figure 3. For comparison, the relatively smaller areas of the State covered in the two preceding years—October 1974 through September 1975 and October 1975 through September 1976—are shown in figure 4. The influence of the recent 1976–77 drought and attempts to mitigate it through emergency cloud seeding account for the dramatically increased coverage for the reporting year ending September 1977. Seven projects were conducted during each of these 2 earlier years, compared with 14 in 1976–77.⁵³

⁵³ State of California, the Resources Agency, Department of Water Resources, Weather Modification Activities in California; Oct. 1, 1974, to Sept. 30, 1975; and Oct. 1, 1975 to Sept. 30, 1976.

State-sponsored emergency projects

In July 1977, the State of California initiated its own emergency cloud-seeding program, intended to alleviate drought conditions. Weather Modification, Inc., of Bowman, N. Dak., was awarded a contract with the Department of Water Resources, who were themselves the client in this first operational weather modification project ever to be funded by the State (see project No. 44-77-1(E) in table 13). Seeding was carried out in the Kern River watershed and over a wide swath of the State extending from the Merced River north to the Oregon border. Objectives of the program were to reduce fire danger and to augment dwindling water supplies in drought-stricken northern counties of the State.⁵⁶ This summer emergency seeding was totally supported by State funds.

⁵⁶Alexander, George, "State Seeks To Wring Rain From Clouds," Los Angeles Times, July 2, 1977, pt. 1, pp. 1, 17.

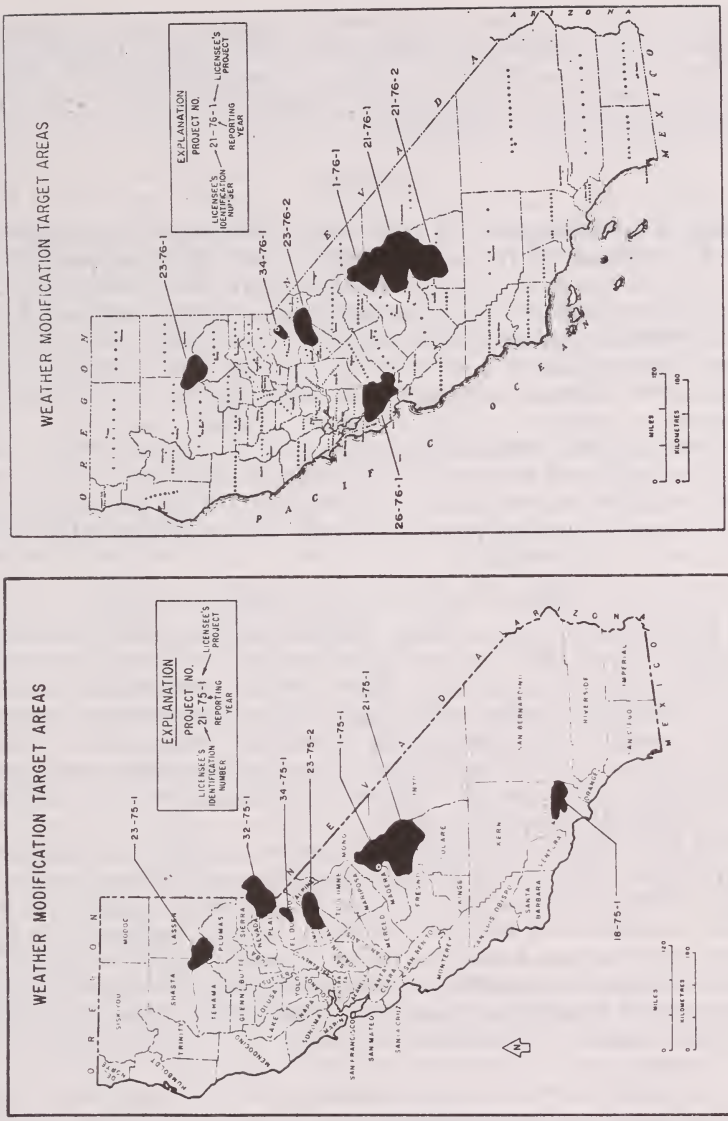


FIGURE 4.—Target areas for seven weather modification projects conducted in California for (a) water year 1975 (Oct. 1, 1974, through Sept. 30, 1975), and (b) water year 1976 (Oct. 1, 1975, through Sept. 30, 1976). (From California Department of Water Resources, 1975 and 1976.)

Under the Drought Emergency Act of 1977, the State received \$300,000 in grants from the Bureau of Reclamation of the U.S. Department of the Interior.⁵⁷ A winter emergency weather modification program has been initiated by the State, supported by these funds. Since the winter project was initiated since October 1, 1977, it is not included in

⁵⁷ See chapter 5, p. 266.

the projects listed in table 13 or shown in figure 3. The contractor for these operations is Atmospherics, Inc., of Fresno, Calif. The emergency funds from the Bureau of Reclamation are also supporting two weather modification studies, one on the development of operational criteria and the other on project evaluation.⁵⁸

ILLINOIS

Illinois is an example of a Midwestern State in which there has been a high degree of interest in weather modification, particularly with regard to potential benefits to agriculture from increased rainfall and from decreased hail damage. The State does not finance weather modification operations, but does encourage such activities, supported through local private funding. The Illinois law, recently passed in 1973, is concerned essentially with regulation of operations; however, it is positive in that it fosters weather modification, with proper controls and protection guarantees. The Illinois State water survey has led in endorsing and in evaluating properly conducted weather modification operations in the State and has a record of prominent and extensive activity across a broad spectrum of weather modification research activities.

Illinois weather modification law and its administration

The Illinois State water survey initiated efforts in 1971 to develop and secure a State law that would both permit and regulate weather modification activities in Illinois. There was no previous law and such a law was considered to be essential not only to insure proper execution of weather modification experiments in the State but also ". . . for the general benefit of citizens of Illinois through encouragement to properly conducted activities and protection from improperly conducted weather modification operations."⁵⁹

Efforts thus begun in October 1971 were completed in September 1973 with enactment of the Illinois weather modification control bill and its accompanying appropriation bill. It was intended to be a "model" law, reflecting the best aspects of similar legislation in other States and serving as a model for future legislation in other States.^{60, 61}

With objectives of encouraging weather modification operations and research and of minimizing possible adverse effects of such activities, the Illinois Weather Modification Control Act contains three types of provisions:

1. It establishes an institutional structure to deal with regulation of cloud seeding activities;
2. It contains substantive regulatory provisions controlling intentional atmospheric manipulation in the State; and
3. It establishes basic rules of procedure according to which the regulatory provisions will be enforced.⁶²

The Illinois law is merely regulatory and does not authorize a State government agency to carry out weather modification operations. In

⁵⁸ Finlayson, Donald J., private communication.

⁵⁹ Ackerman, William C., Stanley A. Changnon, Jr., and Ray Jay Davis, "The New Weather Modification Law for Illinois," *Bulletin of the American Meteorological Society*, vol. 55, No. 7, July 1974, p. 745.

⁶⁰ *Ibid.*

⁶¹ The Illinois law (Ill. Ann. Stat. Ch. 146 3/4, § 1-32) in its entirety is found along with those of other States in app. D, pp. 533 to 541.

⁶² Ackerman, Changnon, and Davis, "The New Weather Modification Law for Illinois," 1974, p. 747.

the process of controlling weather modification operations, three State entities are involved:

1. The weather modification board is composed of five Illinois residents, appointed by the director of the department of registration and education, who have qualifications and practical experience in agriculture, law, meteorology, and water resources. The board meets annually and at such times and places it determines. The director of the department of registration and education can exercise his regulatory authority only upon recommendation in a written report from the majority of the members of the board.

2. The department of registration and education, working through advisory groups like the weather modification board, supervises most of the professional licensing in Illinois. All formal documents required by the Weather Modification Control Act are issued by the department.

3. The State courts are part of the institutional structure in that persons adversely affected by weather modification are afforded a right to judicial review of final administrative decisions of the department of registration and education. The department may also seek a writ of injunction to restrain repetitious violations of the act.⁶³

Regulatory provisions of the Illinois law prohibit a person's engaging in weather modification activities (a) without both a professional weather modification license and a weather modification permit for a specific project or (b) in violation of any term, condition, or limitation of such license and permit. Some activities may be exempted from license and permit requirements by administrative regulation. Such exemptions are granted for research activities and for fire, frost, or fog protection, so long as the exempted activities do not interfere with operations conducted by permit.⁶⁴ The rules of procedure, established by the weather modification board and the department of registration and education are found in appendix M of this report. Under these procedures one permit was granted in 1976 for a rain enhancement project, and three were granted in 1977.⁶⁵

Operational projects

The first permit for weather modification operations under the Illinois law was obtained by a group of farmers and other interested businessmen, called Rain, Inc., who contracted for cloud seeding services in a five-county area in the southern part of the State. This area was centered in Colt County, about 45 miles south of the Champaign-Urbana area. This cooperative voluntary-funded organization initiated an aircraft seeding program in July 1976. The program was renewed in 1977; however, there seemed to be less interest the second season owing to less critical rainfall shortages. Evaluation of 1976 results by the Illinois State Water Survey showed that there was an estimated 12- to 50-percent rainfall increase.⁶⁶

Another group of farmers from McLean County in north central Illinois, organized as Rain Gain, Inc., was formed in June 1977, and contracted for weather modification operations, which began July 12.

⁶³ *Ibid.*, p. 748.

⁶⁴ *Ibid.*

⁶⁵ Fosse, E. Ray, member of Illinois weather modification board. Briefing before U.S. Department of Commerce Weather Modification Advisory Board, Champaign, Ill., Oct. 13, 1977.

⁶⁶ Schilling, David, President, Rain, Inc., briefing before the U.S. Department of Commerce Weather Modification Advisory Board, Champaign, Ill., Oct. 13, 1977.

Rains were heavy during July, and the operations were stopped on August 4. Costs for these operations were estimated at about 40 cents per acre. There is a present attempt, along with the State water survey, to evaluate results of the seeding, and the group is contemplating a second season of operations in 1978.⁶⁷

Research activities

The Illinois State Water Survey initiated research into the potential of modifying the weather in the late 1960's, recognizing the potential for this emerging technology. In 1970 a major research effort was launched by the survey in two general aspects of the subject: (1) studies of inadvertent weather modification produced by cities and industrial activities, and (2) studies of planned or intentional weather modification. In the latter category the research is intended to answer the questions of whether the weather can be modified and whether it can be done beneficially without undue harm.⁶⁸

The survey has been a national leader in studies on planned weather modification. There has been a concentrated interest in experiments to determine the usefulness of weather modification in Illinois and elsewhere in the Middle West, recognizing that most U.S. weather modification operations have been conducted in the Great Plains and in the Rockies where capabilities to augment precipitation have at least partly been demonstrated. Thus, survey scientists have given considerable attention to the design of experiments to increase summer rainfall and to suppress hail. With some support from the National Science Foundation (NSF) they have recently completed development of a design for a major 8-year hail suppression experiment for Illinois. The State is now ready to launch a hail experiment if it is determined desirable to do so.⁶⁹ Interest in hail suppression also led the survey to join with other experts in performing an NSF-sponsored national-scale technology assessment of hail suppression.⁷⁰

In 1968 the water survey also began a project to develop the design of an experiment in precipitation modification, funded by the NSF and the Bureau of Reclamation. A capability was developed in numerical cloud modeling, using computers; and a field program was initiated, using meteorological aircraft and radar for sampling clouds to determine seedability criteria. After a major reduction in Federal support during 1973 had curtailed this design project before its completion, renewed support from the Bureau of Reclamation has enabled survey scientists to develop a design for a rainfall modification experiment in the High Plains. They are now prepared to resume design for a warm rain experiment in Illinois, after completion of the cloud sampling research.⁷¹

Survey scientists have discussed rainfall requirements with Midwest agricultural interests and are developing a plan for a Midwestern rain-

⁶⁷ Gildersleeve, Ben. Briefing before U.S. Department of Commerce Weather Modification Advisory Board, Champaign, Ill., Oct. 13, 1977.

⁶⁸ Changnon, Stanley A., Jr., "Accidental and Planned Weather Modification in Illinois," *Water Resources Bulletin*, vol. 13, No. 6, December 1977, p. 1166.

⁶⁹ *Ibid.*, p. 1172.

⁷⁰ Changnon, Stanley A., Jr., Ray Jay Davis, Barbara C. Farhar, J. Eugene Haas, J. Lorena Ivens, Martin V. Jones, Donald A. Klein, Dean Mann, Griffith M. Morgan, Jr., Steven T. Sonka, Earl R. Swanson, C. Robert Taylor, and Jon Van Blokland, "Hail Suppression; Impacts and Issues," Urbana, Ill., Illinois State Water Survey, April 1977, 432 pp. (A summary of the report has also been published: Farhar, Barbara C., Stanley A. Changnon, Jr., Earl R. Swanson, Ray Jay Davis, and J. Eugene Haas, "Hail Suppression and Society," Urbana, Ill., Illinois State Water Survey, June 1977, 25 pp.)

⁷¹ Changnon, "Accidental and Planned Weather Modification in Illinois," 1977, pp. 1172-1173.

fall modification experiment, along with representatives from agricultural colleges in Midwestern States and from Federal Government agencies. When funding is secured for this project, hopefully during 1978, the experiment will be initiated; it will incorporate both physical and statistical assessment of cloud and rainfall modifications as well as studies of public attitudes and economic and ecological impacts from altered precipitation.⁷²

In an attempt to evaluate precipitation modification operations conducted during the 1976 growing season in central Illinois, the survey and the College of Agriculture at the University of Illinois installed a rain gage network. Examination of these data led to a conclusion that the seeded areas received 12 to 50 percent more rainfall; however, the differences could not be established as due to the seeding in view of the small sample size (6 rain days).⁷³

Survey scientists have also participated in a number of experiments on inadvertent weather modification, including the METROMEX in the vicinity of St. Louis⁷⁴ and similar studies downwind of Chicago and Kansas City. They have also studied effects on rainfall of the massive irrigation which has been developed in the Great Plains since World War II.⁷⁵

Over the past 10 years the survey has spent about \$3 to \$4 million in weather modification research, including both planned and inadvertent aspects. Of these funds about one-third was provided by the State, while the remainder has come from various Federal agencies. The latter include the National Science Foundation, the Bureau of Reclamation, and the Environmental Protection Agency (EPA).⁷⁶ The funds for EPA-supported research in inadvertent weather change are not considered to be weather modification research by the EPA, so that agency does not appear among the Federal agencies supporting weather modification in chapter 5.⁷⁷

KANSAS

Kansas Weather Modification Act

In 1974 Kansas legislature passed H.B. 1216, known as the Kansas Weather Modification Act, providing for licensing by the State of all qualified persons who desire to engage in weather modification activities within the State and requiring that a permit be obtained for each specific activity.⁷⁸ Responsibility for administering the act is placed with the Kansas Water Resources Board; however, the law also requires the board to appoint an advisory committee to assist the board's executive director in developing licensing standards and report forms and to assist in other areas as directed by the board. Rules and regulations prepared by the board and the advisory committee specify how the law is administered and procedures to follow in applying for licenses and permits.⁷⁹ The objectives of the rules and regulations are to "encourage the development and evaluation of weather modification technology, to protect the public through the requirement that operators . . . possess certain basic qualifications, and

⁷² *Ibid.*, p. 1173.

⁷³ *Ibid.*

⁷⁴ See chs. 4 and 5 for a discussion of METROMEX.

⁷⁵ Changnon, "Accidental and Planned Weather Modification in Illinois," 1977, pp. 1173-1174.

⁷⁶ Changnon, Stanley A., Jr., briefing before U.S. Department of Commerce Weather Modification Advisory Board, Champaign, Ill., Oct. 13, 1977.

⁷⁷ See p. 243, for list of Federal agencies reporting weather modification research programs.

⁷⁸ The Kansas weather modification statute is reproduced in app. D, p. 543.

⁷⁹ The rules and regulations are reproduced in app. M, p. 683.

to establish procedures for the issuance of permits with a minimum of delay and to clarify administrative policy.”⁸⁰

Research activities

Drought conditions during the spring of 1972 and pleas from agricultural interests in western Kansas to “do something about it” spurred the State to undertake plans for weather modification operations. Release of \$100,000 in emergency funds by the legislature provided support for cloud seeding in northwestern Kansas, and the water resources board was directed to manage the operations. The board contracted with the U.S. Bureau of Reclamation to oversee the project; however, prior to the start of the seeding, the drought situation improved and emphasis was shifted from drought relief to weather modification research. Since 1972 all weather modification activities conducted by the State of Kansas have been experimental. Such experiments were conducted under the management of the Bureau of Reclamation for 9 weeks, starting August 5, 1972, near Colby, Kans., and for an 8-week period in the late summer of 1973 at Scott City, Kans. During a 6-week period starting April 25, 1974, a demonstration project was conducted, with the target area again centered near Scott City. This latter project was carried out by a commercial firm under direct contract to the State board and also included funding from four counties in the target area. Results of these experiments, called the Kansas Cumulus projects (KANCUP), are summarized in table 14.⁸¹

TABLE 14.—SUMMARY OF THE KANSAS CUMULUS PROJECT (KANCUP) EXPERIMENTS

[From Kostecki: Weather Modification Activities in Kansas, 1972-77, 1977]

Project	Objectives	Assessment ¹
KANCUP 1972, Aug. 5 to Sept. 30 (cost \$95,000, fiscal year 1973).	Assuming technology works, seed for rain increase; experiment with both silver iodide (AgI) and hygroscopic materials (salt); test ground release of materials; inform general public about project and technology.	Opportunities difficult to predict and recognize; positive, predicted response to AgI on 2 of 16 days (20 percent of seeded cells); salt seeding only occasionally encouraging; moderate response on only 1 of 11 days (10 percent of seeded cells); ground-based seeding unreliable; not enough attention given to control clouds.
KANCUP 1973, Aug. 15 to Oct. 5 (cost \$58,000, fiscal year 1974).	Verify computer models of cloud processes; seed selectively with AgI and salt; assess use of local pilots and aircraft; inform general public about project and technology.	Models helpful; seeding frequently produced predicted response; positive, predicted response to AgI on 7 of 14 days (42 percent of seeded cells); however, marginal response on 5 of the same 7 days; salt seeding on only 2 days; moderate response from 33 percent of seeded cells; design and instrumentation inadequate; local pilots need experienced guidance to be effective.
KANCUP 1974, Apr. 5 to June 8 (cost \$54,000, fiscal year 1974).	Assess minimum operational requirements; seed with AgI and salt using randomized controls; evaluate character and frequency of opportunities in spring compared to summer; inform general public about project and technology.	Selective seeding sometimes produced desired response; positive response to AgI on 8 of 13 days; however, marginal response on 6 of the same 8 days; moderate response to salt seeding on 1 of 2 days; springtime cloud systems usually more organized but seedability less predictable; design and instrumentation inadequate for remaining uncertainties.

¹ KANCUP 1974 assessment done by KWRB personnel, following criteria given in KANCUP 1972 and 1973 final reports.

⁸⁰ Kansas Water Resources Board, The Kansas Weather Modification Act; State statutes, rules, and regulations plus applicable forms, State of Kansas, Topeka, 1977, p. ii.

⁸¹ Kostecki, Donald P., “Weather Modification Activities in Kansas; 1972-77,” bulletin No. 22, special report to the Governor and legislature, State of Kansas, Topeka, 1977, pp. 1-3.

Since quantitative data from KANCUP experiments were limited by time and funding, the board concluded that further projects of similar type and refinement would not likely increase understanding of weather modification science and technology. Consequently, starting in fiscal year 1975 all appropriations have been directed to studies on economic, social, legal, and environmental impacts of weather modification within the State.⁸²

Earlier in this report plans and research activities to date under the Bureau of Reclamation's High Plains Project (HIPLEX) were discussed.⁸³ One of three sites selected for HIPLEX is in the vicinity of Goodland and Colby, Kans., where limited field activities were begun in 1975, but where seeding experiments are to begin in 1979. The States of Kansas, Colorado, and Nebraska have signed a Memorandum of Understanding, agreeing to cooperate with the Bureau of Reclamation in the planning and conduct of HIPLEX. Funding contributed to the project by the States under this agreement is summarized in table 11 in chapter 5.⁸⁴ Under this agreement the Kansas Water Resources Board will (1) establish and operate a data gathering network in the Colby, Kans., area to provide data for agricultural, environmental, and climatological research studies and to monitor the effects of cloud seeding; (2) perform a wide range of associated studies including investigation of potential crop yield increases and related economic benefits, the effects of additional moisture on insects, crop disease vectors, incremental runoff and soil infiltration, and study of social attitudes and acceptance of cloud-seeding technology; and (3) perform research to develop criteria for guiding operational cloud-seeding decisions, including the initiation, suspension, and termination of seeding. For its part, the Bureau of Reclamation will perform the atmospheric research and field tests, including (1) design of the observation and cloud-seeding experiments, (2) processing and analysis of data to evaluate seeding effects and develop and verify cloud models, and (3) coordination of research activities at the Colby-Goodland site with the overall HIPLEX project.⁸⁵

Pursuant to the cooperative agreement with the Bureau of Reclamation, the Kansas Water Resources Board has initiated several studies. Completed and on-going projects sponsored by the board since the latter part of fiscal year 1974 are listed in table 15.

TABLE 15.—Kansas research projects related to weather modification (source: Kostecki, 1977)

Title	<i>Contractor</i>
A Survey of the Radar Echo Population over the western Kansas High Plains.	Department of Physics, Kansas State University.
Characteristics of Cumulus Cloud Fields over western Kansas.	Department of Geography-Meteorology, University of Kansas.
The Measurement of Silver Concentration in Rainwater in Kansas.	Department of Geology, University of Kansas.
A Comprehensive Study of the Effects of Altering the Precipitation Pattern on the Economy and Environment of Kansas.	Kansas Agricultural, Experiment Station.
Data Collection and Analysis-----	Various Federal, State, and local agencies.

⁸² *Ibid.*, p. 2.

⁸³ See ch. 5, p. 258.

⁸⁴ See p. 263.

⁸⁵ Kostecki, "Weather Modification Activities in Kansas: 1972-77," 1977, p. 5.

Operational activities

Since the Kansas Weather Modification Act has been enacted there has been only one license and permit sought and granted annually. During the period April 15 through September 15 in each of the recent 3 years the Muddy Road project has been conducted in west-central and southwest Kansas, under the auspices of the Western Kansas Groundwater Management District No. 1. Funds have been almost completely provided by groundwater management districts and counties in the area. In 1975 the Muddy Road I project conducted cloud seeding for rain increase on 39 days and for hail suppression on 27 days. Total cost for the 5-month seeding period was \$80,000. The Muddy Road II project in 1976 included 47 days of seeding for rain enhancement and 25 days for hail suppression, at a cost of \$153,000, about \$40,000 of which was granted to the project by the Ozarks Regional Commission. During 1977 the Muddy Road III project included seeding for rain on 50 days, during 28 of which hail seeding was also conducted; there were also 7 days for exclusive hail suppression. The \$180,000 for operating expenses during 1977 was raised by the counties and groundwater districts but these funds were partly reimbursed in September through a grant under the Emergency Drought Act of 1977.^{86, 87}

The Kansas law does not require evaluation of results of a weather modification project; however, the rules and regulations do require that a final report be submitted within 90 days following the close of the project. Information required includes daily records during the project period of starting and ending times and location of seeding, the type of clouds seeded, and the purpose of the seeding activity, as well as the permit holder's interpretation of the project effects in comparison with those anticipated in the permit application. This evaluation is, generally speaking, qualitative, based on the project meteorologists' recollections of cloud response observed by radar during seeding. Effects of the Muddy Road projects have been evaluated in this manner, with the conclusion that additional rain was obtained and crop damage was reduced by the seeding. In order to assist in a more quantitative evaluation, the Muddy Road project has been provided by the State Water Resources Board with a computer terminal linked to the Bureau of Reclamation's Environmental Data Network.⁸⁸ Products from the data network provide the project meteorologist with daily decision criteria for cloud seeding and could also be used to evaluate operating procedures and effectiveness of seeding if additional information were available. Due to lack of staff and lack of sufficient data for an adequate evaluation, detailed evaluation of the Muddy Road projects has not yet been conducted. However, an independent evaluation of the three seasons of cloud seeding in Muddy Road is currently being attempted on all available data, using funds provided under the Emergency Drought Act of 1977.⁸⁹

Emergency Drought Act of 1977

In October 1977, the Kansas Water Resources Board was awarded a grant of \$300,000 from the Bureau of Reclamation under the provisions of the Emergency Drought Act of 1977.⁹⁰ A limitation of this grant

⁸⁶ See ch. 5, p. 266.

⁸⁷ Kostecki, "Weather Modification Activities in Kansas; 1972-77," 1977, pp. 10-11.

⁸⁸ See ch. 5, p. 250.

⁸⁹ Kostecki, "Weather Modification Activities in Kansas; 1972-77," 1977, pp. 11-12.

⁹⁰ See ch. 5, p. 267.

was that all funds had to be expended by January 31, 1978; consequently, the grant was used primarily to purchase equipment for future summer seeding operation measurements and evaluations. A portion of the funds has been used to commission an evaluation of the operational projects under Muddy Road, conducted by local groundwater districts and counties in western Kansas.⁹¹

Following an exchange of letters between the board and the Bureau of Reclamation, the grant, under Public Law 95-18, was approved with the following conditions and limitations:

1. The request was increased from the \$218,600 to \$300,000 because of the probability of an understimation of equipment costs. (This total was subsequently adjusted to \$293,000.)

2. Expenditures of grant funds by the State were to be limited to equipment purchased and available for operational use on or before January 31, 1978.

3. All funds not expended by January 31, 1978, were to be returned to the U.S. Government.

4. In the event that the Kansas legislature did not appropriate funds to implement the cloud-seeding program, or that such funds were not provided by other non-Federal sources for use during the 1978 irrigation season, all equipment purchased with the grant funds were to be returned to the U.S. Government.⁹²

Of the total funds granted, \$22,000 was used to reimburse sponsors of the operational cloud-seeding program in Western Kansas (Muddy Road), for the cost of operations during September 1977. The evaluation of the operational programs conducted during the 1975, 1976, and 1977 seasons was contracted for \$27,000. The remaining expenditures were for repair and replacement of equipment or purchase of new equipment for use within Groundwater Management District No. 1 or for general use by the Kansas Water Resources Board in the future.⁹³

NORTH DAKOTA

Weather modification law and administration of regulations

The State of North Dakota is active in the encouragement and the regulation of weather modification projects. As stated in the following excerpt from the State law, North Dakota claims ownership of all water acquired within its boundaries through weather modification activities:

In order that the State may share to the fullest extent in the benefits already gained through fundamental research and investigation on new and improved means for predicting, influencing, and controlling the weather, for the best interest, general welfare, health, and safety of all the people of the State, and to provide proper safeguards in applying the measures for use in connection therewith in order to protect life and property, it is deemed necessary and hereby declared that the State of North Dakota claims its sovereign right to use the moisture contained in the clouds and atmosphere within the sovereign State boundaries. All water derived as a result of weather modification operations shall be considered a part of North Dakota's basic water supply and all statutes, rules, and regulations applying to natural precipitation shall also apply to precipitation resulting from cloud seeding.⁹⁴

⁹¹ Kostecki. "Weather Modification Activities in Kansas; 1972-77," 1977, p. 14.

⁹² Kansas Water Resources Board, final report; Emergency Drought Act (Contract No. State-07-70-X0017), (preliminary draft), Topeka, Feb. 3, 1978, p. 2.

⁹³ *Ibid.*, pp. 6-8.

⁹⁴ North Dakota Century Code, ch. 2-07, "Weather Modification, Sec. 2-07-01. Ownership of Water." (Pertinent sections of the North Dakota Century Code, dealing with weather modification, are reproduced in app. D, p. 573.)

The policy of the State toward weather modification is summarized as follows:

The legislative assembly finds that weather modification affects the public health, safety, and welfare, and that, properly conducted, weather modification operations can improve water quality and quantity, reduce losses from weather hazards, and provide economic benefits for the people of the State. Therefore, in the public interest, weather modification shall be subject to regulation and control, and research and development shall be encouraged. In order to minimize possible adverse effects, weather modification operations shall be carried on with proper safeguards, and accurate information shall be recorded concerning such operations and the benefits obtained therefrom by the people of the State.⁹⁵

North Dakota encourages weather modification research and development through its laws and regulations and through State-supported research projects; however, there is also a fairly well-developed scheme for regulation and control of operational activities. State law also permits local jurisdictions to raise funds to support local weather modification operations, in which the State shares funding.

Regulation of weather modification activities takes place to some extent through application of certain provisions of environmental and aviation laws; however, there are specific portions of the North Dakota Century Code that are directly applicable.⁹⁶ Control, regulation, and coordination of weather modification projects, through the issuance of licenses and permits and promulgation of rules and regulations, is vested in the North Dakota Weather Modification Board, which operates under the direction and supervision of the State's aeronautics commission. The board is composed of the director of the aeronautics commission, a representative of the environmental section of the State department of health, the State engineer of the water conservation district, and seven other members, appointed by the Governor, one from each of seven lists of three nominees given to him by the weather modification authorities from seven districts in the State. The seven districts are comprised of geographical groupings of the State's 53 counties.⁹⁷

The powers and duties of the board include:

1. Authority to appoint an executive secretary to serve at the board's discretion and to perform such duties as assigned by the board.
2. Authority to employ such a staff as is necessary to carry out the provisions of the law.
3. Preparation of reasonable rules and regulations concerning licensing and permits; standards and instructions governing operations, monitoring, and evaluation; and recordkeeping and reporting of activities.
4. Authority to contract for weather modification operations; with the requirement that the board must also carry on monitoring and evaluation activities in connection with such operations.
5. Authority to order operators whose activities are in violation of the law to cease and desist from further operations.
6. Cooperation and contracting with Federal, local, and State agencies whose activities are similar to the work of the board and are consistent with the intent and purpose of the State law. The board may also, in accordance with the law, accept grants or services from com-

⁹⁵ *Id.*, sec. 2-07-01.1, "Declaration of Policy and Purpose."

⁹⁶ *See app. D*, p. 573.

⁹⁷ North Dakota Century Code, secs. 2-07-02.1, 2-07-02.2, and 2-07-02.3.

missions, organizations, agencies, or persons and use such funds or services to carry out the provisions of the law.

7. Authority to administer and enforce the provisions of the law.

8. Maintain interstate contact with bordering States and provinces for the purposes of coordinating interstate weather modification projects. North Dakota is a member of the North American Interstate Weather Modification Council, through which the board attempts to provide an input to such Federal weather modification laws and regulations which may be enacted and impact on North Dakota.⁹⁸

In addition to the responsibilities and authorities listed above, based upon the State law, the Governor of North Dakota has also charged the board with the following tasks:

1. Assure that operations are concerned with the health, safety, and welfare of the public.

2. Make certain that research and operational aspects of weather modification activities are concerned with improvement of water quality and distribution as well as quantity.

3. Insure that the weather modification program is seriously concerned with reduction of losses from such weather hazards as severe storms, excessive rainfall, and hail.

4. Guarantee that the program is designed to improve both the social and economic benefits to all segments of the State's population.

5. Assure that all activities are prefaced with appropriate technical planning and scientific research.⁹⁹

Licenses are required for weather modification operations in North Dakota, and for each project a permit must be obtained. Rules of eligibility for licensees and procedures for application for licenses and permits, in accordance with the State law, are detailed in "Rules and Regulations Relating to Weather Modification Operations," published by the Weather Modification Board.¹ Application for a license must include information on the applicant's former record of applications elsewhere; previous instances of refusal, suspension, or revocation of a license; and a statement of qualifications for individuals designated to be in control of operations, including: education, professional memberships, professional certificates or licenses, experience, publications and patents, and professional references who will attest to the applicant's character. Applicants meeting minimum requirements and approved by the board are granted licenses to conduct weather modification operations in North Dakota for 1 calendar year; however, licenses may be renewed annually upon reapplication and board approval. Causes for which the board may suspend, revoke, or refuse to renew a license include incompetency, dishonest practice, false or fraudulent information in obtaining a license or permit, failure to comply with provisions of the weather modification laws or with rules promulgated by the board, and violation of any permit or permit condition.²

⁹⁸ Rose, R. Lynn (executive secretary of the North Dakota Weather Modification Board). Testimony before the U.S. Department of Commerce Weather Modification Advisory Board, Grand Forks, N. Dak., Aug. 27, 1977.

⁹⁹ *Ibid.*

¹ North Dakota Weather Modification Board, "Rules and Regulations Relating to Weather Modification Operations" (published in a booklet along with rules of practice and procedure pertaining to hearings before the board, adopted July 1, 1976; and North Dakota Century Code, chapter 2-07, weather modification, SL-75, 51 pp. The rules and regulations relating to weather modification operations are reproduced in app. M, p. 691.)

² *Ibid.*, pp. 5-7.

Permits are required for each project to be conducted by a licensee and may be issued following satisfactory application for a permit, public comment and possible hearings, recommendation by the director of the Weather Modification Board, and final action by the board. Information accompanying the application must include the applicant's North Dakota license number; data on any previous suspension, revocation, or refusal of permits; registration to do business in North Dakota; registration of pilots and aircraft with the North Dakota Aeronautics Commission; evidence of financial responsibility; and a complete description of the operational plan, which includes:

1. The nature and object of the operation;
2. The legal description of, and a map showing the operations area and the target area;
3. The approximate starting date of the operation and its anticipated duration;
4. The kind of seeding agent(s) intended for use and the anticipated rate of their use;
5. A list of equipment which will be used and the method(s) of seeding for which they will be used;
6. An emergency shutdown procedure, which states conditions under which operations will be suspended because of possible danger to the public health, safety, and welfare or to the environment;
7. The means by which the operation plans will be implemented and carried out, such as the location of the main operational office and any other offices used in connection with the operation; the location of ground equipment such as seeding generators, radar, and evaluation instrumentation; the number and kinds of aircraft which will be used; and the extent to which weather data will be made available to the licensees and other personnel carrying out the project; and
8. How conduct of the operation will interact with or affect other weather modification operations.³

The board gives notice of its consideration of a particular permit application and allows 20 days for public comment on the proposed project. Upon receiving objection or on its own motion, the board may conduct a hearing after at least 10 more days of further notice in a newspaper circulated in the county where the notice of consideration was first published. Within 45 days after close of the comment period the board takes action to approve or disapprove a permit request, taking into consideration recommendations from the director of the board and testimony received at the hearing. The board may attach conditions which it deems appropriate to permits which it otherwise approves. Such conditions may include modifications or restrictions to methods and times of operation, change of target and operations areas, safety precautions, and recordkeeping. Permits may be suspended, revoked, or modified if the board perceives that such action is necessary, either on the basis of noncompliance with conditions of the permit by the operator or the general welfare of the people of the State. Permits expire on December 31 of the year in which they are issued and may not be renewed.⁴

The Weather Modification Board, under rules which they are to

³ *Ibid.*, pp. 8-9.

⁴ *Ibid.*, pp. 9-10.

publish, may exempt the following activities from permit and license requirements:

1. Research and development in weather modification conducted by the State, political subdivisions of the State, colleges and universities of the State, agencies of the Federal Government, or bona fide research corporations.

2. Weather modification operations of an emergency nature taken against fire, frost, or fog.

Such exempted activities are to be conducted in such a way that they will not unduly interfere with weather modification projects conducted under a permit.⁵

There is also another statute provision in North Dakota which enables the State to suspend weather modification activities if precipitation enhancement could contribute to the severity of a disaster such as a flood. This provision, which supersedes authorities given to the board to issue permits in times of such disasters, states that:

The Division of Disaster Emergency services shall keep continuously apprised of weather conditions which present danger of precipitation or other climatic activity severe enough to constitute a disaster. If the division determines that precipitation that may result from weather modification operations, either by itself or in conjunction with other precipitation or climatic conditions or activity, would create or contribute to the severity of a disaster, it shall direct the officer or agency empowered to issue permits for weather modification operations to suspend the issuance of the permits. Thereupon, no permits may be issued until the division informs the officer or agency that the danger has passed.⁶

The rules and regulations disseminated by the weather modification board require the keeping of records and the submission of reports. Permittees must complete and retain daily logs and monthly summaries for the activities of each unit of weather modification apparatus used during an operation, obtain and retain copies of all daily precipitation records available for the target area from the National Weather Service, keep a roster of the names and addresses of all employees participating in an operation for which a permit has been issued, and permit duly authorized agents of the board to inspect any equipment and records required. Persons conducting projects exempted from permit requirements by the board must maintain all of the same kinds of records required of permittees.⁷

Within 10 days after the conclusion of each calendar month permittees must submit a written report to the board, including the following information:

1. A copy of the monthly summary record of activity for each unit of weather modification apparatus used in the operations;
2. A copy of the roster of all names and addresses of employees participating in the operations;
3. A copy of the Federal interim activity report filed for that month with the National Oceanic and Atmospheric Administration, in accordance with rules adopted under the authority of Public Law 92-205⁸; and
4. A narrative account of the manner in which operations during the month did not conform to the operational plan filed with the permit application.

⁵ North Dakota Century Code, sec. 2-07-03.1.

⁶ North Dakota Century Code, sec. 37-17.1-15.

⁷ North Dakota Weather Modification Board, "Rules and Regulations Relating to Weather Modification Operations," pp. 11-12.

⁸ See ch. 5, p. 232.

Within 30 days after final completion of the operation, a permittee must file a final report with the board which is to include (1) copies of the daily logs on usage of units of apparatus and of the total usage for each unit for the entire operational period, (2) a copy of the final Federal activity report filed with the National Oceanic and Atmospheric Administration, and (3) a narrative account of the manner in which the operation did not conform to the operational plan filed with the permit application.⁹

Within 60 days after completion of an operation, the permittee must file with the board a narrative evaluation of the operation. Data in this report is to be assembled in conformance with the evaluation plan submitted with the permit application. The board may choose to require all or any of these reports to be filed by persons conducting weather modification projects excluded from permit requirements.¹⁰

Authority and organization for local projects

In 1965 the North Dakota legislature enacted a law,¹¹ which authorized electors of townships within the State to levy taxes for weather modification activities, if approved by a majority vote at annual township meetings. This action, however, did not stimulate uniform cloud seeding projects and resulted in a checkerboard pattern of participating townships over the State. In the same year the legislature enacted chapter 2-07 of the State code,¹² authorizing boards of county commissioners to levy up to 2 mills on net taxable valuation of property in the county for a weather modification fund, upon majority approval in a countywide election. No counties are known to have taken advantage of this provision, and the legislature amended chapter 2-07 in 1969 to provide for county weather modification authorities, which can request the board of county commissioners to levy up to 2 mills for cloud-seeding purposes. Seven counties used this provision for the 1970 season, and 10 additional authorities were created in 1973 and 1974 as dry summers brought about more interest.¹³

North Dakota law specifies that the county authorities are created for a 10-year period, either by petition or by countywide election. The 17 authorities established through 1975 were all formed on the basis of petitions containing signatures of at least 51 percent of voting residents in the county. When two counties included a question on creation of an authority in county elections in 1976, both attempts failed. The law also provides for repeal of authorities through similar procedures, and opposition groups succeeded in obtaining signatures of at least 51 percent of the voters on petitions repealing authorities in six counties during the winter of 1976-77.¹⁴

Amendments to the North Dakota weather modification law (Century Code, chapter 2-07) passed by the legislature during 1975 required the North Dakota Weather Modification Board to establish weather modification districts and an advisory committee for each

⁹ North Dakota Weather Modification Board, "Rules and Regulations Relating to Weather Modification Operations," pp. 12-13.

¹⁰ *Ibid.*, p. 13.

¹¹ North Dakota Century Code, sec. 58-03-07, powers of electors.

¹² North Dakota Century Code, ch. 2-07, weather modification.

¹³ Schock, Martin R., "Weather Modification Activities in North Dakota, South Dakota, and Minnesota from 1951 Through 1976," University of North Dakota, Department of Aviation, Grand Forks, N. Dak., June 1977 (sponsored by U.S. Department of the Interior, Bureau of Reclamation, Division of Atmospheric Water Resources Management, HIPLEX program), p. 5.

¹⁴ *Ibid.*, p. 6.

district. Seven such districts have been formed on the basis of clusters of counties having authorities, although all 53 counties are assigned to one of the seven districts. Each county authority, with five persons managing the program from the county level, sets up annual program objectives, requests funds from the county commission, and holds an annual meeting. The multicounty districts then form the second level of local administration, through the operations advisory committees, composed of one representative from each county within the district. The committee, meeting monthly throughout the operational season and sporadically during the remainder of the year, formulates basic goals and policies for the project in the given district along State guidelines and reviews all activities.¹⁵

Annually, individual contracts are drawn up between the State Weather Modification Board and the county authorities, written as service contracts and defining in detail the operations advisory committee organization, weather modification services provided, responsibilities of each party, and funding. For all counties within an operational district the contracts are identical for all counties, except for county funding amounts.¹⁶

The Weather Modification Board is empowered to receive and expend funds which may become available from Federal grants or appropriations, gifts, bequests, and county funds received for weather modification. With the exception of funds received from the counties, the board may spend any of these funds for the encouragement of research and development in weather modification by private persons, the North Dakota State University, the University of North Dakota, or any other appropriate public agency in the State, through direct grant, contract, or other means. All such funds are transferred to the State Treasurer and placed in a weather modification fund. County weather modification authorities which have contracted with the State board for weather modification services contribute to the State weather modification fund in accordance with the determination of the board regarding funding necessary to provide the county with weather modification services.¹⁷

North Dakota operational projects in 1975 and 1976

In accordance with the provisions of the North Dakota Century Code and the rules and regulations of the Weather Modification Board, operational projects in the State were sponsored by local or regional weather modification associations through the 1975 season. Since that year all regional projects have been conducted by the State under the North Dakota cloud modification project, in conjunction with weather modification associations. Figures 5 and 6 shows the regions covered by weather modification operations during the 1975 and 1976 seasons, respectively, in North Dakota, South Dakota, and Minnesota. (The latter two States are included in the maps since data on their activities were also part of the report from which North Dakota information was obtained.¹⁸ The cross-hatched circle in western South Dakota in figure 5 indicates the general location of a research project during 1975.

¹⁵ Rose, testimony before the U.S. Department of Commerce Weather Modification Advisory Board, August 1977.

¹⁶ *Ibid.*

¹⁷ North Dakota Century Code, secs. 2-07-11 and 2-07-11.1.

¹⁸ Schock, "Weather Modification Activities in North Dakota, South Dakota, and Minnesota from 1951 Through 1976," June 1977, pp. 62, 64.

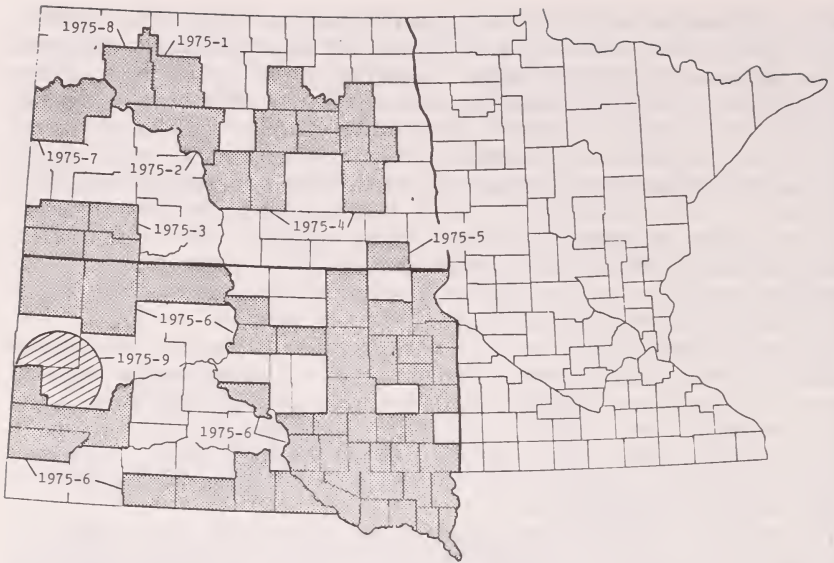


FIGURE 5.—Counties in North Dakota, South Dakota, and Minnesota in which operational weather modification projects were conducted during 1975. (The cross-hatched area indicates the approximate target area for a research project.) (From Schock, 1977.)

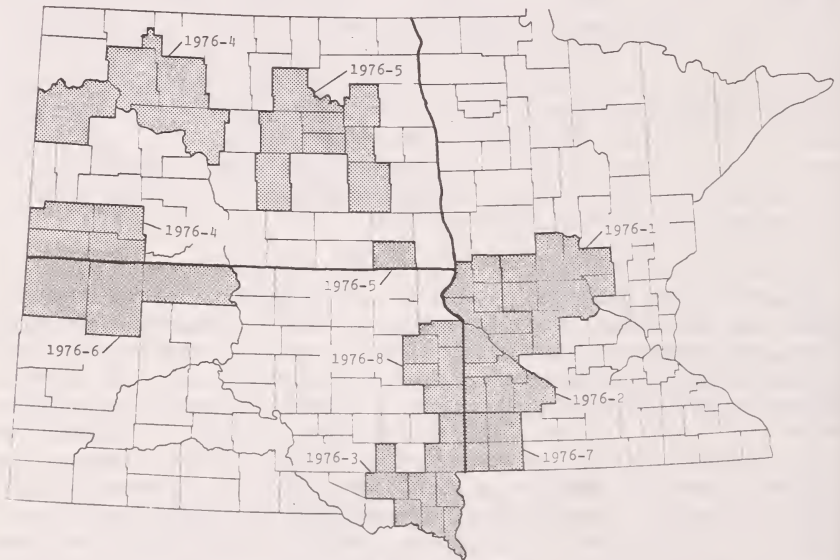


FIGURE 6.—Counties in North Dakota, South Dakota, and Minnesota in which operational weather modification projects were conducted during 1976. (From Schock, 1977.)

Tables 16 and 17 provide information on the projects in the three States for the 1975 and 1976 seasons, respectively, as shown in the maps in figures 5 and 6. Reference numbers where footnoted in the first column of the tables correspond to North Dakota projects. Other columns identify operators, sponsors, operational periods, seeding agents, delivery modes, whether or not the project incorporated randomized seeding, and the objectives. Note that none of the operational projects included random seeding.

Figure 7 shows the number of years from 1951 through 1976 that counties in the three-State area were totally or partially included in target areas of weather modification projects, according to an intensive study of projects in the area over this timespan by Schock.¹⁹ Statistics on these projects are given in table 18.

¹⁹ *Ibid.*, pp. 15-15.

TABLE 16.—INFORMATION ON SPECIFIC WEATHER MODIFICATION PROJECTS CONDUCTED IN NORTH DAKOTA, SOUTH DAKOTA, AND MINNESOTA DURING CALENDAR YEAR 1975

[From Schock, 1977]

Reference No.:	Operator	Project name/sponsor	Operational period	Seeding agent	Delivery mode	Randomized?	Objective
1975-1:	Aviation Services, Inc.	Ward project/Ward WMA	May 15 to Sept. 15, 1975	AgI-NH ₄ I—acetone (2 percent by weight), pyrotechnics.	2 aircraft each equipped with 2 generators and flare racks, seeding at cloud base and near —5C.	No	Rain augmentation, hail reduction.
1975-2:	Aviation Services, Inc.	McLean project/McLean WMA	May 15 to Aug. 31, 1975	do	1 Twin Commanche with 2 generators and flare racks, seeding at cloud base and near —5C.	No	Do.
1975-3:	Weather Modification, Inc.	Southwestern North Dakota Hail Suppression Association	June 1 to Aug. 31, 1975	AgI-NH ₄ I—acetone (4 percent by weight).	4 aircraft each equipped with 2 generators, seeding at cloud base.	No	Do.
1975-4:	Weather Modification, Inc.	Nodak Weather Modification Association, Inc.	May 15 to Aug. 31, 1975	AgI-NH ₄ I—acetone (2 percent by weight), pyrotechnics.	5 Twin Comanches each equipped with 2 generators, seeding at cloud base and at —5C.	No	Do.
1975-5:	Weather Modification, Inc.	Sargeant project/Sargeant WMA	June 15 to Aug. 31, 1975	do	1 Twin Comanche aircraft with 2 generators, seeding at cloud base and at —5C.	No	Do.
1975-6:	South Dakota Weather Modification Commission.	South Dakota weather modification program/State of South Dakota, counties.	May 1 to Aug. 31, 1975	do	16 aircraft, seeding at cloud base and at —5C.	No	Do.
1975-7:	Maurice D. Birkholz, Consultant.	McKenzie project/McKenzie WMA	May 1 to Aug. 15, 1975	AgI-NH ₄ I—acetone (3 percent by weight).	1 single-engine aircraft equipped with 2 generators.	No	Do.
1975-8:	Maurice D. Birkholz, Consultant.	Mountrail project/Mountrail WMA	June 1 to Sept. 14, 1975	do	1 aircraft equipped with 2 generators.	No	Do.
1975-9:	Cloud Physics Laboratory, Denver Research Institute.	Project SOFT/National Oceanic and Atmospheric Administration, State of South Dakota.	June 1 to July 31, 1975	1,5-dihydroxynaphthalene	1 aircraft, seeding with 1 generator at —5C.	Yes	Rain augmentation test nuclear-ability of treatment material.

i North Dakota projects.

TABLE 17.—INFORMATION ON SPECIFIC WEATHER MODIFICATION PROJECTS CONDUCTED IN NORTH DAKOTA, SOUTH DAKOTA, AND MINNESOTA DURING CALENDAR YEAR 1976
 [From Schock, 1977]

Reference No. : Operator	Project name/sponsor	Operational period	Seeding agent	Delivery mode	Randomized?	Objective
1976-1: WRDC	Central Minnesota Weather, Inc.	May 22 to Nov. 25, 1976 (contract period).	AgI	Ground-based generators.	No	Precipitation augmentation.
1976-2: WRDC	Big Stone County Weather, Inc.	May 25 to Nov. 25, 1976 (contract period).	AgI	do	No	Do.
1976-3: Atmospherics, Inc.	Southeast Association of Counties, State of South Dakota.	May 1 to Aug. 31, 1976.	AgI-NH ₄ I—acetone techniques.	pyro- 3 aircraft seeding at cloud base.	No	Rain augmentation, hail reduction.
1976-4: † North Dakota Weather Modification Board.	North Dakota cloud modification project/State of North Dakota, WMA S.	May 1 to Aug. 31, 1976	do	8 aircraft at cloud base, and at —5C.	No	Do.
1976-5: † North Dakota Weather Modification Board.	do	May 15 to Sept. 15, 1976	do	6 aircraft at cloud base, and at —5C.	No	Do.
1976-6: Weather Modification, Inc.	Northwest Association of Counties, State of South Dakota.	May 1 to Aug. 31, 1976	do	Aircraft at cloud base, and at —5C.	No	Do.
1976-7: Atmospherics, Inc.	Minnesota Weather Modification Association.	June 20 to Aug. 31, 1976	do	1 aircraft at cloud base, and at —10C.	No	Do.
1976-8: Weather Modification, Inc.	Farmers Weather Corp.	Sept. 17 to Nov. 1, 1967	AgI-NH ₄ I—acetone	1 twin-engine aircraft equipped with generators.	No	Rain augmentation.

† North Dakota projects.

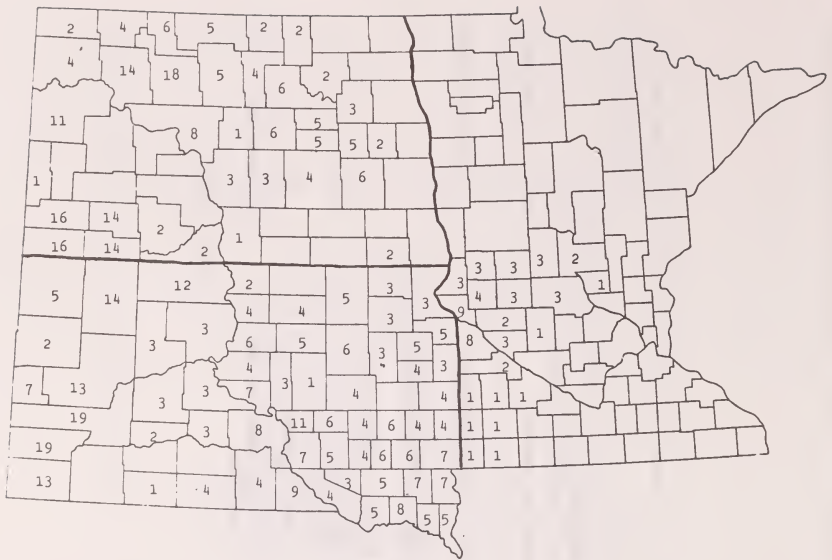


Figure 7.—Counties in North Dakota, South Dakota, and Minnesota which were partially or totally included in weather modification target areas during the years 1951 through 1976. The numbers indicate the number of seasons during that time period that a given county included target areas for weather modification projects. (From Schock, 1977.)

TABLE 18.—*Statistics on operational and research weather modification projects conducted in North Dakota, South Dakota, and Minnesota during the period 1951 through 1976.*

Number of projects	63
Number of seasons projects conducted	162
Number of research projects	14
Number of seasons research projects conducted	27
Number of research projects financed totally with Federal dollars	9
Number of applied projects for which Federal dollars supported an evaluation	2
Maximum number of counties in applied projects during a single year (1974)	64

Source : Schock, 1977.

SOUTH DAKOTA

In the late 1940's and early 1950's there was a proliferation of weather modification projects throughout the Great Plains, and as much as 50 percent of the State of South Dakota is estimated to have been under cloud seeding during the peak years. Financed through voluntary contributions mostly from farmers and ranchers, the techniques most often employed ground-based silver iodide generators. The first weather modification legislation in South Dakota, enacted in 1953, established the South Dakota Weather Control Commission and instructed the commission to promote and regulate cloud-seeding activities.²⁰

²⁰ Donnan, John A., Jackson L. Pellett, Richard S. Leblang, and Leo F. Ritter, "The Rise and Fall of the South Dakota Weather Modification Program," the *Journal of Weather Modification*, vol. 8, No. 1, April 1976, pp. 1-2.

There was no Government support of weather modification until 1955, so that all projects until that year were voluntarily funded. In 1955 the legislature amended the State law, authorizing each county to levy up to 1 mill on assessed valuation to support weather modification. Counties took advantage of this new authority and some joined together so that cooperative projects could be conducted in blocks of contiguous counties. In 1959 the State Board of Regents established the Institute of Atmospheric Sciences at South Dakota School of Mines and Technology, and the first Federal funds for weather modification were made available to the institute in 1961. Through 1970 at least \$3,800,000 in Federal funds had been invested in the State to study summertime cumulus clouds and thunderstorms and to develop weather modification techniques, mostly from the Bureau of Reclamation, but also from the Defense and Commerce Departments and from the National Science Foundation.²¹

The Weather Control Commission instructed the Institute of Atmospheric Sciences to develop an operational weather modification plan for the State in 1969, and in February 1970 individuals representing various sections of the State's economy were invited to review and give direction to such a possible operational program. To coordinate development efforts the South Dakota Water Development Association was established from those assembled. In April of that year the executive committee of the Legislative Research Council included this program among its studies of the year and in June and September the Agriculture and Conservation Committee of the Legislative Research Council heard testimony in support of a statewide weather modification program. In October the committee approved an amendment to the existing weather modification law, directing the Weather Control Commission to carry out a statewide program of precipitation management and appropriating \$100,000 in State funds to develop the program. The bill was subsequently approved, March 17, 1971, by a two-thirds majority of both legislative houses, as required for all special appropriations bills.²²

The Commission was attached to the State Department of Agriculture for administrative purposes, but was given full authority to direct the design and development of the program. In April 1971 the commission selected a director, who assumed his position in September and immediately began planning the statewide program for the summer of 1972. To emphasize and obtain local support, contact was made with and support sought from agricultural organizations, water groups, and the South Dakota County Commissioners Association. Counties were asked to participate in the program, and it was proposed that one commissioner from each participating county serve on a Weather Modification Advisory Committee, each with complete control over cloud seeding activities in his county. The Weather Control Commission established a cost share ratio of 25 percent for the county versus 75 percent for the State. Of the State's 67 counties, 26 agreed to participate during the 1972 summer season and entered into contract with the Commission. As shown in figure 8, 21 of these counties constituted a nearly solid block in the southeast part of the State, 3 were in a block in the Black Hills, and 2 other large counties were in the ex-

²¹ *Ibid.*, pp. 2-3.

²² *Ibid.*, pp. 3-4.

treme northwest corner of the State, constituting a combined land area of 17,181,000 acres.²³

In 1972 the legislature passed another special appropriation measure, requiring two-thirds support in both houses, which provided \$250,000 to support the 1972 operational program and administrative functions of the Commission for fiscal year 1973. About \$90,000 was received in cost-share funds from participating counties. In view of insufficient funds, full-scale operations were conducted only in the southeast part of the State, and supplemental support was provided elsewhere; 1972 field operations, costing about 3.2 cents per acre, were performed under contract to the State by private firms.²⁴

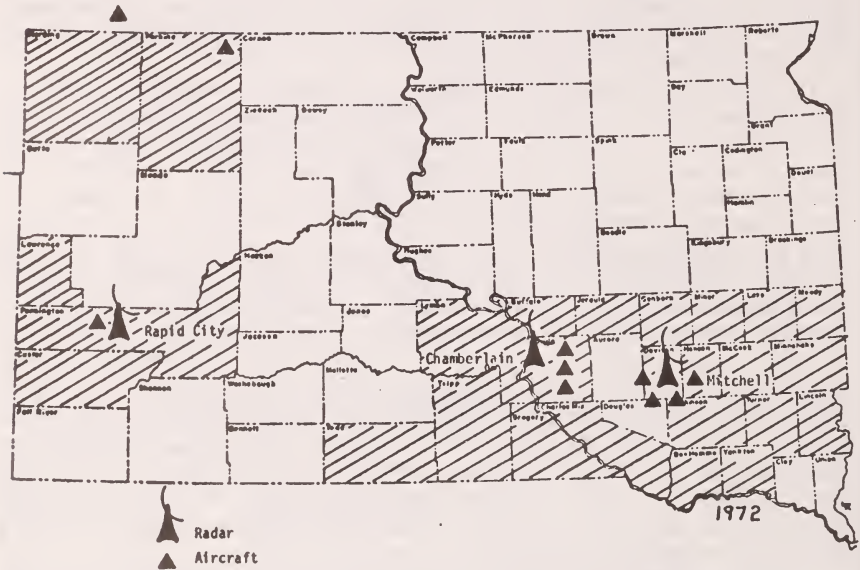


FIGURE 8.—Twenty-six counties in South Dakota which contracted with the State Weather Control Commission in the first year of the statewide weather modification program during the 1972 operating season. (From Donnan, Pellett, Leblang, and Ritter, 1976.)

²³ *Ibid.*, pp. 4-6.

²⁴ *Ibid.*, pp. 6-8.

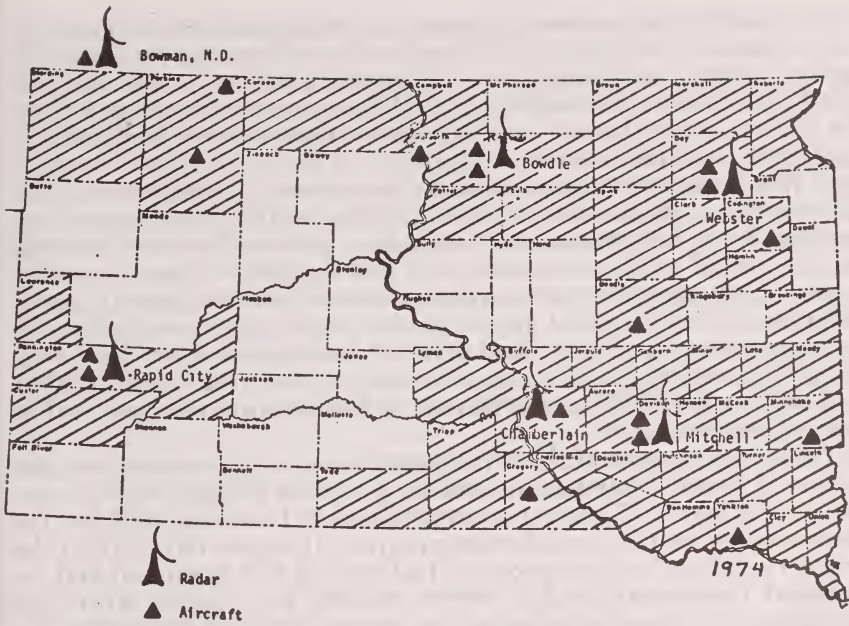


FIGURE 9.—Forty-six counties in South Dakota which contracted with the State Weather Modification Commission and participated in the statewide weather modification program during the 1974 operating season. (From Donnan, Pellett, Leblang, and Ritter, 1976.)

The special State appropriation for 1973 approved by the legislature was \$643,818, supplemented by \$190,141 in county funds and \$7,000 from the Federal Government. The law was also amended that year to make changes in the administrative structure and in regulations. The Weather Control Commission became the Weather Modification Commission with modified membership provisions, the Commission and all of its functions were transferred to the Department of Natural Resources, and license and permit requirements and violation penalties were instituted.²⁵ The 1973 summer operating season began May 1, with 42 participating counties, divided into 6 operational districts.²⁶

Plans for the 1974 season included the intent for 46 counties to participate, constituting 29,547,000 acres. In the fall of 1973 the Governor considered the program so well established that he included its funding in his general appropriations bill, requiring only a simple majority vote for passage. The \$803,700 included was to fund operations for July and August 1974 and May and June 1975. A special appropriation bill was also introduced to provide \$171,000 for contracted services in May and June 1974. Both bills passed the legislature, and \$243,600 in county moneys and \$30,200 in Federal funds were also available. The latter funds were received from the Bureau of Reclamation and were to be used for evaluation of operations. The overall cost of the 1974 seeding program was 3.6 cents per acre.²⁷ Counties participating in this peak year for the statewide program are shown on the map in figure 9.

²⁵ The present South Dakota statutes relating to weather modification are reproduced in app. D, p. 604.

²⁶ Donnan, et al., "The Rise and Fall of the South Dakota Weather Modification Program," 1976, pp. 8-11.

²⁷ *Ibid.*, pp. 12-14.

For the 1975 summer seeding season, 45 counties expressed interest in participation. The Commission developed an increased emphasis on public information through over 100 public meetings in the fall and winter of 1974-75, institution of a daily news release program during the 1975 operational season, and expansion of the advisory committee to include representatives from all the counties in each district. The fiscal year 1976 budget was again included in the general appropriations bill. Although evaluations had indicated positive results from the previous seeding, South Dakota was suffering from a potentially severe drought and the mood of the legislature was less supportive than in earlier years. An attempt to move the appropriations from the general appropriations bill to a special appropriation requiring a two-thirds vote test was defeated, however, and \$776,500 was approved for fiscal year 1976. With county funds, the total budget for that year was \$1,076,800, and another \$41,500 from the Bureau of Reclamation was provided to support evaluations.²⁸

With the approach of the 1976 summer season, 42 counties provided letters of intent to participate, and the proposed budget in the Governor's fiscal year 1977 general appropriations bill included \$855,000 for the statewide weather modification program. It became obvious that the group opposing the State program had become well organized and influential. Concentrating their efforts in a few key counties where the commissioners were overwhelmed by groups of strong opponents, the opposition was instrumental in changing the decisions to participate by those counties. In turn, these actions had negative effects on neighboring counties. Consequently the 42 counties indicating intention to participate in 1976 dwindled to 22 counties which signed contracts with the Weather Modification Commission. In the legislature, meanwhile, there was a successful move to remove the weather modification budget from the Governor's general appropriation bill. A special appropriation bill was promptly introduced, along with two other weather modification bills. One would have repealed the entire, existing weather modification law, and the other would have required a hearing by each county commission prior to issuance of a permit. None of these bills, including the special appropriation measure, passed the legislature, so that no funds were available to conduct the State program in fiscal year 1977. The Weather Modification Commission continued to function as the State regulatory agency for issuance of licenses and permits.²⁹

Support of operational weather modification projects in South Dakota reverted, therefore, to the pattern of private and county funding which existed prior to establishment of the statewide program, and the number of such projects decreased dramatically. With funds available for part of the 1976 season, the State weather modification provided some support to local projects in nine southeastern counties and to three counties in the northwest. The latter joined with the project in southwestern North Dakota for the 1976 season. The South Dakota Commission also contracted with the State of North Dakota to carry out an evaluation program for 1976 operations in South Dakota. Another five-county area in the eastern part of the State operated a project with no State support during September 1976, originating after

²⁸ *Ibid.*, pp. 12-14.

²⁹ *Ibid.*, pp. 14-16.

the drought extended into that area.³⁰ Counties included in projects carried out in South Dakota during 1975 and 1976 are shown in the maps in figures 5 and 6, and information on these projects is included in tables 16 and 17, all of which appear in the section on the discussion of North Dakota activities.

Four weather modification bills were introduced into the 1977 legislature, one of which was a special appropriation bill which would have provided 50-percent State support to operations in the estimated 30 counties interested in such a cooperative program. The special appropriation failed as did the other bills, and during 1977 only Harding County, in the northwest, sponsored a seeding program, using county funds and contracting with the adjacent project in North Dakota for some of the required services. An attempted 1977 cooperative project in five southeastern counties, supported by private and some county funds, did not get underway. No weather modification bills were presented in the 1978 legislature, though minimal funding has been approved by the legislature in the past two sessions in the general appropriations bill to maintain the Weather Modification Commission.³¹

UTAH

The State of Utah has both one of the largest State weather modification programs and one of the more complete organizational structures for administering State projects and regulations provided by law. The Division of Water Resources is charged with developing the waters of the State to the best beneficial use for citizens of Utah, considered to be the second driest State in the Nation.³² The Utah weather modification law, titled Cloud Seeding to Increase Precipitation, was passed by the State legislature March 5, 1973, and became effective May 8, 1973. In part, the law states:

The State of Utah through the Division of Water Resources shall be the only entity, private or public, that shall have authority to authorize, sponsor, and/or develop cloud seeding research, evaluation, or implementation projects to alter precipitation, cloud form, or meteorological parameter within the State of Utah, except cloud seeding for suppression of fog is excluded. The Division of Water Resources shall authorize, sponsor, and/or develop local or statewide cloud seeding projects that conform to overall State water planning objectives which are determined to be feasible by the Division of Water Resources. . . . A cloud seeding project as used in this act shall be a planned project to evaluate meteorological conditions, perform cloud seedings, and evaluate results.³³

As designated by this law, the Division of Water Resources is the State agency responsible for regulation and sponsorship of weather modification projects. A Board of Water Resources has approved a set of rules and regulations which stipulate requirements for licensing of operations and obtaining permits on specific projects.³⁴ These rules are included in appendix M.

³⁰ Butler, Vern D., "Report of weather modification activities in South Dakota" (part of report of area No. 5—North Central States), North American Interstate Weather Modification Council, business meeting, Dec. 2-3, 1976. In NAIWMC publication No. 77-1. September 1977, p. 78.

³¹ Butler, Vern D., private communication.

³² Summers, Paul C., Utah cloud seeding program, briefing before the U.S. Department of Commerce Weather Modification Advisory Board, Sept. 24, 1977.

³³ Utah Code Annotated No. 73-15-3. Cloud seeding to increase precipitation—control of division of water resources—powers and authority of division—"cloud seeding" and "cloud-seeding project" defined. (The Utah weather modification law is included in its entirety along with similar laws of other States in app. D, p. 612.)

³⁴ State of Utah, Department of Natural Resources, Division of Water Resources, "Rules, Regulations, and Procedures Relating to the Utah Cloud Seeding Act of 1973" (Laws of Utah, ch. 193), March 1976, 13 pp.

The State's cloud seeding program is administered by a small staff in the Division of Water Resources, augmented by two advisory groups of experts. The Program Advisory Committee (PAC) includes representatives from State, Federal, and local agencies, such as the Forest Service, the National Park Service, State Lands, and local user groups who have either a direct or indirect interest in the program. The Technical Advisory Group (TAG) is composed of meteorologists from the National Weather Service, the Bureau of Reclamation, the University of Utah, and Utah State University as well as statisticians from the Soil Conservation Service and the University of Utah.³⁵

The operational cloud-seeding program in Utah is organized on a State-county basis, where costs are shared between the State and the counties or other political subdivisions. The cost sharing ratio is approximately 60 percent State to 40 percent local. From 1973 through 1975, before State funds were available, a group of counties in the southern part of the State, an area of somewhat constant drought, contracted for seeding winter clouds to increase mountain snowpack. In 1975 the legislature appropriated State funds, however, which permitted expansion of seeding operations to 14 southern counties, covering about 60 percent of the land area of the State. That same year three northern counties joined three southern counties in Idaho, initiating a project for rain enhancement and hail suppression that has been conducted during the summers of 1976 and 1977. The severe drought conditions of the past year led to increased interest from local officials and increased funding from the State legislature, so that projects were conducted in all but three of the State's 29 counties during 1977.³⁶

The Utah program also supports weather modification research. State funds have been earmarked for research activities as well as for evaluation and environmental monitoring. In particular, weather modification research at the Utah Water Research Laboratory, formerly supported by the Bureau of Reclamation, is now funded by the State, since Federal "Skywater" funds have not been available in recent years. The State has officially agreed to support the proposed plan of the Bureau of Reclamation to augment water supplies in the Colorado River through cloud seeding in the major watersheds in the river basin. The Division of Water Resources recently concluded an agreement with the Bureau to begin preliminary project design in the Uinta Mountains of eastern Utah in preparation for this project.³⁷

WASHINGTON

Under the weather modification law of the State of Washington³⁸ the Department of Ecology is charged with responsibility for supervision and control of all weather modification activities conducted within the State. The department also represents the State in all interstate contacts relating to weather modification. In accordance with regulations promulgated by the State to implement the administration of the law, the Department of Ecology carries out the State's program of regulation which requires the issuing of licenses and permits, the payment of fees, and the reporting of activities. These regulations, reproduced in appendix M, apply to all weather modification

³⁵ Summers, "Utah Cloud Seeding Program," 1977.

³⁶ *Ibid.*

³⁷ *Ibid.*

³⁸ RCW 43.37.010 through 910. See app. D for the text of the Washington law, p. 613.

activities in all parts of the State except as specifically exempted.³⁹ Activities which are exempted from licensing, permit, and liability requirements include the following:

1. All research and experiments related to weather modification and control conducted within laboratories;
2. Those weather modification operations designed to alleviate sudden, unexpected, hazardous conditions which require expeditious localized action for:
 - a. Protection against fire,
 - b. Prevention of frost,
 - c. Dispersal of fog; and
3. Field research and development by institutions of higher learning.⁴⁰

Persons intending to conduct activities under the second exemption above are required to make "every reasonable effort" prior to the operations to notify the Department of Ecology of the proposed action and to provide certain information on operations to be conducted. Persons planning to conduct field research under the third exemption above must provide information on their proposed project in writing to the department 10 days prior to commencement of activities and must report periodically on the status of the project.⁴¹

Licensing is required for each individual or organization planning to conduct nonexempted operations, and qualifications for such a license include the requirement for responsible individuals to be certified professional members of the American Meteorological Society or to possess academic achievements and professional experience necessary to receive such certification. Permits are required for each operation not exempted, and applicants for such permits must publish notice of intention to conduct weather modification operations in a legal newspaper having general circulation in the county or counties in which the affected area is located. The permittee is required to maintain daily reports on operations and to submit bimonthly reports to the Department of Ecology. Proof of financial responsibility must also be provided to the department.⁴²

Normally the State of Washington does not finance weather modification operations; however, the severe drought conditions in late 1976 led the State legislature, upon the recommendation of the Senate Committee on Agriculture, to pass an emergency cloud-seeding bill on February 18, 1977. This act authorized the Department of Natural Resources to enter into a contract with the University of Washington's Cloud Physics Group to conduct emergency cloud seeding.⁴³ The contract required the university to carry out a program of weather modification, using aircraft, in an attempt to increase snowpack in the Cascade Mountains and to augment precipitation in critical areas of eastern Washington, although highest priority and maximum effort were given to the Cascade Mountain work following subsequent direction from the Department of Natural Resources.⁴⁴

All of the seeding in this program was done from aircraft in order

³⁹ Ch. 173-495 WAC, weather modification, adopted Dec. 28, 1977.

⁴⁰ *Ibid.*, WAC 173-495-040.

⁴¹ *Ibid.*

⁴² *Ibid.*

⁴³ Additional weather modification projects were carried out by public utility companies and private organizations under the general authorization of this act; two of these projects are discussed briefly below.

⁴⁴ Hobbs, Peter V., "The State of Washington's Emergency Cloud Seeding Program (February-June 1977)." University of Washington, Department of Atmospheric Sciences, Cloud Physics Group, Seattle, July 1977, pp. 1-3.

to eliminate uncertainties from ground-based seeding. Crushed dry ice was dispensed over the Cascades, but the warm clouds in eastern Washington were to be seeded with ammonium nitrate had that portion of the program not been curtailed. Since the State's emergency cloud seeding program was an operational program and not experimental, it was not designed nor operated in a way that could provide a scientific evaluation of the seeding effects. A scientist aboard each flight assessed the potential for seeding and decided upon the optimum flight route and rate of dispersal for seeding material. Wherever possible, effects of seeding were documented through visual observation, photography, or direct measurements. It was apparent, in spite of the limitations imposed on evaluation, that "significant modifications to cloud structures and increases in precipitation-sized particles were produced by the cloud seeding. It is likely that these modifications produced increases in precipitation on the ground, although this cannot be proved scientifically from the data collected in this operational program."⁴⁵

Hobbs has proposed that a demonstration cloud-seeding project for the State of Washington be designed and implemented, using both physical and statistical criteria to determine the effects of seeding. Such a project is currently under consideration by the Washington State Department of Commerce and Economic Development and would be conducted by the University of Washington.⁴⁶

Two other projects conducted during the 1977 drought by a commercial operator under contract may be noted. In one case farmers in Garfield and Columbia Counties in eastern Washington formed a local association, collected a 10-cent per acre assessment, and deposited the funds with the State Department of Natural Resources, who contracted on their behalf for the requested services. Non-randomized weather modification operations were conducted in May and June of 1977, using a cloud-seeding aircraft and a weather radar system installed at Pomeroy, Washington. Based on preliminary analysis of precipitation data from National Weather Service stations and from other local stations in the target and control areas, a 15 to 20 percent increase in rainfall from seeded storms was suggested.⁴⁷

The other operational program, conducted by the same contractor, was initiated by the Tacoma City Light and Power Company, as a possible means of enhancing water supplies from the Cowlitz and Nisqually watersheds in southwestern Washington. Funding was passed from the company to the State Department of Natural Resources, which contracted for the seeding in March 1977, and operations were carried out from late March through June, using an aircraft and a weather radar system for support. Preliminary analysis, based on comparisons of precipitation data from the control and target areas, again suggested rainfall increases of 15 to 20 percent from the seeded storms.⁴⁸

⁴⁵ *Ibid.*, p. 5, 9, and 23.

⁴⁶ *Ibid.*, pp. 26-27.

⁴⁷ Henderson, Thomas J., "The Eastern Washington Cloud Seeding Program, a summary of cloud seeding activities conducted over portions of Garfield and Columbia Counties in Washington during the period May 18, 1977 through June 30, 1977." Atmospherics, Inc., report prepared for the Department of Natural Resources, State of Washington, Fresno, Calif. July 20, 1977, pp. 2, 3, and 21.

⁴⁸ Henderson, Thomas J., "The Cowlitz-Nisqually Cloud Seeding Program, a summary of cloud seeding activities conducted over the Cowlitz-Nisqually Drainage in Washington during the period March 25, 1977 through June 30, 1977." Atmospherics, Inc., report prepared for the Department of Natural Resources, State of Washington, Fresno, California, July 26, 1977, pp. 2 and 17.

CHAPTER 8

PRIVATE ACTIVITIES IN WEATHER MODIFICATION

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INTRODUCTION

Two previous chapters reviewed, respectively, the weather modification activities and interests of the Federal Government and of State and local jurisdictions. Many of the operational services performed for agencies in these governmental bodies and for private sponsors, have been carried out under contract by commercial firms who have developed expertise in a broad range of weather modification capabilities or who specialize in particular services essential to both research and operational projects. A summary of the kinds of activities performed by these companies is contained in this chapter. Other private organizations—such as cooperative associations of farmers and orchardists, utilities, airlines, and lumber companies—are among the sponsors and organizers of operational weather modification projects. Some of these privately sponsored projects have been discussed in several sections of the previous chapter under activities conducted within and under the regulation of the States.

While the majority of universities whose atmospheric science and other departments have participated significantly in weather modification research projects are public institutions, mostly in the Western States, a few private universities and research foundations have also contributed to the understanding of weather modification through their research activities. Since the efforts of universities are so closely tied to the discussions on the status of the technology and needed research, Federal and State activities, and other particular aspects of the subject addressed in later chapters, activities of academic institutions are not discussed separately.

Important among the private institutions concerned with weather modification are the professional organizations of which research and operational weather modifiers and other interested meteorologists are members. These include the American Meteorological Society, the Weather Modification Association, and the Irrigation and Drainage Division of the American Society of Civil Engineers. In addition, the North American Interstate Weather Modification Council (discussed in the previous chapter) is an organization whose membership consists of governments of U.S. States and Canadian Provinces and the government of Mexico, which serves as a forum for interstate coordination and exchange of information on weather modification. Two professional organizations, the Weather Modification Association and the American Meteorological Society, will be discussed in this chapter.

Weather modification is controversial, and both formal and informal opposition groups have developed in various sections of the country. Reasons for such opposition are varied and are based on both real and perceived adverse consequences from weather modification. Some of the objections often voiced by private groups and some examples of formal opposition groups are reviewed in this chapter.

COMMERCIAL WEATHER MODIFIERS

SCOPE AND SIGNIFICANCE OF CONTRACT ACTIVITIES

Weather modification operations, which now cover a significant area of the United States, are almost exclusively conducted on a contract basis for specific users by professional cloud seeding organizations. Contracts often cover only one season of the year; however, a large number of such projects are renewed annually. Target areas range from a few hundred to a few thousand square miles. In 1976, 6 of 10 major companies having substantial numbers of contracts received about \$2.7 million in contract awards for operations within the United States. In addition, a few of these companies also had overseas contracts.¹ Owing to the increased demand for emergency programs during the recent drought, it is estimated that 1977 contracts totaled about \$3.5 million. Most weather modification operational activities are carried out in the region of the country from the Great Plains westward, though some projects do occur from time to time in Eastern States as well. The distribution of these projects is shown in figure 2 in the previous chapter; and statistics on commercial operators and projects in which they provide services are contained in tables in that chapter.²

The initial role of the private weather modification operators was to sustain weather modification activity during its early years. During that period there was heated scientific controversy with other professional meteorologists on the efficacy of cloud seeding. Later, their operations provided a valuable data base which permitted the early evaluation of seeding efforts and estimation of the potential prospects for the technology, especially by several select committees assembled for such assessment within the Federal Government.³ Meanwhile, commercial operators, who decreased in number after the initial surge of the early 1950 era, have grown in competence and in public respect. Their operations have incorporated the benefits of accumulated experience and research findings. Today, more often than not, they work hand in hand with researchers in weather modification, and, in fact, they often participate in research projects, contributing much of their know-how acquired through their unique experiences.

SUMMARY OF CONTRACT SERVICES

The first scientific weather modification activities were conducted by the private sector. In an earlier chapter we noted the now famous pioneering work of Schaefer, Langmuir, and Vonnegut—all with the General Electric Co.—in the mid- to late 1940's.⁴ After the early

¹ Elliott, Robert D., private communication, December 1977.

² See ch. 7, pp. 345 and 347.

³ Elliott, private communication, 1977.

⁴ See ch. 2, p. 37.

General Electric discoveries, the first early cloud seeding was initiated by crop dusters, operating on their own behalf or in service to farm groups.⁵ In addition to providing some extra water and accumulating information on seeding effects, these private projects provided testing for various seeding modes and for different operational schemes.⁶

Since the early 1950's cloud-seeding activities have been carried on at a moderately uniform level following the initial flurry of activities immediately after the General Electric discoveries. Excluding fog clearing (which is customarily not performed in the context of weather modification but rather as part of other airport operations), the annual number of private weather modification projects has been about 30, mostly concentrating in rain or snowpack enhancement.⁷ The number of such projects and the number of operators were 47 and 15, respectively, during calendar year 1975, according to the records of the National Oceanic and Atmospheric Administration (NOAA).⁸ (The NOAA statistics include operations in fog dispersal at airports.) Many of the operations discussed earlier and summarized in tables and figures on U.S. weather modification activities for 1975 and 1976 include operations that have either been conducted or sponsored by private concerns.⁹

During the 1950's and 1960's these projects were conducted for the most part by five major companies though a larger number were involved during the early 1950's. Developing in the 1960's and moving into the 1970's a number of operators, inclined to depend mostly on aircraft seeding, began summer cumulus seeding in the northern Great Plains. Their emphasis has been primarily on increasing rainfall and suppressing hail, and their principal sponsors have been farm groups.¹⁰

Since the 1950's there have been conducted, on an annual basis, between six and nine operational projects intended to increase precipitation in watersheds in the West, sponsored by utility companies. A number of these projects were continued over an extended period of years. The Southern California Edison project, for example, in the upper San Joaquin River basin in the Sierra Nevada Mountains has been in operation continuously every winter since the 1950-51 season.¹¹ Such utility company projects tend to run for a number of successive years when demand exceeds power resources; after new generating plants with full reservoirs become operational, cloud seeding is often curtailed until again required by increased power demands.

There has also been some interest in cloud seeding on the part of the Western lumber industry, when drought conditions reduce fuel moisture indices and increase the attendant potential for forest fires. Enhancement of precipitation from summer cumulus clouds, through contracts with weather modification operators, has been employed to increase moisture and, on occasions, to assist in limiting or extinguishing fires.¹²

⁵ Elliott, Robert D. "Experience of the Private Sector," in Wilmot N. Hess (editor), "Weather and Climate Modification," New York, Wiley, 1974, p. 46.

⁶ *Ibid.*

⁷ *Ibid.*

⁸ Charak, Mason T., "Weather Modification Activity Reports: Calendar Year 1975," National Oceanic and Atmospheric Administration, Office of Environmental Monitoring and Prediction, Rockville, Md., June 1976, p. 4.

⁹ See ch. 7, p. 343 ff, and see app. G.

¹⁰ Elliott, 1974, "Experience of the Private Sector," 1974, pp. 47-48.

¹¹ *Ibid.*, p. 48.

¹² *Ibid.*

Under the guidance of the airlines, the use of weather modification to clear airport fog was initiated as an operational procedure during the 1960's. Since the current operational procedures apply almost exclusively to cold fogs, airports in more northerly or higher altitude locations in the United States are the ones which can benefit from this technology. Each winter, there are about 15 projects underway throughout the country. The seeding flights are usually conducted by local operators under contract to the airlines. Low-flying aircraft usually seed with crushed dry ice, which is dropped into the fog.¹³ In 1975 there were nine cold fog and one warm fog dispersal projects conducted at U.S. airports under contract to airlines.¹⁴

The principal U.S. commercial weather modification operators are also involved in contract services in other parts of the world. In particular, such projects have been conducted in Canada, in Central and South America, in Africa, in the Near East, and in Europe.¹⁵

EVALUATION AND RESEARCH BY COMMERCIAL FIRMS

Commercial weather modification firms, under contract to private organizations or local jurisdictions, are expected to develop additional water resources or to modify effects of damaging storms in order to alleviate immediate or impending economic and personal losses brought on by drought or other severe weather. They are therefore usually obliged to expend most if not all of their efforts and supporting funds in attempting to mitigate these extreme conditions and to attend less to scientific evaluation of their activities than would be true in a carefully designed experimental or demonstration project.

The private sector has contributed to evaluation, however. It has pioneered in evaluation of results through comparison of data from seeding operations with historical data, using the latter as the unseeded samples. Using relationships based on historical precipitation records, for example, predictions have been made of what precipitation can be expected in the target area when seeded. There is, of course, the possibility that historical data contain inconsistencies, so that, in a project performed purely for research purposes, this practice is replaced by randomization. This kind of evaluation has also been applied in projects designed to increase snowpack, where snow course measurements, taken at monthly intervals in the West for the past 20 to 40 years, have provided the historical record.¹⁶ Statistics on annual stream flow and on crop hail damage have also been used as criteria for project evaluation.

The private sector of the weather modification community has also been involved in the conduct of projects designed for pure research purposes, when under contract to provide a variety of professional services in connection with projects. A series of such experiments have been carried out, for example, in the vicinity of Santa Barbara, Calif. The first Santa Barbara randomized seeding project (1957-60) involved one major private contractor, North American Weather Consultants, along with a number of State and local agencies from California and some agencies of the Federal Government. The second

¹³ *Ibid.*, pp. 48-49.

¹⁴ See tables 6 and 7, ch. 7, and also see app. G.

¹⁵ Elliott, "Experience of the Private Sector," 1974, p. 49.

¹⁶ *Ibid.*, p. 66.

Santa Barbara randomized seeding experiment (1967-70) was conducted by North American Weather Consultants under contract to the Naval Weapons Center at China Lake, Calif. Also, during the 1970's, a randomized seeding project was sponsored by the Pacific Gas & Electric Co. in the Lake Almanor drainage basin of the Sierra Nevada.¹⁷ There are other examples where users have conducted randomized projects for a number of years in order to "calibrate" their watersheds and cloud types.

PARTICIPATION IN FEDERAL RESEARCH PROJECTS

A number of private firms have performed a variety of meteorological services under contract to Federal agencies sponsoring weather modification research projects. These companies include both those who also provide professional weather modification services in privately or publicly financed operational projects as well as meteorological firms who do not otherwise engage in weather modification. Although most weather modification programs of the several Federal agencies have at some time contracted with such private companies as well as with universities, the principal sponsor of research projects using these contractors in recent years has been the Bureau of Reclamation through its atmospheric water resources management program (Project Skywater). Some of these commercial organizations, who have performed various services for "Skywater" are identified in table 8 in chapter 5.¹⁸ Prior to reduction of weather modification research activities in the 1970's, the Department of Defense was a major sponsor of contracted research with industrial and academic weather modification groups.

While a contracting firm is customarily responsible for most aspects of an operational project if funded privately or by State or local tax assessments, its participation in a Federal research project is more often limited to one or a few specialized services which it can provide especially well, based on its unique experience. Such services are usually of the operations type and include aircraft support, seeding, equipment maintenance, data gathering, or other field services. Some highly specialized companies assist with project design, meteorological measurements, data analysis, and report preparation. The overall project planning and design, project monitoring, integration of participant responsibilities, and final evaluation are usually managed by the responsible field personnel of the Federal agency itself, while specialized analyses, evaluations, and related studies are most often performed by scientists and other experts associated with participating universities or research organizations.

WEATHER MODIFICATION ORGANIZATIONS

PROFESSIONAL ORGANIZATIONS

There are three professional organizations in the United States to one or more of which most weather modifiers and others interested in weather modification belong and through which scientific, technical, and legal problems and findings are aired and discussed. In addition.

¹⁷ *Ibid.*, p. 68.

¹⁸ See p. 250.

various other matters are addressed by these groups, including statements on weather modification policy, opinions on pending legislation, social implications, and professional standards and certification. These organizations are the Weather Modification Association, the American Meteorological Society, and the American Society of Civil Engineers. The first of these three is concerned exclusively with weather modification, while the latter two represent professional interests and activities across a wide range of meteorological and engineering fields, respectively; however, each of the larger societies has a committee concerned particularly with weather modification. Two of these professional organizations are discussed below.

Weather Modification Association

Recently the following four stated purposes of the Weather Modification Association (WMA) were given in testimony:¹⁹

1. Promotion of research, development, and understanding of weather modification for beneficial uses;
2. Encouraging and promoting the highest standards of conduct, including certification of individual members qualified to execute field experiments and operations in weather modification;
3. Serving as a clearinghouse and dissemination agent for weather modification oriented literature and information; and
4. Assuming an active role and maintaining a strong voice in the production and dissemination of policy statements concerning all aspects of weather modification practice.

The WMA was conceived in April 1951 at a meeting of weather modifiers and their clients in Riverside, Calif., called to discuss possible methods of organizing and controlling weather modification operations and evaluations in California in order to raise the standards of those engaged in cloud seeding operations. At that meeting an organization, tentatively called "The Artificial Precipitation Operations Association," was formed; a second was held later the same month and the name was changed to the "Weather Control Research Association." In the following years the organization developed, its activities increased, and its membership grew and became more representative of other parts of the country. Its current name was adopted in March 1967.²⁰

Current membership in the WMA is approximately 250, including both individuals and corporations interested in the field of weather modification. Members are mostly from the United States; however, there are members from some foreign countries as well. The diverse interests and backgrounds of the members range from concerned water users to university professors.²¹

The WMA conducts semiannual business and technical meetings, usually in the West or the Midwest, where weather modification projects are more common and where the membership is more heavily represented. The 1977 meetings were held in April in Salt Lake City and in October in Champaign, Ill. The latter meeting was conducted jointly with the Sixth Conference on Planned and Inadvertent

¹⁹ Griffith, Don A., Thomas J. Henderson, Theodore B. Smith, and Arnett S. Dennis, testimony before the U.S. Department of Commerce Weather Modification Advisory Board, Champaign Ill., Oct. 13, 1977.

²⁰ "Background of the Weather Modification Association," the *Journal of Weather Modification*, vol. 9, No. 1, April 1977, p. 207.

²¹ Griffith, et al., testimony before the Weather Modification Advisory Board, 1977.

Weather Modification of the American Meteorological Society, of which the WMA was one of two cosponsors. The 1978 spring meeting of the WMA is to be held in Tucson, Ariz.

Beginning in 1969, the WMA has published the *Journal of Weather Modification*. While it has been the practice of the association to produce a single annual issue of the journal in most years, usually in April, two issues were published in 1975 and 1976.²² Another recent publication of the WMA is a brochure, which presents the basic concepts of weather modification, discusses the involvement of various levels of government, and relates some facts on the WMA itself.²³

Since 1968 the WMA has officially supported the concept of developing a model law for regulation of weather modification activities at the State and/or Federal level. A main feature of such a law would be the establishment of a weather modification board, whose membership would be selected mainly from the private sector, representing interests concerned with water resources as they affect agriculture and industry. The envisioned board would perform various functions such as licensing, review, and recordkeeping. The WMA also supported the formation of the Advisory Board on Weather Modification by the Secretary of Commerce to conduct the study and prepare the report required by the National Weather Modification Policy Act of 1976.²⁴

One of the purposes of the WMA is to certify individual members who are deemed to be qualified to direct weather modification operations and/or experiments. Certification is granted only upon the unanimously favorable vote by a certification board, which examines each applicant in the areas of knowledge, experience, and character. The WMA considers certification to be desirable in order to “* * * accomplish other purposes of the association, namely, promoting research and engineering advancement, encouraging and promoting the highest standards for professional conduct, and assisting in arranging liability insurance upon application from members performing operations or experiments.”²⁵ As of April 1977 the WMA had certified 35 of its members, the majority of whom are officers and/or meteorologists with weather modification contractors; however, others are associated with universities or with various public and private organizations. Two of the certified members are Mexican, and the remainder are from the United States.²⁶

The WMA has been considering the adoption of a statement on standards and ethics for weather modification operators. A draft statement, prepared by the WMA committee on standards and ethics, was presented to the members at the 1977 fall meeting for review and comment and will be considered for its adoption or further modification at the 1978 spring meeting. Copies of the WMA proposed draft statement on standards and ethics for weather modification operators, the WMA constitution and bylaws, and the qualifications and procedures for certification by the WMA are all contained in appendix N.

²² The latest available issue of *The Journal of Weather Modification* is vol. 10, No. 1, April 1978. All previous issues of the journal are available from the Weather Modification Association, P.O. Box 8116, Fresno, Calif. 93727.

²³ Weather Modification Association, “Weather Modification; Some Facts About Seeding Clouds,” Fresno, Calif., August 1977, 16 pp.

²⁴ Griffith, et al., testimony before the Weather Modification Advisory Board, 1977.

²⁵ Qualifications and procedures for certification by the Weather Modification Association, *The Journal of Weather Modification*, vol. 9, No. 1, April 1977, p. 202.

²⁶ “Weather Modification Association: Certified Members,” *The Journal of Weather Modification*, vol. 9, No. 1, April 1977, p. 208.

In July 1977, the Chairman of the U.S. Department of Commerce Weather Modification Advisory Board invited the officers of the WMA to provide testimony on the purposes and activities of the association. A series of questions was also forwarded to the WMA, asking that responses be provided to the Board when its officers appeared at its October meeting. The responses to these questions, prepared by the executive committee of the WMA, serve to provide an insight into the current position of the WMA on weather modification policy issues. The questions from the Weather Modification Board and the WMA responses follow:²⁷

A. What should be the role of the Federal Government in supporting emergency operations? In supporting long-term location projects? What should the State role be?

1. What should the role of the Federal Government be in supporting emergency operations?

The WMA has had a rather longstanding policy statement relevant to this subject. The statement was originally prepared a few years ago when drought conditions in the Midwest began to seriously impact on the agricultural community. In general, this WMA position dealt with the feasibility of cloud seeding programs during drought conditions, the preferred choice of operational capabilities, and the availability of equipment and professional personnel. The following points summarize the WMA position:

Cloud seeding should not be considered a panacea for drought relief although the technology may produce some economic benefit if the programs are properly designed and conducted during drought periods.

Cloud seeding should be considered one of many water resources management tools available for use when meteorological conditions indicate a reasonable potential for beneficial results.

The Federal Government should support emergency operations through a close interface with individual State agencies. However, there needs to be a strong recognition that seedable clouds are probably scarce during drought periods and opportunities may be minimal.

The extensive field experience within the private sector should be called upon to provide a strong operational input to these emergency operations if it is finally decided that such programs have a reasonable chance of producing a beneficial result.

Because of the Federal Government's historic role in weather modification research, the appropriate Government agencies should provide backup capability to these programs in the form of monitor and evaluation systems. If the Federal Government is to accept responsibility for initiating emergency programs, it must also accept responsibility for potential damage liability covering the results.

2. In support of long-term local projects?

Here again, the WMA has developed over the years some specific position papers with respect to long-term local programs. Some of the primary points are: The WMA supports Federal Government inputs to local long-term programs, particularly if these inputs are research oriented and are designed to provide information which can improve future operations plus assist in the careful evaluation of results.

3. What should the State role be?

²⁷ Griffith, et al., testimony before the Weather Modification Advisory Board, 1977.

The WMA supports a strong State role in weather modification. Where States have demonstrated a reasonable willingness to organize and administer weather modification activities, the Federal Government should encourage and assist these programs, particularly in the areas of research, monitoring, and evaluations.

States should develop statutes which address licensing and permit requirements. There is a high priority requirement for strong administration of these statutes through a set of rational rules and regulations.

The States should be responsive to cooperative Federal Government assistance in the form of research activities and should make their programs available to such "piggy back" activities.

B. Are Federal regulations, permits, licensing, and so forth, desirable?

1. Federal regulations are presently limited to reporting of weather modification activities including times, amounts, locations, and purposes. These activities have been valuable and have apparently not placed undue burden on most operators. These reporting activities should be continued with due consideration being given to a consolidation or uniformity of State and Federal reporting requirements to eliminate unnecessary duplication. No other Federal regulations are considered to be necessary at this time.

2. Permits to operate are considered to be essential in order to have a mechanism for resolving potential conflicts in local interests. Because of the urgent need to respond effectively to these local problems it is considered necessary that the permits be granted at a State level. Federal permits do not appear to be a viable solution.

3. Licenses, as well as permits, are granted by a number of States. The license has the role of passing judgment on the operator, while the permit is granted on a project basis. The requirements for licensing are generally very loose in keeping with our limited ability to define the caliber of the operator in definitive terms. The mechanism for examining the qualifications of operators, however, exists in a number of States and can be utilized to screen out the incompetent operators, if needed. As our ability to evaluate operators becomes more definitive, the machinery exists to become increasingly demanding of the applicants' qualifications. The licensing function is intimately associated with the permit process and should stay at the State level for the present.

4. A principal argument for Federal permits and/or licensing relates to interstate transport of seeding material and potential extra area effects. The few cases of this type which have arisen have been handled on a case basis. At such time as the regular seeding operations become more widespread and when the evidence of downwind effects becomes better documented, the need for the Federal licensing or permit process may become apparent. For the time being, it is the opinion of the WMA that the process should be left in State hands but be made more uniform so as to include separate licensing and permit functions.

5. The concept of an independent, licensed designer for each project was vigorously opposed by a number of WMA members. These members felt that the required expertise for the proper design of a specific program frequently rested within one individual group by reason of

experience or background. An independent designer, called in from the outside, could not be expected to know the specific meteorology and terrain of each area as well as those already experienced in the area or in similar storm types. There was no objection expressed by this group to the concept of a licensed group or individual within the group being required for project design. The concept of an independent designer with infinite wisdom for a variety of projects, however, was strongly rejected.

A further consideration is the damage that such a concept would have to the opportunities for growth in technical competence for the private weather modification operator. Importation of the outside designer would severely restrict the operator from developing the internal technical stature and strength so vital for the development of competency in the field.

C. Are there established professional standards for weather modifiers? Does the WMA have an active ethics review process?

Although there are no established standards for weather modifiers, this matter has received considerable attention within the WMA. At the 1977 spring meeting an ad hoc Committee on Standards and Ethics was established. Two meetings of the committee with some correspondence in the interim resulted in a draft statement which was submitted to the membership at the 1977 fall meeting on October 10. The draft was referred back to the ad hoc committee and is expected to come up again at the 1978 spring meeting. The code of ethics contained in the proposed statement covers relationships between WMA members and governmental agencies, the general public, clients, and other members of the meteorological profession. While there has been no active ethics review process so far, it is expected that such a process will be activated following adoption of a code. The proposed statement also sets forth standards for individual projects, covering such points as staffing, public disclosure of methods, and the need for evaluation.

For the last several years, the WMA has sought to improve professional standards by a certification program. It is hoped that this certification program will be strengthened by the adoption of a code of ethics and a statement of requirements for individual projects.

D. Is communication between weather modification operators and scientists a problem? If so, how can it be improved?

The WMA has provided an effective channel for communications between weather modification operators and scientists. These individuals come from diverse backgrounds. In addition to twice yearly meetings, the WMA publishes an annual Journal of Weather Modification which receives widespread distribution.

Communications between operators and scientists could, of course, be improved. The need for improved communications is due in part to the expansion of weather modification operations and the recent increased awareness of man's impact on his environment.

Other means of communications available (outside of the WMA) include the scientific literature, scientific conferences, personal contact, and the publication of informational pamphlets and policy statements.

Interdisciplinary conferences on weather modification should be encouraged. Scientists should be directly exposed to field programs whenever possible to gain firsthand knowledge of the modification tech-

niques employed and the problems encountered by the weather modification operators.

American Meteorological Society

The stated purposes of the American Meteorological Society (AMS) are: The development and dissemination of knowledge of meteorology in all its phases and applications, and the advancement of its professional ideals. The society shall be a nonprofit organization and none of its net income or net worth shall inure to the benefit of its members. In event of dissolution, any property belonging to the society shall be donated to some organization or organizations of a similar purpose and character, and in no event shall any of such property be distributed to members of the society.²⁸

Members of the AMS number about 900 and include meteorologists and other scientists whose interests and activities cover the complete range of atmospheric sciences and services, well beyond the scope of weather modification. The organization of the AMS was recently reviewed in the Bulletin of the American Meteorological Society.²⁹ Considerable attention has been given to weather modification within the AMS, however, and a number of its members are or have been participants in research and operational aspects of the field. While some AMS members are engaged full-time in weather modification activities others are partly or intermittently involved, depending upon their current interest, research funding, or particular management responsibilities.

The AMS took an early interest in weather modification when it was urged by the Director of the Weather Bureau to look into what were considered extravagant claims of Langmuir on the effects of his cloud seeding operations.³⁰ Accordingly, the AMS issued its first policy statement on weather modification, which was somewhat conservative in tenor, and, without refuting Langmuir's claims directly, stated that it was not yet proven that cloud seeding could produce economically significant amounts of rain.³¹

The AMS provides a means for exchange of ideas and findings, particularly in the research aspects of weather modification, through its journals and other publications, through professional meetings, and through the deliberations within its committees and governing bodies. The society has a Committee on Weather Modification, established in 1968, which is quite active and has from time to time produced public statements on the state of the art of weather modification. Some of these have been adopted by the council of the AMS, the most recent one in January 1973. (Policy statements of the AMS may not necessarily coincide with those of its subordinate committees, such as the one on weather modification.) The 1973 AMS policy statement is reproduced in appendix O; it summarizes the status of planned weather modification, inadvertent weather modification, public issues, and recommendations for further activities, noting that changes which had

²⁸ Constitution and bylaws of the American Meteorological Society, art. II. Bulletin of the American Meteorological Society, vol. 58, No. 8, August 1977, p. 721.

²⁹ "Organization of the American Meteorological Society," Bulletin of the American Meteorological Society, vol. 57, No. 8, August 1976, pp. 900-907.

³⁰ See the history of weather modification, discussed in ch. 2, for the background of this controversy.

³¹ Elliott, "Experience of the Private Sector," 1974, pp. 84-85.

occurred since the previous 1967 statement had dictated such an update.³² Since the official AMS position of the society is that all policy statements are valid only for 3 years after issue, there is technically no official AMS statement on weather modification. The 1973 statement is currently being reevaluated and revised; however, no major changes are contemplated.³³

The frame of reference for the AMS committee on weather modification follows:

Established in 1968 to promote and guide the society's contributions to the increasingly important field of weather modification, this committee is responsible for keeping abreast of one of the more challenging and promising interfaces between meteorology and society. The functions of this committee are the following:

1. To serve as the official arm to relate the society to the large segments of the public who are affected by, interested in, or concerned about weather modification.
2. To develop and update official policy statements on weather modification as may be needed by the society.
3. To plan and oversee the society's major meetings and conferences on weather modification.
4. To provide a platform for atmospheric scientists and other specialists to discuss the results of their research and to develop general guidelines for future research in weather modification.
5. To advise the society of current activities, trends, and prospects for weather modification by means of an annual report to the society's Scientific and Technological Activities Commission.
6. To promote advancement in the broader aspects of weather modification including: (a) the societal utilization, planning, and management of weather modification; (b) experimental design and evaluation, simulation, and prediction, and modification technology; (c) technological mitigation of weather hazards; and (d) the use of land and energy resources to achieve more desirable responses in weather and climate.³⁴

The AMS committee on weather modification has been instrumental in planning and conducting a series of AMS national weather modification conferences. The first of six such conferences was held in 1968 at the State University of New York at Albany.³⁵ The first conference was part of a call for an assessment of the technical status of weather and climate modification and stemmed from a recommendation received by the AMS from the Interdepartmental Conference on Weather Modification, the annual meeting of representatives of Federal Government agencies engaged in weather modification.^{36, 37}

The second, third, and fourth AMS conferences on weather modification were held, respectively, in Santa Barbara, Calif., in April 1970;

³² Policy statement of the American Meteorological Society on purposeful and inadvertent modification of weather and climate. *Bulletin of the American Meteorological Society*, vol. 54, No. 7, July 1973, pp. 694-695. (Adopted by the AMS Council, January 28, 1973.)

³³ Baum, Werner A. (President of the American Meteorological Society). In testimony before the U.S. Department of Commerce Weather Modification Advisory Board. *Champaign, Ill.*, October 14, 1977.

³⁴ Frames of reference for scientific and technological activities committees. *Bulletin of the American Meteorological Society*, vol. 55, No. 8, August 1974, p. 1011.

³⁵ American Meteorological Society. "Proceedings of the First National Conference on Weather Modification," Apr. 28-May 1, 1968, Albany, N.Y., Boston, 1968, 532 pp.

³⁶ *Ibid.*, p. i.

³⁷ See section on coordination of Federal weather modification activities, ch. 5, p. 223.

in Rapid City, S. Dak., in June 1972; and in Fort Lauderdale, Fla., in November 1974.^{38, 39, 40} The third conference, at Rapid City, was co-sponsored by the irrigation and drainage division of the American Society of Civil Engineers.

The fifth AMS conference was coincident with the Second Conference on Weather Modification, sponsored by the World Meteorological Organization (WMO) during August 1976 in Boulder, Colo.⁴¹ The AMS was a cosponsor of this conference along with the International Association of Meteorology and Atmospheric Physics (IAMAP) of the International Union of Geodesy and Geophysics.

The sixth AMS conference, held in Champaign, Ill., in October 1977, was cosponsored by the American Society of Civil Engineers and the Weather Modification Association.⁴² This was the first conference in which a significant number of papers on inadvertent weather modification were presented, and the title of the conference reflected this new emphasis. The sixth AMS conference was also the occasion for two other related weather modification meetings, also held in Champaign, during and after the AMS meeting. The Weather Modification Association, a cosponsor of the technical conference, conducted its regular fall business meeting; and the U.S. Department of Commerce Weather Modification Advisory Board conducted its fifth meeting, during which testimony was provided to the board from various groups, particularly officers of professional organizations concerned with weather modification.

Because of the particular division of interests within the AMS, one major aspect of weather modification, the suppression of hurricanes and other severe tropical storms, has not been a concern of the Committee on Weather Modification, nor have papers on this subject generally been presented at the AMS weather modification conferences. Modification of such storms has been considered as one part of the overall subject of tropical meteorology and has, therefore, received the attention of another AMS committee, the Committee on Hurricanes and Tropical Meteorology. That committee has been responsible for planning and sponsoring a number of technical conferences on hurricanes and tropical meteorology, at which papers on hurricane modification are customarily given. There is also an overlap between the functions of the Committee on Weather Modification and the Committee on Cloud Physics. AMS conferences are sponsored in both subject areas; the more applied papers tend to be given at the weather modification conferences, while those on more basic cloud research are presented at cloud physics conferences. The distinction is sometimes blurred, however, so that many papers can easily fall into either category.

At least seven periodicals are published by the AMS. While there is not a single journal devoted to weather modification, papers on the

³⁸ American Meteorological Society, "Second National Conference on Weather Modification" (preprints), April 6-9, 1970, Santa Barbara, Calif., Boston, 1970, 440 pp.

³⁹ American Meteorological Society, "Third Conference on Weather Modification" (preprints), June 26-29, 1972, Rapid City, S. Dak., Boston, 1972, 336 pp.

⁴⁰ American Meteorological Society, "Fourth Conference on Weather Modification" (preprints), Nov. 18-21, 1974, Fort Lauderdale, Fla., Boston, 1974, 575 pp.

⁴¹ World Meteorological Organization, papers presented at the Second WMO Conference on Weather Modification, Aug. 2-6, 1976, Boulder, Colo. Secretariat of the World Meteorological Organization, Geneva, Switzerland, 1976.

⁴² American Meteorological Society, "Sixth Conference on Planned and Inadvertent Weather Modification," Oct. 10-13, 1977, Champaign, Ill., Boston, 396 pp.

subject most often appear in the Bulletin of the American Meteorological Society and in the Journal of Applied Meteorology; articles of a survey nature appear in the former, and more technical contributions are found in the latter. Pertinent papers are also cited in the AMS Meteorological and Geostrophysical Abstracts. Among the many publications of the AMS is a glossary of weather modification terms.⁴³

In 1973 a group of scientists at the University of Washington, in consultation with a number of experts from other organizations, conducted a study and prepared a report, intending to clarify some policy issues relating to weather modification.⁴⁴ The AMS took the initiative in publishing this report and distributing it to a large number of State and Federal Government officials.

Members of the AMS may become certified consulting meteorologists, upon meeting qualifications in the areas of knowledge, experience, and character, as determined by an AMS board of certified consulting meteorologists. Such certification is a formal recognition that the applicant is well qualified to carry on the work of a consulting meteorologist. The fivefold purpose of certification is stated as follows:

(1) To foster the establishment and maintenance of a high level of professional competency, and mature and ethical counsel, in the field of consulting meteorology.

(2) To provide a basis on which a client seeking assistance on problems of a meteorological nature may be assured of mature, competent, and ethical professional counsel.

(3) To provide incentive for the continued professional growth of the meteorologist after completion of his academic training.

(4) To enhance the prestige, authority, success, and emoluments of consulting meteorology specifically, and of professional meteorology generally, by encouraging such a consistently high order of professional activity that unqualified practitioners will either labor to achieve this recognition or retire from the field.

(5) To provide a guide for eventual licensing of consulting meteorologists by State governments.⁴⁵

As of August 1977 there were 169 certified meteorologists in the AMS. While these certified consulting meteorologists are involved in a large variety of public-oriented professional services, this certification would also be applicable for some who are engaged in weather modification, although the certification discussed in the previous section on the Weather Modification Association applies more directly to such professional services. A few meteorologists are certified by both the AMS and the WMA.

Recently the president of the AMS, Dr. Werner A. Baum, and the chairman of its Committee on Weather Modification, Dr. Bernard A. Silverman, testified before the U.S. Commerce Department's Weather Modification Advisory Board and answered questions from the Board on weather modification positions of the AMS. Dr. Baum expressed

⁴³ American Meteorological Society, "Glossary of Terms Frequently Used in Weather Modification," Boston, 1968, 59 pp. (This glossary was prepared initially by the AMS for use in the Second Seminar for Science Writers on Weather Modification, New York City, Apr. 25, 1968, sponsored by the AMS and the National Association of Science Writers.)

⁴⁴ Fleagle, Robert G., James A. Crutchfield, Ralph W. Johnson, and Mohamed F. Abdo, "Weather Modification in the Public Interest," Seattle, American Meteorological Society and the University of Washington Press, 1974, 88 pp.

⁴⁵ Certification Program for Consulting Meteorologists, bulletin of the American Meteorological Society, vol. 58, No. 8, August 1977, p. 798.

his opinion that weather modification needs a major research effort and that its future is bright in view of its potential for benefiting humanity. He felt that the Federal Government ought to take a more dominant role, since the various State actions have been taken with little uniformity, but urged that the functions of regulation and operation be separated in any Federal organizational structure.⁴⁶

Dr. Silverman discussed in detail the areas of atmospheric research which the AMS Committee on Weather Modification has identified as significant for the progress of weather modification. These included cloud physics, precipitation forecasting, cloud climatology, and inadvertent weather effects. (These research recommendations were presented in an earlier chapter in connection with a discussion of weather modification research needs.)⁴⁷ He urged support for a strong research program, emphasizing the continued need for university research and for continued support by the National Science Foundation.⁴⁸

OPPOSITION TO WEATHER MODIFICATION

General discussion

There are individuals and groups who for one reason or another voice strong opposition to weather modification. Sometimes with little or no rational basis there are charges heard that various otherwise unexplained and usually unpleasant weather and weather-related events are linked to cloud seeding. Such events might include droughts, floods, severe storms, and extreme temperatures. Often charges are made, again usually without substantiating data, that the silver iodide from cloud seeding has caused harm to vegetation or polluted water supplies.

There are also cases in which some farmers are economically disadvantaged through receiving more or less than optimum rainfall for their crops, when artificial inducement of these conditions may have indeed been beneficial to those growing different crops whose moisture requirements are out of phase in time with those of the disadvantaged farmer. A frequent complaint of some farmers is that hail suppression to reduce damage to ripening fruit in orchards has attendantly reduced the needed rain for growth of field crops.

Sometimes disastrous events have occurred during or soon after cloud seeding, and, rightly or wrongly, they have been associated with the seeding. The June 1972 flooding from excessive rainfall in the Rapid City, S. Dak., area is an example of such a disaster which occurred nearly simultaneously with cloud seeding operations in the vicinity by the South Dakota School of Mines and Technology. Though subsequent technical evaluations disclaimed any direct connection between the flooding and the seeding, opposition in the form of legal suits and general public reaction persists today.

Opposition to the seeding project above Hungry Horse Dam

Elliott recounts an interesting case where opposition developed to a seeding project which his company, North American Weather Consultants, had conducted for five winter seasons from 1967-68 through

⁴⁶ Baum, testimony before the Weather Modification Advisory Board, 1977.

⁴⁷ See p. 139, ch. 3.

⁴⁸ Silverman, Bernard A., "Testimony Before the U.S. Department of Commerce Weather Modification Advisory Board," Champaign, Ill., Oct. 14, 1977.

1970-71.⁴⁹ This project, carried out for the Bonneville Power Authority under contract to the Bureau of Reclamation, required seeding to increase snowpack over the watershed above Hungry Horse Dam in northwestern Montana. Increased water for hydroelectric power generation would result in less interruption in industrial power and more steady employment in adjacent regions of Montana, Idaho, Washington, and Oregon.⁵⁰

Local opposition to the program was sharp, however, on the basis of the possible reduction in the elk population in the nearby Bob Marshall Wilderness Area; an estimated additional 10 percent in snowpack was considered capable of destroying the browse needed by the elk in the winter. The influx of elk hunters each year, spending about \$100 per day each, was an important source of income to the area, and seeding was regarded as a threat to the hunting industry. Fears were quieted, however, after a successful program of explaining and teaching about cloud seeding. Over the 5 years during which seeding occurred, the elk herds grew larger than they had ever been before.⁵¹

Tri-State Natural Weather Association

Sometimes the groups opposing weather modification are organized so that they can more effectively solicit and influence public opinion for general support of their opposition, or so that they can more effectively bring suits or injunctions against weather modifiers. One of the more persistently vocal groups, active in the Potomac Valley region of the Mid-Atlantic States, is the Tri-State Natural Weather Association, discussed in the next section. Activities of an opposition group in Colorado are considered in a subsequent section.

In the 1960's, a drought affecting much of the Northeast was blamed in some counties of West Virginia, Maryland, and Pennsylvania on cloud seeding. A local group of orchardists, the Blue Ridge Weather Modification Association, had been contracting with various commercial firms to suppress hail in the region. With the increasing drought, intense opposition developed against both the seeding company and the orchardists. Bills outlawing weather modification were introduced in the legislatures of Maryland, Pennsylvania, and West Virginia, at the urging of an organized group called the Natural Weather Association. A bill passed the Maryland legislature making weather modification illegal; however, this act has since been repealed. Though no measures were enacted in the other States, ordinances prohibiting cloud seeding were passed in several south-central Pennsylvania counties, and a generally negative public reaction to weather modification persists throughout this region. There has been no seeding for some years in Pennsylvania.⁵² In 1969 Pennsylvania and West Virginia, both passed weather modification laws that did not prohibit weather modification, but they were so restrictive that many operators felt that their activities were ruled out for all practical purposes.

With the breaking of the drought of the 1960's and several years of wet weather, some of the controversy subsided. However, the successor to the Natural Weather Association, the Tri-State Natural Weather Association, Inc., has continued strong opposition to cloud seeding and

⁴⁹ Elliott, "Experience of the Private Sector," 1974, p. 84.

⁵⁰ *Ibid.*

⁵¹ *Ibid.*

⁵² *Ibid.*, pp. 82-83.

has maintained charges that such seeding activities have been carried out illegally in the region, both by operators under contract to the Blue Ridge Weather Modification Association (the group of orchardists seeking hail suppression) and by the U.S. Air Force, while State enforcement officials have "looked the other way." Tri-State has charged that :

Defense Department aircraft work all weather patterns in the mid-Atlantic States. One section of heavy concentration is the southern tier of Pennsylvania counties; according to the Federal Aviation agency, there are as many as 160 flights in a twenty-four hour period. These aircraft disperse ice nuclei at almost infinity concentrations [sic] and inject it into the atmosphere, starting 24 to 48 hours before weather patterns move into the area. This seeding will dissipate all summer cumuli storms. In the winter, snows are changed into rain with the possibility of some increase of precipitation. This additional winter rain helps make the annual precipitation record look decent. However, rain during the winter leaches the soil of fertility and severely erodes crop fields. Snow is so desperately needed for a cover to prevent this damage as well as protection to prevent heaving of perennials such as alfalfa.⁵³

With regard to enforcement of State laws requiring licensing, and regulation of weather modification, the following accusation has been made :

Pennsylvania has earned a reputation of lawlessness relative to cloud seeding. The past two Secretaries of Agriculture have both stymied all efforts to regulate weather modification. The Pennsylvania State University has engaged in black-mail activities against those who want the law enforced, have conducted research in contempt of the law and lied about the outcome of their own results of cloud seeding. These various agencies have all helped to obstruct law enforcement in the State of Pennsylvania : Department of Agriculture, Bureau of Aviation, Federal Aviation Agency, Federal Bureau of Investigation, the Pennsylvania State University, and all branches of the Federal Government who have or are doing cloud seeding work. A meteorological Watergate !⁵⁴

Public sentiment in the Potomac Valley, especially among farmers, has remained strongly opposed to weather modification of all kinds, and Tri-State Natural Weather Association has continued to lead the opposition. Once charging only that hail suppression had caused decreased rainfall at critical times for farmers, they later also claimed that cloud seeding materials pollute the atmosphere and induce cancer and even credited abnormally heavy rainfall to seeding operations. Paul Hoke, president of Tri-State once stated :

There's no question that during a dry season, cloud seeding aggravates conditions to produce drought, and during a wet cycle, it triggers even more rain and probably floods.⁵⁵

With the return of especially dry conditions in very recent years, a new wave of opposition was aroused and new charges of illegal cloud seeding have been forthcoming from the Tri-State Association. Its vice president, Dr. Edmund R. Hill, professor of earth science at Gettysburg College and a member of the Pennsylvania Weather Modification Board, stated that :

According to complaints we get, the pattern is still remaining as it did in the early 1960's. When a thunderstorm appears to the west or is starting to build up, a plane will move in mysteriously out of nowhere, and maybe fly once or twice

⁵³ Tri-State Natural Weather Association, "Cloud Seeding ; the Crime of the Century," St. Thomas, Pa. (no publication date), p. 2.

⁵⁴ *Ibid.*, p. 1.

⁵⁵ Elliott, "Experience of the Private Sector," 1974, p. 84.

along the leading edge of the thunderstorm, disappear, and the thunderstorm just practically dissipates.⁵⁶

In a recent article contributed by the Tri-State Natural Weather Association to a nationally circulated publication devoted to organic agriculture, the following evils, supposedly brought on by weather modification, were cataloged:

1. Cloud seeding has been responsible for the great 5-year drought in the Northeast United States.
2. Isolated sections in the Northeast have experienced 18 years of drought due to cloud seeding.
3. Weather disturbances in the South Atlantic [sic] have been eliminated and has reduced [sic] the east coast's rainfall by 30 percent—rain that is needed if agriculture is to be successful.
4. The average dairy farmer on the east coast, living in an area of cloud seeding, has averaged a net financial loss because of cloud seeding.
5. Crop production losses in Franklin County, Pa., alone have amounted to \$50 million.
6. When effects of seeding wear off, cloudbursts occur, causing floods, destroying crops, buildings, and drowning people as well as livestock.
7. Seeding has been responsible for the serious air pollution problems.
8. Mental retardation and insanity are traceable to cloud seeding chemicals.
9. Poisoning of all living matter is directly related to cloud seeding.
10. Emphysema is three times higher in areas of heavy cloud seeding.
11. Cancer is virulently out of proportion.
12. Financial losses to agriculture and related industries run into the billions.
13. Forest trees as well as cultivated orchards are dying from chemical reactions taking place in the air due to the addition of cloud seeding agents.
14. The atmosphere has been rendered completely biologically incompatible with all living matter, which includes animals, plants, and humans.⁵⁷

Tri-State reported that it has requested the President of the United States to announce a ban on all cloud seeding on or over the Appalachian Mountains and the Atlantic Coastal Plain for 3 years, or until a Federal regulatory commission is established, in order to "permit the economy to recover."⁵⁸

Citizens for the Preservation of Natural Resources

Commercial cloud seeders were welcomed by many farmers throughout the High Plains region in the 1950's when that region was hit by a severe drought; and, even after the drought subsided, interest in weather modification continued. In the San Luis Valley of southern Colorado, where precipitation averages 6.5 inches per year and where

⁵⁶ Hill, Edmund R., in testimony, U.S. Congress, House of Representatives, Committee on Science and Technology, Subcommittee on the Environment and the Atmosphere, "Weather Modification," hearings, 94th Cong., 2d sess., June 15-18, 1976, p. 372.

⁵⁷ Tri-State Natural Weather Association, "The Rain-Making Myth," Acres, U.S.A.; a Voice for Eco-agriculture, vol. 7, No. 6, June 1977, Kansas City, Mo., pp. 37-38.

⁵⁸ *Ibid.*, p. 39.

crop-damaging hail storms inflict their tolls during summer months, there has been a continuing interest in the potential for mitigating these effects through weather modification. In particular, Moravian barley, an important cash crop used in beer manufacture, is especially susceptible to damage from hail and dampening from too much rain during its critical 6-week ripening and harvest period in late summer. As a possible means of reducing such damages, William K. Coors, president of the Coors Co., which had contracted to buy most of this crop from local barley growers, initiated a weather modification program for the San Luis Valley which was designed to suppress hail and divert rainfall during this critical season.⁵⁹

Barley growers in the five-county San Luis Valley were outnumbered by other kinds of farmers and ranchers, however, whose interests were not benefited from decreased rainfall, though suppression of hail was of some interest to them. As a result, weather modification became controversial and many farmers were convinced that cloud seeding was responsible for the 1970 drought. That year about 400 ranchers and farmers banded into a group then called the San Luis Citizens Concerned About Weather Modification; subsequently, its name was changed to Citizens for the Preservation of Natural Resources. By 1971, valley people were demanding that weather modification be stopped, and many charges, some farfetched, were made in opposition to the seeding project. When citizens of the valley learned that current State law could not restrain weather modifiers once they had obtained licenses, there was a campaign, led by State Representative Clarence Quinlan, himself a rancher in the valley, to enact a new weather modification statute in Colorado. Since sentiment about weather modification throughout the State was mixed, the new law passed by the legislature in 1972 did not ban such activities but does require closer regulation and public hearings in local areas affected. It is required that operators clearly show prospects for economic benefit before a permit is granted.⁶⁰

In 1972, in spite of much local opposition to the seeding project, and the recommendation for permit denial by the hearing officer, the permit was granted with the stipulation that the suppression effort include hail but not rain. Opposition grew stronger by November, however, and, at the request of the Citizens for the Preservation of Natural Resources, county commissioners placed an advisory referendum on the ballot in the five valley counties. The vote went heavily against weather modification throughout the valley, including Rio Grande County where most of the barley is grown. In a letter to each of the barley growers, Coors threatened to eliminate its barley purchases from the valley if the weather modification program were not conducted in 1973 and subsequent years. Both sides were represented by legal counsel and technical witnesses at the controversial spring hearing in 1973; however, there was no concrete evidence presented by witnesses on either side showing an increase or decrease in rainfall from past seeding. This second round of permit hearings resulted again in a recommendation against

⁵⁹ Carter, Luther J., "Weather Modification: Colorado Heeds Voters in Valley Dispute," *Science*, vol. 180, No. 4093, June 29, 1973, p. 1347.

⁶⁰ *Ibid.*, pp. 1347-1348.

the permit from the hearing officer. This time the advisory committee concurred in the recommendation and the State's natural resource director denied the permit.⁶¹

Coors did carry through with the threatened cutback of barley purchases; however, the barley growers are now receiving contracts with another brewery which seems less concerned with the consequences of weather modification. It has been reported that Valley Growers, Inc., the organization of barley farmers in the San Luis Valley, are producing more barley than ever.⁶²

No further summertime hail modification has been conducted in the San Luis Valley, though Valley Growers, Inc., still interested in benefits from weather modification, decided in 1975 to sponsor an operational snowpack enhancement project in the mountains west of the valley to increase the water supply from runoff. Though former opponents opposed this new project, they agreed to discuss the situation and aired their concerns before the project's sponsors and operator. The meeting resulted in an agreement between project supporters and opponents that became the condition under which the project was to be conducted. The condition called for (1) a citizen committee to monitor operations, and (2) veto authority by a majority of the committee to suspend operations at any time during the winter season. Both proponents and opponents from different geographical regions affected by the operations were represented on the committee, and a committee member was contacted for clearance prior to each planned seeding operation. This is the only known instance of an organized opposition group agreeing to permit a weather modification project after successfully stopping earlier operations. It is possible, however, that there was less public opposition and skepticism in the case of the newer project, owing to the different goals and effects of snowpack enhancement compared with hail suppression and possible attendant rainfall decrease.⁶³

⁶¹ *Ibid.*, pp. 1349-1350.

⁶² Tri-State Natural Weather Association, Inc., "The Rain-Making Myth," 1977, p. 15.

⁶³ Changnon, Stanley A., Jr., Ray Jay Davis, Barbara C. Farhar, J. Eugene Haas, J. Lorena Ivens, Martin V. Jones, Donald A. Klein, Dean Mann, Griffith M. Morgan, Jr., Steven T. Sonka, Earl R. Swanson, C. Robert Taylor, and Jon van Blokland, "Hail Suppression: Impacts and Issues," final report, Technology Assessment of the Suppression of Hail, ERP75-09980, National Science Foundation, Illinois State Water Survey, Urbana, Ill., April 1977, pp. 48-50.

CHAPTER 9

FOREIGN ACTIVITIES IN WEATHER MODIFICATION

(By Robert E. Morrison, Specialist in Earth Sciences, Science Policy Research Division, Congressional Research Service)

INTRODUCTION

The United States has been the world leader in weather modification research and operations, particularly since World War II, following the historic discoveries of Schaefer and others. Nevertheless, other countries have also been active in the field, notable among which is the Soviet Union. Activities in that country as well as those of some other nations with larger programs will be discussed in a later section of this chapter.

Information on foreign weather modification activities is not uniformly documented and is not always available. Some information has been provided through papers which appear in professional journals or are delivered at professional meetings in this country or abroad.¹ There is also information exchange through contacts with U.S. meteorologists who have visited, or have been visited by, their foreign counterparts. However, expenditures for weather modification activities in a given country are seldom identified, and the size and significance of the program in a country may be judged disproportionately by the abundance or dearth of published or other information received through various channels.

Changnon has collected data from a wide variety of sources which show that, since the opening of the modern era of weather modification following World War II, planned weather modification projects have existed at various times in at least 62 nations through the year 1973.² His tabulations take into account only those projects directed toward precipitation enhancement and/or hail suppression; 57 of the countries identified had projects aimed at increasing precipitation, while in 14 countries projects were designed to decrease hail. In 9 countries there were projects with both goals. These 62 nations, shown on the map in figure 1, are distributed over all the world's continents except Antarctica.

Although the locations of the performance of the rain and hail modification projects are shown in figure 1, the country of origin of support of weather modification operations is not always evident. Thus, while projects in the countries of Europe, much of North America, and a few other developed countries like Israel, Japan, and the USSR have involved their own scientists and resources; most of the

¹ Charak, Mason T., "Weather Modification Activity Reports; Calendar Year 1975," National Oceanic and Atmospheric Administration, Office of Environmental Monitoring and Prediction, Rockville, Md., June 1966, p. 48.

² Changnon, Stanley A., Jr., "Present and Future of Weather Modification; Regional Issues," *The Journal of Weather Modification*, vol. 7, No. 1, April 1975, p. 167.

projects in South America, Africa, and Southeast Asia were undertaken by American companies or with American financial and technological support.³

In an attempt to assemble uniform information on the weather modification activities of member nations, the World Meteorological Organization (WMO) in 1975 instigated a system of reporting of, and maintaining a register on, such activities. This WMO mechanism for collection and dissemination of weather modification project data is discussed in the next section.

³ *Ibid.*, p. 170.

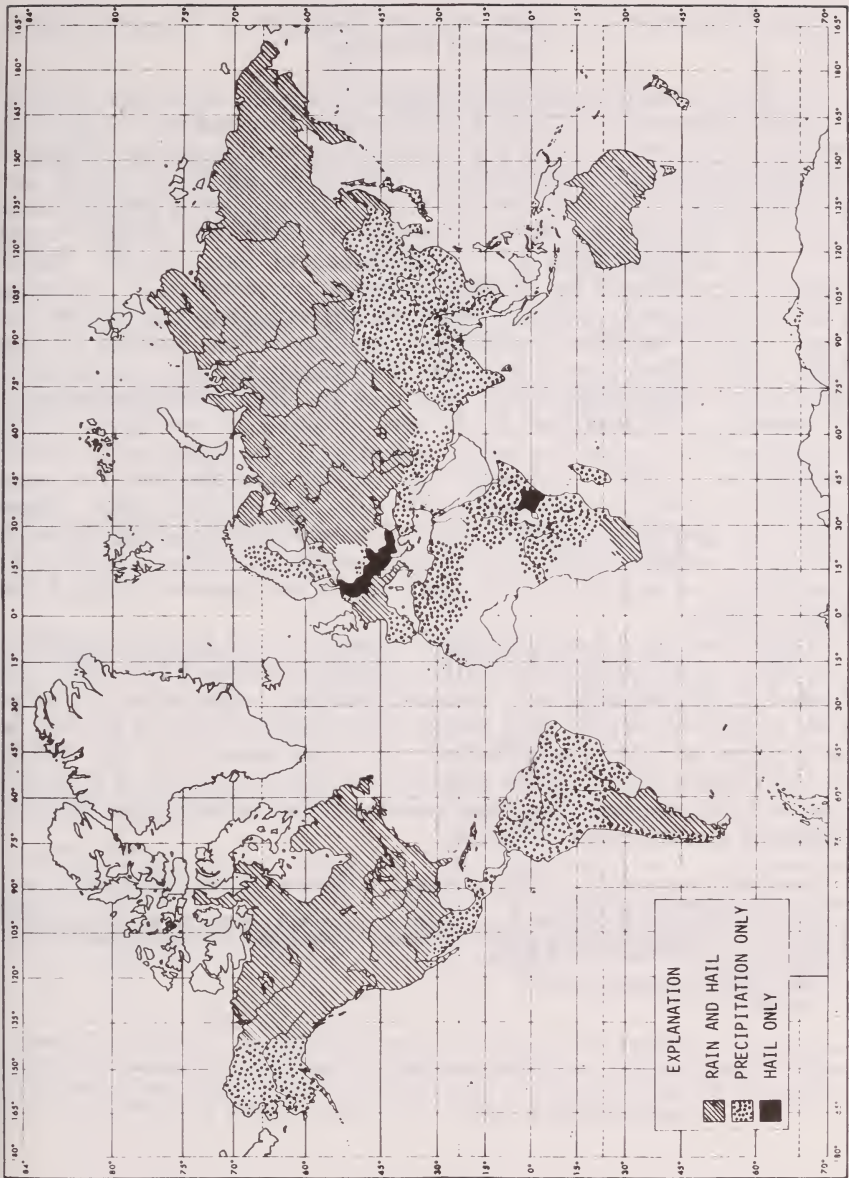


FIGURE 1.—Nations in which weather modification (rain enhancement or hail suppression) has been employed during all or portions of the 1946-73 period. (From Changnon, *Present and Future of Weather Modification*, 1975.)

WORLD METEOROLOGICAL ORGANIZATION REGISTER OF WEATHER MODIFICATION PROJECTS

At the Seventh World Meteorological Congress in Geneva in 1975, the WMO approved a Weather Modification Programme, one part of which is a requirement that the Secretary-General maintain a register of experiments and operations in weather modification carried out within member countries. Two reports on these reported projects have been published by the WMO, covering activities for calendar years 1975 and 1976, respectively.^{4, 5} Submission of data for the WMO register is voluntary for member countries; however, most countries with projects do provide the requested information. Twenty-five nations reported weather modification projects which occurred during 1976, while 16 had provided similar information for 1975. In addition, member countries with no such activities are also asked to so indicate; 58 countries reported that there were no weather modification field activities, either experimental or operational, conducted within their boundaries in 1976.⁶ Although the list was not identical, the same number of countries reported no projects the previous year. Some countries, including Rhodesia and the Republic of South Africa, with past and current weather modification projects, are not members of the WMO; consequently, their projects are not reported through the WMO register.

Table 1, adapted from the WMO report of 1976 weather modification activities,⁷ shows the WMO member countries, other than the United States, within which reported weather modification activities were conducted during 1976, along with characteristics of the one or more projects within each country. Projects reported to the WMO by the United States, which account for nearly one-half of those included in the register, have been removed from table 1, since they are tabulated elsewhere in this report.⁸

⁴ World Meteorological Organization, "Register of National Weather Modification Projects: 1975," Geneva, 1976, 39 pp.

⁵ World Meteorological Organization, "Register of National Weather Modification Projects: 1976," Geneva, 1977, 24 pp. (An addendum to the report on 1976 projects included information on activities in the U.S.S.R.)

⁶ *Ibid.*, app. A.

⁷ *Ibid.*, pp. 6-12 and addendum.

⁸ See app. G.

Type of weather modification		Approximate size of project area (km ²)	Name of project	Location of project area	Year project commenced	To be continued	Nature of organization sponsoring project	Apparatus agents, dispersal rates, etc.	Active period during reporting year	No. of days of seeding, etc.
1	2										3	4	5	6	7	8	9	10
ARGENTINA										
H	a) 5,000 b) 1,000	National Anti-Hail Programme	34°S 68°W	1970	Yes	AGR (G)	Rocket pyro PBI, 400gm per km rocket trajectory. Seeding preferably between -5 and -10°C isotherms, taking account of radar reflectivity.	Oct-Mar	Nil to date	
BRAZIL										
PE	b) 800	MUDAPT (feasibility study of precipitation enhancement SE Brazil)	9.4°S 40.5°W	1971	Yes	Res (G)	Air dispersal NaCl, NH ₄ NO ₃ and urea at 7.5 l/min at cloud base (approx 1500m)	Dec	5	
CI	a) 1.6x10 ⁶ b) 0.9x10 ⁶	MOCLIMA (feasibility of climate modification through carbon dust dispersal to absorb solar energy)	1-10°S 35-47°W	1975	Yes	Res (G)	G/S and Air dispersal of carbon dust particles (-0.1μ) by incomplete combustion of hydrocarbons	-	None	
BULGARIA										
H	a) 11,000	Anti-hail cloud seeding	42°N, 24°E 43.5°N 23.5°E	1969	Yes	AGR (G)	Rocket PBI ₂ at 115 Kg/h	May-Sept	24	
CANADA										
PE	a) 200,000 b) 200,000	Forest Fire Rainfall Enhancement Project, Yellowknife, N.W.T. 1976 (N.W.T. 76-01)	62.5°N 114.5°W	1975	Yes	For (G)	Air flares AgI at 50-700g/h or 50-700g/20 sec. Seeding level -10°C isotherm or 300m below cloud top, whichever lower	Jun-Jul	8	
H	a) 35,000 b) 27,000	Alberta Hail Project (Alta 76-01)	52.2°N 113.9°W	1970	Yes	AGR (G)	Air flares AgI at 3000g/h (wing), 7200g/h (droppable). Cloud top seeding at temperatures 0 to -8°C (4500-5500m) and seeding at base	Jun-Sept	42	
CHINA										
PE	a) >5000	-	-	1968	Yes	AGR Hyd (G)	Air dispersal CO ₂ and NaCl	Apr-Sept	7	
CZECHOSLOVAKIA										
PE	a) 130 b) 90	Hail and precipitation modification	S.W. Slovakia	?	Yes	AGR Hyd (G)	Rockets			
FEDERAL REPUBLIC OF GERMANY										
H	a) 1440 b) 1200	Hail suppression project Rosenheim	47.8°N 12.0°E	1975	Yes	AGR For (G)	Air dispersal AgI	May-Oct	45	
HUNGARY										
H	a) 3500 b) 1200	Hail Suppression Experiment of the Hungarian People's Republic	45.8°N 16.3°E	1976	Yes	AGR Hyd Insur ance Co. (G)	Rocket pyro PBI ₂ seeding in Gb "accumulation zone"	Jul-Oct	12	

TABLE 1.—Weather modification projects reported, by country, through the World Meteorological Organization Register, with U. S. projects deleted. (See key at end of table for explanation of columns.) (Adapted from WMO Register of National Weather Modification Projects, 1976, and addendum.)

Type of weather modification	Approximate size of project area (sq)	Name of project	Location of project area	Year project commenced	To be continued	Name of organization sponsoring project	Approximate amounts, dispersal rates, etc.	Active period during reporting year	No. of days of seeding, etc.
1	2	3	4	5	6	7	8	9	10
ISRAEL									
FE	a) 10,000 b) 10,000	Israel Rainfall Enhancement Project - RMP III	Central & Southern Israel	1960	Yes	AGR (G)	(i) G/B gen (42) AgI (ii) Air gen (3) AgI at 600 g/h	Nov-Apr	60
ITALY									
FE	a) 200 b) "	Alto-Tagliamento Project	46.4°N 12.7°E	1974	Yes	ERG (G)	G/B gen (6) AgI at 150g/h	Oct-Apr	108 (1975/76)
FE	a) 3000 b) 1200	Sarca-Chiese Project	46°N 10.7°E	1967	?	ERG (G)	G/B gen (35) AgI at 50 g/h	Through-out	150
H	a) 1800 b) 1000	Vicenza Project	45.7°N 11.5°E	1972	Yes	AGR (G)	(i) G/B gen(40) AgI at 30 g/h (ii) G/B gen mobile (5) AgI at 150 g/h (iii) Air dispersal at cloud base (1000-2000m)	Apr-Oct	82
H	a) 900	Mantua Project	45°N 10.9°E	1969	?	AGR (G)	(i) G/B gen (32) AgI at 30 g/h (ii) G/B gen mobile (2) AgI at 150 g/h (iii) Air dispersal at cloud base (1000-2000m)	Apr-Sept	75
MALAYSIA									
X	a) 22,600 b) 2,916	Flood control by cloud seeding	6.3°N 102.5°E	1975	Yes	Met (G)	Air dispersal CaCl ₂ solution at 450m/min at cloud tops or in cloud at 3000 m.	Nov-Dec	15
MEXICO									
FE (B)	a) 9000	Experimental rain stimulation programme, Ruesnada region	32°N 116.5°W	1970	Yes	AGR Hyd (G)	G/B gen RB ₄ 1/AgI	Jan-Apr	?
FE (B)	b) 800	Experimental rain stimulation, Valley of Mexico	19°N 99°W	1974	Yes	See	G/B butane-fired (5) and electric arc (5) gen each gen AgI 5-7 g/h	Jun-Oct	50(G/B) 37(sp-ree) 47(fla-ree)
FE	a) 82450	Sonora Project	Sonora State approx. 30°N 110°W	1976	Yes	AGR Hyd (G)	G/B butane-fired gen (9) AgI at 6 g/h, 3h each of 50 seeding days, Air spraying at base cu/sec (1800-2800m) AgI and PbI solution 20-40 l/h Air flares in cu uong. (5000-5800m)		
NICARAGUA									
FE	a) 11,900	Artificial rainfall	15°N 86°W	1972	Yes	AGR (G)	Air flares AgI Air gen AgI 0.16-G.22 1/min,	Jul-Aug	55
NIGER									
FE	a) 300,000 b) 300,000	Rain stimulation operation	Southern part of country and AIR	1975	Yes	AGR For Hyd (G)	Air dispersal AgI in clouds at temp. -7 to -12°C (5500-6000m)	Jul-Sep	34
NORWAY									
CF	a) 10	Fog dispersal	Oelo A/F	1965	Yes	Tpn (G)	Air dispersal CO ₂	Jan-Mar Nov-Dec	?
PHILIPPINES									
FE (B)	a) 15,000 b) 6,102	WENKI - Project Ulap-Ulan	Central Luzon	1976	Yes	See (G)	Air dispersal AgI 3.5g/s in cold clouds (about -4°C or 5000-5500m) Air dispersal H ₂ O in warm clouds at about -7.50 m	Mar-Jun	15

Type of weather modification		Approximate size of project area (sq°)	Name of project	Location of project area	Year project commenced	To be continued	Nature of organization sponsoring project	Apparatus, agents, dispersal, rates, etc.	Active period during reporting year	No. of days of seeding, etc.
1	2										3	4	5	6	7	8	9	10
ROMANIA										
H	a) 25 b) 25	C-185, 186		Approx 45°N 25°E	1969	Yes	Agr (C)	Rocket (autodestructive) AgI or PbI ₂	Apr-Oct	2
SPAIN										
H (H)	a) 40,000	Anti-hail experiment: Valle Ebro Levante La Mancha		42-45°N 2-3°W 39-40°N 0-2°W 39-40°N 2-4°W	1974	Yes	Agr (G)	C/B Dessens gen AgI	May-Oct	80 - 100
SWITZERLAND										
H b)	a) 4,000 b) 1,000	SEPP (randomized anti-hail seeding)		Central Switzerland	1976	Yes	Agr (G)	C/B dispersal (rockets) AgI	Jul-Sept	None*
TRAILAND										
FE	-	-		-	-	-	-	-	-	-
TURKEY										
FE (S)	a) 10,000 b) 10,000	Precipitation Enhancement Project studies		S and SE Turkey	1976	Yes	Met (G)	Initial studies, data collection only	-	-
UNION OF SOVIET SOCIALIST REPUBLICS										
H	a) 3500	Protection of valuable crops against hail		Georgian SSR	1965	Yes	Agr (C) (G)	Artillery injection AgI	May-Oct	34
H	a) 4500	- ditto -		Tadzhikskaya SSR	"	"	"	Rocket and artillery injection AgI	Mar-Aug	34
H	a) 2750	"		Krimea (Ukraine)	"	"	"	Rocket injection AgI	May-Aug	28
H	a) 7300	"		Moldavian SSR	"	"	"	"	"	37
H	a) 8900	"		Armenian SSR	"	"	"	Artillery injection AgI	May-Oct	76
H	a) 5870	"		Azerbaijani SSR	"	"	"	"	"	51
H	a) 4580	"		Krasnodarsk region	"	"	"	"	May-Sept	33
H	a) 6250	"		E. Caucasus	"	"	"	"	"	30
H	a) 3000	"		Uzbekistan SSR	"	"	"	Rocket and artillery injection AgI	Apr-Jul	42
FE	a) 10000	Seeding Cb for additional pptn		Ukrainian plains	1972	"	Res (C)	Air gen AgI seeded at cloud base	May-Aug	50
FE	a) 10000	Winter cloud seeding for additional pptn		Erivoy Bog (Ukraine)	1971	"	Res (G)	Air dispersal Solid CO ₂	Nov-Dec	28
FE	a) 1700 b) 90	Pptn enhancement to combat forest fires		(Krasnoyarsk Irkutsk Yakutsk SSR Khabarovsk Chita Buryat ASSR)	1969	"	For (G)	Air Pyro AgI and Pb I ₂	May-Oct	57
UPPER VOLGA										
FE (R)	a) 30000 b) 10000	Rain stimulation operation		12.5°N 2°W	1973	?	Hyd (P)	Air dispersal: AgI 150g cartridges at -10°C (600cm) I cartridges, 11g/lr descent Urea cartridges 300g between 0°-10°C (4000-6000m) Anhydrous NaClO ₃ particles 30-50u Powdered clay particles 50u	May-Oct	120
YUCOSLAVIA										
H	b) 25000	Hail suppression		41-44.5°N 19.5-22.5°W 45-46.5°N 15.5-19°E	1968	?	Agr (G)	Rocket AgI at 600m (200-400g)	Apr-Oct	50

EXPLANATION OF COLUMNS IN TABLE 1

Col. 1—Type of weather modification (indicated by letters) as follows:

Cl=Climate modification.

Cy=Tropical cyclone moderation.

F=Fog dispersal.

FC=Cold fog dispersal.

FW=Warm fog dispersal.

H=Hail suppression.

L=Lightning suppression.

PE=Precipitation enhancement.

S=Snow enhancement.

R=Research experiment.

X=Flood control.

Z=Inhibition of convective cloud development.

Col. 2—Approximate size of project area: Area given in square kilometers; (a) indicates overall area, (b) target area.

Col. 4—Location of project area: In some cases where coordinates of several points delineating the area were given, these have been replaced by a single point at approximately the center of the area. Towns and islands may be denoted by name; A/P=airport.

Col. 7—Nature of national organization sponsoring project (indicated by abbreviations) as follows:

Agr=Agricultural.

Erg=Energy.

For=Forestry.

(G)=Governmental.

Hyd=Hydrological.

Ind=Industrial.

Met=Meteorological.

(P)=Private.

Res=Research.

Ski=Winter sports.

Tpn=Transportation.

Col. 8—Apparatus, agents, dispersal rates, etc.: Chemical and SI symbols are used. Abbreviations are as follows:

Air=Airborne/Aircraft.

G/B=Ground-based.

gen=Generator.

Pyro=Pyrotechnic.

R/C=Remote-controlled.

A copy of the questionnaire and reporting instructions circulated to WMO member nations for reporting weather modification activities is included in appendix P of this report. Also included in appendix P is a list of the names and addresses of the reporting agencies of the member countries which have weather modification activities.

DESCRIPTION OF WEATHER MODIFICATION ACTIVITIES IN SOME FOREIGN NATIONS

THE UNION OF SOVIET SOCIALIST REPUBLICS

Overview of projects in the U.S.S.R.

The largest weather modification effort outside the United States is in the Soviet Union, where there are both a continuing research program and an expanding operational program. The latter is primarily concentrated in a program designed to reduce crop damage from hail. In 1976, about 5 million hectares⁹ of Soviet farmland were included under this operational hail suppression program, whose costs are met by the Ministry of Agriculture. Both administrators and scientists in the U.S.S.R. have maintained that these hail-seeding operations—underway since the mid-1960's—are successful, and they are to be expanded in future years. The hail suppression techniques developed in the Soviet Union are being used in many parts of the country, including the North and South Caucasus, Moldavia, and Middle Asia, as well as in the neighboring countries of Bulgaria and Hungary.¹⁰

Battan estimated that the overall Soviet operational hail suppression program could employ as many as 5,000 people.¹¹ The Soviet hail abatement program is obviously an important national effort and is clearly the largest such program in the world. Other interests and activities in weather modification in the U.S.S.R. include precipitation augmentation and fog dispersal.

⁹ Approximately 15 million acres.

¹⁰ Battan, Louis J., "Weather Modification in the Soviet Union; 1976," *Bulletin of the American Meteorological Society*, vol. 58, No. 1, January 1977, p. 4.

¹¹ *Ibid.*, p. 13.

A review of Soviet weather modification activities was written in 1973 by Ye. K. Federov, Director of the U.S.S.R. Hydrometeorological Service.¹² He traces the history of activities in the U.S.S.R. from early prescientific use of hail cannons, through the scientific investigations by the Institute of Experimental Meteorology in the 1930's, to the recent activities in cloud physics research and weather modification, particularly in precipitation augmentation and hail control.¹³ Federov concludes that cloud-seeding experiments carried out in a number of places in the U.S.S.R. indicate an approximate 10 to 15 percent increase in precipitation is possible.¹⁴ Because of the great space-time variability in areas of hail damage, estimates of hail suppression effectiveness are difficult; however, a method of evaluation has been developed, based on changes in the area damaged by hail.¹⁵ Table 2 shows areas of coverage and reported decreases in hail damage reported for the years 1966 through 1970, in the Northern Caucasus and in Georgia, using hail suppression techniques developed at three Soviet institutions (identified by the abbreviations VGI, IGAN, and ZakNIGMI).¹⁶ Based on these results, it has been concluded that the average decrease of the area in which crops were damaged by hail was about 80 percent.¹⁷

TABLE 2.—MEAN DECREASE OF HAIL DAMAGE AREAS IN HAIL SUPPRESSION REGIONS OF THE NORTHERN CAUCASUS (VGI) AND GEORGIA (ZakNIGMI, IGAN) FOR THE YEARS 1966-70

[From Sulakvelidze, et. al., 1974]

	1966	1967	1968	1969	1970
Total area of protected territory (hectares times 1,000):					
VGI	615	890	785	890	960
IGAN	220	320	460	460	460
ZakNIGMI	50	80	110	150	200
Average decrease in hail damage area (percent):					
VGI	90	50	87	99	62
IGAN	76	82	67	69	88
ZakNIGMI		96	91	94	87

Summary of weather modification and related atmospheric research in the U.S.S.R.

Federov's summary of Soviet activities is concluded with an extensive and valuable listing of 179 references in the Russian literature on weather modification, cloud physics, and related research, dating from 1961 through 1972. The citations are listed under the following topics and subtopics, which give some idea of the scope and direction of the Soviet research through the early 1970's:¹⁸

Micro- and macro-structure of clouds:

Studies of the micro- and macro-structure, water content, and phase state of clouds; and

Experiments on convection.

Radar studies:

The use of polarization methods of radar study of clouds and the results of their modification;

¹² Federov, Ye. K., "Modification of Meteorological Processes," in Wilmot N. Hess (ed.), "Weather and Climate Modification," New York, Wiley, 1974, pp. 387-409.

¹³ Ibid., p. 389-397.

¹⁴ Ibid., p. 395.

¹⁵ Ibid., p. 397.

¹⁶ Sulakvelidze, G. K., B. I. Kiziriya, and V. V. Tsykunov, "Progress of Hail Suppression Work in the U.S.S.R.," in Wilmot N. Hess (ed.), "Weather and Climate Modification," New York, Wiley, 1974, p. 428.

¹⁷ Ibid.

¹⁸ Federov, "Modification of Meteorological Processes," 1974, pp. 402-409.

Radar methods of measuring microstructure of clouds and precipitation;

Orderly and turbulent motions in clouds;

Radar characteristics of shower and cumulonimbus clouds and cloud systems; and

Methods of identifying hail zones and determining the degree of risk.

Creation and breaking up of convective clouds:

Results of experiments on breaking up cumulus clouds with loose powders; and

Stimulating updrafts by means of artificially created jets which trigger cloud development.

Elementary physical and chemical processes in clouds:

Experiments with the use of a device for modeling cloud processes;

Studies of elementary processes in clouds, physics of condensation, coalescence, freezing, and electrification of cloud elements;

Laboratory investigations of action of crystallized reagents, properties of crystalline and drop fogs, norm of flow rate of reagents;

Mechanism of formation of crystals on crystallization nuclei;

Regularities in growth of individual crystals and droplets;

Stochastic theory of condensation; and

Quantitative theory of processes of formation of crystallization nuclei, formation of crystallization on zone and its rate of spread, technique for introducing reagent, characteristics of open zone.

Dissipation of supercooled clouds and fogs:

Study of conditions permitting fog dissipation, and experiments on clearing large areas (on the order of 10,000 square kilometers) of overcast due to a change in the radiation balance.

Modification of hail processes:

Results of studies of processes of formation of hail cloud, growth of hail and its transformation; development of techniques for modifying hail processes and results of experimental work.

Augmentation of precipitation from clouds and cloud systems:

Results of modifying frontal cloud systems and air-mass clouds by means of dry ice; and increasing precipitation from cumulus and powerful-cumulus clouds over a Ukrainian test area.

Extinguishing forest fires by cloud modification:

Results of first experiments showing practicability of work on extinguishing forest fires by stimulating artificial precipitation over fire regions.

Water reserves of clouds suitable for modification:

Studies of water reserves of seedable clouds over various regions of the U.S.S.R.

Estimating the effectiveness of cloud modification:

Estimating effectiveness of cloud modification experiments and monitoring of results of modification.

That such a diversity of research is possible is not too surprising when one considers the manpower available. Hess notes that Academician Federov, Chief of the Hydrometeorological Service, has about

75,000 people who work for him on all problems of weather and oceanography. By contrast, a somewhat similar agency in mission in the United States, the National Weather Service, has about 6,000 employees.¹⁹

On his 1976 trip to the U.S.S.R., Battan visited a number of research institutions throughout the country at which weather modification research is conducted. He estimated that about 600 people are engaged in various aspects of research in weather modification and cloud physics, and noted that a younger group of scientists seems to be replacing the previous researchers in the past few years. The Soviets have also invested heavily in experimental facilities.²⁰

While hail suppression is considered to be a demonstrated technology in the Soviet Union and operations continue to increase, Battan notes that research in hail modification is currently at a low level. He also reports that research on rainfall augmentation is mostly concentrated in the Ukraine as it has been for many years; but, it appeared to him that, overall, the interest in rainfall augmentation research is relatively low in view of the importance of rainfall to agriculture. Current rainfall stimulation operations are designed for extinguishing forest fires rather than increasing water for agriculture. Battan concludes that the Soviet scientists seem to be no closer to a proven technology for precipitation augmentation than is the United States and that there still remain unresolved questions on the efficacy of the Soviet hail suppression techniques.²¹

ISRAEL

Cloud seeding activities began in Israel in 1948, and research on precipitation augmentation was conducted in parallel with that in other countries throughout the 1950's. Beginning in 1961, a series of carefully conducted major experiments were initiated which have produced convincing evidence on the possibility of increasing precipitation through aircraft seeding of the convective clouds which move eastward over Israel from the Mediterranean Sea. The first of these major experiments was conducted from 1961 through 1967, and the second 6½-year experiment was begun in 1969 and recently completed. Though early research had been conducted by the Israeli Defense Ministry, present research and operations are supported by the Ministry of Agriculture.²²

Weather modification experimentation in Israel has been accompanied by basic cloud physics research, and it is believed that these intensive physical studies have contributed greatly to understanding of the precipitation processes, required for development of rain enhancement techniques.²³

Results of the first Israeli experiment indicated a statistical increase of 15 to 24 percent in precipitation as a result of seeding, at a high significance level, while the second experiment showed a 20-percent

¹⁹ Hess, Wilmot N., "Progress in Other Countries," in "Weather and Climate Modification," New York, Wiley, 1974, p. 385.

²⁰ Battan, "Weather Modification in the Soviet Union; 1976," 1977, p. 18.

²¹ *Ibid.*, pp. 18-19.

²² Gagin, A., "Testimony Before the U.S. Department of Commerce Weather Modification Advisory Board," Reston, Va., Dec. 18, 1977.

²³ Gagin, A., and J. Neumann, "Rain Stimulation and Cloud Physics in Israel," in Wilmot N. Hess (ed.), "Weather and Climate Modification," New York, Wiley, 1974, p. 462.

rainfall increase in the catchment area of the Sea of Galilee. In 1976 an operational cloud seeding program was initiated in the northern part of Israel, based on these optimistic results, where the target area is the Sea of Galilee catchment area. Since earlier results for the southern part of the country are not definitive, however, a third major experiment has been undertaken for that part of the country.²⁴

Water increases through the Israeli precipitation augmentation program have been estimated at about 300 million metric tons per year, at a cost of \$400,000. This is equivalent to a rough cost of \$1 per acre-foot. By comparison, the ratio of costs for increasing water through desalination to those through weather modification is approximately 700 to 1.²⁵

AUSTRALIA

Although, in recent years, field experiments have been curtailed, there has been a major Australian research effort in the past directed toward precipitation enhancement through weather modification. A major research program in cloud physics, supportive of weather modification as well as other aspects of meteorology, is continuing there, under the Commonwealth Scientific and Industrial Research Organization (CSIRO). Since much of Australia consists of deserts where rainfall is sparse and unreliable, augmenting rainfall through artificial means has been appealing there.²⁶

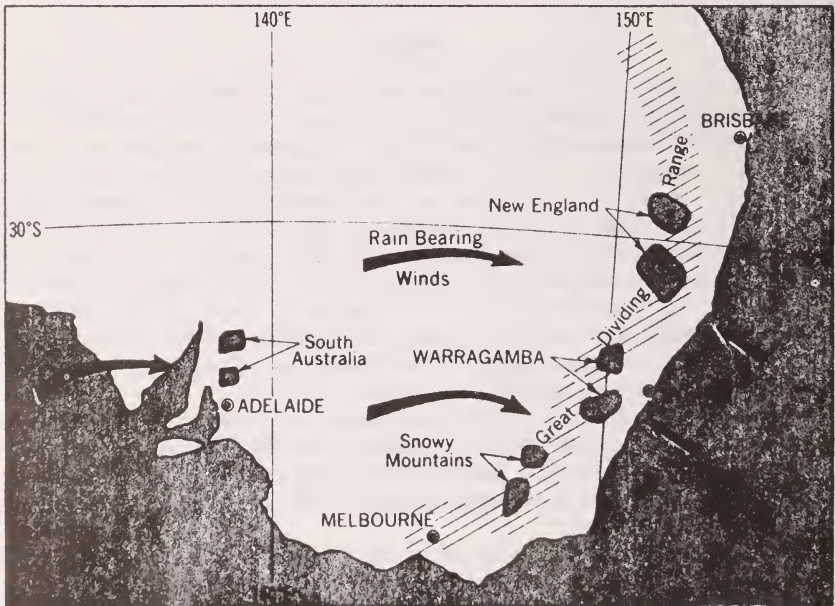


FIGURE 2.—Location of cloud seeding experiments in southeastern Australia. (From Smith, *Cloud Seeding in Australia*, 1974.)

²⁴ Gaglin, testimony before the Weather Modification Advisory Board, 1977.

²⁵ *Ibid.*

²⁶ Smith, E. J., "Cloud Seeding in Australia," in Wilmot N. Hess (ed.), "Weather and Climate Modification," New York, Wiley, 1974, p. 432.

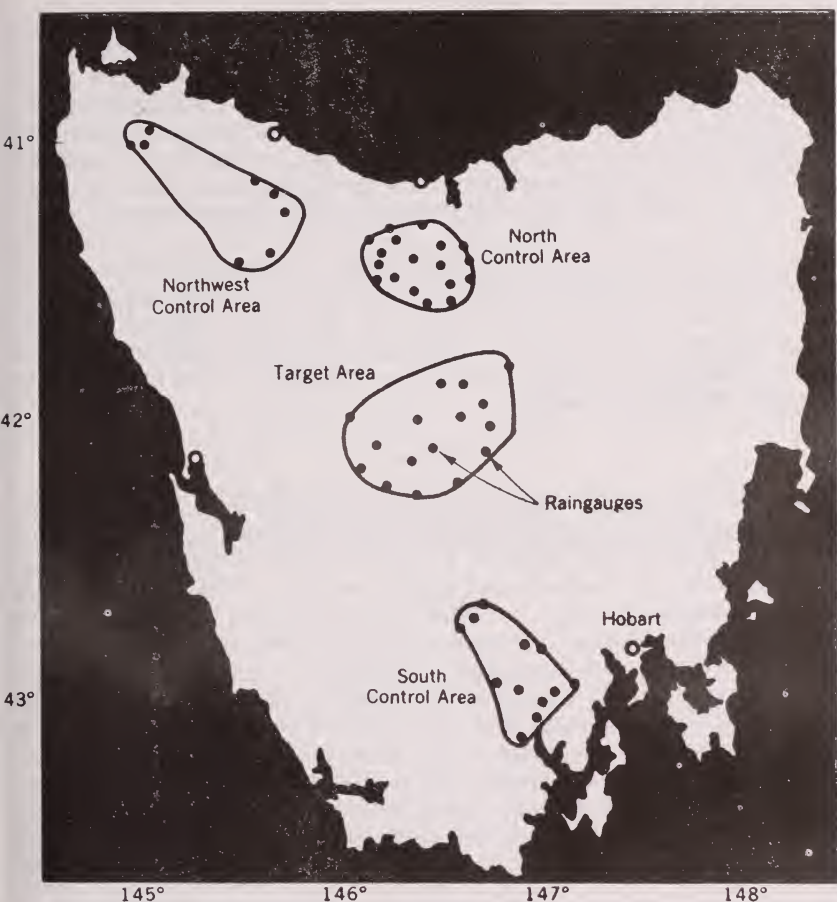


FIGURE 3.—Experimental areas in Tasmania. (From Smith, *Cloud Seeding in Australia*, 1974.)

As elsewhere, early weather modification experiments in Australia were conducted between the late 1940's and the mid-1960's. During the period 1955 through 1963 four experiments were carried out at locations shown in figure 2, in order to determine whether rain over the specific areas could be increased from airborne silver iodide seeding. These experiments were only partially successful, owing partly to their design.²⁷ Starting in 1964 and running through 1971, a very successful experiment was conducted in Tasmania, results of which have indicated a 15- to 18-percent precipitation increase in winter, though there was no apparent increase during the other seasons.²⁸ (See fig. 3.)

²⁷ *Ibid.*, p. 442.

²⁸ Bowen, E. G., private communication, January 1978.

In the late 1960's operational weather modification programs for increasing precipitation were set up and supported by four Australian States—Queensland, New South Wales, Victoria, and South Australia—using privately contracted seeding aircraft. The CSIRO operated courses of instruction in weather modification techniques and provided information on the state of the art to the States and the operators. These operational programs have since been discontinued, however, and there are no such operational programs now in existence.²⁹

During the period of Australian weather modification experiments, the funding was partitioned about equally between laboratory research in cloud physics and the field activities. With the close of the Tasmanian experiment, nearly all effort is currently performed in the laboratory or in theoretical studies. The funding level of the program is about \$1 million annually.³⁰

CANADA

The most noteworthy weather modification activities in Canada are the research and operational hail reduction projects carried out since 1956 in the Province of Alberta. Commercial hail suppression operations, supported by farmers and conducted from 1956 through 1968, were summarized recently.³¹ These nonrandomized operations were evaluated on the basis of insurance statistics, that is, loss-risk ratios, and the following conclusions were reached:³²

1. Commercial hail suppression operations (based on the Alberta project from 1961 through 1968) show a benefit-to-cost ratio of 47 to 1. Added benefits in the study target from rain increase were 30 to 1. Thus, total benefit-to-cost in the target is about 77 to 1.

2. For the 1961–68 period of operations, the hail damage in the study target was 71 percent less than during the historical period 1938–60 while at the same time no significant change occurred in the control area.

3. Fringe benefits from the inevitable rain increase phase over a total of about 6 million acres (3 times the size of hail suppression target) yielded a benefit-to-cost of around 90 to 1.

During the same period the Alberta Research Council (ARC) sponsored a concentrated study of hail and hailstorms, and seeding was begun on such storms in 1970. It became apparent in the early 1970's that there was a disparity between results obtained through this research and the earlier operations.³³ As a result, the legislative assembly appointed a special committee of 10 members to evaluate the situation and take action which seemed appropriate. A government corporation was formed for the purpose of running a hail suppression research program, and an interim weather modification board was appointed by the Minister of Agriculture.³⁴

²⁹ *Ibid.*

³⁰ *Ibid.*

³¹ Krick, Irving P. and Newton C. Stone, "Hail Suppression in Alberta: 1956–1968," the *Journal of Weather Modification*, vol. 7, No. 1, April 1975, pp. 101–115.

³² *Ibid.*, p. 114.

³³ SImpson, Joanne, "The National Hail Research Experiment Report on the Alberta Hail Project," national hail research experiment technical report NCAR-7100-76/2. National Center for Atmospheric Research, Boulder, Colo., February 1976, p. 3.

³⁴ *Ibid.*, p. 3.

The Alberta hail project was initiated in 1973 to accelerate development of hail suppression technology and test that technology. Seeding of the 18,000 square mile target area with silver iodide from aircraft was begun in 1974. While there is randomization by days in the northern half of the target area, there is full operational seeding in the southern half.³⁵ Although data from the first 2 years of the experiment were still being analysed when Simpson wrote her evaluation in 1976, she concluded that the following information would likely be gained from the research under the Alberta hail project:³⁶

1. Resolving the conditions for multicell versus supercell, leading to resolution of whether or not different seeding strategies are required.

2. Resolving the merits of on-top versus cloud-base seeding for various storm types.

3. Providing "transfer functions" between crop damage, hailfall parameters, meteorological conditions, hailpads and hail report cards.

4. Developing and testing, with an adequate data base, numerical simulations of hailstorms and the conditions conducive to them.

Another Canadian weather modification project of some interest was initiated in the Northwest Territories in 1975. The purpose of this Summer Cumulus Rainfall Experiment is to study the possibility of controlling forest fires through increased precipitation by cloud seeding.³⁷

MEXICO

In a 1976 report on weather modification activities in Mexico, Kraemer of the Mexican Ministry of Hydraulic Resources summarized ongoing projects in three principal areas of the country.^{37a}

Initiated in 1949 with the purpose of augmenting runoff for hydroelectric power generation, the most sustained operational program had been sponsored by the Mexican Light & Power Co. in the Necaxa River watershed. After 1954 ground based silver iodide generators replaced aircraft seeding, and target and control areas were set up for evaluation. Since 1956 selection of seeding days was randomized. Following the 1974 season, seeding operations were suspended, and a reevaluation of the project was undertaken, preparatory to a redesign of the seeding operations. A restricted area pilot project was underway to study techniques of seeding with salt, in view of the warm clouds passing over the area.³⁸

The Ensenada project on the Baja California Peninsula has been conducted with the intention of evaluating cloud seeding techniques for augmenting water resources in this arid region, where both surface and ground water are scarce. Since 1970, experiments have been carried out by the Secretary of Hydraulic Resources in the northern part of the peninsula, where seeding is performed during the winter rainy season, using ground-based generators. Precipitation increments of 10 to 15 percent were reported over the 9,000-square-kilometer target area, based on results of a 5-year period of operation of this

³⁵ *Ibid.*, pp. 13-15.

³⁶ *Ibid.*, p. 39.

³⁷ Charak, "Weather Modification Activity Reports: Calendar Year 1975," 1976, p. 51.

^{37a} Kraemer, Dieter (report on recent weather modification activities in Mexico), in "Proceedings of Conference on Weather Modification, Today and Tomorrow," 2d annual meeting of the North American Interstate Weather Modification Council, Kansas City, Mo., Jan. 15-16, 1976, publication No. 76-1, pp. 85-88.

³⁸ *Ibid.*, p. 85.

randomized experiment. In 1976 a decision was made by the Governor of the state to contract continuation of this project to an American firm, which would employ aircraft seeding.³⁹

A joint project was established in 1973 by the National Council of Science and Technology, the Institute of Geophysics at the University of Mexico, and the Federal Ministry of Hydraulic Resources, with the purpose of carrying out cloud seeding operations in the area of the Chichinautzin Sierra, near Mexico City, to augment water supplies. Initial seeding operations, begun in 1974, were accomplished with ground-based generators, with the intention to expand into aircraft seeding later if advisable. Based on analysis of data from the first 2 years of these randomized operations, the average precipitation increments over or near the target area were reported to range from 15 to 75 percent, depending upon the specific location.⁴⁰

Other pilot or demonstration projects were underway during 1975 and 1976 in southern Baja California and in the Yacamiya River Basin, and the start of three new programs within a year was being contemplated.⁴¹

In an earlier report Kraemer discussed progress on the projects discussed above and also included a discussion on the history of experimental weather modification projects in Mexico. The earliest experiments there were conducted in the neighborhood of Mexico City in 1947. Subsequent cloud seeding experiments were sponsored by various government agencies, some universities, and a few private companies. Lack of adequate design and control led to suspension of most of the earlier projects, their subjective, nonstatistically significant evaluations providing no valid conclusions.⁴²

PEOPLE'S REPUBLIC OF CHINA

In 1974 a delegation of U.S. meteorologists, representing the American Meteorological Society (AMS), visited a number of meteorological institutions in the People's Republic of China, at the invitation of the Chinese Meteorological Society. As part of their overall orientation to the activities of their counterparts, they learned about weather modification research and operational projects in Red China.⁴³ Such activities are sponsored principally by the Institute for Atmospheric Physics of the Academia Sinica and by the Central Meteorological Bureau, both in Peking.

To the visitors there appeared to be an emphasis on application of weather modification technology over research, and there was an attempt to incorporate the cooperation and suggested ideas from the local peasants into the use of such technology. This latter emphasis has even motivated some experiments which are designed to verify some of the plausible weather folklore.⁴⁴

³⁹ *Ibid.*, p. 86.

⁴⁰ *Ibid.*, pp. 86-87.

⁴¹ *Ibid.*, p. 88.

⁴² Kraemer, Dieter, "Cloud Seeding Activities in Mexico," in "Proceedings of Conference on Weather Modification—A Usable Technology: Its Potential Impact on the World Food Crisis," North American Interstate Weather Modification Council, Denver, Colo., Jan. 16-17, 1975, pp. 110-120.

⁴³ Kellogg, William W., David Atlas, David S. Johnson, Richard J. Reed, and Kenneth C. Spengler, "Visit to the People's Republic of China: A Report From the A.M.S. Delegation," Bulletin of the American Meteorological Society, vol. 55, No. 11, November 1974, pp. 1291-1330.

⁴⁴ *Ibid.*, pp. 1313-1314.

Cloud physics and weather modification were listed as major areas of research at the Institution for Atmospheric Physics. Although there was a clear historical interest in hail control technology, the actual hail suppression program had only recently begun and appeared modest to the visitors. The academy's suppression experiments were conducted in Shansi Province and had been underway for 2 years in 1974. Lacking an organized raingage or hailpad network, evaluation of seeding operations is through after-the-fact ground surveys and interviews to estimate hail size, concentration, and crop damage. Seeding criteria are based on visual and radar observations.⁴⁵

A program involving the seeding of warm cumulus clouds in Hunan Province of southern China is being conducted by the Research Institute of the Central Meteorological Bureau. Intended to increase rainfall during arid summers, this project had been in progress for about 5 years. Seeding was done with pulverized salt, released near the cloud base from aircraft. Although the project was not randomized, there was an attempt to evaluate seeding efforts through visual observation, by examination of raindrop spectra, and by comparison of rainfall in adjacent regions. This work was purported to be "promising."⁴⁶

There had also been some dry ice seeding experiments during the spring in the cold clouds in northern and northwestern China. The sparse raingage network impeded evaluation in the mountainous regions, and the program was discontinued because results were not encouraging. Research using ground-based silver iodide burners was also suspended because of the conviction that the seeding material had not reached the clouds.⁴⁷

KENYA

An operational hail suppression program was initiated in 1967 in Kenya, about 130 miles northwest of Nairobi. The target areas, covering about 45,000 acres where select tea is grown, are shown in figure 4. The seeding program, supported through 1975 by private tea companies, employed aircraft for dispensing silver iodide at the base of the clouds. More than 5,700 individual cumulus cloud cells were seeded during this period, with an average reduction in damage to tea of about 40 percent, based on comparisons of hail damage from seeded and nonseeded cloud systems.⁴⁸

⁴⁵ Ibid.

⁴⁶ Ibid., p. 1313.

⁴⁷ Ibid.

⁴⁸ Henderson, Thomas J., "The Kenya Hail Suppression Program," the *Journal of Weather Modification*, vol. 7, No. 1, April 1975, p. 192.

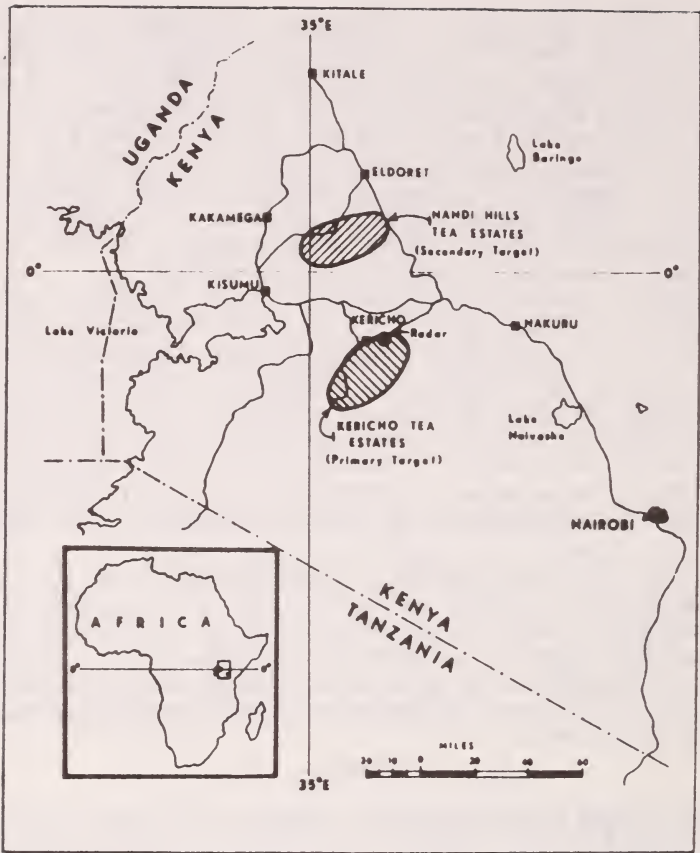


FIGURE 4.—Location of target areas in the Kenya Hall Suppression Program. (From Henderson, 1975.)

REPUBLIC OF SOUTH AFRICA

South African crops suffer severely from hail damage. Near Nelspruit in the heart of the tobacco area, where citrus and vegetable crops are also grown, there are typically 50 hail days per year. The main hail season extends from October to March, coinciding with the tobacco growth and harvest periods; consequently, damage to this ultrasensitive crop is often catastrophic.⁴⁹

The Nelspruit hail suppression seeding project, conducted jointly by the Lowveld Tobacco Cooperative and the Colorado International Corp., completed 41½ years of operation in May 1976, at which time Simpson had evaluated the first 3½ years of the program. Hail in the 7,000 square kilometer target area is produced by warm-based storms, mostly of the multicell type, and seeding is performed from above,

⁴⁹ Simpson, Joanne, "Report on the Hail Suppression Program at Nelspruit, Transvaal, Republic of South Africa." National Hail Research Experiment technical report NCAR-7100-76/5. National Center for Atmospheric Research, Boulder, Colo., June 1976, pp. 3-5.

where silver iodide flares are dropped from jet aircraft.⁵⁰ Analysis of the results showed decreases of about 40 percent in damage and 20 percent in severity for the seeded cases, based on a comparison with historical control data, though the project is not randomized. Simpson felt that these results should be regarded with cautious optimism and found the program to have sufficient merit to warrant its continuation, but with greater emphasis on evaluation.⁵¹

RHODESIA

Experiments were conducted in Rhodesia during 1973-74 to confirm the effectiveness of seeding the tops of single cumulus clouds by aircraft, using pyrotechnic cartridges, to augment rainfall. Randomized trials on 20 seeded and 16 nonseeded clouds resulted in average rainfall about five times heavier for seeded cases than for nonseeded cases. There was also evidence of less seeding effect under wet conditions.⁵² The experiments were continued in 1974-75, and it was subsequently learned that seeding by the silver pyrotechnic method is unsuccessful when cloud tops fail to reach a temperature level of -10° C. It has been concluded that economic viability of the cloud seeding required that clouds reach at least to the -10° C level, the -13° C level being even more preferable.⁵³

INDIA

Indian scientists have continued studies of warm cloud seeding. In one reported study of the dynamic effects of seeding cumulus clouds with salt in 1973, there was a temperature rise from 1° to 2° C and an increase in liquid water content before the onset of rain. The clouds also grew in the vertical by a few thousand feet following the seeding. These observed features were explained qualitatively by a kind of chain reaction which involves the process of condensation and updraft generation.⁵⁴

Further analysis of data from seeding experiments during the 1974 summer monsoon showed additional positive modification effects. Conclusions drawn from radar observations, in-cloud electrical measurements, and microphysical observations following seeding of these maritime warm clouds with hygroscopic particles are stated below:

1. Out of the four seeded cloud cases, two showed remarkable increases in areal extent. In the remaining two cases, the areal echo coverage remained nearly constant in one and decreased in the other. The echo intensity increased in three cases and decreased in one case. The height of the echo top increased in all the four cases. Such features were not noticed in the echoes from the control clouds.

⁵⁰ *Ibid.*, p. 1.

⁵¹ *Ibid.*

⁵² McNaughton, D. L., "Seeding Single Clouds Using Pyrotechnic Cartridges, 1973-74," *the Journal of Weather Modification*, vol. 7, No. 1, April 1975, pp. 4, 14-15.

⁵³ McNaughton, D. L., "Cloud Seeding Experimental Program in Rhodesia: 1974-75," *the Journal of Weather Modification*, vol. 9, No. 1, April 1977, pp. 89-90.

⁵⁴ Ramachandra Murty, A. S., A. M. Selvam, and Bh. v. Ramana Murty, *Dynamic Effects of Salt Seeding in Warm Cumulus Clouds*. *The Journal of Weather Modification*, vol. 7, No. 1, April 1975, p. 36.

2. The in-cloud temperature showed an increase of 0.8° C following seeding.

3. The median volume diameter of the cloud droplets and the cloud liquid water content showed increases in the subsequent traverses compared to the initial traverses made in the seeded clouds.

4. The vertical electric field in the cloud, a few hundred meters above the cloud base, was initially negative and showed sign reversal before the onset of precipitation in seeded clouds. The sign reversal may be attributed to the transport of positive charges from the higher levels to the lower levels inside the cloud by the precipitation particles which are generally formed at the higher levels in the strong updraft regions. The electric field also showed intensification following seeding which could be due to the increased convective activity.⁵⁵

THE SWISS HAIL EXPERIMENT

In Western Europe hail suppression is conducted by commercial firms and farmers' cooperatives on a large scale, though scientifically proven techniques are not currently in use. Hail reduction damage levels claimed by well-conducted commercial suppression programs are in the range of 40 to 50 percent; however, the value of the statistical evaluation is limited due to lack of randomization in the projects.⁵⁶

In 1976, the Swiss Federal Division of Agriculture initiated a 5-year hail-suppression experiment, conducted by the Institute of Atmospheric Physics at Zurich and the Polytechnical Institute. The purpose of the experiment, called Grossversuch IV, is to test the translatability of the Soviet hail suppression techniques to a site in central Europe. Specifically, the experiment has been designed to answer the following questions:

1. Can the Soviet rocket method be used successfully in Europe, given the climatic, geographic, and logistic conditions there?
2. What is the effectiveness of the Soviet method and what is the relationship between cost and benefits which may accrue to a given region?

The U.S.S.R. claims that their operations are 70 to 90 percent successful in reducing hail damage; a similar success rate in Switzerland, taking into account the hail frequency there, should permit completion of the experiment with statistically significant results during the projected 5-year period.⁵⁷

The Swiss Federal Air Office has reserved a space 100,000 hectares (1,000 km²) by 8 km high in the Napf Highlands, on the northern slopes of the Swiss Alps, for the experiment. Storms which occur in this region mostly come from the southwest and travel to the north-

⁵⁵ Chatterjee, R. N., A. S. Ramachandra Murty, K. Krishna, and Bh. B. Ramana Murty. Radar Evaluation of the Effect of Salt Seeding on Warm Maritime Cumulus Clouds. *The Journal of Weather Modification*, vol. 10, No. 1, April 1978, p. 56.

⁵⁶ Federer, Bruno, W. Schmid, and A. Waldvogel. "The Design of Grossversuch IV, a Randomized Hail Suppression Experiment in Switzerland," presented at the First International Workshop on the Measurement of Hail, Banff, Canada, Oct. 21-26, 1977, Alberta Research Council, 1977, p. 1.

⁵⁷ *Ibid.*

east, and hail occurs on 16 out of 35 stormy days. Rockets furnished by the Soviet Union have been employed in the seeding experiment, following a brief training period by a Soviet expert on use of the launching ramp. The experiment includes five launching stations and a command post equipped with three weather radars.⁵⁸

The experiment has been underway since 1976, following, reasonably close to the plan of attack as developed then. In addition to the Swiss investigators, there is cooperative participation from the French and the Italians, whose contribution is mainly in operating the hailpad network. Beginning in the 1978 summer seeding season there will also be U.S. participation from scientists at the National Center for Atmospheric Research (NCAR).⁵⁹

⁵⁸ *Ibid.*, pp. 2-3.

⁵⁹ Squires, Patrick, private communication.

CHAPTER 10

INTERNATIONAL ASPECTS OF WEATHER MODIFICATION

(By Lois McHugh, Foreign Affairs Analyst, Foreign Affairs and National
Defense Division Congressional Research Service)

INTRODUCTION

Recent years have seen increased international awareness of the potential benefits and possible risks of weather modification technology and increased international efforts to control such activities. The major efforts of the international community in this area are to encourage and maintain the high level of cooperation which currently exists in weather reporting and research and to insure that man's new abilities will be used for peaceful purposes rather than as weapons of war. This two sided approach is evident in the activities of the United States which has strongly encouraged and supported cooperative efforts to gain knowledge of the weather and at the same time has endeavored to restrict the use of this knowledge to peaceful purposes through the adoption of international agreements.

Weather research and reporting has long been one of the areas having the closest international cooperation. Because of the global nature of weather systems, making the prediction of weather in one area dependent on reported weather in other parts of the world, cooperation and exchange of information and techniques of weather research and reporting are necessities. This cooperation transcends ideological differences and hostilities.

International cooperation in the exchange of ideas on and methods of weather modification has also been extensive. Many well attended international conferences as well as more informal exchanges of scientists and research documents have given nations the opportunity to expand their own knowledge of weather modification. More recently, pressures of world population and food shortages, drought, and the continuing devastation of natural disasters such as earthquakes, floods, and tropical storms have made the development of weather modification abilities more critical to nations. The increasing interest in, and the developing technology relating to man's ability to affect rainfall, prevent hail, and curb the damage of tropical storms foresees a time when it will be essential that the effects of such activities on the world's weather system be understood and any adverse effects of such modification be controlled. As with many other scientific areas, the problems arising out of use and experimentation with weather modification techniques are not just scientific problems, but political problems. Although the technology to use weather modification, as well

as the ability to determine how successful such modification technology is, are still in the early stages of development, attempts to modify weather conditions are being made by commercial firms and by governments. Thus, with or without a scientific assurance of success, weather modification has become a source of controversy between nations.

The increased activity in weather modification world wide has also resulted in increasing complaints of perceived or potential damage to the environment both domestically and internationally. For example, during 1975, at a time when the U.S. Government was supporting research activities to modify the strength of hurricanes, although not actually seeding any hurricanes, Hurricane Fifi devastated Honduras. There were several claims at the time, both in domestic and international news media that the hurricane was either purposely, or at least inadvertently, directed at Honduras. More recently, Project Stormfury, a U.S. sponsored research program into tropical storm control, has been forced to limit its areas of experimentation because two of the countries potentially affected by experimentation in the western Pacific, the People's Republic of China, and Japan, objected to experimentation near them, although other nations in the same area welcomed such activities. Although the United States is ready to resume experimentation, recent statements indicate that the Carter administration wants to look into the liability problem before resuming any actual modification activities. The international community has also been troubled by the issue of liability. In November 1975 the World Meteorological Organization (WMO) and the United Nations environment program held a 4-day meeting to discuss, among other issues, the possible liability of WMO and the other participants in the worldwide precipitation enhancement program which was beginning in response to the Stockholm Conference on the Human Environment.¹

In addition to the problems of damage to countries by commercial or experimental weather modification activities, another growing area of concern is that weather modification will be used for hostile purposes * * * that the future will bring weather warfare between nations. The United States has already been involved in one such instance during the Vietnam war when attempts were made to impede traffic on the Ho Chi Minh Trail by increasing the amount of rainfall during the monsoon season. After initial public denials of such activities, former Secretary of Defense Laird, acknowledged that such activities had taken place during 1967 and 1968. This information was contained in a classified letter to the Senate Foreign Relations Committee in January 1974, and made public later in 1974. Having the capability to cause natural disasters will further blur the line between conventional and unconventional warfare and increase the risk to civilian populations, who would be caught in the same natural disaster as the enemy army. Additionally, if weather modification techniques are developed by nations without corresponding understanding or concern for the world weather system, widespread, and conceivably irrevocable damage can be done to nations not involved in the hostilities, as well as to those at war.

¹ U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Environmental Monitoring and Prediction, "Weather Modification Activities for Calendar Year 1975," Rockville, Md., June 1976, p. 47.

Even the perception that weather modification techniques are available and are in use could lead to an increase in international tensions. Natural drought in a region, or any other unusual natural disaster, will be suspect or blamed on an enemy. The results of this insecurity were discussed by Edith Brown Weiss, a scientist and proponent of passage of a treaty banning the use of weather modification as a weapon of war, during her testimony before the Senate Foreign Relations Committee:

Accepting any environmental modification techniques as legitimate weapons undermines the already shaky distinction between conventional and unconventional means of warfare. It makes acceptable the idea of using techniques of environmental modification as a weapon of war. . . . Even the chance that States will be able to use some techniques for hostile purposes without violating the Conventions casts suspicion on the development and use of weather modification technology for peaceful purposes. In the long run, it can endanger the international cooperative programs in weather forecasting and atmospheric research, which help us to understand and use weather to benefit mankind.²

In light of these problems, the international community has made scattered attempts both to further the study of weather and its modification and to insure the peaceful use of this new technology. The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, which was signed in Geneva for the United States on May 18, 1977 (but which has not yet been submitted to and approved by the Senate) and the precipitation enhancement program sponsored by the World Meteorological Organization are the most outstanding examples of these attempts.

In the United States, the Congress has taken the lead in formulating a foreign policy on weather modification. Passage in 1973 of Senate Resolution 71, calling for an international agreement to limit the use of weather modification in warfare, was the first major step taken in this area and occurred over the objections of the administration. The National Weather Modification Policy Act of 1976 required the Secretary of Commerce to develop a national policy, or alternative national policies on weather modification, including international aspects of it.

This chapter will briefly outline the activities of international organizations in the area of weather modification as well as the activities of the Congress and the executive branch which deal with international activities in weather modification. United States military activities and the activities of other nations will be discussed elsewhere in this report.

CONVENTION ON THE PROHIBITION OF MILITARY OR ANY OTHER HOSTILE USE OF ENVIRONMENTAL MODIFICATION TECHNIQUES

DEVELOPMENT OF THE TREATY

On July 3, 1974, the United States and the Soviet Union issued a joint statement recognizing the potential danger of the use of environmental modification in warfare and agreeing to:

1. Advocate the most effective measures possible to eliminate the dangers of this type of warfare; and
2. Meet during 1974 to explore the problem and its solution.

One year prior to this communique, the Senate had adopted by a

² U.S. Congress, Senate, Subcommittee on Oceans and International Environment, "Prohibiting Hostile Use of Environmental Modification Techniques," hearing, 94th Cong., 2d sess., Jan. 21, 1976, Washington, U.S. Government Printing Office, 1976, p. 29.

large majority a resolution calling upon the U.S. Government to negotiate a treaty controlling the use of environmental modification as a weapon of war.

On August 7, 1974, Soviet Foreign Minister Gromyko sent a letter to the Secretary-General of the United Nations asking that a resolution advocating the conclusion of an international convention prohibiting environmental modification for military purposes be added to the agenda of the 1974 U.N. General Assembly.³ The Soviet Union submitted, on September 24, 1974 a resolution calling for a convention and a draft convention entitled "Prohibition of Action to Influence the Environment and Climate for Military and Other Purposes Incompatible with the Maintenance of International Security, Human Well-Being and Health."⁴

The proposed convention was quite far reaching. For example, article 1 stated that each party to the convention "undertakes not to develop meteorological, geophysical or any other scientific technological means of influencing the environment, including the weather and climate, for military and other purposes incompatible with the maintenance of international security, human well-being and health, and, furthermore, never under any circumstances to resort to such means of influencing the environment and climate or to carry out preparations for their use." Article 2 listed 12 specific activities which were to be prohibited. Other articles prohibited parties from assisting other states in such activities and noted that nothing in the convention was meant to impede scientific progress or the development of methods to improve the environment for peaceful purposes. Violations were to be reported to the Security Council, and parties would adopt national controls to prevent their citizens from taking actions contrary to the treaty. After 5 years a conference of the parties would be held to revise the convention if necessary in light of scientific developments.⁵

After debate, the General Assembly amended the resolution to eliminate some of the ambiguities the members found, adopted it on December 9, 1974, and requested the Conference of the Committee on Disarmament (CCD) to proceed "as soon as possible to achieving agreement on the text of such a convention" as the one proposed by the Soviet Union and to submit a report on the finding to the next session of the General Assembly.⁶ (The United States abstained on this vote after noting in the debate that the problem had not been defined and it was premature to conclude that a convention would be feasible or effective.)⁷

³ United Nations mimeographed document No. A/9702, 1974.

⁴ United Nations mimeographed document No. A/C1/L675, 1974.

⁵ United Nations document A/9910, Dec. 6, 1974.

⁶ A/Res/3264 (XXIX).

⁷ Senator Stuart Symington, a member of the U.S. delegation to the 29th session of the United Nations General Assembly summed up the reasons for the United States stand as follows:

"The public explanation of our stand was that 'even with the commendable changes accepted by the Soviet delegation, the resolution as it now stands still appears to prejudice how the committee would consider the question.'

"The reason for our abstention appeared to be the fear that this general recommendation might result years hence in a treaty, subject to a two-third vote of approval by the Senate, that in some respect the executive branch might not like. This fear to explore even the possibility of a legal regime for environmental modification seems to approach excessive caution."

U.S. Congress, Senate, Committee on Foreign Relations, "The United Nations, the United States and Arms Control," report by Senator Stuart Symington, member of the delegation to the United Nations, May 1975, 94th Cong., 1st sess., committee print, Washington, U.S. Government Printing Office, 1975, p. 4.

Early in November 1974, the United States and the Soviet Union began meeting to develop a joint approach to a treaty prohibiting the use of environmental modification as a weapon of war. These meetings continued through the summer of 1975. During the summer of 1975, the CCD was also holding meetings on the draft convention proposed by the Soviet Union in September 1974. In August of 1975, the Soviet Union and the United States submitted identical draft conventions to the CCD. At the time the U.S. delegate noted that the submission of identical texts was important, that the major issues had been identified and that discussions had shown that a consensus had clearly been reached on the desirability of achieving such an agreement.⁸

On July 1, 1976, the CCD established a working group to consider the modifications of the joint draft convention and in early September transmitted a completed draft convention to the United Nations General Assembly. The General Assembly adopted the resolution, calling for acceptance of the draft convention on December 10, 1976, by a recorded vote of 96 to 8 with 30 abstentions.⁹

The resolution directed the Secretary General to open the convention for signature and ratifications. The convention was opened for signature in Geneva on May 18, 1977, and was signed by the United States and 33 other nations.

CRITICISM OF THE CONVENTION

Even before the Convention was opened for signature, there was a great deal of criticism of its contents. Critics claimed that it contained loopholes that seriously weakened the treaty. One action taken by several environmental groups was to file a law suit against the State Department on the grounds that the Department was required to file an environmental impact statement on the effects of the Convention.

In addition to these environmental groups, several members of the United Nations, scientists and members of Congress have been critical of the Convention. The main criticism is that the treaty only partially bans environmental modification techniques in warfare. The questionable language is centered in the language of article I, which reads:

Each State Party to this convention undertakes not to engage in military or any other hostile use of environmental modification techniques having *widespread, long-lasting, or severe* effects as the means of destruction, damage or injury to another State Party. [Emphasis added.]¹⁰

The italicized language is the so-called troika language, which was not in the original Soviet draft, but was used in the joint Soviet/United States communique, leading to the conclusion that it was added at the insistence of the United States.

In a paper prepared for the General Assembly debate, the Government of Mexico called this phrase "in every respect inadequate and ambiguous."¹¹ And Dr. Edith Brown Weiss, in testifying on January 21, 1976, before the Senate Foreign Relations Committee stated:

Article 1 indicates that the convention covers only environmental modification techniques "having widespread, long-lasting, or severe effects". Ironically, the

⁸ United Nations, General Assembly, Conference of the Committee on Disarmament, report, vol. I, New York, United Nations, 1976, p. 61. (United Nations, document A/31/27 United Nations, General Assembly, official records, 31st sess. suppl. No. 27.)

⁹ Text of the resolution published in the Department of State bulletin, Jan. 1, 1977, pp. 6-29.

¹⁰ Text of treaty included in app. C.

¹¹ See United Nations Document No. A/C.1/31/S Nov. 16, 1976, p. 2.

language sounds like it covers only those techniques which are least developed—such as techniques for climate modification. . . . There are important ambiguities in this draft about the extent to which weather modification activities are covered by its prohibitions and about whether the use of environmental modification techniques incidental to facilitating the effectiveness of other weapons is covered.¹²

Secondly, the Convention was criticized for its lack of effective enforcement procedures. Complaints of violations of the Convention are to be referred to the Security Council where both the United States and the Soviet Union, the countries with the leading capabilities to develop technology for weather warfare, have a veto. Critics contend that giving the power to investigate violations and determine whether damages can be claimed to the veto-prone Security Council makes enforcement of the treaty impossible.

In defending the proposed treaty to Congressman Gilbert Gude, the Director of the U.S. Arms Control and Disarmament Agency, Fred C. Ickle, wrote in September 24, 1975:

The anticipatory nature of the proposed Convention carries with it many of the basic uncertainties of the future, and I anticipate criticisms of different aspects of the agreement from several sides. The alternative to action now would be to attempt restraint at a later time, when the possibilities of hostile use of environmental modification techniques may be more real. An agreement on prohibitions might then be more difficult to achieve.¹³

In a followup letter to the Senate Foreign Relations Committee commenting on the comments of Dr. Weiss, Mr. Ickle stated:

Because certain effects are not listed, she questions whether all uses are prohibited. The presence or absence of any technique in the list does not indicate that it is allowed or prohibited—all hostile uses of all environmental modification techniques having widespread, long-lasting, or severe effects would be prohibited by the Convention.¹⁴

Finally, concerning the enforcement procedures, this same letter commented:

It is unlikely, as a practical matter, that a permanent member of the Security Council would exercise its veto to prevent an investigation of a complaint brought against it (or an ally), since such an act would probably be taken as confirmation of a violation by many UN members.¹⁵

The Convention, as approved by the General Assembly, calls upon the parties to look again at the provisions of the Convention in 5 years time to insure that the Convention is in fact fulfilling its purpose. This will give critics an opportunity to strengthen the Convention.

ACTIVITIES SINCE THE UNITED NATIONS APPROVAL OF THE CONVENTION

The Convention was opened for signature on May 18, 1977. At that time Secretary of State Vance made a statement which many regarded as an indication that the United States was willing to reexamine the use of the so-called troika language. His comments were:

In the view of the United States, the effect of the convention should be to eliminate the danger of environmental warfare because it prohibits all significant

¹² U.S. Congress, Senate, Committee on Foreign Relations, Subcommittee on Oceans and International Environment, "Prohibiting Hostile Use of Environmental Modifications Techniques," hearing, Jan. 21, 1976, 94th Cong., 2d sess., Washington, U.S. Government Printing Office, 1976.

¹³ *Ibid.*, p. 6.

¹⁴ *Ibid.*, p. 18.

¹⁵ *Ibid.*, p. 17.

hostile use of environmental modification techniques. According to the present terms, the convention limits the prohibition to those uses having "widespread, long-lasting or severe effects." The United States will be prepared to reexamine this limitation on the scope of the convention at the review conference or possibly before.¹⁶

In the fall of 1977, the law suit against the Department of State was dropped when the Department agreed to prepare an environmental assessment statement (not an environmental impact statement), and submit it to the Senate with the Convention. According to the Department of State, this statement will discuss what the Convention does, in the Department's understanding, what weather modification techniques are currently available and thus covered by the Convention, and will state that the only use of weather modification for hostile use ever engaged in by the United States was in Vietnam (see section on congressional activities).¹⁷ The way has now been cleared for transmittal of the Convention to the Senate, which is expected to take place during 1979.

As of mid 1978, 50 nations had signed the Convention, and 19 had ratified it.

ACTIVITIES OF THE WORLD METEOROLOGICAL ORGANIZATION IN WEATHER MODIFICATION

The World Meteorological Organization (WMO) has been a specialized agency of the United Nations since 1951, although its predecessor, a nongovernmental organization, the International Meteorological Organization, dates to 1873. WMO's responsibilities include the coordination, standardization, and improvement of meteorological services throughout the world and the encouragement of an efficient exchange of meteorological information between countries.

The WMO is the international organization which historically more than any other has been involved in various aspects of weather modification. According to a WMO background paper prepared for the precipitation enhancement project WMO activities in the area of weather modification began as early as 1955 with the publication of a technical note (study) devoted to the scientific aspects of cloud and precipitation control.¹⁸ By the early 1970's the general awareness and interest in inadvertent as well as planned weather modification had increased to the point that WMO felt it necessary to issue guidelines to handle inquiries from member nations on weather modification. The statement, entitled "Present State of Knowledge and Possible Practical Benefits in Some Fields of Weather Modification" was first published in 1971, and revised and amplified in 1975.

By 1972 WMO found it necessary to issue "Guidelines for Advice and Assistance Related to the Planning of Weather Modification Activities" in order to answer the more specific questions being asked of WMO. At the same time, a working commission of WMO was designated as a panel of experts on weather modification for the WMO, thus creating a permanent panel to monitor and study weather modification.

¹⁶ "United States Signs Convention Banning Environmental Warfare," statement by Secretary Vance, Department of State bulletin, June 13, 1977, pp. 633-4.

¹⁷ See p. 441.

¹⁸ World Meteorological Organization, "Plan for the Precipitation Enhancement Project (PEP)," PEP report No. 3, Geneva, November 1976.

PRECIPITATION ENHANCEMENT PROGRAM (PEP)

Following a world wide survey of weather modification activities and interests in 1972 and 1973, the WMO concluded that it should become more active in weather modification and during 1974 began formulating a program on weather modification and estimating its costs with the view that these could be studied and implemented during the 1976-79 financial period. The WMO Weather Modification Programme was adopted in 1975. At the time, the WMO Congress stated that:

WMO was the appropriate international body with the necessary scientific and technical expertise in this field, and agreed that the time had come for the organization to become more active in order to provide the best possible advice to members, the United Nations and other international organizations concerning weather modification. In view of the urgent need to find ways of increasing world food production and conserving water supplies, it was agreed that priority in this field had to be given to increasing precipitation.

Considering that the results of most rainmaking projects up to that time had been inconclusive because of the lack of sound scientific planning, operation and evaluation, Congress agreed that scientifically convincing answers concerning the feasibility of precipitation enhancement could best be advanced through an internationally planned, executed and evaluated experiment in precipitation stimulation.¹⁹

Thus the major element of the new Weather Modification Programme would be a precipitation enhancement project (PEP). The aim of PEP is to plan, set up, and carry out an international, scientifically controlled precipitation enhancement experiment in a semiarid region under conditions where the chances of increasing precipitation on the ground in amounts big enough to produce economic benefits are optimal. The objectives listed by WMO are as follows:

(a) To provide members with reliable information about the probabilities of successful artificial intervention in meteorological processes with the object of increasing the amount of precipitation, over an area of the order of 10,000 km². The size of the area for the proposed project (that is, the target and nearby control areas) should be somewhere around 50,000 km², a scale large enough to provide adequate evaluation of scientific feasibility and economic benefit, but small enough to permit the use of adequate methods for seeding and observations;

(b) To demonstrate at a satisfactory statistical significance level over a relatively short experimental period (5 years) that any increase observed is not a chance event but is associated with the seeding. The principal evaluation of this experiment will be in terms of precipitation at the ground;

(c) To obtain sufficient understanding of the meteorology and cloud physics in the area of the experiment to insure that the statistical association of seeding and any increase in precipitation will be generally acceptable as a cause-and-effect relationship;

(d) To make an examination outside the target area in order to determine whether any benefits of seeding extend over areas greater than the target area, or whether there has merely been a comparatively local redistribution of precipitation;

¹⁹ Ibid., p. 21.

(e) To make systematic measurements varying from mesoscale to cloud microstructure in order to develop additional covariates to strengthen the power of the statistical analysis;

(f) To obtain well documented scientific evidence that may lead to the optimization of the effects of seeding. For this purpose a series of systematic cloud physics measurements should be taken on a routine basis. This would allow the application of statistical stratification techniques to relevant physical parameters, and could shed more light on the quantitative aspects of the seeding technique;

(g) To be able to make some recommendations about the applicability of the PEP procedures to other areas of the world; and

(h) To make an assessment of the environmental impact of precipitation enhancement activities both within and outside the experiment target area.²⁰

The plan for PEP is divided into three phases. A preparatory and site selection phase of at least 2 years will develop criteria for the selection of regions and sites, develop the plan for the precipitation enhancement experiment, and select the sites to be used. This phase has already begun. The second phase will be the actual scientific field experiment and will last 5 years. The third phase will be an evaluation of the results. While this will begin during the second phase, it will extend 1 year beyond the end of the phase two.²¹

PEP will be funded by members on the basis of their participation and by the individual efforts of interested members. The WMO budget will fund only the costs related to international coordination and guidance and not the experiment itself or its evaluation. The main role of the WMO is to encourage members in the cooperative effort, to safeguard the scientific integrity of the program, to insure that it is conducted in the best possible way, and to disseminate the results to interested members. WMO will support three separate groups responsible for the international coordination and guidance aspects of the experiment as follows:

(a) The Precipitation Enhancement Project Board should be an intergovernmental Board consisting of representatives of members making the major contributions to the project and to which observers from interested UN organizations and ICSU should be invited. The Board will represent the main management body; proposing plans of action to the Executive Committee within the limits of available financial resources;

(b) The Executive Committee Panel on Weather Modification with supplementary expertise as necessary will provide the Executive Committee and the Secretary-General with advice on details of the objectives of PEP and how these could be achieved in principle. It should guide the preparation of the plans to be reviewed by the Board; and

(c) The Scientific Planning Group at WMO headquarters will work on PEP as a part of the WMO Research and Development Programs, using the available experience and support of the

²⁰ *Ibid.*, p. 2.

²¹ *Ibid.*, p. 3.

Secretariat. The detailed functions of the Scientific Planning Group should decide upon the relationships between the Scientific Planning Group, the PEP Board, and the Executive Committee Panel on Weather Modification.²²

OTHER WMO ACTIVITIES IN WEATHER MODIFICATION

Other WMO activities have paralleled U.S. domestic activities in weather modification. These have included conferences of experts, registration of weather modification activities of member nations, and the problems of liability for potential damage caused by weather modification activities.

Registration and reporting of weather modification projects

One important effort of the WMO has been in the area of registration of weather modification projects. Beginning in 1973, the WMO began sending questionnaires to member nations asking them to report on their weather modification activities. While compliance with this request was completely voluntary, well over half of the members did report on their activities. In 1975, as part of the weather modification program adopted by the WMO Congress, the WMO Secretary General was required to maintain a register of experiments and operations in the weather modification field carried out within member countries. Out of a total 1975 membership of 138, 74 nations replied and 16 reported weather modification activities. Parts of the most recent report, covering activities for calendar year 1976, are included and discussed in the chapter on foreign activities. (See chapter 9.)

WMO conferences on weather modification

The WMO has sponsored two conferences on weather modification. These were preceded by another international conference, which was sponsored jointly by the Australian Academy of Science and the American Meteorological Society and was held in Canberra, Australia, from September 6 through 11, 1971. The first WMO international conference on weather modification, sponsored jointly with the International Association of Meteorology and Atmospheric Physics, was held in Tashkent, U.S.S.R., on October 1 through 7, 1973. The conference included 270 participants from around the world, both from countries with active weather modification programs and from those only interested in the subject. The conference covered fog dispersal, rain and snow enhancement, hail suppression, modification of tropical storms and thunderstorms, technical and operational aspects of weather modification, physical, statistical and economic evaluations of weather modification and ice nucleus technology.²³ A second conference, sponsored by WMO with the National Oceanic and Atmospheric Administration, the International Association of Meteorology and Atmospheric Physics, the American Meteorological Society and the

²² List, Roland, "Objectives and Status of the WMO Precipitation Enhancement Project (PEP)," Department of Physics, University of Toronto, Toronto, Ontario, Canada, p. 6, (Unpublished paper provided by National Oceanic and Atmospheric Administration.)

²³ The proceedings of this meeting were published by the WMO in 1974, WMO publication No. 399, Geneva, Switzerland.

Australian Academy of Sciences was held in Boulder, Colo., from August 2 through 6, 1976.²⁴

Typhoon and serious storm modification

Another area of weather modification activity, typhoon and serious storm modification, has also been an area of concern to the WMO. Several efforts at learning about and controlling typhoons or tropical cyclones have been jointly sponsored by the WMO. Together with the Economic Commission for Asia and the Far East of the United Nations (now the Economic and Social Commission for Asia and the Pacific), the WMO has established a Typhoon Committee which concentrates on improving civil preparedness against typhoon damage. Because so little is understood about typhoons, most of the activities undertaken have been research and the collection and analysis of meteorological information about tropical weather.

A WMO sponsored Technical Conference on Typhoon Modification, which was held in Manila in October of 1974, endorsed a 24-hour limit on typhoon modification experiments, which would permit experimental seeding of typhoons if they were not expected to reach land within 24 hours.²⁵ A 1972 resolution of the UN General Assembly praised the efforts of the WMO in this area and requested the WMO to keep the UN informed of progress in its tropical cyclone project.²⁶

Global Atmospheric Research Programme

An important project sponsored jointly by WMO and the International Council of Scientific Unions is known by the acronym GARP for Global Atmospheric Research Programme. This is an information gathering and research project, rather than a weather modification project per se. The data from GARP is expected to contribute to the development of long-range weather prediction and the development of large scale weather modification theories. Hopefully, successful new methods of weather forecasting will emerge from this program and the new information can be used to carry out computer simulations of weather modification activities on a global scale. GARP is expected to complement the worldwide measurement of atmospheric particulates and gases to be undertaken as part of the Earthwatch Program of the U.N. Environment Program established by the Stockholm conference.

Legal aspects of weather modification

The WMO and the United Nations Environment Program jointly sponsored an informal meeting on the legal aspects of weather modification in Geneva, Switzerland during November 17 to 21, 1975. This meeting had a double purpose. First, the group was asked to consider the formulation of legal principles for weather modification, bearing in mind the principles adopted at Stockholm in 1972. (See the following section on United Nations Conference on the Human Environment.) Second, the group was asked to give particular consideration to legal liability of the WMO regarding the precipitation enhancement program, then in the early planning stages. The principles considered but not adopted are contained in the mimeographed report of the meeting, pages 5 through 8, which is reproduced as appendix Q.

²⁴ The WMO publication on this conference was entitled, "Papers Presented at the Second WMO Scientific Conference on Weather Modification," WMO-No. 443, Geneva, Switzerland, 1976.

²⁵ WMO Technical Conference on Typhoon Modification, Manila, Oct. 15-18, 1974, statement on typhoon moderation, mimeographed WMO document.

²⁶ United Nations document No. A/Res/2914 (XXVIII) Nov. 13, 1972.

UNITED NATIONS CONFERENCE ON THE HUMAN ENVIRONMENT

The United Nations Conference on the Human Environment, held in Stockholm, Sweden, from June 5 through 16, 1972, has been the pivotal point in much recent international environmental activity, and it has also been an important catalyst in international activities relating to weather modification. Conferences held in preparation for the Stockholm Conference and programs initiated by it are the major cooperative weather modification activities of the 1970's, and it is the internationally agreed upon principles adopted at Stockholm which are being considered in the development of international legal principles applying to cooperative weather modification activities. Many of these activities are discussed in other sections. The Conference adopted an "Action Plan for the Human Environment" based on a "Declaration" agreed to by the participants.

DECLARATION OF THE UNITED NATIONS CONFERENCE ON THE HUMAN ENVIRONMENT

The declaration consists of a preamble and 26 principles of conduct intended to serve as guides for states in dealing with environmental problems of international significance. Principles 21 and 22 particularly affect weather modification activities. Principle 21 deals with state responsibility for damage to the environment of other nations, and principle 22 calls on states to cooperate in developing international law regarding liability and compensation for such damage. The two principles are:

"Principle 21

"States have, in accordance with the Charter of the United Nations and the principle of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to insure that activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond the limits of national jurisdiction.

"Principle 22

"States shall cooperate to develop further the international law regarding liability and compensation for the victims of pollution and other environmental damage caused by activities within the jurisdiction or control of such states to areas beyond their jurisdiction."²⁷

ACTION PLAN FOR THE HUMAN ENVIRONMENT

The action plan consists of some 200 recommendations for national and international action—a framework for future environmental agreements. Although much of the action plan relates to weather more generally and pollution of the air and water, one recommendation in

²⁷ U.S. Congress, Senate, Committee on Foreign Relations. "United Nations Conference on the Human Environment," report to the Senate by Senators Claiborne Pell and Clifford Case, members of the delegation to the United Nations Conference on the Human Environment, October 1972, 92d Cong., 2d sess., committee print, Washington, U.S. Government Printing Office, 1972, p. 18.

particular applies to climate modification. Recommendation 70 reads as follows:

It is recommended that Governments be especially mindful of activities in which there is an appreciable risk of effect on climate; and

(a) Carefully evaluate the likelihood and magnitude of climatic effects and, to the maximum extent feasible, disseminate their findings before embarking on such activities;

(b) Consult fully other interested states when activities carrying a risk of such effects are being contemplated or implemented.²⁸

In discussing this provision, Senators Claiborne Pell and Clifford Case, members of the U.S. delegation to the Conference, criticized what they saw as an amendment which "considerably weakened" the provision. This amendment, introduced by the United States and adopted by the Conference, added the phrase "to the maximum extent feasible" to section (a) as printed above. Concerning this amendment, the Senators' report states:

The U.S. amendment appears to provide a loophole whereby any country could conduct covert military weather modification operations without any form of international control or responsibility. This, we feel, is contrary to a resolution which we and 14 other Senators have introduced in the Senate which expresses the sense of the Senate that the U.S. should seek the agreement of other governments to a proposed treaty prohibiting the use of any environmental modification activity as a weapon of war. We adamantly oppose the use of environmental techniques as weapons of war and strongly urge the Administration to actively promote the negotiation and ratification of such a treaty.²⁹

The resolution referred to in the above quotation, and the discussion surrounding its passage, are discussed in the section on congressional activities.

EARTHWATCH PROGRAM

The major project developing from the Stockholm Conference in the area of atmospheric changes is the Earthwatch program. While the program as a whole is designed to assess global environmental conditions in all areas from water pollution to food contamination, one of its first projects will be to measure pollution levels around the world and study their effects on climate * * * the inadvertent modification of weather. The Earthwatch program which will be set up under the auspices of the World Meteorological Organization, will consist of the following major elements:

Ten baseline stations to measure the long term global trends which may ultimately cause climate changes. These stations would be established in remote areas far from any sources of pollution.

One hundred additional stations to monitor the air quality on a regional basis. This monitoring will be coordinated by the WMO.

Establishment of water borne stations to measure contaminants in major rivers, lakes, and seas.

Establishment of research centers and biological centers to analyze changes in soil conditions and plant and animal life.

STUDY OF MAN'S IMPACT ON CLIMATE

Of the many conferences and preparatory meetings held prior to the Stockholm Conference, one in particular is noteworthy. In 1970, sup-

²⁸ Ibid., p. 36.

²⁹ Ibid., p. 5.

ported by the U.N. Secretariat and the World Meteorological Organization,³⁰ scientists from 14 countries participated in the Study of Man's Impact on Climate (SMIC), sponsored by the Massachusetts Institute of Technology and hosted in Sweden by the Royal Swedish Academy of Sciences and the Royal Swedish Academy of Engineering Sciences.³⁰ The purpose of the study was to provide an authoritative assessment of the state of scientific understanding of the possible impacts of man's activities on the regional and global climate. Based on this assessment, specific recommendations were developed for programs that would provide the knowledge necessary for more definitive answers in these complex areas. Many of these recommendations were incorporated into the Action Plan for the Human Environment. One in particular bears mentioning separately. This suggested "that an international agreement be sought to prevent large-scale (directly affecting over 1 million square kilometers) experiments in persistent or long term climate modification until the scientific community reaches a consensus on the consequences of the modification."³¹

OTHER INTERNATIONAL ACTIVITIES

UNITED STATES/CANADIAN AGREEMENT

The Agreement between the United States of America and Canada Relating to the Exchange of Information on Weather Modification Activities was signed and entered into force on March 26, 1975.³² The agreement provides that the United States and Canada will exchange information on weather modification activities occurring within 200 miles of their common border or wherever else they may occur if it is expected that the activities will affect the "composition, behavior, or dynamics of the atmosphere over the territory of the other Party." When possible, this information will be transmitted to the other party prior to the beginning of the activities.

NORTH AMERICAN INTERSTATE WEATHER MODIFICATION COUNCIL³³

The North American Interstate Weather Modification Council (NAIWMC) was organized on January 17, 1975, by representatives of the governments of several U.S. States and Canadian provinces and the Mexican Government. Its purpose is to coordinate and serve as a focal point for intrastate, interstate, and international weather modification activities. This would include research into weather modification, legislation and treaties governing weather modification activities, and public information activities as well as its coordination functions. Membership is open to any state or province of the United States, Canada, and Mexico.

Affiliate membership is available to national agencies, political subgroups within the States, professional organizations and scientific

³⁰ "Study of Man's Impact on Climate," Stockholm, 1970, inadvertent climate modification; report, Cambridge, Mass., MIT Press, 1971.

³¹ *Ibid.*, p. 19.

³² 26 UST 54; TIAS 8056, reproduced in app. F.

³³ This information is taken from a document entitled: "Weather Modification. North American Interstate Weather Modification Council. Its purpose and activities." Office of the NAIWMC, Executive Secretary, Box 3CE, NMSU, Las Cruces, N. Mex., 88003 September 1976, publication No. 76-2.

societies. Current membership of NAIWMC consists of 15 members and affiliates in all three countries. In its brief history, NAIWMC has taken an active role in legislation (including testifying) proposed at both the State and Federal level concerning weather modification. Additionally, NAIWMC has supported directly or indirectly five interstate conferences on weather modification and made the proceedings of the conferences available to the public.³⁴

CONGRESSIONAL ACTIVITIES

Although congressional interest in domestic weather modification activities has grown steadily for many years, interest in the international aspects is more recent. With the exception of one resolution discussed in the following section, all such activities in the Congress have taken place since 1970.

WEATHER MODIFICATION AS A WEAPON OF WAR

Senate Resolution 71, prohibiting environmental modification as a weapon of war

In December 1971, Senator Claiborne Pell inserted a statement in the Congressional Record indicating his concern over the possible use by the United States of precipitation enhancement (rainmaking) in Southeast Asia and the future use of these and other weather modification techniques in warfare. He expressed concern that such activities carried on by any countries for other than peaceful purposes might endanger international cooperation in peaceful weather collection and modification activities. The Senator urged that the United States, through the President, renounce the use of geophysical and environmental research for other than peaceful purposes and take the initiative in framing and introducing a treaty imposing a prohibition on all forms of geophysical and environmental warfare. Senator Pell said he would introduce a resolution setting forth a draft treaty on weather modification in order to generate discussion and action in this area.

At the time of Senator Pell's statement, the Department of Defense had completed several precipitation enhancement projects for Government agencies both in the United States and abroad.

Several news columnists had claimed that precipitation enhancement had been used in Vietnam in articles appearing early in 1971, and these operations were later mentioned in the Pentagon papers, which were released in June 1971. On January 26, 1972, Senator Pell inserted in the Congressional Record his correspondence with the Department of Defense in attempting to confirm or deny the newsmen's allegations.³⁵ After several months of correspondence, the Defense Department declined to answer the questions publicly on the basis that such a reply would threaten the national security. Senator Alan Cranston and Congressman Gilbert Gude received the same response to their inquiries. During an April 1972 appearance before the Senate

³⁴ See ch. 7, p. 333, for references to the five meetings and other activities of the North American Interstate Weather Modification Council.

³⁵ Congressional Record (daily edition) Jan. 20, 1972 : S 507-508.

Foreign Relations Committee, Secretary of Defense Laird was questioned by both Senator Pell and Senator Fulbright about rainmaking in Vietnam. The Secretary said: "We have never engaged in that type of activity over North Vietnam."³⁶

On March 17, 1972, Senator Pell and 15 cosponsors introduced S. Res. 281, stating the sense of the Senate that the U.S. Government should seek agreement with other governments to a treaty calling for the complete cessation of any research, experimentation, and use of environmental or geophysical modification activity as a weapon of war. Hearings were held on S. Res. 281 on July 26 and 27, 1972.³⁷ At the time the Department of State indicated that they were not in favor of passage of the resolution and proposed treaty. The State Department spokesman stated:

* * * we believe that there is at present too much uncertainty about essential facts and that the factual basis itself is insufficient to make possible any fundamental decisions on whether a treaty dealing with military aspects is feasible and desirable.

It is therefore our conclusion that actions such as those recommended in S. Res. 281 are premature. Accordingly, the Department of State recommends that this resolution not be adopted.³⁸

Several other witnesses made comments on the proposed treaty, as well as commenting on the need for a treaty. Several resolutions on the subject of a treaty were offered in the House of Representatives during 1972, but no final action was taken in either the House or Senate during the 92d Congress. S. Res. 281 was endorsed unanimously by the NATO North Atlantic Assembly on November 21, 1972, indicating a broad international interest in the subject of an international weather modification treaty.³⁹

On February 22, 1973, Senator Pell introduced S. Res. 71 for himself and 18 cosponsors. This resolution was identical to S. Res. 281, and after consideration by the Foreign Relations Committee, was recommended favorably to the Senate on June 27, 1973 with three amendments. The amendments indicated that the committee felt the United States should seek a multilateral treaty, including all the permanent members of the United Nations Security Council, that the treaty contained in the resolution was only a model, and that the resolution in no way intended to impede or restrict research or experimentation on use of environmental modification techniques for peaceful purposes. S. Res. 71 was approved by the Senate by a vote of 82 to 10 on July 11, 1973.⁴⁰

Congressional activities related to hostile use of weather modification, 1974-76

In January and March 1974, Senator Pell's Subcommittee on Oceans and International Environment of the Senate Foreign Relations Committee held more hearings "concerning the need for an international

³⁶ Shapley, Deborah, "Rainmaking: Rumored Use Over Laos Alarms Arms Experts, Scientists," *Science*, June 16, 1972, as reproduced in *Congressional Record* (daily edition) June 16, 1972: S 9555-9556.

³⁷ U.S. Congress, Senate, Committee on Foreign Relations, Subcommittee on Oceans and International Environment, "Prohibiting Military Weather Modification," hearings on S. Res. 281, 92d Cong., 2d sess., July 26 and 27, 1972, Washington, U.S. Government Printing Office, 1972, 162 pp.

³⁸ *Ibid.*, p. 20.

³⁹ U.S. Congress, Senate, Committee on Foreign Relations, "Eighteenth meeting of the Atlantic Assembly," report of the U.S. delegation, committee print, 93d Cong., 1st sess., May 11, 1973.

⁴⁰ S. Res. 71 reproduced in app. R.

agreement prohibiting the use of environmental modification and geophysical modification as weapons of war."⁴¹ At the time Senator Pell noted that since the administration had made no move in 6 months, the hearing was being held to shed light on the reasons for the delay. During the hearing the State Department spokesman stated:

* * * the Secretary (of State) expressed regret that it was not yet possible to provide a coordinated executive branch response on S. Res. 71. He assured you that the matter would be looked into closely to determine how the executive branch might be responsive to the resolution's recommendations.

In this regard the President has directed that a study of the military aspects of weather and other environmental modification techniques be undertaken. Further steps will be determined subsequent to the findings of this study and the review of those findings.⁴²

At the classified March briefing (later declassified and printed with the above hearing) the Department of Defense outlined the precipitation enhancement project which took place over Laos, North Vietnam, and South Vietnam between 1967 and 1972. According to both the Department of Defense spokesman and the Senators present at the hearing, the program was very modest, its success was questionable, and because of this questionable success, the environmental impact was most likely negligible.

During 1974 and 1975, the House International Relations Committee considered several resolutions calling for an international agreement prohibiting the use of weather modification as a weapon of war. None of the resolutions passed, but hearings were held during both 1974 and 1975.⁴³

On January 21, 1976, the Senate Foreign Relations Committee, Subcommittee on Oceans and International Environment, held a hearing which concentrated on executive branch comments on the Draft Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques which was then being considered by the Conference of the Committee on Disarmament.⁴⁴

OTHER CONGRESSIONAL ACTIONS RELATING TO WEATHER MODIFICATION

Senate Concurrent Resolution 67—U.S. Participation in the World Weather Program

Senate Concurrent Resolution 67, which passed the Senate, as amended by the House, on May 29, 1968, made it the sense of the Congress that the United States should participate in, and give full support to, the world weather program then being developed under the auspices of the United Nations. This weather program included the World Weather Watch, an international system for the observation of the global atmos-

⁴¹ U.S. Congress, Senate, Committee on Foreign Relations, Subcommittee on Oceans and International Environment, "Weather Modification" hearings: 93d Cong., 2d sess., Jan. 25 and Mar. 20, 1974. (Top secret hearing held on Mar. 20, 1974; made public on May 19, 1974) Washington, U.S. Government Printing Office, 1974; 123 pp.

⁴² *Ibid.*, p. 9.

⁴³ U.S. Congress, House, Committee on Foreign Affairs, Subcommittee on International Organizations and Movements, "Weather Modification as a Weapon of War," hearing, 93d Cong., 2d sess., Sept. 24, 1974, Washington, U.S. Government Printing Office, 1974; 39 pp. Committee on International Relations, "Prohibition of Weather Modification as a Weapon of War," hearing, 94th Cong., 1st sess., July 29, 1975, Washington, U.S. Government Printing Office, 1975, 51 pp.

⁴⁴ U.S. Congress, Senate, Committee on Foreign Relations, Subcommittee on Oceans and International Environment, "Prohibiting Hostile Use of Environmental Modification Techniques," hearing, 94th Cong., 2d sess., Jan. 21, 1976, Washington, U.S. Government Printing Office, 1976, 46 pp.

phere and more rapid and accurate processing of weather data. A second part of the world weather program was to be the conduct of a comprehensive program of research for the development of a capability in long-range weather prediction, and for the "theoretical study and evaluation of inadvertent climate modification and the feasibility of international climate modification."⁴⁵

*National Weather Modification Act of 1976*⁴⁶

The National Weather Modification Policy Act of 1976 (Public Law 94-490, Oct. 13, 1976) stated as its purpose to "develop a comprehensive and coordinated national weather modification policy and a national program of weather modification research and development." This would include the development of "both national and international mechanisms designed to minimize conflicts which may rise with respect to the peaceful uses of weather modification." The law called for a study which shall include "a review of the international importance and implications of weather modification activities by the United States," a review and analysis of the necessity and feasibility of negotiating an international agreement concerning the peaceful uses of weather modification, and "formation of one or more options for a model international agreement concerning the peaceful uses of weather modification and the regulation of national weather modification." Finally, the law required that the Secretary of Commerce report to the Congress within 1 year on, among other things, the international agreement specified above.

In response to this directive from the Congress, the Secretary of Commerce established the Weather Modification Advisory Board which has recently begun holding meetings to develop this national policy and provide the Secretary with information necessary to make the report to Congress.⁴⁷

Senate Resolution 49

Another piece of legislation, Senate Resolution 49, was introduced by Senator Pell on January 24, 1977. This resolution, which was also introduced during 1976, calls upon the President to initiate negotiation of a treaty requiring the preparation of an environmental impact statement for any activity which may reasonably be expected to have a significant effect on the environment of other nations or a global common area. Senator Pell held that a treaty of this sort would insure that environmental modification activities could not be carried out without considering the consequences of such activity beyond a nation's own territory. A hearing was held on this resolution by the Senate Foreign Relations Committee on March 31, 1977, and again on May 18, 1978.

U.S. FOREIGN POLICY

Congress has shown a growing interest in the development of a U.S. policy toward international weather modification activities. However, the executive branch has seemed reluctant to develop such

⁴⁵ Congressional Record (bound ed.) vol. 114, part 7, Apr. 1, 1968, p. 8419.

⁴⁶ Text included in app. I.

⁴⁷ See ch. 5 for discussion of the activities of the Weather Modification Advisory Board.

a policy, preferring to await further developments in weather modification technology. The National Weather Modification Policy Act of 1976 (discussed in a previous section) requires that the Secretary of Commerce suggest a national policy including both domestic and international aspects of weather modification. In pursuance of this legislation, the Secretary of Commerce established the Weather Modification Advisory Board under the chairmanship of Harlan Cleveland to assist her in developing such a policy. The report of this Board is expected to be submitted to the Secretary for her approval and subsequent transmittal to the President and the Congress during 1978.⁴⁸

VARIOUS EXECUTIVE BRANCH PROPOSALS

Despite executive branch reluctance to develop a comprehensive policy in dealing with weather modification, including its international aspects, many statements have been made by various executive branch spokesmen on the subject and many studies encouraging the United States to develop such a policy have been made. As early as 1961, President John F. Kennedy proposed before the United Nations further cooperative efforts between all nations in weather prediction and control, and U.S. financial support for international weather activities has been substantial. In the intervening years, additional statements have been made. These have generally been of a cautious nature, expressing hope that the technology can be used to help mankind, but fearful of its consequences if used foolishly or with malicious intent. On January 26, 1971, Secretary of State William P. Rogers stated the common theme:

We are anxious to apply weather modification technology, as it becomes operational, to the problems of developing countries. We are also alert to the need to consider international arrangements to deal with the implications of this new phenomenon.⁴⁹

During the same year, the National Academy of Sciences, an organization of distinguished scientists and engineers which has a long and close relationship with the U.S. Government, prepared a study of the future of the atmospheric sciences which made the following recommendations to the United States:

The U.S. Government is urged to present for adoption by the United Nations General Assembly a resolution dedicating all weather modification efforts to peaceful purposes and establishing, preferably within the framework of international nongovernmental scientific organizations, an advisory mechanism for consideration of weather modification problems of potential international concern before they reach critical levels.⁵⁰

Again in 1972, in a program proposed by its review panel on weather and climate modification, the National Academy of Sciences recommended efforts to develop a weather modification program devoted to peaceful and safe international uses with the proposal of a three-goal program for U.S. activities. The goals outlined by the panel were:

Completion by 1980 of research to put precipitation control on a sound basis;

⁴⁸ See discussion of activities of the Weather Modification Advisory Board in ch. 5, p. —.

⁴⁹ Department of State Bulletin, vol. LXIV, No. 1651, Feb. 15, 1971, p. 198.

⁵⁰ U.S. National Academy of Sciences, Committee on Atmospheric Sciences, "The Atmospheric Sciences and Man's Needs," report, 1971, p. 56.

Development, in the next decade, of the necessary technology to move toward mitigation of severe storms; and

Determination by 1980 of the extent of inadvertent modification both of local weather and of global climate.⁵¹

As early as 1965, the Special Commission on Weather Modification of the National Science Foundation (a Federal agency) issued a report on weather and climate modification which included the following suggestions for the national policy on the international uses of weather modification:

"The Commission believes that:

"1. It would be highly desirable for the Government of the United States, in connection with the expansion of its program of weather and climate modification, to issue a basic statement of its views on the relationship of this national effort to the interests, hopes, and possible apprehensions of the rest of the world. Early enunciation of national policy embodying two main points are recommended:

"(a) That it is the purpose of the United States * * * to pursue its efforts in weather and climate modification for peaceful ends and for the constructive improvement of conditions of human life throughout the world; and

"(b) That the United States, recognizing the interests and concerns of other countries, welcomes and solicits their cooperation, directly and through international arrangements, for the mutual achievement of human well-being.

"This cooperation should cover both research and ultimately, operational programs of interest to other countries. It should be concerned not only with deliberate, but also inadvertent human interventions in the atmosphere that affect weather and climate. Such a policy declaration could be issued by the President or appropriately incorporated in any basic legislation on the subject of weather modification which the Congress may enact.

"2. Steps should be taken by the United States, in concert with other nations, to explore the international institutional mechanisms that may be appropriate to foster international cooperation and cope with the problems which may be anticipated in the field of weather and climate modification.

"3. Attention should be given to the question of how greater emphasis can be given to atmospheric sciences in existing bilateral and multilateral programs of education and technical cooperation; and to what additional measures may be needed to fill this deficiency.

"4. Encouragement should be given to research on the impact of weather modification measures in foreign countries. The need has been previously discussed for greater attention to the biological, economic and social aspects of weather modification in the United States. A different set of problems may well be encountered in many of the developing countries where the natural environment and patterns of economic and social life present contrasts to those prevailing in this country. A greater understanding of the significance of these differences must precede any attempt to evaluate the suitability of various

⁵¹ Sullivan, Walter, "Goals for U.S. Urged on Weather Control," New York Times, Dec. 29, 1972, p. 50.

weather and climate modification practices for specific foreign areas and to design appropriate programs of cooperation."⁵²

NATIONAL ADVISORY COMMITTEE ON THE OCEANS AND ATMOSPHERE

Public Law 92-125, adopted in 1971, established the National Advisory Committee on Oceans and Atmosphere (NACOA). One purpose of NACOA is to "undertake a continuing review of the progress of the marine atmospheric science and service programs of the United States,"⁵³ and the committee was required to submit an annual report to the President and the Congress. Among the recommendations for action in its first annual report (1972) were the following which concerned international aspects of weather modification:

International: International agreement should be arrived at and the necessary institutional arrangements developed to eschew the hostile uses of weather modification and to investigate changes in the global climate * * *.

NACOA wishes to associate itself with the position taken by the Nation Academy of Sciences that, in order to safeguard the life-sustaining properties of the atmosphere for the common benefit of mankind, the U.S. Government is urged to present for adoption by the United Nations General Assembly a resolution dedicating all weather modification efforts to peaceful purposes and establishing, preferably within the framework of international nongovernmental scientific organization, an advisory mechanism for consideration of weather-modification problems of potential international concern before they reach critical levels.⁵⁴

After mentioning the subject in intervening reports, the Fifth NACOA Annual Report of June 1976 discussed U.S. weather modification activities in detail. A 1975 report of a subcommittee of the Domestic Council was cited as an excellent basis for U.S. policy regarding weather modification activities.⁵⁵ Among its recommendations for domestic policy changes, the subcommittee also discussed the importance of assessing the potential international implications of weather modification activities. The Federal weather modification program was criticized for, among other things, its fragmented approach to the problems and technological developments involved. In discussing the United States effort in weather modification, NACOA supported this criticism and added the following paragraph dealing with the international weather modification situation:

An important element in the weather modification picture is its international aspect. The World Meteorological Organization is proceeding with its own plans for an international weather modification research program, and it is important that the United States be prepared to participate. There are also international aspects to the pursuit of our own program goals. NOAA's Stormfury project, which studies the effects of intervening in the dynamics of tropical convective storms and offers hope of a future ability to modify hurricanes, was to be moved from the Atlantic to the western Pacific for scientific reasons. Objections on the part of some western Pacific nations prevented this move and it will instead be conducted in the eastern Pacific and western Atlantic. It is important to the ultimate success of this effort that we recognize that other nations which might be affected, or

⁵² "Weather and Climate Modification," report of the Special Commission on Weather Modification, National Science Foundation, 1965, pp. 27-29.

⁵³ National Advisory Committee on Oceans and Atmosphere, "A Report to the President and the Congress," first annual report, June 30, 1972, Washington, U.S. Government Printing Office, 1972, p. 43.

⁵⁴ *Ibid.*, p. 21.

⁵⁵ "The Federal Role in Weather Modification," a report of the Subcommittee on Climate Change of the Environmental Resources Committee, Domestic Council, December 1975.

which believe they might be, have a legitimate interest in understanding its expected benefits, the risks involved, and the safeguards proposed.⁵⁰

ACTIVITIES IN 1977

The Weather Modification Advisory Board, established under the chairmanship of Harlan Cleveland to assist the Secretary of Commerce develop a national policy on weather modification, has held several meetings during 1977. Its final report to the Secretary of Commerce is expected during 1978.

In a reorganization prompted by the new administration, coordination of international weather modification activities has been placed under the Bureau of Oceans and International Environmental and Scientific Affairs in the Department of State. The Interagency Study Group, which is responsible to the Bureau of Oceans and International Environmental and Scientific Affairs, has as its function dealing with the problems of international relations in weather modification experimentation by the United States. Thus far it has dealt solely with the problems involved in the continuation of Project Stormfury, a project concerned with tropical storm modification, at the request of NOAA. In addition to negotiating with other countries, primarily Mexico, concerning experimentation, the study group is examining the potential problems of liability of the United States for damage done by official U.S. weather modification activities.

⁵⁰ National Advisory Committee on Oceans and Atmosphere. "A Report to the President and the Congress," fifth annual report, June 30, 1976. Washington. U.S. Government Printing Office, 1976. pp. 53-54.

CHAPTER 11

LEGAL ASPECTS OF WEATHER MODIFICATION

(By Nancy Lee Jones, Legislative Attorney, and Daniel Hill Zafren, Assistant Chief, American Law Division, Congressional Research Service)

DOMESTIC*

The legal issues presented by weather modification are complex and unsettled. These issues can be divided generally into four broad categories: Private rights in the clouds, liability for weather modification, defenses which may be raised against such liability, and methods of controlling weather modification. Before a discussion of these issues is begun, it should be noted that the body of law concerning weather modification is slight and existing case law offers few guidelines for the determination of these issues. For this reason it is often necessary to attempt to analogize the issues which arise concerning weather modification to other, more settled, areas of law such as the general law of water distribution.

PRIVATE RIGHTS IN THE CLOUDS

Several different issues have been raised concerning private rights in the clouds: First, are there any private rights in clouds or in the water which may flow from them; second, does a landowner have any particular rights in atmospheric water; and third, does a weather modifier have rights in atmospheric water. It has been argued that there are no private rights in the clouds or their water since they are common property which belongs to everyone who would benefit from them. Analogies have been drawn to animals *ferae naturae*. As one commentator has stated:

Clouds, and therefore the ability to modify weather, differ from most types of property, either real or personal, in that there is no way in which they may be captured or possessed. Man cannot force a cloud to stay over his property or keep it from passing over his property. In this respect clouds have often been compared to animals *ferae naturae*. Animals *ferae naturae* cannot be owned because they cannot be possessed. Therefore since this common law element of ownership cannot be met, they are the common property of all, not the individual property of any one person. (Citations omitted.)¹

This theory of common ownership of the clouds and any water they might contain has also found support in one of the few cases discussing weather modification. In *Pennsylvania Natural Weather Association v. Blue Ridge Weather Modification Association*, 44 Pa. D. & C. 2d 749 (1968), the court stated:

We are of the opinion that clouds and the moisture in the clouds, like air and sunshine, are part of space and are common property belonging to everyone

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¹ "Legal Aspects of Weather Modification in Texas," 25 Baylor L. Rev. 501, 502 (1973).

who will benefit from what occurs naturally in those clouds. There could be just as much injury or harm from weather modification activities as there could be from air and water pollution activities. We hold specifically that every landowner has a property right in the clouds and the water in them. No individual has the right to determine for himself what his needs are and produce these needs by artificial means to the prejudice and detriment of his neighbors.²

Before the issues of the rights of the landowner and the weather modifier in atmospheric water are discussed, it should be noted that some State statutes specifically reserve the ownership or right to use atmospheric water to the State.³

There have been a few cases which have discussed the rights of a landowner in atmospheric water. As quoted above the Pennsylvania court in *Pennsylvania Natural Weather Association v. Blue Ridge Weather Modification Association* did state that "* * * every landowner has a property right in the clouds and the water in them." Similarly, in *Southwest Weather Research, Inc. v. Duncan*, 319 S.W. 2d 910 (1958), aff'd. sub. nom. *Southwest Weather Research, Inc. v. Jones*, 327 S.W. 2d 417 (1959), the Texas court stated:

We believe that the landowner is entitled, therefore and thereby, to such rainfall as may come from clouds over his own property that Nature, in her caprice, may provide.

This theory enunciated in *Southwest Weather Research, Inc. v. Duncan* is similar to the common law doctrine of natural rights which is basically a protection of the landowner's right to use his land in its natural condition. One commentator has stated that "All forms of natural precipitation should be elements of the natural condition of the land. Precipitation, like air, oxygen, sunlight, and the soil itself, is an essential to many reasonable uses of the land * * *."⁴

However, in *Slutsky v. New York*, 97 N.Y.S. 2d 238 (1950), a New York court held that resort owners who were attempting to enjoin weather modification experiments "* * * clearly (had) no vested property rights in the clouds or the moisture therein." The weather modification experiments in this case were undertaken in an attempt to supply the city of New York with an adequate supply of water in the face of a drought and the court also stated that it must balance the competing interests involved.

All three of these cases have limited value in resolving the issue of a landowner's rights in atmospheric water since they involved only the narrow issue of the right of a landowner to have a temporary injunction against cloud seeding. Also both the Pennsylvania and New York decisions rested on the issue of causation; they both determined that the landowner was not entitled to relief since he had not proved that weather modification would interfere with the weather.

In the absence of a statutory determination of the ownership of atmospheric water and in the lack of a well developed body of case law, analogies may be drawn to some general common law doctrines. The doctrine of "natural rights" has already been noted above; in addition to this doctrine, the "ad coelum" doctrine may also be instructive. This concept has been attributed to Accursius of Bologna

² *Pennsylvania Natural Weather Association v. Blue Ridge Weather Modification Association*, 44 D. & C. 2d 749, 759-760 (1968).

³ Colo. Rev. Stat. sec. 36-20-103; La. Rev. Stat. Ann. 37 sec. 2201; Neb. Rev. Stat. sec. 2-2401; N. Mex. Stat. Ann. sec. 75-37-3; N. Dak. Cent. Code sec. 2-07-01; and Wyo. Stat. sec. 9-267.

⁴ "Who Owns the Clouds?" 1 Stan. L. Rev. 43 (1948).

who stated "Cujus est solum ejus debet esse usque ad coelum." This maxim has been translated as whoever has the land ought to be possessed of all the space upward to an indefinite extent.⁵ Blackstone accepted this doctrine and stated:

Land hath also, in its legal signification, an indefinite extent, upwards as well as downwards. Cujus est solum, ejus est usque ad coelum (whoever has the land possesses all the space upwards to an indefinite extent), is the maxim of the law; upwards, therefore, no man may erect any building, or the like to overhang another's land: . . . So that the word "land" includes not only the face of the earth, but every thing under it, or over it.⁶

The coming of the airplane required some modification of this doctrine, since if a landowner owned the space above his land to an infinite extent, airplanes would have been unable to fly over land without committing a trespass. In *United States v. Causby*, 328 U.S. 256 (1945), the Supreme Court rejected the "ad coelum" doctrine and stated that "The air is a public highway . . ."⁷ The Supreme Court also stated how much of the space above his property the landowner owns:

The landowner owns at least as much of the space above the ground as he can occupy or use in connection with the land . . . The fact that he does not occupy it in a physical sense—by the erection of buildings and the like—is not material.⁸

It could be argued from this language that since a landowner can use the space above the ground for weather modification he also owns it.

Other analogies may be drawn to the doctrines of riparian rights and appropriation. Riparian rights have been defined as ". . . those appurtenant to land abutting a watercourse, granting the landowner the right to reasonable use of the water, subject to similar correlative rights held by owners of other lands abutting the watercourse."⁹ This analogy is also not a close one since atmosphere does not flow in watercourses. It has been stated that ". . . the analogy is farfetched, if not false. . ."¹⁰ An analogy with the doctrine of appropriation may be considered more appropriate since it gives a priority of right based upon actual use; however, like riparian rights, appropriation rights in water are limited to water naturally flowing in the watercourses.

This doctrine of appropriation would probably be of greater help in arguing that the weather modifier has certain rights in atmospheric water.¹¹ The appropriation doctrine recognizes legal interests based on development and use of water, not on land ownership. It has been stated that:

The appropriation of water consists in the taking or diversion of it from some natural stream or other source of water supply, in accordance with law, with the

⁵ R. Wright, "The Law of Airspace" 13-14 (Indianapolis 1968). It has been stated that Accursius had in mind the rights of the owners of burial plots to have such land free from overhanging buildings. D. Halacy, Jr. "The Weather Changers" 205 (New York, 1968).

⁶ 2 Blackstone, "Commentaries on the Laws of England" ch. 2, at 19 (p. 445 in Cooley ed. 1899) cited in R. Wright, "The Law of Airspace" 12-13 (Indianapolis, 1969).

⁷ *United States v. Causby*, 328 U.S. 256, 260 (1945).

⁸ *Id.* 264. For a detailed discussion of this case and aviation and airspace ownership generally see R. Wright, "The Law of Airspace" 101-209 (Indianapolis, 1968).

⁹ 4 "Waters and Water Rights" 471 (R. Clark, ed. 1970).

¹⁰ The Weather Modification Law Project Staff, University of Arizona, School of Law, "The Legal Implications of Atmospheric Water Resources Development and Management" 17 (1968).

¹¹ It should be noted that the doctrine of appropriation is based on State statutory or constitutional provisions. These provisions must be examined carefully in determining rights in a specific State.

intent to apply it to some beneficial use or purpose, and consummated, within a reasonable time, by the actual application of all of the water to the use designated.¹²

It has been argued that the extension of the appropriation doctrine to weather modification would offer several advantages: This doctrine is being adopted by increasing numbers of States and is supported by a large body of statutory and case law; the administrative procedures of these statutes could be extended to cover the water obtained from weather modification; and the use of this doctrine would offer a unified approach to water law.¹³ Disadvantages have also been noted with respect to the extension of the doctrine: in most States which subscribe to the doctrine of appropriation, the first weather modifier to comply with the appropriation requirements could take all the moisture, and others would have no legal rights to natural rainfall; the measurement of the rain falling on the land of a rain appropriator would be difficult; other rainmaking in an area around the appropriator's land would have to be prohibited if his rights were to be protected and the questions of proof if the first appropriator claimed he did not get his share would be very difficult.¹⁴

Comparisons have also been made between oil and gas law and weather modification. This analogy is based upon the early theory that oil and gas, like water, were fugitive and migratory substances. This early theory evolved into two main doctrines of ownership in oil and gas: the "nonownership theory" and the "ownership-in-place theory":

The essence of the "nonownership theory" is that no person owns oil and gas until it is produced and any person may capture the oil and gas if able to do so. An interest in land is a prerequisite to the attempt to reduce the oil to possession. In "ownership-in-place" States, the nature of the interest of the landowner in oil and gas contained in his land is the same as his interest in solid minerals. [Citations omitted.]¹⁵

Applying either of these two theories to weather modification would appear to be of little help in establishing rights of a weather modifier to atmospheric water since both involve ownership interests in land. It should be noted that the physical differences between oil and gas and atmospheric water may render the analogy inapplicable.¹⁶

Analogies to the concepts of "developed water" and "imported water" may prove to be more appropriate. Developed waters are waters that "would not but for man's improvements, have become part of a stream, or waters that would otherwise have been lost by seepage or evaporation. As a general rule these waters are subject to appropriation by the parties developing or saving them."¹⁷ One of the factors used in determining whether water is developed water is whether the water was added to the natural flow by the energy and expenditure of the claimant from a source which previously had no outlet.¹⁸ The main difficulty faced in applying this concept to weather

¹² 2 Kinney, "Irrigation and Water Rights" (2d ed.) 1216 cited in W. Fischer, "Weather Modification and the Right of Capture," 8 Natural Res. Lawyer 639, 642 (1976).

¹³ 4 "Waters and Water Rights" 474, (R. Clark, ed., 1970).

¹⁴ *Ibid.* 473-474.

¹⁵ The Weather Modification Law Project Staff, University of Arizona, School of Law, "The Legal Implications of Atmospheric Water Resources Development and Management," 22 (1968).

¹⁶ R. Davis, "State Regulation of Weather Modification," 12 Arizona L. Rev. 35 (1970).

¹⁷ 1 "Waters and Water Rights" 341-342 (R. Clark, ed., 1970).

¹⁸ The Weather Modification Law Project Staff, University of Arizona, School of Law, "The Legal Implications of Atmospheric Water Resources Development and Management," 25 (1968).

modifiers is establishing that the modifier actually developed the water.¹⁹

Imported water, which is sometimes referred to as foreign water, is "water that has been imported by a user from one watershed into another."²⁰ Imported water, like developed water, is not part of the natural flow of water. Persons who import water are generally given a prior right to the capture and use of such waters.²¹ It has been stated that the application of the doctrine of imported water to weather modifiers would be advantageous since imported water is frequently exempted from the control of interstate river compacts.²² Problems would also be presented by this analogy. The weather modifier must show that the water he has produced has been shifted from one watershed to another, and he must also show that the water is imported rather than contributory. In addition, the general question of proof, that is establishing that the modifier actually produced the water, would present difficulties.

LIABILITY FOR WEATHER MODIFICATION

If a drought or a severe storm occurs after weather modification attempts have occurred, issues concerning liability for damages may arise. These issues would include causation as well as the application of a number of theories of tort recovery including nuisance, strict liability, trespass, and negligence. Other bases of liability might be present depending on the particular facts and circumstances attending any specific incident. In addition, issues concerning air and water pollution could be raised. Before a general discussion of these issues is begun, it would be helpful to examine briefly State statutes which discuss liability.

Ten State statutes were found which discuss liability for weather modification. These statutes vary widely in effect and complexity. Eight of these statutes specifically provide that the State is immune from liability.²³ Five statutes were found which provide that obtaining a license for weather modification is not a defense to legal actions.²⁴ The statutes on weather modification are stated not to affect private contractual or legal obligations in four States.²⁵ Three statutes provide that weather modification is not ultrahazardous²⁶ while three State statutes provide that weather modification is not a trespass²⁷ or, in one State, not a public or a private nuisance.²⁸ In addition, Colo-

¹⁹ For a detailed discussion of this question of proof, see W. Fischer, "Weather Modification and the Right of Capture," 8 *Natural Res. Lawyer* 639, 645-651 (1976).

²⁰ 1 "Waters and Water Rights," 339 (R. Clark, ed. 1970).

²¹ *Id.*

²² The Weather Modification Law Project Staff, University of Arizona, School of Law, "The Legal Implications of Atmospheric Water Resources Development and Management," 29 (1968).

²³ Colo. Rev. Stat. sec. 36-20-122; Ill. Ann. Stat. ch. 14 3/4, sec. 27; Kan. Stat. sec. 82a-1420; N. Dak. Cent. Code sec. 2-07-10; Okla. Stat. Ann. Title 2 sec. 1418; Tex. Water Code Ann. title 2 sec. 14.101; Wash. Rev. Code sec. 43.37.190 and Wyo. Stat. Ann. sec. 9-276.

²⁴ Col. Rev. Stat. sec. 36-20-123; Ill. Ann. Stat. ch. 14 3/4, sec. 27; Kan. Stat. sec. 82a-1420; N. Dak. Cent. Code sec. 2-07-10; Tex. Water Code Ann. title 2 sec. 14.101.

²⁵ Okla. Stat. Ann. title 2 sec. 1418; Tex. Water Code Ann. title 2 sec. 14.101 (with certain exceptions); Wash. Rev. Code Ann. sec. 43.37.190; Wis. Stat. Ann. sec. 195.40.

²⁶ Ill. Ann. Stat. ch. 14 3/4, sec. 27; N. Dak. Cent. Code sec. 2-07-10; Tex. Water Code title 2 sec. 14.101.

²⁷ Ill. Ann. Stat. ch. 14 3/4, sec. 27; N. Dak. Cent. Code sec. 2-07-10; Colo. Rev. Stat. sec. 36-20-123.

²⁸ Colo. Rev. Stat. sec. 36-20-123.

rado and Illinois statutes provide that failure to obtain a license or a permit for weather modification constitutes negligence²⁹ per se while Wisconsin provides that unregulated weather modification operations shall be subject to summary abatement public nuisances.³⁰ Illinois and North Dakota also provide that a person adversely affected by weather modification shall not be prevented by a statute on weather modification from recovering damages resulting from intentional harmful actions or negligent conduct.³¹ Finally, West Virginia provides that any licensee who causes a drought or a heavy downpour or storm which causes damage to land as determined by the West Virginia Aeronautics Commission shall compensate farmers and property owners for such damage.³²

Before any case for liability for weather modification can be made, it must first be proved that the weather modifier did in fact cause the drought, storm, or heavy rainfall which led to the damage for which compensation is sought.³³ Due to scientific uncertainties, this is a very heavy burden of proof for the plaintiff and is not often met. State statutes on weather modification provide few guidelines concerning causation. Of the 10 State statutes which discuss liability for weather modification, only the West Virginia statute discusses causation and there the statute simply recites that whether or not a weather modifier causes a drought or a storm shall be determined by the West Virginia Aeronautics Commission.

The test which is used most often in tort law to determine whether a causal relationship exists is the "but for" test. This test states that an activity is the cause in fact of a claimed consequence where the event would not have occurred but for the conduct of the actor.³⁴ This test has been used in some weather modification cases³⁵ but "judicial experience to date has shown that proof of cause in fact is a serious obstacle to recovery of damages from a weather modifier and to securing injunctive relief to bar his continued operations."³⁶

Several different theories of tort liability may be argued in a weather modification case; strict liability, nuisance, negligence, and trespass. As noted above, some State statutes specifically allow or prohibit some of these types of suits. Illinois, North Dakota, and Texas all provide that weather modification is not ultrahazardous which in effect bars the use of the theory of strict liability. Strict liability results when an activity is found to be ultrahazardous, which has been defined as "necessarily involving . . . a risk of serious harm to the person, land, or chattels of others which cannot be eliminated by the

²⁹ Colo. Rev. Stat. sec. 36-20-123; Ill. Ann. Stat. ch. 14 3/4, sec. 27.

³⁰ Wis. Stat. Ann. sec. 195.40.

³¹ Ill. Ann. Stat. ch. 14 3/4, sec. 27; N. Dak. Cent. Code sec. 2-07-10.

³² W. Va. Code sec. 29-2B-13.

³³ This question of proof is very similar to that which is faced by the weather modifier in attempting to prove that certain waters are his since he caused them. See W. Fischer, "Weather Modification and the Right of Capture," 8 *Natural Res. Lawyer* 639, 645-651 (1976).

³⁴ 4 "Waters and Water Rights" 477-478 (R. Clark, ed. 1970).

³⁵ See, e.g. Davis and St. Amand, "Proof of Legal Causation in Weather Modification Litigation: *Reinbold v. Sumner Farmers, Inc., and Irving P. Krick, Inc.*" 7 *J. of Weather Modification* 127 (April 1975); 4 "Waters and Water Rights" 478-479 (R. Clark, ed. 1970).

³⁶ The Weather Modification Law Project Staff, University of Arizona, School of Law, "The Legal Implications of Atmospheric Water Resources Development and Management" 12 (1968); see also, R. Johnson, "Weather Modification Legal Study" 2-4, prepared for the Weather Modification Advisory Board, Feb. 28, 1977.

utmost care."³⁷ In determining whether cloud seeding is an abnormally dangerous activity, it has been stated that courts would consider the following factors:

- (a) Whether the activity involves a high degree of risk of some harm to the person, land, or chattels of others;
- (b) Whether the gravity of the harm which may result from it is likely to be great;
- (c) Whether the risk cannot be eliminated by the exercise of reasonable care;
- (d) Whether the activity is not a matter of common usage;
- (e) Whether the activity is inappropriate to the place where it is carried on; and
- (f) The value of the activity to the community.³⁸

No case has been found where a court characterized weather modification as ultrahazardous and therefore subject to strict liability; however, this may occur in the future particularly with regard to certain types of attempted weather modification such as that involving hurricanes.

Nuisance is another liability theory which may prove useful in weather modification cases. Nuisance has been described as conduct which ". . . invades an owner's interest in the use and enjoyment of his land, and such invasion is intentional and unreasonable, negligent or reckless or regarded as an abnormally dangerous activity."³⁹ Controversies over nuisances are often resolved by balancing the utility of the defendant's conduct with the harm it causes.⁴⁰ Due to these characteristics of nuisance, it has been regarded by some writers ". . . as potentially the most useful in weather modification cases."⁴¹ However, it should be noted that a Colorado statute specifically provides that weather modification is not a public or private nuisance.⁴²

Negligence may also be used as a theory for recovery in weather modification cases. There are four main elements which are necessary to provide a cause of action using negligence. There must be: (1) A duty recognized by the law, which requires the actor to conform to a certain standard of conduct; (2) a failure to conform to the standard required; (3) a reasonably close causal connection between the conduct and the resulting injury; and (4) actual loss or damages suffered by the plaintiff.⁴³ Aside from the difficulties presented by showing a causal connection, another difficulty with the application of this theory to weather modification is that a standard for performance must be established against which the weather modifier can be measured.

Trespass as a theory of tort liability may also prove to be applicable to weather modification. Trespass may consist of an entry of a person or thing upon land which is in the possession of the plaintiff.⁴⁴ The rejection of the "ad coelum" doctrine in *United States v. Causby*, 328

³⁷ 4 Restatement of Torts sec. 319.

³⁸ R. Davis, "Weather Modification Litigation and Statutes," in "Weather and Climate Modification" 773 (ed. W. Hess 1974).

³⁹ *Id.*

⁴⁰ Prosser Torts, sec. 87, 4th ed. (1971).

⁴¹ R. Davis, "Weather Modification Litigation and Statutes", in "Weather and Climate Modification" 773 (ed. W. Hess 1974).

⁴² Colo. Rev. Stat. sec. 36-20-123.

⁴³ Prosser Torts sec. 30 (4th ed. 1971).

⁴⁴ *Id.* sec. 13.

U.S. 256 (1945), indicates that the flight of an airplane over a person's land would not necessarily be considered a trespass. However, it could be argued that the release of particles into the air by an airplane or by a weather modification station on the ground might be considered a trespass if they invaded the plaintiff's land. It could also be argued that rain, hail or other precipitation produced by weather modification would be a trespass since it did not fall there naturally but was produced artificially.⁴⁵ These arguments could be supported by citing various cases which have found a trespass even where invisible or microscopic particles have entered on the plaintiffs land they have caused harm.⁴⁶

In addition to the various types of tort liability discussed above, weather modifiers may also be held liable for pollution or for adverse environmental impacts. Weather modification not only attempts to change the environment by producing precipitation but also adds small quantities of silver iodide or other artificial nucleants to the water or other precipitation it causes. In *Pennsylvania Natural Weather Association v. Blue Ridge Weather Modification*, 44 D. & C. 2d 749 (1968), the court discussed the possible environmental damage which could be done by weather modification and quoted a report of a bureau of reclamation which stated the artificial nucleants used in cloud seeding are to varying extents poisonous. However, the court held that there was no more than a possibility of harm and so did not issue an injunction. It should also be noted that the National Environmental Policy Act of 1969, 42 U.S.C. § 4321 et seq., may be relevant when weather modification is federally sponsored.⁴⁷ For example an environmental impact statement would be necessary in certain circumstances where the Federal Government was involved.

DEFENSES WHICH MAY BE RAISED AGAINST CLAIMS OF LIABILITY

In addition to the general defense that the plaintiff has failed to establish a cause of action, certain other defenses may be available to a weather modifier. These would include immunity, privilege, consent and waste.

If the weather modifier was operating under the auspices of the Federal, State, or local government, the doctrine of sovereign immunity from suit may be employed. The Federal Tort Claims Act, 28 U.S.C. § 2671 et seq., waived certain immunities of the Federal Government; specifically, its immunity from liability from the negligent or wrongful acts of its employees who are acting within the scope of their employment. This act kept immunity for the exercise of discretionary functions, however. It has been stated that the application of this doctrine to weather modification on the Federal level means that:

Federal weather modifiers, then, may expose the United States to liability for injury careless performance of their day-to-day operations; but likely the Federal Government will be immune from liability for its decision to conduct weather modification operations and for its plans relating to the operations.⁴⁸

⁴⁵ Note, "Legal Aspects of Weather Modification in Texas," 25 Baylor L. Rev. 501, 509-510 (1973).

⁴⁶ Prosser Torts, sec. 13 (4th ed. 1971).

⁴⁷ See R. Davis, "Weather Modification Law Developments," 27 Oklahoma L. Rev. 409, 436-439 (1974); "Weather Modification," hearings before the Subcommittee on the Environment and the Atmosphere of the House Committee on Science and Technology, 94th Cong., 2d sess. 421-426 (1976). (Statement of the Natural Resources Defense Council, Inc.)

⁴⁸ 4 "Waters and Water Rights" 493-494 (R. Clark, ed. 1970).

The doctrine of sovereign immunity with regard to the States is in a somewhat uncertain condition although it may provide immunity to State employed weather modifiers in some cases. It should also be noted that eight States, Colorado, Illinois, Kansas, North Dakota, Oklahoma, Texas, Washington, and Wyoming, statutorily mandate that the State is immune from certain liability for weather modification.⁴⁹

The application of the doctrine of sovereign immunity to local governments has resulted in a distinction between proprietary and governmental functions. It has been stated that:

The application of this most unwieldy and unreliable test to weather modification will not be easy. For instance, a municipality's operation of a waterworks for supplying water to its inhabitants (which would seem at first glance to be a governmental operation) has been held to be a proprietary operation—subjecting the municipality to liability in tort. Thus, water supply augmentation through precipitation modification may well be a part of that proprietary function.⁵⁰

Public necessity could also be argued as a defense to liability. This defense has actually been suggested in two cases although it was not determinative in either of them. In *Slutsky v. New York*, 97 N.Y.S. 2d 238 (1950), resort owners had filed for a temporary injunction to prohibit New York City from engaging in experiments which attempted to produce rain. The court held that these experiments would not interfere with the plaintiffs resort business "to any appreciable extent" and so denied the injunction. In arriving at this holding, the court emphasized that it must balance the competing interests and stated that "The relief which plaintiffs ask is opposed to the general welfare and public good. * * *" Similarly, in *Pennsylvania Natural Weather Association v. Blue Ridge Weather Modification Association*, 44 D. & C. 2d 749 (1968), the court refused to issue an injunction in the absence of proof that damages resulted from weather modification activities but did discuss public necessity. The court there stated:

No individual has the right to determine for himself what his needs are and produce those needs by artificial means to the prejudice and detriment of his neighbors. However, we feel that this cannot be an unqualified right. Weather modification takes many forms and produces, or appears to produce, desirable effects. For example, there is fog suppression, lightning suppression, and hail suppression. In addition, cloud seeding has been used and will continue to be used to produce rain to relieve the water shortage in our urban areas. We feel then that weather modification activities undertaken in the public interests, and under the direction and control of governmental authority should and must be permitted.⁵¹

The consent of a landowner to weather modification which may affect his land may also be raised as a defense to liability. In addition, a weather modifier could also attempt to raise as a defense the public policy against waste.⁵²

INTERSTATE ALLOCATION OF ATMOSPHERIC WATER

Weather modification activities and their results do not always fall neatly inside State boundaries. When they do not, substantial issues

⁴⁹ For citations to these statutes see footnote 23 supra.

⁵⁰ 4 "Waters and Water Rights" 494 (R. Clark, ed. 1970).

⁵¹ *Pennsylvania Natural Weather Association v. Blue Ridge Weather Modification Association*, 44 D. & C. 2d 749, 760 (1968).

⁵² For a discussion of these two theories of defense see 4 "Waters and Water Rights" 497-498 (R. Clark, ed. 1970).

may arise; for instance, does cloud seeding in one State take water which should have fallen in another State? No cases have arisen which directly deal with the issues raised by the interstate nature of weather modification although *Pennsylvania ex rel. Township of Ayr v. Fulk*, No. 53 (Court of Common Pleas, Fulton County, Pa., Feb. 28, 1968), did touch upon some of these issues. In that case a weather modifier who operated a generator in Ayr Township to suppress hail in West Virginia and Maryland was convicted of violating an ordinance which made cloud seeding an offense. The weather modifier alleged that the township ordinance was unconstitutional because it imposed an undue burden on interstate commerce but the court did not agree and stated that the ordinance was never intended to regulate commerce and that weather modification may not even be commerce.⁵³

More recently, a dispute has arisen between Idaho and Washington concerning cloud seeding in Washington which allegedly takes water from clouds which would normally discharge their water over Idaho. Some Idaho officials have termed the cloud seeding "cloud rustling" and threatened to file suit.⁵⁴ No suits on this controversy have yet been filed, however.

Although no court resolution of the interstate problems involved in weather modification has been found, some States have attempted to resolve the problem by the use of legislation or interstate compacts. Twelve States have been found which have legislation discussing the interstate aspects of weather modification. Eight of these have statutes which authorize the board or commission which is responsible for weather modification to represent the State concerning interstate compacts or agreements on weather modification.⁵⁵ Two States, Colorado and New Mexico, have statutes which provide that weather modification for the benefit of other States cannot be carried on in the State with this legislation unless the State which could be benefited also allows weather modification to benefit the State with this legislation.⁵⁶

Pennsylvania and West Virginia have statutes which provide that their weather modification law does not authorize a person to carry out a cloud seeding operation from these States for the benefit of another State which forbids weather modification.⁵⁷ Utah has a statute which prohibits cloud seeding in Utah for an adjoining target State except upon full compliance with the laws of the target State and the law of Utah.⁵⁸

Another method of overcoming the problems presented by the interstate nature of weather modification would be to arrive at informal agreements with adjoining States. Several States provide that the board which is responsible for weather modifications has the power to enter into these agreements. However, organizations resulting from these agreements would possess little power to make binding decisions.⁵⁹

⁵³ For a more detailed discussion and criticism of this case see R. Davis, "Weather Modification Litigation and Statutes," in "Weather and Climate Modification" 782-783 (ed. W. Hess 1974).

⁵⁴ B. Richards, "Rainmaking Effort Triggers Battle Over Cloud Rustling," the Washington Post, A-5 Mar. 1, 1977.

⁵⁵ Conn. Gen. Stat. Ann. sec. 24-7; Ill. Stat. Ann. ch. 146 3/4, sec. 9; Kan. Stat. sec. 82a-1405(f); Nev. Rev. Stat. sec. 544.080(7); N. Mex. Stat. Ann. sec. 2-07-02.5; Okla. Stat. Ann. sec. 1403(7); Tex. Water Code Ann. title 2 sec. 14.018; Wash. Rev. Code sec. 43.37.040.

⁵⁶ Colo. Rev. Stat. sec. 36-20-118, N. Mex. Stat. Ann. sec. 75-37-12.

⁵⁷ Pa. Stat. Ann. title 3 sec. 1115; W. Va. Code sec. 29-2B-14.

⁵⁸ Utah Code Ann. sec. 73-15-8.

⁵⁹ R. Davis, "State Regulation of Weather Modification," 12 Arizona L. Rev. 35, 67 (1970).

A method which could also be used would be that of an interstate compact. Article I, § 10, cl. 3 of the U.S. Constitution states that "No State shall, without the Consent of Congress, * * * enter into any Agreement or Compact with another State. * * *". With the exception of the limitation that the consent of Congress must be obtained, the Constitution confirmed the right of the States to make compacts with each other. It has been stated that an interstate compact has the same effect as a treaty between sovereign powers.⁶⁰

No interstate compacts specifically concerning weather modification were found; however, some existing compacts, especially those which allocate waters of interstate streams, may be applicable to weather modification. For example, if a compact provides that half of the waters in a river are to go to one State and half to another, the weather modifier may have no rights in the water he has allegedly produced since it would go into the river and be subject to the provisions of the compact.⁶¹ It could also be argued that an agency like the New York Port Authority has the authority to engage certain weather modification techniques such as fog dissipation.⁶² Certain Supreme Court decisions concerning the use of interstate waters may also be helpful in allocating water in clouds which pass over State boundaries.⁶³

METHODS OF CONTROLLING WEATHER MODIFICATION

There are several methods by which weather modification is or could be controlled. These include State or local regulation, regulation by professional associations and Federal regulation. Twenty-eight States were found which have some type of statute pertaining to weather modification. These statutes differ greatly in their content. Hawaii, for example, simply states that the board of land and natural resources shall have the power "To investigate and make surveys of water resources, including the possibility and feasibility of inducing rain by artificial or other means . . ." On the other hand, some States, such as Colorado, have comprehensive laws which include such provisions as declaration of general policy, licensing, operations affecting weather in other States, legal recourse, and judicial review.⁶⁴ The basis for the enactment of this type of legislation is the police power. The police power enables a State to take action to protect and promote the health, safety, morals and general welfare of its people.⁶⁵

Some State statutes provide for control of weather modification by administrative agencies. In these cases the legislature would most likely provide some guidance for the agency and then let the agency provide for more specific situations by promulgating regulations.⁶⁶ It

⁶⁰ For a more detailed discussion of the legal effect of interstate compacts see Congressional Research Service, *The Constitution of the United States of America—Analysis and Interpretation* 419-423 (1973).

⁶¹ For a discussion of some of these compacts see note, "Weather Modification and the Right of Capture," 8 *Natural Res. Lawyer* 639, 652-654 (1976).

⁶² R. Davis, "State Regulation of Weather Modification," 12 *Arizona L. Rev.* 35, 67 (1970).

⁶³ See note, "Weather Modification and the Right of Capture," 8 *Natural Res. Lawyer* 639, 641-653 (1976).

⁶⁴ Copies of the weather modification statutes and a chart can be found in appendix D.

⁶⁵ Shapiro and Tresolini, "American Constitutional Law" 116-117 (New York 1975).

⁶⁶ The Weather Modification Law Project Staff, *University of Arizona, School of Law, "The Legal Implications of Atmospheric Water Resources Development and Management"* (1968).

has been stated that regulation of weather modification by an administrative agency would have certain advantages including administrative expertise, continuity of the administrative regulatory program, and flexibility and completeness of control.⁶⁷

State statutes would also be subject to judicial review. Although there have been very few cases discussing weather modification, the number of these cases has risen in recent years and there are indications that there will be even more litigation in the future. Such lawsuits, which determine the specific legal rights of individual plaintiffs and defendants, will provide precedents which will be helpful not only in future cases but also in advising individuals who have not become involved in a lawsuit what the law has been so that they may act with some knowledge of the possible consequences.⁶⁸ However, it has been stated that judicial control alone would be incomplete and would not have the continuity or expertise of an administrative agency.⁶⁹

A State may also attempt to control weather modification by becoming the proprietor of weather modification activities. Using this method the State could use either government employees or hire contractors to modify the weather. It has been stated that State regulation of weather modification by this contract method would have several advantages: It would be comparatively easy to administer, it would provide a source of funds, and it would provide a method for enforcing payment to weather modifiers by those who receive the benefit of their services.⁷⁰

State regulation of weather modification in general has also been seen to have certain advantages and disadvantages. It has been observed that the advantages would include the following: First, State statutes provide a testing ground to experiment and see what scheme of regulation is the most successful; second, some States have no need for regulation of weather modification since no weather modification occurs in these States; and third, State agencies would be closer to the persons regulated and those affected by weather modification than a Federal agency. Disadvantages have also been observed in State regulation; for example, the fact that clouds are no respecters of State boundary lines. In addition, it has been argued that State legislatures may be susceptible to local lobbying.⁷¹

Professional associations of weather modifiers could also attempt to regulate their members. Although this would have the advantage of having knowledgeable persons doing the regulating and could cover interstate situations, it would also have disadvantages. For example, such regulators might be reluctant to impose restrictions which might harm their business. In addition, not all weather modifiers would necessarily be members of such professional associations and their powers of enforcement of regulations would be exceedingly limited.

⁶⁷ R. Davis, "State Regulation of Weather Modification," 12 *Arizona L. Rev.* 35, 55 (1970).

⁶⁸ For discussions of judicial control of weather modification see R. Davis, "Strategies for State Regulation of Weather Modification," in "Controlling the Weather" 182-194 (ed. H. Taubenfeld 1970); The Weather Modification Law Project Staff, University of Arizona, School of Law, "The Legal Implications of Atmospheric Water Resources Development and Management" 85-86 (1968).

⁶⁹ R. Davis, "State Regulation of Weather Modification," 12 *Arizona L. Rev.* 35, 56 (1970).

⁷⁰ *Id.* 60-61.

⁷¹ *Id.* 64-65.

CONGRESSIONAL AUTHORITY UNDER THE CONSTITUTION TO REGULATE OR
LICENSE WEATHER MODIFICATION ACTIVITIES

Weather modification could also be controlled by Federal statute. However, in order to enact valid legislation, Congress must find a grant of power in the Constitution which would allow such legislation. There are several grants of power to Congress which would be sufficient authority for the regulation of weather modification activities. The most important of these is the power given to Congress under the commerce clause which states that "The Congress shall have Power To . . . regulate Commerce with foreign Nations, and among the several States, and with the Indian Tribes."⁷² Authority for such regulation may to some extent also be found under the sections granting Congress fiscal power, war power, property power and treaty power. The major emphasis of this section will be on the commerce clause; however, the other powers will be discussed briefly. Prior to a discussion of the commerce power, it would be helpful to briefly discuss the principle of federalism.

Federalism

Federalism is one of the basic concepts underlying the U.S. Constitution. It has been defined as " * * * a principle of government which provides for the division of powers between a national government and a collection of State governments operating over the same geographic area."⁷³ The Federal Government possesses all those powers which are delegated to it either expressly or by implication by the Constitution. As is explicitly stated in the 10th amendment, the State governments possess those powers which are not given to the Federal Government or denied to the States. Recent Supreme Court cases, in particular *National League of Cities v. Usery*, 426 U.S. 833 (1976), have been interpreted by some commentators as indicating a " * * * resurrection of the Madisonian concept of a restricted Federal Government resulting in a more active role for the 10th amendment."⁷⁴ This recent change in interpretation, if indeed there has been a significant change, has occurred mainly as a limitation on congressional use of the commerce clause power and will be discussed in more detail in the discussion of the commerce clause.

The commerce clause

The commerce clause has generally been interpreted broadly by the Supreme Court and has been described as " * * * the direct source of the most important powers which the Federal Government exercises in peacetime, and except for the due process and equal protection clauses of the 14th amendment, it is the most important limitation imposed by the Constitution on the exercise of State power."⁷⁵ The use of the commerce clause as a source of Federal power is the most relevant to the discussion here; however, it should be noted that the only case found which discussed the commerce clause and weather modification

⁷² U.S. Constitution art. I, sec. 8, cl. 3.

⁷³ Chase and Ducat, "Constitutional Interpretation" 375 (St. Paul 1974).

⁷⁴ Note, "Constitutional Law—Tenth Amendment as an Affirmative Limitation on Commerce Power. *National League of Cities v. Usery*, 426 U.S. 833 (1976)," 8 Toledo L. Rev. 796, 809 (1977).

⁷⁵ Congressional Research Service, "The Constitution of the United States of America—Analysis and Interpretation" 142 (Washington 1973).

was one in which the commerce clause was discussed as a limitation on the exercise of State power. This case, *Pennsylvania ex rel. Township of Ayr v. Fulk*, No. 53 (Court of Common Pleas, Fulton County, Pa., Feb. 28, 1968), arose when a weather modifier who operated a generator in Ayr Township to suppress hail in West Virginia and Maryland was convicted of violating an ordinance which made cloud seeding an offense. The weather modifier alleged that the township ordinance was unconstitutional because it imposed an undue burden on interstate commerce but the court did not agree and stated that the ordinance was never intended to regulate commerce and that weather modification may not even be commerce. This case has been strongly criticized as ignoring the numerous Supreme Court cases which have interpreted the term "commerce" very broadly and it is of questionable use as persuasive authority.⁷⁶

The commerce clause generally.—The commerce clause was first discussed in *Gibbons v. Ogden*, 9 Wheat. (22 U.S.) 1 (1824). This landmark case arose when a monopoly granted by New York State on the operation of certain vessels in its waters was challenged by Gibbons who transported passengers pursuant to an act of Congress. Speaking for the Court, Chief Justice Marshall stated:

The subject to be regulated is commerce; and our Constitution being, as was aptly said at the bar, one of enumeration, and not of definition, to ascertain the extent of the power, it becomes necessary to settle the meaning of the word. The counsel for the appellee would limit it to traffic, to buying and selling, or the interchange of commodities, and do not admit that it comprehends navigation. This would restrict a general term, applicable to many objects, to one of its significations. Commerce, undoubtedly, is traffic, but is something more: it is intercourse. At 189.

Chief Justice Marshall also addressed the question of what is the power to regulate commerce and stated:

It is the power to regulate; that is, to prescribe the rule by which commerce is to be governed * * *. The power of Congress, then, comprehends navigation within the limits of every State in the union; so far as that navigation may be, in any manner, connected with "commerce with foreign nations, or among, the several States, or with the Indian tribes." At 196-197.

Although the commerce power was interpreted more narrowly during the early 1930's,⁷⁷ the expansive interpretation was soon evident again. Several cases were decided by the Supreme Court in 1942 discussing the commerce clause. In *United States v. Wrightwood Dairy Co.*, 315 U.S. 110, 119 (1942), the Supreme Court stated that:

The commerce power is not confined in its exercise to the regulation of commerce among the States. It extends to those activities intrastate which so affect interstate commerce, or the exertion of the power of Congress over it, as to make regulation of them appropriate means to the attainment of a legitimate end, the effective execution of the granted power to regulate interstate commerce * * * the marketing of a local product in competition with that of a like commodity moving interstate may so interfere with the interstate commerce or its regulation as to afford a basis for congressional regulation of the intrastate activity.

⁷⁶ See R. Davis, "Weather Modification Litigation and Statutes" in "Weather and Climate Modification" 782-783 (ed. W. Hess 1974).

⁷⁷ See e.g., *Schechter Poultry Corp. v. United States*, 295 U.S. 495 (1935).

This same rationale was used in *Wickard v. Filburn*, 317 U.S. 111 (1942), where the Supreme Court upheld Federal commodity regulations which applied to a farmer who was growing wheat for his own use. The Court concluded there that even though this particular amount of wheat was trivial, when combined with that of others in similar situations, it could be sufficiently competitive with wheat in interstate commerce to justify its regulation.

More recently, the Court in *Perez v. United States*, 402 U.S. 146 (1971), upheld title II of the Consumer Credit Protection Act which prohibited certain extortionate credit transactions. The Court found that although the transactions in question in this case were purely intrastate, they could adversely affect interstate commerce and thus their regulation was a permissible congressional exercise of its powers under the commerce clause.

As is exemplified by these cases, the power of regulation given to Congress under the commerce clause may deal with the channels of commerce, instrumentalities of commerce, activities affecting commerce and articles of commerce. Since the devices used in weather modification would most likely involve commercial marketing, it is likely that weather modification could be regulated since its instruments would probably be in interstate commerce. In addition, weather modification activities could by themselves affect commerce. An even stronger case could be made that weather modification can be regulated under the commerce clause since it would have an affect on navigable waters.

The commerce clause and the regulation of navigable waters.—There is a line of cases stretching from *Gibbons v. Ogden* concerning congressional authority under the commerce clause to regulate navigable waters. As was quoted above in *Gibbons* Chief Justice Marshall stated that commerce “* * * comprehends navigation within the limits of every State * * *.” The congressional regulation of waterways was further elaborated in *Pennsylvania v. Wheeling & Belmont Bridge Co.*, 13 How. (54 U.S.) 518 (1852), and *The Daniel Ball*, 10 Wall (77 U.S.) 557 (1871). As a result of this power over navigation, Congress has also acquired the right to develop hydroelectric power⁷⁸ and to legislate in the area of flood control. In *United States v. Appalachian Electric Power Co.*, 311 U.S. 377 (1940), the Supreme Court discussed “* * * the scope of the Federal commerce power in relation to conditions in licenses, required by the Federal Power Commission, for the construction of hydroelectric dams in navigable rivers of the United States.” At 398. Discussing the power of the United States over its waters, the Court stated:

In our view, it cannot properly be said that the constitutional power of the United States over its waters is limited to control for navigation. By navigation respondent means no more than operation of boats and improvement of the waterway itself. In truth the authority of the United States is the regulation of commerce on its waters. Navigability, in the sense just stated, is but a part of this whole. Flood protection, watershed development, recovery of the cost of improvements through utilization of power are likewise parts of commerce control. As respondent soundly argues, the United States cannot by calling a project of its own “a multiple purpose dam” give to itself additional powers, but equally truly

⁷⁸ *United States v. Chandler-Dunbar Co.*, 229 U.S. 53 (1913).

the respondent cannot, by seeking to use a navigable waterway for power generation alone, avoid the authority of the Government over the stream. At 426.⁷⁹

Since weather modification activities could have an effect upon the waterflow of navigable waters, they thereby would be subject of congressional regulation under the commerce power. This is particularly true in the case of activities such as cloud seeding where the activities of weather modifiers could potentially cause flooding and may well affect the watershed.

Limitations on the commerce power.—An argument could be made that Congress does not have authority under the commerce clause to regulate weather modification activities. States and localities could argue that such regulation would be an unconstitutional infringement of the rights of the States under the 10th amendment. In *United States v. Darby*, 312 U.S. 100 (1941), the Supreme Court characterized the 10th amendment as stating “* * * but a truism that all is retained which has not been surrendered.” At 124. This was interpreted by the Supreme Court in *Fry v. United States*, 421 U.S. 542 (1975) :

While the Tenth Amendment has been characterized as a truism stating merely that all is retained which has not been surrendered, * * * it is not without significance. The Amendment expressly declares the constitutional policy that Congress may not exercise power in a fashion that impairs the States' integrity or their ability to function effectively in a federal system (citation omitted).

The Supreme Court in *National League of Cities v. Usery*, 426 U.S. 833 (1976), quoted this language from *Fry* with approval. *National League of Cities* held that Congress may not exercise its power to regulate interstate commerce so as to force directly upon the States its choice as to how essential decisions regarding the conduct of integral governmental functions are to be made. More specifically, the Court held that the 1974 amendments to the Fair Labor Standards Act which extended the statutory minimum wage and maximum hours provisions to employees of States and their subdivisions was unconstitutional in that it exceeded congressional power under the commerce clause.

It could be argued that *National League of Cities* indicates that the Supreme Court is placing limitations on the power of Congress under the commerce clause and that a more narrow reading of this clause would make Federal regulation of weather modification questionable. However, it is unlikely that such an argument would be successful. The majority opinion in *National League of Cities*, despite its broad language, did accommodate most of the previous Supreme Court cases where broad congressional power to regulate commerce was upheld. In addition, the Court noted that “* * * there are attributes of sovereignty attaching to every State government which may not be impaired by Congress * * *” and that “* * * (o)ne undoubted attribute of State sovereignty is the States' power to determine the wages which shall be paid to those whom they employ * * *” At 845. It is unlikely that weather modification would be considered to be one of these undoubted attributes of State sovereignty. It should also be noted that four jus-

⁷⁹ See also *Douglas v. Seacoast Products*, 431 U.S. 265 (1977) where the Supreme Court struck down a Virginia statute which limited the right of nonresidents to catch fish in Virginia waters since it conflicted with Federal requirements. The Supreme Court stated: “While appellant may be correct in arguing that at earlier times in our history, there was some doubt whether Congress had power under the commerce clause to regulate the taking of fish in State waters, there can be no question today that such power exists where there is some effect on interstate commerce.” At 281-282 (footnote omitted).

tices dissented from the majority opinion in *National League of Cities* and in a concurring opinion Justice Blackmun stated:

I may misinterpret the Court's opinion, but it seems to me that it adopts a balancing approach, and does not outlaw Federal power in areas such as environmental protection, where the Federal interest is demonstrably greater and where State facility compliance with imposed Federal standards would be essential. At 856.

An area such as weather modification would seem to be more akin to environmental protection than to minimum wage laws. And although States have enacted legislation concerning weather modification, the fact that weather patterns often have national effects would seem to make the imposition of Federal standards arguably as logical as they are in the area of environmental protection.⁸⁰

Fiscal powers

Congress is given the power to tax and provide for the general welfare of the United States in article I, section 8, clause 1 of the Constitution. This section specifically states:

The Congress shall have Power to lay and collect Taxes, Duties, Imposts and Excises, to pay the Debts and provide for the common Defence and general Welfare of the United States * * *

This power to tax has been interpreted broadly and the Supreme Court has held that the power of Congress to tax to provide for the common welfare is not limited by the other direct grants of legislative power found in the Constitution.⁸¹ However, although the power of Congress was not found to be limited by other direct grants in *United States v. Butler*, the Supreme Court also indicated there that the power to tax for the general welfare was limited by the 10th amendment. The limitation of the 10th amendment on this power was narrowly interpreted in *Steward Machine Co. v. Davis*, 301 U.S. 548 (1937). In *Steward*, the Court upheld the Social Security Act and found that the relief of unemployment was a legitimate object of Federal expenditure under the general welfare provision.

Federal grants-in-aid which are conditioned upon State compliance with certain regulations have also been found constitutional. In *Oklahoma v. Civil Service Commission*, 330 U.S. 127 (1947), the Supreme Court found that section 12(a) of the Hatch Act was constitutional and that it did not violate the 10th amendment by diminishing the amount of a Federal grant-in-aid for the construction of highways if the State failed to remove a member of the State highway commission from office. The highway commissioner had been found to have taken an active part in political campaigns while a member of the commission. In arriving at this holding, the Supreme Court stated:

While the United States is not concerned and has no power to regulate local political activities as such of State officials, it does have power to fix the terms

⁸⁰ Numerous commentators have discussed the implications of *National League of Cities*. For examples see: L. Tribe, "Unravelling *National League of Cities*: The New Federalism and Affirmative Rights to Essential Government Services," 90 Harv. L. Rev. 1065 (1977); B. Matsumoto, "National League of Cities—From Footnote to Holding—State Immunity from Commerce Clause Regulation," 1977 Ariz. St. L. J. 35 (1977); Note, "Constitutional Law—10th Amendment as an Affirmative Limitation on Commerce Power, *National League of Cities v. Usery*, 426 U.S. 833 (1976), 8 Toledo L. Rev. 796 (1977); Note, "The Re-emergence of State Sovereignty as a Limit on Congressional Power Under the Commerce Clause," 28 Case W. Reserve L. Rev. 166 (1977).

⁸¹ *United States v. Butler*, 297 U.S. 1, 65-66 (1936).

upon which its money allotments to the State shall be disbursed. The Tenth Amendment does not forbid the exercise of this power in the way that Congress has proceeded in this case * * * The end sought by Congress through the Hatch Act is better public service by requiring those who administer funds for national needs to abstain from active political partisanship. So even though the action taken by Congress does have effect upon certain activities within the State, it has never been thought that such effect made the Federal act invalid. * * * We do not see any violation of the State's sovereignty in the hearing or order. Oklahoma adopted the "simple expedient" of not yielding to what she urges is Federal coercion * * * The offer of benefits to a State by the United States dependent upon cooperation by the State with Federal plans, assumedly for the general welfare, is not unusual. [Citations omitted.] At 143-144.

Given this precedent, it is likely that Congress would be able to condition grants for weather modification activities on the following of certain regulations without raising constitutional problems.⁸²

War powers

The U.S. Constitution article I, section 8, clause 1 provides in relevant part that "The Congress shall have the Power To * * * provide for the common defence * * *". In addition clause 11 provides that Congress shall have the power to declare war. These specific grants of power have been used by the Supreme Court to uphold certain congressional acts.⁸³ The Supreme Court has also found that there was an inherent power to make war. In *United States v. Curtiss-Wright Corp.*, 299 U.S. 304 (1936), the Supreme Court stated:

* * * that the investment of the Federal Government with the powers of external sovereignty did not depend upon the affirmative grants of the Constitution. The power to declare and wage war, to conclude peace, to make treaties, to maintain diplomatic relations with other sovereignties, if they had never been mentioned in the Constitution, would have vested in the Federal Government as necessary concomitants of nationality. At 318.

It is likely that the war power could be used to find congressional power to regulate weather modification since weather modification has potential military use. Also, Congress has used the war power as a basis for the regulation of atomic energy and electricity. For example, in *Pauling v. McElroy*, 164 F. Supp. 390 (D.D.C. 1958), aff'd 278 F. 2d 252 (1960), cert. denied, 364 U.S. 835 (1960), the district court found that the Atomic Energy Act was constitutional and stated: "The Act is a valid exercise of the authority of Congress to promote and protect the national defense and safety under the constitutional war power." At 393. And in *Ashwander v. Tennessee Valley Authority*, 297 U.S. 288 (1935), the Supreme Court upheld the construction of Wilson Dam as a valid exercise "* * * by the Congress of its war and commerce powers, that is, for the purposes of national defense and the improvement of navigation." At 326.

Property power

Article IV, section 3, clause 2 of the Constitution provides that "The Congress shall have Power to dispose of and make all needful Rules and Regulations respecting the Territory or other Property belonging to the United States * * *". This power has been interpreted broadly and State legislation has been held not to interfere with the power of

⁸² For a more detailed discussion of the fiscal power see K. Dam, "The American Fiscal Constitution," 44 U. Chi. L. Rev. 271 (1977).

⁸³ See *Lichter v. United States*, 334 U.S. 742 (1948).

Congress under this clause.⁸⁴ One of the most recent pronouncements of the Supreme Court concerning the property power of Congress was in *Kleppe v. New Mexico*, 426 U.S. 529 (1976). In *Kleppe* the Supreme Court held that the Wild Free-roaming Horses and Burros Act was a constitutional exercise of congressional power under the property clause. In arriving at this holding the Court stated:

* * * the Clause, in broad terms, gives Congress the power to determine what are "needful" rules "respecting" the public lands * * * And while the furthest reaches of the power granted by the Property Clause have not yet been definitively resolved, we have repeatedly observed that "(t)he power over the public land thus entrusted to Congress is without limitations" * * * The decided cases have supported this expansive reading. It is the Property Clause, for instance, that provides the basis for governing the Territories of the United States. And even over public land within the States, "(t)he general Government doubtless has a power over its own property analogous to the police power of the several States, and the extent to which it may go in the exercise of such power is measured by the exigencies of the particular case." [Citations omitted.] At 539-540.

The property clause could be used to regulate weather modification over public lands. As one commentator has stated:

Superficially the power over property might not seem the most promising source of power to regulate weather modification. In the western states, though, such a high percentage of the land area is owned or controlled by the federal government that regulation of weather modification over or affecting them would, in many cases, effectively control weather modification in many of the areas where such activities are apt to be conducted.⁸⁵

Treaty power

Article II, section 2, clause 2 of the Constitution provides that the President "* * * shall have Power, by and with the consent of the Senate, to make Treaties, * * *" Congress is often able to enact legislation supplementing treaties which it may not have the power to reach otherwise. As one commentator has stated:

In a word, the treaty-power cannot purport to amend the Constitution by adding to the list of Congress' enumerated powers, but having acted, the consequence will often be that it has provided Congress with an opportunity to enact measures which independently of a treaty Congress could not pass; the only question that can be raised as to such measures will be whether they are "necessary and proper" measures for the carrying of the treaty in question into operation.⁸⁶

It is possible, then, that if a treaty concerning weather modification were made, Congress could regulate weather modification activities by enacting legislation supplementing the treaty.

Conclusion

The commerce clause as it has been interpreted by the Supreme Court would provide sufficient authority for Congress to enact legislation regulating weather modification activities. Although the Supreme Court did place certain limitations on the commerce clause in *National League of Cities*, it is unlikely that this case would so limit the reach of the commerce power as to effect weather modification regulation. As one commentator has noted "* * * the potential of the case may be

⁸⁴ See Congressional Research Service, "The Constitution of the United States of America—Analysis and Interpretation" 848 (Washington 1973). See also *Kleppe v. New Mexico*, 426 U.S. 529, 546 (1976).

⁸⁵ R. Davis, "The Legal Implications of Atmospheric Water Resources Development and Management," 102 (Report to the Bureau of Reclamation, October 1968).

⁸⁶ Congressional Research Service, "The Constitution of the United States of America—Analysis and Interpretation" 848 (Washington 1973).

quite restrained.”⁸⁷ Authority for the regulation of weather modification might also be found in other powers of Congress including the fiscal power, war power, property power, and treaty power. However, the use of these powers may not provide as far-reaching authority as is given under the commerce clause. For example, under the property power, Congress would be limited to regulation of weather modification activities on public lands. Some commentators have also argued that the *National League of Cities* decision may serve to limit other congressional powers, such as the fiscal power, in addition to limiting the commerce power.⁸⁸ It is unlikely that even if the *National League of Cities* holding were extended to other sources of congressional power that it would affect weather modification regulation.

INTERNATIONAL*

The major focus on the potential legal problems associated with weather modification activities in the United States has been on the domestic repercussions. However, there is increasing attention and interest in international involvement and implications.⁸⁹ The National Weather Modification Policy Act of 1976⁹⁰ contains a congressional finding that: “Weather modification programs may have long-range and unexpected effects on existing climatic patterns which are not confined by national boundaries.” Two of the stated purposes of the act are: “(6) to develop both national and international mechanisms designed to minimize conflicts which may arise with respect to peaceful uses of weather modification; and (7) to integrate the results of existing experience and studies in weather modification activities into model codes and agreements for regulation of domestic and international weather modification activities.” The Secretary of Commerce is directed to conduct a study which is to include, among other things, “(10) a review and analysis of the necessity and feasibility of negotiating an international agreement concerning the peaceful uses of weather modification; and (11) formulation of one or more options for a model international agreement concerning the peaceful uses of weather modification activities; and a review and analysis of the necessity and feasibility of negotiating such an agreement.” Thus, because the atmospheric processes producing weather operate independently of national boundaries, weather modification is inherently an international problem.⁹¹

Any international concern about weather modification should include attention to the international legal issues:

Serious international questions have arisen in conjunction with the capability to modify the weather. For example, do countries have the right to take unilateral action in all weather modification activities? What liability might a country incur for its weather modification operations which destroy life and property in a foreign State? On what theory could and should that State base its

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⁸⁷ Id. at S. 10 (Washington 1976).

⁸⁸ See note, “The Re-Emergence of State Sovereignty as a Limit on Congressional Power Under the Commerce Clause,” 2S Case Western Reserve L. Rev, 166, 198-199 (1977).

⁸⁹ See ch. 10.

⁹⁰ 15 U.S.C. § 330 note, Public Law 94-490, 90 Stat. 2359.

⁹¹ Note, “Weather Modification: A Modest Proposal,” 4 Ga. J. of Int’l & Comp. L. 159, 164 (1974).

claim? The international ramifications of weather modification are obvious, and in time may lead to potentially major international controversy.⁹²

Actually, some of the international legal issues are similar to those in the domestic realm which pertain to interstate activities or damages. Because of national sovereignty over airspace, nations are likely to assert rights of control over clouds and other weather phenomena in their national airspace. On the one hand, this involves the right to "use" the weather over their territory. On the other hand, it also raises a claim to "receive" weather due to arrive from another country.⁹³

The domestic law concerning weather modification has been described herein as being "unsettled." International law governing this subject is barely in the formative stage. It is not even clear at this point whether there will be a separate particular body of international law on or pertaining to weather modification, or whether international rules and regulations governing weather modification will merely become part of a larger and more general growing area of international law, namely international environmental law.

As an example of an international approach dealing directly with weather modification as a separate consideration, on March 26, 1975, the United States and Canada entered into an agreement relating to the exchange of information on weather modification activities⁹⁴ which recognizes "the desirability of the development of international law relating to weather modification activities that have transboundary effects." This bilateral agreement, however, is limited to unilateral reporting and consultation. The right to act unilaterally is preserved, and article VII even states:

Nothing herein relates to or shall be construed to affect the question of responsibility or liability for weather modification activities, or to imply the existence of any generally applicable rule of international law.

As an example of an international approach which deals with weather modification in the broader concept of environment, on May 18, 1977, the United States signed the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques,⁹⁵ which will enter into force after ratified by 20 signatory nations, in which each State party "undertakes not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting, or severe effects as the means of destruction, damage or injury to any other State party."

The primary practical international legal problem is probably that of liability for transnational injury or damage. Such a situation could conceivably arise involving the United States either directly or indirectly in a number of general fact situations:

1. Injury or damage in another nation caused by weather modification activities executed within the United States;
2. Injury or damage in another nation caused by weather modification activities executed in that nation or a third nation by the United States or a citizen of the United States;

⁹² Comment, "Weather Genesis and Weather Neutralization: A New Approach to Weather Modification," 6 Calif. W. Int'l L.J. 412, 414 (1976).

⁹³ Taubenfeld, "Weather Modification and Control: Some International Implications," 55 Calif. L. Rev. 493, 497 (1967).

⁹⁴ TIAS 8056 26 UST 540.

⁹⁵ 16 Int'l Materials 88 (1977). It has been submitted by the President to the Senate for approval. See Exec. K, 95th Cong., 2d sess.

3. Injury or damage in another nation caused by weather modification activities executed in an area not subject to the jurisdiction of any nation (e.g., over the high seas), by the United States or a citizen thereof; and

4. Injury or damage to an alien or an alien's property within the United States caused by weather modification activities executed within the United States.

Different and highly complex legal considerations might be present with any one (or combination) of such variable factors as:

1. The purpose and motivation of the weather modification activity:
 - (a) Was it performed for peaceful or hostile purposes?
 - (b) Was it originated for some public interest or a private interest?
2. The authority and character of the weather modifier:
 - (a) Is the weather modifier a Federal or State governmental agency, a private party under contract from the Federal or a State government, or a private party engaged in a private pursuit?
 - (b) Has the modifier complied with all necessary prerequisites surrounding that particular activity (e.g., license, notification, and environmental impact statement)?
 - (c) Has the other nation consented to or requested the weather modification?
 - (d) Has the weather modifier acted pursuant to the authority granted and in a competent and acceptable manner?
3. The forum chosen for commencement of any legal action, and the defendant(s) chosen:
 - (a) Does the plaintiff have standing to bring such a suit?
 - (b) Does the forum recognize a cause of action upon which the suit might be brought?
 - (c) Is proper jurisdiction obtained over the defendant(s)?
 - (d) If suit is brought against a governmental entity, is a defense of sovereign immunity available?
 - (e) If suit is brought in a foreign nation and judgment obtained, can or would it be recognized and enforceable in the United States?
 - (f) What are the conflicts of law decisions of the forum?
4. The type and extent of injury or damage sustained:
 - (a) Can it be proven that the weather modification activity caused the injury or damage complained of?
 - (b) Is the injury or damage slight compared with any benefits resulting from the activity?
 - (c) Can any of the injury or damage have been avoided or foreseen, by either party?
 - (d) What legal analogies can be drawn?

This listing is not exhaustive, but it is readily apparent that legal considerations can vary drastically depending on the facts and circumstances surrounding any particular incident and questions pertaining to legal liability therefor. Following is a brief description of some of the international law principles that might arise, both public and private, in any given situation.

CERTAIN HOSTILE USES OF WEATHER MODIFICATION ARE PROHIBITED

Besides the prohibition against the use of environmental modification techniques contained in the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques as to the military or other hostile use of environmental modification techniques having widespread, long-lasting or severe effects in another nation which is a party to that Convention, other sources of international law can be pointed to as declaring similar principles. For example, the International Committee of the Red Cross Protocol II after the Second Diplomatic Conference of the Reaffirmation and Development of International Humanitarian Law Applicable in Armed Conflicts, protects the natural environment from combat methods that cause widespread, long-term and severe damage. Article 28 states: "It is forbidden to employ methods or means of combat which are intended or may be expected to cause widespread, long-term and severe damage to the natural environment."⁹⁶ Extreme forms of weather modification, if used as a weapon, could arguably also be in contravention of the "laws of war" as being in contravention of the principles of military necessity, humanity, proportionality, and discrimination.

NATIONS ARE RESPONSIBLE FOR ENVIRONMENTAL CONDUCT WHICH CAUSES INJURY OR DAMAGE IN OR TO OTHER NATIONS

On the issue of liability, a continuous flow of international decisions, conventions, and practices indicates acceptance of a standard of strict liability among states for damage caused by or deprivations resulting from manipulation of environmental variables. This standard has been developed by extension of three well-known cases: The *Trail Smelter* arbitration, in which an international tribunal found Canada liable for fumes emanating from a smelter located in British Columbia and doing damage in the State of Washington; the *Corfu Channel* case, in which the International Court of Justice held Albania responsible under international law for damage to British ships from mine explosions in Albanian territorial waters; and the *Lac Lannoux* arbitration, where it was said that France would be strictly liable if, due to its hydroelectric utilization of a French lake, damage resulted to waters draining into Spain. Strict liability among states has similarly found expression in several multilateral conventions. Such liability has usually been enforced in the first instance by and against states, leaving to national legal systems its assertion directly against private parties.⁹⁷

The *Trail Smelter* case contains the following often-quoted language:

Under principles of international law, as well as of the law of the United States, no State has the right to use or permit the use of its territory in such a manner as to cause injury by fumes in or to the territory of another or the properties or persons therein, when the case is of serious consequence and the injury is established by clear and convincing evidence."⁹⁸

⁹⁶ Cantrell, "Civilian Protection in Internal Armed Conflicts: The Second Diplomatic Conference," 11 *Texas Int'l L.J.* 305, 308, 326-327 (1976).

⁹⁷ Note, "New Perspectives on International Environmental Law," 82 *Yale L.J.* 1959, 1665-1666 (1973). The *Trail Smelter* case (*United States v. Canada*), 3 U.N.R.I.A.A. 1938 (1941). 35 *Am. J. Int'l L.* 684 (1941). The *Corfu Channel* case, [1949] *I.C.J.* 4. The *Lake Lannoux* case, 12 U.N.R.I.A.A. 281 (1957), 52 *Am. J. Int'l L.* 156 (1959).

⁹⁸ It should be noted, however, that there is commentary to the effect that the implications of this case are not as they seem to be. See, Nanda, "The Establishment of International Standards for Transnational Injury," 60 *Iowa L. Rev.* 1089, 1097 (1975).

Further diplomatic exchanges over incidents such as compensation paid by the United States for the Japanese fishermen subject to excessive radiation in the 1954 hydrogen bomb tests in the Marshall Island Trust Territories, the exchange of notes between Japan and the United States involving the 1958 U.S. Pacific nuclear tests, and the exchange of notes between Mexico and the United States involving pollution of Ciudad Juarez, Chihuahua, Mexico, have been pointed to as effectively extending the doctrine of state responsibility set forth in the *Trail Smelter* case.⁹⁹ One recent commentator describes this as an unformulated principle in international law that is called the "principle of neighborship." "It is clear, once we formulate it, that the principle does impose limitations on a state's right to adversely affect the territorial sovereignty of its neighbors by acts carried out in its own territory."¹

NATIONS ARE LIABLE FOR INJURIES SUSTAINED BY ALIENS WITHIN THEIR TERRITORY CAUSED BY TORTIOUS CONDUCT IN VIOLATION OF INTERNATIONAL LAW

"A state is responsible under international law for injury to an alien caused by conduct subject to its jurisdiction, that is attributable to the state and wrongful under international law."² If the conduct is not wrongful under international law, the alien would in most instances have the same remedies and recourse as those available to citizens of the United States,³ and be subject to the same defenses.⁴

NATIONS OR ITS CITIZENS MAY BE LIABLE FOR INJURY AND DAMAGE THEY CAUSED TO CITIZENS OF ANOTHER NATION OCCURRING IN THAT NATION

If the citizen of the foreign nation is injured in that nation by tortious conduct attributable to the United States or one of its citizens, the injured party would have the option of bringing a cause of action within that country if jurisdiction can be obtained and such a suit is permitted there, or by bringing suit within the United States in an appropriate forum. Private litigation between citizens of two different nations can produce a host of legal issues. For example, a conflicts of law problem would arise in that the tribunal called upon to determine the matter would have to choose which nation's laws (or political subdivision thereof) would apply to the situation.⁵ If the litigation involved a citizen of another nation and the United States, local law

⁹⁹ Nanda, "The Establishment of International Standards for Transnational Injury," 60 Iowa L. Rev. 1089, 1098-1100 (1975).

¹ Elkind, "Footnote to the Nuclear Test Cases: Abuse of Right—A Blind Alley for Environmentalists," 9 Vand. J. Transnational L. 57 (1976). This same commentator criticizes the International Court of Justice for sidestepping the necessity of deciding whether nuclear testing which causes fallout on neighboring territory is lawful in the 1975 nuclear test cases (*Australia v. France, New Zealand v. France*).

² Restatement (second) of the Law "Foreign Relations Law of the United States," sec. 164(1) (1951).

³ 42 U.S.C. sec. 1981 (1970 ed.) grants all persons within the jurisdiction of the United States the right to sue. Treaties of friendship, commerce and navigation, usually also grant such a right. For example, see the Treaty of Friendship, Commerce and Navigation Between the United States and Japan (1953), 4 U.S.T. 2063.

⁴ If a United States citizen would be foreclosed from pursuing a claim for damages because of the defense of sovereign immunity, as an example, an alien would likewise be barred.

⁵ See, e.g., S. C. McCaffrey, "Pollution Suits Between Citizens of the Republic of Mexico and the United States: A Study in Private International Law" (1976), at 34-35, 106.

would probably be determinative. "Generally, international law governs the relations of sovereign states. Therefore, private parties have no standing to espouse a claim in the international system. Usually, the only direct recourse for an injured private party against a foreign nation is through that nation's municipal law. If no satisfaction can be obtained in local courts, then only the nation of the injured party may demand redress by the foreign nation for any alleged violation of its duty under international law."⁶

⁶ Comment, "State Responsibility to Espouse Claims of Nationals Based on Contracts With Foreign Nations," 2 N.C.J. Int'l & Comm. Reg. 38, 39 (1977).

CHAPTER 12

ECONOMIC ASPECTS OF WEATHER MODIFICATION

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INTRODUCTION

Several weather modification processes have economic implications of great significance. Many sectors of agriculture, industry, and commerce may reap benefits or sustain losses as a result of shifts from historic weather trends. The difficulty is that until the technology is more highly developed and control systems perfected to permit reliable predictions of outcomes, attempts to quantify benefits and costs will, in many cases, be more academic than practical.

The long-term potential for economic gains through weather modification cannot be denied. For example, studies sponsored by the Bureau of Reclamation (1973) of the potential increase in water supply from operational weather modification in the Upper Missouri River Basin indicate that seeding winter orographic storms in headwater areas could provide as much as 1.8 million acre-feet of new water annually.¹ In the Yellowstone subbasin, the estimated potential is 536,000 acre-feet per year. Table 1 summarizes results of the study. These estimates are based on an assumed October-through-April cloud-seeding period. If seeding were extended through May and early June, a further increment of 20 to 25 percent could become available provided that May-June precipitation is increased in proportion to October-April precipitation. The cost of providing this new water is estimated to be \$2.50 per acre-foot.²

¹ U.S. Department of Interior, Water for Management Team, "Report on Water for Energy in the Northern Great Plains Area with Emphasis on the Yellowstone River Basin," Washington, D.C., January 1975.

² Ibid.

TABLE 1.—POTENTIAL ADDITIONAL WATER TO THE UPPER MISSOURI BASIN BY WEATHER MODIFICATION

	Drainage area (square miles)	Average annual runoff (1,000 acre-ft)	Weather modification	
			Area affected (square miles)	Incremental runoff (1,000 acre-ft)
Upper Missouri tributaries:				
Milk River at Milk River, Alberta.....	1,036	278	157	5
Marias River near Shelby.....	3,242	728	491	74
Teton River near Dalton.....	1,308	118	212	22
Sun River near Vaughn.....	1,854	579	736	85
Missouri River at Canyon Ferry Reservoir.....	15,904	3,663	9,973	767
Subtotal.....				954
Yellowstone:				
Yellowstone River at Billings.....	11,795	5,311	5,161	536
Wind River at Boysen Reservoir.....	7,701	997	1,964	125
Greybull River at Meeteetse.....	681	237	512	46
Shoshone River at Buffalo Bill Reservoir.....	1,538	797	1,501	126
Subtotal.....				834
Other.....				49
Total, Upper Missouri (above Sioux City, Iowa).....				1,837

Source of data: "Twelve Basin Investigation," prepared for USBR by North American Weather Consultants, vol. 2, Dec. 31, 1973.

The nature of direct benefits from increased precipitation is obvious, but many indirect benefits and costs are more elusive and suggest that further study of the sociological, legal, and environmental implications of weather modification is needed and should be accelerated.

ECONOMIC SETTING

To place the economic aspects of weather modification in better perspective, a review of the operational status of the principal modification processes will be useful:³

1. Dispersion of cold fog and seeding of winter orographic storms already have limited operational capability.
2. Dispersal of warm fog, modification of precipitation from convective systems, and hail suppression are on the threshold of operational capability.
3. Modification of major storm systems to minimize damage from wind and flooding, lightning suppression, and modification of tornadoes are currently hopes for the future.

Considering the state of the art as summarized above, it is not difficult to realize the tenuity of conclusive economic analyses.

Constraints on reliable quantification of benefits and costs associated with weather modification practices are related not only to the present uncertainty of technology but also to the complex nature of legal and economic aspects of externality problems.^{4, 5} For example, decisions regarding the development of facilities to enhance agricultural production through more efficient use of water on one's own land are essentially independent of imposing costs on others or on bestowing benefits

³ Crutchfield, James A., "Weather Modification: The Economic Potential," draft of paper prepared for Weather Modification Advisory Board, U.S. Department of Commerce, University of Washington, Seattle, Wash., May 1977.

⁴ Lackner, T. O., et al., "Precipitation Modification," National Technical Information Service, PB 201534, Springfield, Va., July 1971, pp. VIII-1 to VIII-14.

⁵ Fleagle, R. G., "Weather Modification—Science and Public Policy," University of Washington Press, Seattle, Wash., 1973, pp. 31-40.

on others for which there is no return. Counter to this is the situation wherein weather modification is employed as the vehicle for such improvement. In this case, increased precipitation could benefit farmers not sharing in payment for the program but impose hardships and costs on others. For example, more rainy days would be detrimental to operators of outdoor recreational facilities. Considering this, it is apparent that collective action will be required for effective weather modification. Unfortunately, development of the appropriate institutions and laws, and clarification of legal liability issues, will likely be a slow process, requiring an unusual degree of cooperation and public-spirited effort.

Finally, it should be recognized that weather modification benefits are bounded by the cost of achieving the same objectives with the "next best" alternative.⁶ For example, crop yields could be increased through the importation of water to deficient areas, modified use of agricultural chemicals, or use of improved plant varieties.

The following sections present a summary of the economic aspects of weather modification procedures, a review of methodology for economic analyses, and a discussion of case studies of the benefits and costs of several operational programs.

ECONOMIC ASPECTS OF WEATHER MODIFICATION PROCEDURES

FOG DISPERSAL

The impact of adverse weather conditions on transportation systems is well known. Of particular significance is fog. About 97 percent of all scheduled airline flights are completed each year, but of the remaining 3 percent about one-half are canceled because of fog. The percentage is small, but as noted by Beckwith⁷ the cost is very large. He points out that during 1964, more than 800 million airline-miles were flown in the United States and that gross revenues generated during that period totaled \$4.25 billion.

At present, seeding of cold fog at temperatures below freezing is an operational technology. This procedure is used at numerous civilian and military airports, and shows net benefits of magnitude significant enough to permit its undertaking by private firms and local governments. According to the Interdepartmental Committee for Atmospheric Sciences, cold fog dissipation programs at several airports have shown benefit-cost ratios of more than 5 to 1 savings in delayed or diverted traffic.⁸

Unfortunately, cold fogs constitute only about 5 percent of the economically disruptive fogs which occur in the United States. The Airline Transport Association estimates that elimination of delays due to warm fogs would result in annual savings of \$75 million at 1971 prices.

⁶ Crutchfield, James A., "Weather Modification: The Economic Potential," draft of paper prepared for Weather Modification Advisory Board, U.S. Department of Commerce, University of Washington, Seattle, Wash., May 1977.

⁷ Beckwith, W. B., 1966, "Impacts of Weather on the Airline Industry: the Value of Fog Dispersal Programs," in: Sewell, W. R. D., ed., 1966, "Human Dimensions of Weather Modification" University of Chicago, Department of Geography, research paper No. 105, pp. 195-207.

⁸ Federal Council for Science and Technology, "A National Program for Accelerating Progress in Weather Modification," ICAS Rept. No. 15a, Executive Office of the President, June 1971.

In addition, about \$300 million in losses are incurred by fog-associated vehicle accidents on the Nation's highways. Little more needs to be said to indicate the payoff which could result from further advances in warm fog dispersal programs. Fortunately, although reliable operational technology for warm fog dissipation does not yet exist, it appears that the technical problems are manageable and that successful procedures are not too far from development.

PRECIPITATION AUGMENTATION

The economic potential of precipitation augmentation through seeding operations is great. In areas of or during periods of marginal precipitation, increases of only a few percent might mean the difference between a plentiful crop and complete failure.

Orographic cloud seeding

The Interdepartmental Committee on Atmospheric Sciences has reported that irrigation benefits of \$50 per acre-foot per year can be generated by snowpack augmentation in the Colorado River Basin.⁹ On the basis of a 15-percent increase in snowpack due to seeding, it is estimated that about 2 million additional acre-feet of water per year could be generated at a cost of about \$1.50 per acre-foot. Other economic benefits such as increased hydroelectric power and salinity control would also result.

By 1977, the scientific community generally supported the thesis that operational capability for seeding winter orographic clouds to produce increased precipitation on the order of 10 to 20 percent had been achieved. Arguments now relate mostly to unknowns regarding individual seeding performances and the separation of seeding effects from natural occurrences.

The economic gains from seeding orographic clouds can be significant, especially when facilities already exist for storing and distributing the increased flows which result. Studies in California and Colorado suggest that benefits from snowpack augmentation exceed costs. Regarding the Colorado experience, Weisbecker said.¹⁰ "On this basis, it appears that the benefits of an operational program could exceed the sum of the direct costs and the indirect costs to the areas of origin in the upper basin."

Convective cloud seeding

From a national viewpoint, the potential for economic gains through the ability to increase precipitation from convective cloud systems is of far greater consequence than that from orographic storms. Unfortunately, operative capability in this area has not yet been achieved. According to Crutchfield:¹¹

Operational procedures for using these very large potential atmospheric resources still await the development of more complete scientific understanding and

⁹ *Ibid.*

¹⁰ Weisbecker, Leo W., "Technology Assessment of Winter Orographic Snowpack Augmentation in the Upper Colorado River Basin," summary report, Stanford Research Institute, Menlo Park, Calif., May 1972, pp. 13-19.

¹¹ Crutchfield, James A., "Weather Modification: The Economic Potential," draft of paper prepared for Weather Modification Advisory Board, U.S. Department of Commerce, University of Washington, Seattle, Wash., May 1977.

the capacity to model convective systems in ways that will indicate appropriate points of attack for enhancement or inhibition of precipitation.

The possibility must not be ruled out that subsequent research may suggest that convective clouds are simply not amenable to controlled modification; a conclusion which would be discouraging but still economically useful in itself. More hopeful, and more likely, is the prospect of developing enough predictive capability to generate rules of thumb about effectiveness of seeding operations. Then, and only then, will farmers change their techniques to take full economic advantage of the additional water.

What makes the potential gains from convective system seeding so attractive is the fact that these storms are widely distributed geographically and they influence grain producing areas of national and international significance. Crutchfield notes that if precipitation were increased in the semiarid high-plains States by 2 or 3 percent, the costs of operating a precipitation augmentation program would be easily covered.¹²

Since limited experience upon which meaningful economic analyses of benefits from modification of convective storm systems exists, only crude estimates are available. Nevertheless, it appears that if operational programs were in effect in North America, Europe, Australia and the U.S.S.R., wheat production in these areas might be increased by as much as 5 percent.¹³ This is very significant since wheat production increases in the range of 3 to 8 percent would meet normal import requirements of a large part of the nonwheat producing regions of the world.¹⁴ The foregoing projections are based on an increase in precipitation on the order of 10 percent, but this might be overly optimistic since most atmospheric scientists believe increases of 3 to 5 percent would be a major breakthrough.

Of considerable interest is the production of additional water during periods of drought. This would have significant economic payoff. The problem, however, is that weather modification depends on the availability of moisture in the atmosphere and is therefore more likely to increase precipitation during periods that would normally be wet. The atmospheric conditions associated with prolonged droughts are anything but conducive to outstanding successes for weather modification programs. A corollary is that the instability of agricultural output due to weather variations might be increased through weather modification practices and this should be recognized.

Precipitation augmentation and energy considerations

Additional water supplies developed through precipitation augmentation will have little direct impact on most energy issues although small increments of hydroelectric power will result. The most significant area of energy-water interaction, in which augmented water supplies could play an important role, is related to coal and oil shale development in the northern Great Plains and Western United States. In these semiarid regions, the incremental development of water could be of an order of magnitude significant enough to resolve conflicts between major water uses—namely energy resource development and

¹² Crutchfield, James A., "Weather Modification: The Economic Potential," draft of paper prepared for Weather Modification Advisory Board, U.S. Department of Commerce, University of Washington, Seattle, Wash., May 1977.

¹³ *Ibid.*

¹⁴ *Ibid.*

irrigated agriculture. Comments on the Missouri River Basin given in the introduction address this issue.

HAIL SUPPRESSION

The economic importance of hail suppression ranks second only to precipitation augmentation in terms of significance to agricultural production. Average annual losses from hail total about \$500 million in the United States. Most of the damage occurs in the Great Plains and in Midwestern and Southwestern States.

While rapid progress in hail suppression technology has been made in recent years, a National Hail Research Experiment, funded by NSF and conducted by the National Center for Atmospheric Research, could not find conclusive evidence that reduction in hail damage was actually achieved in target areas.¹⁵ On the other hand, the Interdepartmental Committee for Atmospheric Sciences reported in 1971 that in one area of the North Caucasus of the Soviet Union, hail suppression had been operational for more than 5 years.¹⁶ It noted that the value of crops saved exceeded the costs of the program by a factor of 10 or more.

The National Center for Atmospheric Research indicates a break-even point of about 10 percent effectiveness in the Great Plains. In the East, a higher percentage reduction of hail would be necessary for cost-effectiveness since hail damages are less. Crutchfield states that at a 25-percent reduction level (about the best to be expected), wheat yields in the United States might be increased by 1 percent¹⁷ but this might be low since research indicates that hail-suppression techniques also tend to increase total precipitation.

LIGHTNING SUPPRESSION AND REDUCTION IN STORM DAMAGE

More distant in terms of operational capability (in some cases this may never be achieved) are procedures for suppressing lightning and modifying damages from major storms.

Although average annual losses of \$100 million from lightning-caused fires appear to make the economics of lightning suppression attractive, there is a growing opinion within the U.S. Forest Service and among professional foresters that naturally occurring forest fires are not as detrimental to long-term net forest yields as had been previously thought.¹⁸ In any event, the technology of lightning suppression is not yet at operational readiness and the economic implications are clouded.

Loss of hundreds of lives and damages totaling billions of dollars are incurred annually as a result of major storms.¹⁹ This makes the prospect of modifying such systems very attractive. At present, however, the knowledge of storm processes and mechanics of alteration

¹⁵ Crutchfield, James A., "Weather Modification: The Economic Potential," draft of paper prepared for Weather Modification Advisory Board, U.S. Department of Commerce, University of Washington, Seattle, Wash., May 1977.

¹⁶ Federal Council for Science and Technology, "A National Program for Accelerating Progress in Weather Modification," ICAS Rept. No. 15a, Executive Office of the President, June 1971.

¹⁷ Crutchfield, James A., "Weather Modification: The Economic Potential," draft of paper prepared for Weather Modification Advisory Board, U.S. Department of Commerce, University of Washington, Seattle, Wash., May 1977.

¹⁸ Crutchfield, James A., "Weather Modification: The Economic Potential," draft of paper prepared for Weather Modification Advisory Board, U.S. Department of Commerce, University of Washington, Seattle, Wash., May 1977.

¹⁹ *Ibid.*

are not adequately understood and, as a result, meaningful assessment of potential economic benefits is not possible. The concept that the major portion of current damages might be eliminated if successful modification of storm characteristics (such as wind velocities) could be achieved is misleading. Until the side effects of changing large storm systems such as hurricanes are known, the benefits to be achieved will elude identification. Modification of wind velocities, for example, might cause increases in damaging rainfall or shifts in regional distribution of precipitation.

The dangers inherent in tampering with major storm systems, on the basis of incomplete understanding of such systems, are pointed out in the following statement by Crutchfield:²⁰

The first tentative experiments in hurricane seeding—limited to four storms—only nibbled at the edges of the scientific problems involved, though the results were certainly interesting enough to suggest an expanded effort. But an attempt to transfer the program to the Pacific Ocean where larger numbers of storms more remote from populated areas could be used for experimental purposes brought such vigorous objections from Japan and China that the program was halted. One can only contemplate with awe the wrangling that would develop if demonstrably workable procedures to reduce peak velocities in storms affecting the continental United States were alleged—correctly or incorrectly—to have influenced the quantity of precipitation received by States in the normal storm path. There is some evidence (not unchallenged, however) that agricultural, municipal, and industrial activities have benefited substantially from the increase in water supplies generated by damaging storms.

In summary, modification of Atlantic or Caribbean hurricanes inevitably involves a mixture of benefits and costs so complex as to defy even the grossest kind of guess as to potential economic gains at this time. Given the inevitable lack of precision in identifying causal relationships running from the modification procedures to perceived winds, waves, and precipitation, public confusion is likely to take the form of vigorous defensive action by those who feel themselves threatened.

ANALYTIC METHODS FOR ECONOMIC ANALYSIS

In 1965, at a symposium on the economic and social aspects of weather modification held at the National Center for Atmospheric Research, the question of identifying and measuring the economic aspects of weather change was considered. An ideal weather pattern model was proposed by Ackerman.²¹ His concept was that the model could be used to determine what weather elements mean to the system of economic production and consumption in any given geographical area and to determine an ideal weather pattern within a given system.

Although the quantification of such a model will require considerable research, the idea of being able to trace the impact of a given weather shift throughout the economic system has merit.

A number of standard analytic tools are available for use in economic analyses of weather changes. They include: input-output models, benefit-cost analysis, simulation, regression analysis, and linear programming. All of these approaches have potential, but they all share the problem of lack of basic data and understanding for quantification of coefficients and parameters fundamental to their successful use. The

²⁰ *Ibid.*

²¹ Ackerman, E. A., 1966, "Economic Analysis of Weather: An Ideal Weather Pattern Model," in Sewell, W.R.D., ed., 1966, "Human Dimensions of Weather Modification," University of Chicago, Department of Geography, research paper No. 105, pp. 61-75.

design of an input-output model has been described by Langford,²² and Gutmanis and Goldner²³ give a good discussion of problems associated with the application of benefit-cost analysis to weather modification issues.

It would appear that economists concerned with weather modification programs are inclined to support the use of benefit-cost analysis as a promising technique for determining comparative social costs and benefits of such programs. A difficulty relates to the extensive geographic scope of weather modification programs compared to those ordinarily assessed by benefit-cost analyses. In addition, there is little data upon which to evaluate the economic consequences of large-scale weather modification activities. For limited-scope weather modification projects such as fog dispersal at airports and cloud seeding to artificially induce rain in a small region, Maunder suggests that many of the problems associated with benefit-cost analysis could be overcome and the procedure readily adopted.²⁴ Based on an evaluation of a study by Gutmanis and Goldner, Maunder summarized the principle limitations on use of benefit-cost analysis for expansive weather modification programs as follows:

- (1) The extensive geographic and functional scope of such programs;
- (2) The difficulties in obtaining the necessary qualitative and quantitative data;
- (3) The difficulty resulting from the availability of several possible technological approaches which may be employed in varying degrees either singly or in combination; and
- (4) The difficulty in integrating and supporting benefit-cost analysis with welfare economic theory.

CASE STUDIES OF THE ECONOMICS OF WEATHER MODIFICATION

HUNGRY HORSE AREA, MONTANA

Cloud seeding above the Hungry Horse area was conducted in 1951, and again during the winters of 1954 through 1958, but these early efforts did not provide an adequate data base for an economic assessment. Then, in 1967, based on the results of a 1966-67 winter seeding program, North American Weather Consultants estimated that runoff in the region would be increased by 5 percent.²⁵ On this basis, it was determined that an increase in energy production at all downstream power installations would total about 200,000,000 kWh per year, with added power benefits of about \$500,000 per year. Initial seeding costs were estimated to be \$300,000, with continuing costs of \$75,000 to \$100,000 per year.

²² Langford, T. W., 1968, "A Proposed Model for the Evaluation of Economic Aspects of Weather Modification Programs for a System of Regions," in Sewell, W.R.D., et al., 1968, "Human Dimensions of the Atmosphere," National Science Foundation, Washington, D.C., pp. 113-120.

²³ Gutmanis, I. and Goldner, L., 1966, "Evaluation of Benefit-Cost Analysis as Applied to Weather and Climate Modification," in Sewell, W.R.D., ed., 1966, "Human Dimensions of Weather Modification," University of Chicago, Department of Geography, research paper No. 105, pp. 111-125.

²⁴ Maunder, W. J., "The Value of the Weather," Methuen & Co., Ltd., London, England, 1970.

²⁵ North American Weather Consultants, "Performance of an Atmospheric Water Resources Research Program in the Hungry Horse Area, Montana," 1966-67, report No. 15-9, North American Weather Consultants, Goleta, Calif., 1967.

CONNECTICUT RIVER BASIN

In a 1969 study, the Travelers Research Corp. estimated that runoff from the entire Connecticut River basin might be increased by about 2 million acre-feet (15 percent) per year through a weather modification program.²⁶ It was calculated that this increment of water would cost \$2.30 per acre-foot, or \$4,600,000 annually. The report also stated that net benefits of \$1,400,000 from municipal water supply, and \$2,600,000 from supply of cooling water for thermal electric generating stations and increased flow for hydroelectric power generation might be realized by the 1980's. Other benefits which were not evaluated include pollution abatement, agriculture, groundwater recharge, flood control, and recreation. These are not all mutually compatible, however. Travelers estimated that an average water supply increase of only about 3 percent would permit the weather modification program to pay for itself in approximately 15 years.

The Travelers study was based on the assumption that precipitation from storms occurring during all seasons of the year would be increased by 15 percent. Their benefit-cost analysis was based on average conditions and did not account for variances in benefit-cost relationships which would occur during wet or dry years.

STATE OF ILLINOIS

In a 1972 study of the impact of weather modification practices on corn and soybean yields in Illinois, Huff and Changnon concluded that in most regions of that State corn and soybean crops could be benefited economically through a cloud-seeding program, provided that precipitation increases of at least 10 percent were achieved.²⁷ It was also stated that rainfall outputs from seeding operations would have to be accurately defined or "more damage than benefit could result."

The study showed that a good deal of variability could be expected from year to year and that differential effects could be expected in a significant percentage of years, that is, one crop might be helped and another harmed.

These studies were based on the use of several seeding models for a sampling period of 38 years and thus represent anticipated results rather than findings based on observation.

NINE-COUNTY SOUTHEASTERN CROP REPORTING DISTRICT, SOUTH DAKOTA

A 1973 study by a special team at the Agricultural Experiment Station of South Dakota State University²⁸ showed that increased precipitation could have considerable direct and indirect effects on the economy of a region by increasing crop yields. As yields increased, total revenue rose rapidly, with costs remaining about the same. A

²⁶ Travelers Research Corporation, "Water From the Sky," Hartford, Conn., 1969.

²⁷ Huff, F. A. and Changnon, S. A., Jr., "Evaluation of Potential Effects of Weather Modification on Agriculture in Illinois," *Journal of Applied Meteorology*, pp. 377 to 384. Vol. 11, No. 2, March 1972.

²⁸ Agricultural experiment station special study team, "Effects of Additional Precipitation on Agricultural Production, the Environment, the Economy and Human Society in South Dakota," South Dakota State University, Brookings, S. Dak., June 1973, pp. 113-128.

conservative multiplier of 3.6 was used to estimate the indirect impact.

For the nine-county Southeastern crop reporting district, historical yields produced an annual total revenue of \$211,200,000, total costs of \$145,700,000 and total profits of \$65,450,000. These base data were compared with the results of nine additional combinations of yields and prices. Yields used were minimum, average and maximum expected increases and prices ranged from the historical average to 5-, 10- or 15-cent-per-bushel decreases for all marketable grains.

For the alternatives considered, total revenues ranged from \$213,100,000 to \$234,200,000 and total costs were found to vary slightly from the historic base value, with the highest total cost up only \$800,000. Total profits ranged up to \$87,700,000 for the run using maximum expected yield increase and historical average prices. In this case, profits increased 34 percent over the base. The lowest profit increase, 3.1 percent, occurred for the combination of the lowest expected yield increase and a 5-cent-per-bushel decrease in the price of marketable grain (10- and 15-cent decreases per bushel in grain prices were not run with the lowest expected yield increase).

Indirect benefits were computed using a multiplier of 3.6 and were found to be positively related to direct effects. This means that for each \$1 added directly to the economy of the area, a \$3.60 final effect on the area's economy results. A manufacturing segment was not included in the analysis and the study team noted that actual indirect benefits might be somewhat higher as a result of this exclusion.

The direct costs of weather modification were found to be approximately 3.2 cents per acre and it was concluded that the direct costs associated with additional precipitation would be much less than the benefits which could be expected.

COLORADO RIVER

The most extensive economic analyses of weather modification practices have been of winter orographic snowpack augmentation (WOSA) in the Colorado River Basin. Experimental results of cloud-seeding operations in southwestern Colorado suggest that runoff in the basin can be increased by about 20 to 25 percent.^{29, 30} This would result in an average annual increase of about 2.3 million acre-feet (maf). An operational program to yield this flow would incur a direct cost of about \$5.4 million per year.³¹

In an intensive study of snow enhancement in Colorado by the Stanford Research Institute, Weisbecker specified two categories of economic impacts. These are:

(1) Effects on the cloud-seeding target areas and those downwind areas that might inadvertently be subjected to additional precipitation; and (2) possible uses of the augmented water supply, whether in the upper or lower basins, or outside the Colorado River Basin.

²⁹ Hurley, Patrick A., "Augmenting Colorado River by Weather Modification," *Journal of the Irrigation and Drainage Division, ASCE*, vol. 94, No. IR4, Proc. Paper 6271, December 1968, pp. 363-380.

³⁰ Rudell, R. K., Stockwell, H. T., and Walsh, R. G., "Weather Modification: An Economic Alternative for Augmenting Water Supplies," *Water Resources Bulletin*, vol. 9, No. 1, February 1977, pp. 115-128.

³¹ Weisbecker, Leo W., "Technology Assessment of Winter Orographic Snowpack Augmentation in the Upper Colorado River Basin," summary report, Stanford Research Institute, Menlo Park, Calif., May 1972, pp. 13-19.

Regarding economic impacts in target areas, the Stanford study stated:

The known effects on the target areas are almost uniformly adverse, with the exception of the possible advantages that extra snowfall, particularly at the beginning of the season, might bring to operators of ski resorts and their patrons. Although the impact on the upland grazing industry appears to be negligible, increased costs of mining operations and timber cutting (and possible suspension of activities); interference with road, rail, and air transport; and shortening of the tourist season would all have repercussions of an unfavorable sort on the economies of a number of small towns, particularly in western Colorado.

Weisbecker commented that measurement of the extent of these effects was not possible on the basis of published information and that extensive field work would be required to adequately assess local economic injury. A rough annual estimate of these costs was given as \$2 million in the basin and \$1 million out of the basin, which is about equivalent to \$1 per acre-foot of water produced. Adding these costs to direct costs of cloud seeding and costs of avalanche control, flood forecasting, and environmental monitoring programs, produced an estimate of the cost of water produced of less than \$3 per acre-foot. Weisbecker noted, "This is still a very inexpensive way of providing extra water in the Colorado River Basin."

It was also found that, although there might be significant costs on a local or regional basis, the small-scale of the economies and the few people affected adversely would assure that the national economic effects would be negligible.

The report concluded that:

If only existing facilities are used to store and distribute water and generate power, benefits of at least \$7.8 million annually could be generated in-basin and \$5 million annually by out-of-basin spillover runoff. Of the \$12.8 million total annual benefits, \$6.2 million is accounted for by electric power generation. This use of WOSA provides the least equivocal form of benefits for an operational program. On this basis, it appears that the benefits of an operational program could exceed the sum of the direct costs and indirect costs to the areas of origin in the upper basin.

It was also noted that, "WOSA is an inexpensive method of augmenting the water supply in the Colorado River Basin." Annual operating costs for the WOSA system were estimated at about \$5.4 million, giving an average cost of \$2.37 per acre-foot for in-basin runoff alone and \$1.58 per acre-foot overall.

In another study of the economic aspects of WOSA, Rudell et al. found that "weather modification is an economically feasible means to provide additional water for the Colorado River Basin."³² The principal findings of their study are given below:

1. The benefit-cost ratio varies with place of water use. It was estimated to be 13.1 to 1 for Arizona, 16.3 to 1 for New Mexico, and 21.3 to 1 for California.

2. Compared with other recognized means of augmenting water supplies, weather modification appears to be one of the least-cost alternatives. Direct costs of \$0.91 to \$1.15 per acre-foot of water produced were reported. Indirect costs of additional snow removal and loss of personal income due to mine closings were estimated to add \$0.15 to

³² Rudell, R. K., Stockwell, H. T., and Walsh, R. G., "Weather Modification: An Economic Alternative for Augmenting Water Supplies," *Water Resources Bulletin*, vol. 9, No. 1, February 1977, pp. 115-128.

\$0.19 per acre-foot. Extra market costs due to traffic delays caused by additional snow were calculated to increase costs by about \$0.15.

3. Only about 12.4 percent of weather modification costs is for capital construction, making the program easily reversible with little loss of sunk costs.

4. Variable costs of operation are about \$975 per day. Thus small increases in daily precipitation would cover the direct costs of operation.

5. Water by weather modification is worth \$2 per acre-foot for power production and \$14.50 to \$26.50 per acre-foot for irrigation of forage crops. If the additional water is used for higher valued crop production, or for domestic and/or industrial purposes, its value is even greater.

6. Extra market values associated with weather modification could include travel delays, grazing and timber rescheduling, and changes in plant and animal communities. While such factors have little effect on the total costs of weather modification, they may be very important to those directly affected and could influence decisions to initiate weather modification projects.

CONCLUSIONS

The state of the art of operational weather modification programs is such that meaningful economic evaluation of such activities is limited to special, localized cases. As stated by Crutchfield,³³ there is a need for substantially greater knowledge of: "(1) the processes that we seek to alter; (2) the methods through which that alteration can be achieved; and (3) the extent to which the resulting effects can be anticipated in time, space and degree."

Nevertheless, the economic potentialities are very attractive. Operating costs of cloud seeding are very small, ranging from 5 to 20 cents per acre of target area, and the needed capital equipment is relatively inexpensive. The few economic studies which are available suggest possible benefit-cost ratios ranging upward to 20 to 1.³⁴

³³ Crutchfield, James A., "Weather Modification: The Economic Potential," draft of paper prepared for Weather Modification Advisory Board, U.S. Department of Commerce, University of Washington, Seattle, Wash., May 1977.

³⁴ Fleagle, R. G., Crutchfield, J. A., Johnson, R. W., and Abdo, M. F., "Weather Modification in the Public Interest," University of Washington Press, Seattle, Wash., 1973, pp. 31-40.

CHAPTER 13

ECOLOGICAL EFFECTS OF WEATHER MODIFICATION

(By William C. Jolly, Analyst, Environment and Natural Resources Policy
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INTRODUCTION

MODIFICATION OF WEATHER AND CLIMATE

"Weather and climate are major factors in human activity. Even when human communities have adapted themselves reasonably well to the climate of a region, temporary deviations from the normal—severe storms, droughts, unseasonable frosts—periodically cause acute monetary loss and personal suffering. Weather modification is thus an age-old dream. Research on atmospheric processes has apparently brought man to the threshold of realizing that dream, at least in part."¹

Written nearly a decade ago, those words still succinctly capture the "why" and the status of planned weather modification efforts. It is axiomatic that weather modification actions which impact human communities also impact natural communities in the ecosystems of which both are but components. This chapter seeks to briefly address the ecological implications of planned and inadvertent weather modification in target and nontarget areas, and to review with respect to those implications, the level of understanding which several investigations in the last decade have sought to advance.

It is the function of this chapter to summarize the current state of knowledge about ecological effects of weather modification and to do so for a general, not a specialist, audience. Accordingly, the chapter represents the author's distillation of salient findings of others rather than any original contribution of either ideas or research.

ECOLOGY AND ECOLOGICAL SYSTEMS

At the risk of merely restating what by now may have become commonly known, if not obvious, it can be said that ecology is generally defined as the study of the relationship between living organisms and their environments (including both living and nonliving components thereof). That is, ecology deals both with organisms in their environment and with the processes of movement of energy and matter which link organisms and place. Ecological systems—the subject matter of ecology and the structure and function of which the ecologist seeks

¹ Charles F. Cooper and William C. Jolly, Ecological effects of weather modification: a problem analysis, Ann Arbor: University of Michigan, School of Natural Resources, 1969, p. 1.

to study and understand—are definable complexes of related biotic assemblages of animals, plants, and microbes together with their particular abiotic, chemico-physical environments. As Kormondy has noted:

Ecosystems are real—like a pond, or a field, a forest, an ocean, or even an aquarium; they are also an abstract in the sense of being conceptual schemes developed from a knowledge of real systems. In spite of the great diversity in types of actual ecosystems—from small to large, terrestrial to fresh water to marine, field to laboratory—and in spite of the unique combinations of particular abiotic and biotic components in any particular one, they have in common certain general structural and functional attributes that are recognizable, analyzable, and predictable.²

In seeking to understand what changes in plant and animal communities may result from any given modification in weather which man might effect deliberately, it is to the young evolving science of ecology and to ecologists that decisionmakers turn for best judgments in interpreting the relationships which may be affected and, in some cases, actually predicting the nature and magnitude of ecological effects which can be expected.

It must be borne in mind that ecological systems require a knowledge of both past and present in order to predict the future. Also, ecology is not independent of time and place, so broad generalizations are not easily nor accurately made. Thus, while descriptive ecology is well-developed, truly predictive ecology is but in its infancy.

KNOWLEDGE OF ECOLOGICAL IMPLICATIONS OF APPLIED WEATHER MODIFICATION TECHNOLOGIES

If 1946 can be taken as the benchmark year for “modern” weather modification technology (when GE scientists Langmuir and Schaefer successfully modified clouds by “seeding” them with pellets of dry ice), 1966 can be said to mark the explicit recognition that environmental effects of applied weather modification technology could be of serious importance and were yet but largely a matter of speculation. In that year, the ad hoc weather working group of the ecological study committee of the Ecological Society of America published its report on biological aspects of weather modification which it had submitted to the National Science Foundation’s Special Commission for Weather Modification.³ The report of the NSF Special Commission, also published in 1966, noted that “from the present crude state of the field, one can roughly predict that the biological outcomes of weather modification are apt to be a mixed bag of economically good and bad effects in man’s artificial ecosystems. It is difficult to visualize any desirable effect on the small preserves of natural communities.”⁴ The Commission advised:

It is the position of the Commission that there should be a strong effort to bring the field of biological forecasting up to a higher level of usefulness. This is man-

² Edward J. Kormondy, *Concepts of Ecology*, 2d ed., Englewood Cliffs, N.J.: Prentice-Hall, 1976, pp. 1–2.

³ D. A. Livingstone, biological aspects of weather modification, a report from the Ecological Society of America’s ad hoc weather working group of the ecological study committee to the Special Commission for Weather Modification of the National Science Foundation, *Bull. Ecol. Soc. Amer.* 47 (1966): 39–78.

⁴ National Science Foundation, weather and climate modification, report of the Special Commission on Weather Modification, Washington, D.C., National Science Foundation, 1966, p. 19.

datory in planning weather and climate modification over areas involving more than a few hundred square miles.⁵

This and other related recommendations of the NSF Special Commission directly or indirectly led to a number of ecological studies which have been specifically concerned with identifying and predicting ecological effects of weather modification.

One of the first sponsored studies was the problem analysis conducted by Cooper and Jolly⁶ for the Bureau of Reclamation, as that agency began to better balance operational weather modification research with studies aimed at understanding ecological, legal, economic, and other social effects of weather modification activity. The report included "sections on anticipated kinds of weather modification; effects in semi-arid climates and in humid climates; pests and diseases; direct effects of seeding agents; biology of lakes and streams: fog, hail, lightning, and hurricane modification; environmental monitoring programs; inferences from ecological theory; recommended research; and recommended premodification field surveys."⁷

An extensive bibliography of relevant literature was also included. Cooper, whose 1967 paper on the effects of weather modification on plant and animal communities represented one of the earliest attempts to anticipate ecological ramifications of the seriously developing weather modification technology,⁸ has continued to publish on the subject.⁹

Other major studies of note include work on the impacts of snow enhancement supported by the National Science Foundation,¹⁰ and the Bureau of Reclamation,¹¹ and on impacts and issues associated with efforts to suppress hail.¹² Also of importance and interest, of course, are the proceedings of the several conferences on weather modification which have been sponsored biennially since 1968 by the American Meteorological Society. Papers on environmental considerations and impacts associated with weather modification efforts and technologies

⁵ *Ibid.*, p. 20.

⁶ Cooper and Jolly, *ecological effects of weather modification*, 160 pp. (Note 1.)

⁷ *Ibid.*, p. 160.

⁸ C[harles] F. Cooper, *effects of weather modification on plant and animal communities*, paper presented at Symposium on Weather Modification, AAAS Committee on Arid Lands, New York, Dec. 30, 1967 (mimeo).

⁹ Charles F. Cooper, *ecological impacts of local and global weather modification*, paper prepared for 51st annual meeting, American Meteorological Society, San Francisco, Jan. 14, 1971, 16 pp. (mimeo).

¹⁰ Charles F. Cooper, *ecological implications of weather modification*, paper prepared for the Weather Modification Advisory Board, U.S. Department of Commerce, 1977, 19 pp. (mimeo).

¹¹ Charles F. Cooper, *what might man-induced climate change mean?* *Foreign Affairs* 56(3) (1978): 500-520.

¹² Charles F. Cooper, George W. Cox, and Warren A. Johnson, *investigations recommended for assessing the environmental impact of snow augmentation in the Sierra Nevada, Calif.*, prepared for the Bureau of Reclamation and the California Department of Water Resources, San Diego: San Diego State University, Center for Regional Environmental Studies, 1974, 84 pp.

¹⁰ Leo W. Weisbecker (comp.), *The impacts of snow enhancement*, contract report prepared for the National Science Foundation, Norman: University of Oklahoma Press, 1974, 624 pp.

¹¹ Harold W. Steinhoff and Jack D. Ives (eds.), *Ecological impacts of snowpack augmentation in the San Juan Mountains, Colorado*, Final report of the San Juan ecological project to the Bureau of Reclamation, 25 papers, 1976, 489 pp.

¹² Stanley A. Changnon, et al., *Hail suppression, impacts and issues*, Final report, technology assessment of the suppression of hail, Office of Exploratory Research and Problem Assessment, RANN program, National Science Foundation, Urbana, Ill.: State Water Survey, 1977, 432 pp.

have been included in the proceedings of these conferences.¹³ The final Environmental Statement for Project Skywater, published in 1977 by the Bureau of Reclamation, consists of a three-volume statement covering the post-1964 research program of the Bureau relating to the effects that cloud seeding for increasing growing season precipitation and mountain snowpacks might have if the technology were applied over long periods of time.¹⁴ One of the appendix reports attached to the statement reviews research relating to environmental effects of seeding agents, particularly silver iodide. The question of the effects of silver iodide on the environment, particularly over time, has also been addressed and reported on in other publications.¹⁵ The definitive review to date of the subject of environmental effects of nucleating agents, based on a 1976 workshop, has recently been prepared by Klein¹⁶ under National Science Foundation sponsorship.

Thus in the 12 years since the National Science Foundation's Special Commission on Weather Modification issued its report, a significant volume of research aimed at determining and evaluating possible ecological effects of weather modification has been undertaken. In summarizing the results and inferences from Project Skywater which relate to environmental impacts, Howell tabulates 17 individual contracts for environmental research sponsored by Project Skywater.¹⁷ They cover the 1964-76 period and total nearly \$3 million.

Some of the more specific findings and conclusions of the research efforts cited above are extracted and summarized under the various topical headings which follow.

IMPORTANT VARIABLES

As Cooper has noted, "Weather modification is by definition a change in the natural climatic environment."¹⁸ He continues: "It is impossible to predict 'the ecological effects of weather modification.' A specific expected alteration in the natural weather pattern must first be defined. Usually this can be done only within probability limits. Unless the expected change in climatic input to the ecosystem is known, no reasonable predictions can be made. Seldom has sufficient informa-

¹³ See: Proc., First National Conference on Weather Modification of the American Meteorological Society, April 28-May 1, 1968, State University of New York at Albany: 173-180. Boston: Amer. Meteor. Soc.;

Proc., Second National Conference on Weather Modification of the American Meteorological Society, April 6-9, 1970, Santa Barbara, Calif.: 411-414. Boston: Amer. Meteor. Soc.;

Proc., Third Conference on Weather Modification of the American Meteorological Society, June 26-29, 1972, Rapid City, S. Dak.: 226-231. Boston: Amer. Meteor. Soc.;

Proc., Fourth Conference on Weather Modification of American Meteorological Society, Nov. 18-21, 1974, Fort Lauderdale, Fla.: 502-534. Boston: Amer. Meteor. Soc.

¹⁴ Bureau of Reclamation, Final environmental statement for Project Skywater. Denver: Bureau of Reclamation Engineering and Research Division, 1977, 340 pp. (vol. 1) plus appendices (vols. 2, 3).

¹⁵ Charles F. Cooper and William C. Jolly. Ecological effects of silver iodide and other weather modification agents: a review. *Water Resources Research* 6 (1) (1970): 88-98; D. A. Klein. Ecological impacts of nucleating agents used in weather modification programs: an interdisciplinary assessment, *J. Weather Mod.* 9(4) (1977): 51-56; Ivan C. Smith and Bonnie L. Carson. Trace Metals in the Environment: Vol. 2. Silver, Ann Arbor, Mich.: Ann Arbor Science Publishers, 1977, 490 pp.

¹⁶ D. A. Klein (ed.), Environmental impacts of nucleating agents used in weather modification. Stroudsburg, Pa.: Dowden, Hutchinson and Ross, 1978.

¹⁷ Wallace E. Howell, Environmental impacts of precipitation management: results and inferences from Project Skywater. *Bull. Amer. Meteor. Soc.* 58(6) (1977): 489.

¹⁸ Cooper, Ecological implications of weather modification, p. 1 (Note 9).

tion about expected weather changes been made available to those who would make ecological assessments."¹⁹ It may be useful to mention a number of the variables which must be considered before one can attempt to predict the ecological impact of a given weather modification. These variables are treated more completely by, inter alia, Cooper and Jolly,²⁰ and by Cooper.²¹

TEMPORAL CONSIDERATIONS

Season of modification effort

Within a given ecosystem reactions of vegetation and associated animal communities to an expected 5-percent to 10-percent increase in mean precipitation during years of normal or subnormal precipitation will vary, for example, depending on whether that increase falls during a dormant or a growing season, or whether the increase comes in the form of rain or snow. Whether there are impacts such as impedance to physical movement (as with deep snow and deer), or threats to nesting and newborn survival (as with heavy, cold rains which can affect incubating ducks or newly hatched pheasant chicks), may also be of importance. Similarly, if a plant community were subject to moisture stress and precipitation enhancement measures produced timely relief, the impact would be different than if the plants had reached a point of no return in their response to moisture deprivation. Thus, the season at which a given effect is achieved may be of prime importance.

Duration of effort: Short-term versus long-term

Biological communities evolve and exist under terms of natural variability in weather and climate. The kinds of reactions of such communities to weather modifications of limited duration will be quite different from those when a given modification recurs with some regularity over time. Pest or disease outbreaks may be triggered by a particular change of critical timing in a moisture regime, for example, but changes in species composition in ecosystems will normally require at the very least more than one season of change in precipitation pattern, and often several seasons are necessary.

Regularity of modification effort

Just as the duration of effected changes in weather pattern, both in terms of days or weeks in a given season and of weeks, months, or seasons of a given year, is significant, so is the regularity with which a given change is produced. Biological communities will react one way if a 10-percent increase in mean precipitation is realized on an annual basis but the timing and distribution of that increase is rather variable over the year and from year to year. The response may well be different if the increase occurs with some fidelity at a given season (or seasons), from one year to the next—especially if the time of such change is coincident with a particularly critical time in the life cycle of an organism or a community.

¹⁹ Ibid., p. 3.

²⁰ Cooper and Jolly, Ecological effects of weather modification (Note 6).

²¹ Cooper, Ecological implications of weather modification (Note 9).

ECOSYSTEM TYPE

The kinds of response to any given change in weather as a result of a modification program will also differ depending on the class of ecosystem being affected. A few dichotomies will illustrate the point.

Aquatic versus terrestrial systems

Organisms in aquatic systems are affected by such variables as turbidity, temperature, stream velocities, periods and durations of low flows, and the chemical quality of the water, including relative levels of dissolved oxygen. Terrestrial organisms are affected by the timing, amount, and continued availability of both soil and surface moisture, and by the form (water, snow, ice) which such moisture may take. The same level of enhanced (or reduced) precipitation in a given area, therefore, will have different significance and meaning for terrestrial than it will for aquatic components. It is necessary to distinguish between systems being affected at this gross level as well as at finer levels of detail, too.

Cultivated versus natural systems

Howell has observed that:

Over most of the civilized world, the natural environment is profoundly acculturated and bears few traits of wilderness. In considering the natural environment, one must, therefore, regard the environment as it is exemplified by the real landscape. Except for a few pockets of wilderness, the environment is the product of an ongoing symbiosis between the land and humankind [attributed by Howell to Dubos]. It is, nevertheless, useful to make the distinction between the direct, intentional impact of precipitation management on a cultural element such as agriculture and the complex of indirect effects that may impinge on other elements of the landscape and biosphere, be these "natural" or cultivated.²²

Cooper, in treating these two classes of ecosystems, says:

As a rule of thumb, the more intensively managed a tract of landscape, and the farther it is from its natural ecological condition, the less its species structure is dependent upon the detail of the local environment and the less sensitive it will be to minor climatic alteration.²³

Because species composition, population structure, growth rate, and behavior of plants and animals in noncultivated ecosystems are significantly different from those attributes of cultivated systems, the effects of any given modification of weather are likely to be significantly different as well.

Arid versus humid systems

As one would expect, a given relative change in mean precipitation in more arid systems would be more likely to result, over time, in not only changes in relative species composition, but possibly changes in vegetative forms (e.g., shrub to grass) than would changes in humid ecosystems. The signal to noise ratio is likely to be stronger in the more arid situation and the response would be ecologically less subtle.

CUMULATIVE AND SYNERGISTIC EFFECTS

Finally, the obvious must be stated, as Cooper and Jolly did earlier:²⁴

Ecological effects of weather modification will be the result of moderate shifts in rates of reproduction, growth, and mortality of weather-sensitive species of plants

²² Howell, Environmental impacts of precipitation management: results and inferences from Project Skywater, p. 493 (Note 17).

²³ Cooper, Ecological implications of weather modification, pp. 6-7 (Note 9).

²⁴ Cooper and Jolly, Ecological effects of weather modification: a problem analysis, p. 2 (Note 1).

and animals. Ecological changes from the kinds of weather modification now visualized will seldom be sudden or catastrophic. Plant and animal communities change rather slowly in response to changed climate. The cumulative effect of slow year-to-year changes in species abundance could be a rather extensive alteration of original condition, but the alteration could take place almost unnoticed by the general public.

The combined effect of such stresses as air pollution, pesticide application, and other environmental changes may interact with weather modification in such a way that the total effect will be substantially greater than the sum of the individual, perhaps relatively small, alterations.

EFFECTS OF SILVER IODIDE

Nearly all current weather modification efforts depend on the use of seeding agents to alter the microphysical processes within clouds. While silver iodide has been the principal nucleating agent to date, it is not the only such agent. It could be replaced in the future because of the relatively high cost of silver and demands that widespread application of silver iodide might place on the silver market. The advantages of silver iodide with respect to substitutes are its capability of inducing ice crystal formation at relatively high temperatures, the ease with which it can be finely divided and carried in updrafts to cloud bases, and the relatively small amounts required to initiate nucleation. Ten to 1,000 times the weight of other substances is required to produce the same quantities of ice crystals.²⁵ Other seeding agents which have been used or whose potential use has been investigated include dry ice, lead iodide, common salt, liquid propane, water spray, and a number of organic compounds. Some of these seeding agents are substitutes for silver iodide, while others are intended for increasing precipitation from warm cloud systems or dispersal of warm fogs through the coalescence process, where silver iodide would not be effective. Since the use of silver iodide in weather modification experiments and operations has been so widespread, the following discussion is limited to the potential for environmental impacts from that compound.

Cooper and Jolly reported that available evidence shows little likelihood of environmental effects from the iodine in silver iodide. They cited a calculation made in an early report that:

A human consumer would have to drink 130 gallons of precipitation from a storm seeded with silver iodide to obtain as much iodide as in eggs flavored with iodized table salt and concluded that iodide is ubiquitous in organic and inorganic environments. . . . It seems reasonable, therefore, to dismiss iodine in silver iodide at present levels of use as a source of ecological concern.²⁶

Particular concern is, therefore, for the effects of concentrations of silver in the soil and aquatic systems, and it should be recognized that weather modification is only one avenue by which silver compounds can enter these systems.

Silver is a paradoxical substance: it is potent as a microbial poison, but relatively harmless to higher animals and to man. It forms many different chemical compounds which differ in their biological activity,

²⁵ Bonnie L. Carson and Ivan C. Smith. Silver: an appraisal of environmental exposure. Technical Report No. 3, for National Institute of Environmental Health Sciences. Contract No. N01-ES-2-2090. Midwest Research Institute, Kansas City, Mo., July 16, 1975. p. 221.

²⁶ Cooper and Jolly. Ecological effects of weather modification. p. 64 (Note 1).

Cooper and Jolly, Ecological effects of weather modification agents: a review, p. 89 (Note 15).

complicating the problem of interpreting data from the literature. Silver is unique among metals in combining very low solubility of most of its compounds with high toxicity of the soluble fraction, with the result that it is substantially more harmful to microorganisms than it is to higher animals and plants.²⁷ Silver, even in its highly soluble form, is only moderately harmful to mammals, but is much more toxic to fish than to terrestrial vertebrates, and silver levels required to damage higher plants are many times greater than those which would occur in precipitation from seeded storms. Because most land plants do not actively take up silver, the likelihood of concentrating the metal through terrestrial food chains is small, both immediately and over a period of perhaps 20 years.²⁸ It was pointed out, however, that continuous reassessment during such a period of application should be made with the accumulation of new information.²⁹

In 1974, Klein and Molise summarized results of their study of two Colorado weather modification projects:

In summary, the silver levels found in soil, litter, and vegetation samples in two Colorado weather modification projects appear to be at least one to two orders of magnitude below where possible interactions between accumulated silver iodide and changes in decomposer functions have been observed in our studies to date. The trend toward silver concentration in the vicinity of plant roots suggests that localized higher concentrations may occur which could be of distinct ecological interest.³⁰

Recently, based on studies supported by Project Skywater, Howell estimated the relative quantities of total silver in various environmental compartments for the contiguous United States.

The soil compartment (including also mud and vegetable litter), calculated for the top 20cm comprising the root zone, contains by far the largest quantity of silver. . . . Living matter of all sorts from microbes and fungi to animals, which has on the average a slight tendency to concentrate silver from the soil, contains the next largest quantity. The exchange between living matter and soil through uptake and decomposition dominates all other exchanges by at least an order of magnitude. . . . The silver concentration and content in lakes and rivers are determined mainly by depositional and erosional exchanges with the soil and by runoff to the sea. . . . The atmospheric domain receives silver in the form of wind-blown dust, some of which returns to the soil . . . and some of which is swept up by particles of precipitation. . . . The silver content of the atmospheric compartment at any moment is small in comparison with the annual transport through it.³¹

Table 1 shows the annual total losses of silver to the environment from various sources, as compiled by Carson and Smith.³² It should be noted, in comparison with other sources of silver, that cloud seeding contributes about 0.1 million troy ounces of silver annually, about 1 percent of the silver received by the atmosphere and one-tenth of 1 percent of that entering the total environment.

²⁷ Cooper and Jolly, "Ecological Effects of Weather Modification," pp. 64-65 (note 1).
Cooper and Jolly, "Ecological Effects of Silver Iodide and Other Weather Modification Agents": a review, p. 89 (note 15).

²⁸ Cooper and Jolly, "Ecological Effects of Weather Modification," pp. 66-70 (note 1).

²⁹ *Ibid.*, p. 70.

³⁰ D. A. Klein and E. M. Molise, Ecological ramifications of silver iodide nucleating agent accumulation in soil and aquatic environments. Proc. Fourth conference on weather modification of the American Meteorological Society, Nov. 18-21, 1974, Fort Lauderdale, Fla., p. 534.

³¹ Howell, "Environmental Impacts of Precipitation Management": results and inferences from Project Skywater, pp. 496-497 (note 17).

³² Carson and Smith, "An Appraisal of Environmental Exposure," pp. 405-406 (note 25).

TABLE 1.—ANNUAL LOSSES OF SILVER TO THE ENVIRONMENT FROM VARIOUS SOURCES

[From Carson and Smith, 1975]

[In millions of troy ounces]

Loss category	Air	Water	Water plus land	Land	Total
Mining and milling, total	0.042	0.70		12.4	3.1
Cyanidation		.024			
Michigan Cu ore tailings				.47	
Other Cu ore tailings				.73	
Mo. Pb ore tailings				.78	
Mine drainage		(?)			
Leaching of tailings		(?)			
Blowing of tailings	(?)				
Primary smelting and refining, total	1.2-1.3?		4.2-4.35		5.5
Of copper	.35-.48		.22-.35		.70
Of lead	.07?		1.5		1.57
Of zinc	>.06?			2.5	2.56
Of silver	.7?				
Secondary smelting and refining, total					(?)
Of precious metal scrap	.8		3.2-7.2		4-8
Of copper scrap	(?)				(?)
Of lead scrap	.0002				(?)
Fabrication, total	.097		.05-.16		.15-.26
Of sterling silver	.0002				
Of medicinals and dental materials	.0001				
Of electroplate	.00025	.03			
Of other coatings	.01175				
Of silver compounds	.00025				
Of photographic products	.084				
Brazing	.00015				
Use and disposal, total	.92	4.0		34.2	39.1
Photography	.07	4.0		12.0	
Brazing alloys	.07?				
Cloud seeding	.1				
Other uses	>.0003			22.2	
Urban refuse	.68	(?)			
Inadvertent sources, total	6.0-7.4?		20.8?		>26.8-28.2?
Iron production:					
Sintering	.03?				
Blast furnaces (5 percent scrap)	.03?				
Steelmaking:					
Open hearth furnaces (44 percent scrap)	.36-1.8?				
Basic oxygen furnaces (29 percent scrap)	.015?				
Electric arc furnaces (97 percent scrap)	.40?				
Iron foundries (-88 percent scrap)	.38?				
Cement manufacture	3.1?		15.1?		
Fossil fuels:					
Petroleum (fuel oil plus gasoline)	.5			5.7	
Coal	1.24				
Total	9.1-10.6		69.6-73.6		78.7-84.2

¹ Tailings ponds.² Residues probably held in inventory.³ Sewage sludge: lagooned, 3.2; landfilled, 6.3; landspreading, 2,500,000 troy ounces.⁴ Dry surface piles: 7,800,000 troy ounces.

Of the ultimate potential for environmental impact from silver in cloud seeding, Howell concluded:

Cloud seeding, if it became widespread, would result in local, temporary concentrations [of silver] in precipitation of the same order of magnitude as the natural concentration in surface waters [streams, lakes, rivers, etc.]. However, the rates of exchange [of silver in surface waters] would remain more than one order of magnitude smaller than the principal exchange [rates] affecting the aquatic department, and they would be many orders of magnitude smaller than those affecting plants and soil, even in localized areas of precipitation management. Widespread and prolonged precipitation management, using silver iodide as the cloud-seeding agent and assuming that all the silver dispersed in the course of a century accumulated in the top two centimeters of soil, would not cause the silver concentration there to exceed the normal background [levels].³³

³³ Howell, "Environmental Impacts of Precipitation Management": Results and inferences from Project Skywater, p. 497 (note 17).

Finally, a workshop of 18 scientists which met in 1976 to assess potential environmental impacts of nucleating agents as used in weather modification efforts concluded their review:

In summary, the members of the workshop felt that the points of major public concern regarding nucleating agents (effects on plant growth, game animals and fish, as points of special public interest) represented negligible environmental hazards. The more subtle potential effects of silver-based nucleating agents, such as a possible ability to potentiate the movement or effects of other materials of environmental concern (other metals, pesticides, etc.) or their ability to influence the activity of microorganisms in soils and aquatic environments, particularly after localized bioconcentration by plants, warrant continued research and monitoring activities, although any effects, if they might occur, are not expected to involve unacceptable risks. The long term use of silver iodide, together with the confidence which the weather modification profession has in delivery systems and the efficacy of this material, make it unlikely that other agents will be used on a large-scale basis in the future, unless improvements in delivery systems and major changes in the economics of silver availability might occur.³⁴

DELIBERATE WEATHER MODIFICATION

Several forms of deliberate weather modification appear worthy of serious consideration over the next few years to a decade or so. They include precipitation enhancement (or reduction), hurricane or other severe storm abatement or other modification, fog dispersal, hail suppression, and control of lightning. The following sections attempt to encapsulate the best, current judgment about the ecological impacts or other effects of applied weather modification technology in each of these categories.

PRECIPITATION ENHANCEMENT

In general efforts to alter (usually enhance) precipitation patterns can be categorized as either attempts to increase rainfall or to augment snowpack. In the former instance the modification primarily seeks to benefit a local economy, usually by aiding crop production; in the latter case, modification is undertaken in one area in order to benefit residents of another, usually by augmenting the snowpack in watersheds to increase water streamflows to the advantage of downstream users.³⁵

Increased rainfall

Cooper and Jolly, Bureau of Reclamation, and Howell all provide more complete discussions of the kinds of ecological effects which can be expected.³⁶ Howell's treatment is excerpted here as follows:³⁷

With respect to the vegetational characteristics of the environment, increasing summer-convective precipitation is accompanied by a gradual transition from desert shrubland to short-grass prairie, to tall-grass prairie, to a sabana of mixed grass and deciduous forest, and finally to forest * * *. Precipitation management would tend to shift the very diffuse boundaries of these grand divisions somewhat westward * * *.

³⁴ Klein, "Ecological Impacts of Nucleating Agents Used in Weather Modification Programs": an interdisciplinary assessment, p. 55 (note 15).

³⁵ Cooper, "Ecological Implications of Weather Modification," p. 2 (note 9).

³⁶ Cooper and Jolly, "Ecological Effects of Weather Modification: a Problem Analysis," p. 1 (note 1).

Bureau of Reclamation, Environmental statement for Project Skywater (note 14). Howell, "Environmental Impacts of Precipitation Management: Results and Inferences From Project Skywater," p. 489 (note 17).

³⁷ Howell, "Environmental Impacts of Precipitation Management: Results and Inference From Project Skywater," p. 494 (note 17).

Precipitation management, to the extent that it may moderate the intensity of extreme droughts, will cause the natural vegetation of each locality gradually to resemble that of regions now slightly moister and may moderate the secular changes in species composition that take place in response to normal climatic fluctuations.

The effect of precipitation management on animal populations is likely to be mainly indirect, through its influence on habitat, rather than directly on the organisms. Particularly in the case of birds and small mammals, populations depend more on the presence of suitable cover, nest sites, and food supplies than on the weather. Though severe storms at critical times may occasionally decimate some species, there is little expectation that precipitation management would affect the frequency of such occurrences.

The best expectation presently available of the impact of summer-convective precipitation management is that each present environmental compartment would gradually come to resemble neighboring compartments on the moister side of the precipitation gradient, with no apparent risk of severe disturbances accompanying this transition.

Snowpack augmentation

As part of the Bureau of Reclamation's Colorado River Basin pilot project (to determine the effectiveness of seeding winter orographic systems for increased snowpack and spring runoff), a 6-year, \$1 million research project was conducted to study the ecological impacts of snowpack augmentation in the San Juan Mountains of Colorado. The study aimed to assess ecological effects of a theoretical increase in snowpack of 16 percent a year of average snowfall and to study the range of increase up to 30 percent. The report, edited by Steinhoff and Ives, includes the results of a team of 33 scientists.³⁸ The basic environmental changes assessed were the addition of more snow and more silver. Primary effects impacting an ecosystem components were: "(1) lower soil temperature in the spring, (2) more moisture in the spring, (3) deeper snowpack, and (4) more silver."³⁹ The following excerpts are taken from the editors' "Summary of Key Conclusions":⁴⁰

Initiation of shoot elongation was delayed for plants both in the tundra and forests as a result of lower soil temperature associated with deeper snowpack for the species studied. These included Englemann Spruce (*Picea engelmannii*), quaking aspen (*Populus tremuloides*), Thurber fescue (*Festuca Thurberi*), and numerous herbaceous species in both the tundra and forest meadows.

Only the lower soil temperature and greater snow depth, which might be expected to follow an increase in snowfall, have been found influential on animal activity. A noticeable decline in forest populations of small mammals occurred following winters of heavy snowfall. This was most evident in the numbers of deer mice (*Peromyscus maniculatus*), but it was also found in chipmunks (*Eutamias minimus*) and in *Microtus* spp. The basic reason for the population decline derives from the delayed growth of essential spring foods and results primarily from a delay in breeding so that fewer litters are produced. The delayed growth of plants was a function of lower soil temperature and the longer snow cover.

As snow depth increased, elk (*Cervus canadensis*) moved to areas where snow was shallower than 40 cm. They avoided regions with more than 70 cm of penetrable snow depth. A 15-percent increase in snowpack may decrease available elk winter range by 8 percent.

No significant increase in silver concentrations were found in the target area, except in small areas near generator sites, after four winters of seeding. No deleterious effects of silver iodide additions have been noted to concentrations which could be expected due to cloud seeding.

³⁸ Steinhoff and Ives (eds.), "Ecological Impacts of Snowpack Augmentation in the San Juan Mountains, Colorado (note 11).

³⁹ *Ibid.*, p. 1.

⁴⁰ *Ibid.*

Additional treatment of effects of snowpack augmentation may be found in the comprehensive report compiled by Weisbecker⁴¹ and in the paper of Howell.⁴² The latter's "bottom line" conclusion, quoting from Steinhoff and Ives' work, is:

There should be no immediate, large-scale impacts on the terrestrial ecosystems of these [San Juan] mountains following an addition of up to 30 percent of the normal snowpack, but with no addition to maximum snowpacks. Further, much of the work reported here suggests that compensating mechanisms within the studied ecosystems are such that any impacts would be buffered, at least for short periods of time, and of lesser magnitude than the changes in snow conditions required to produce them.

Our work has shown three ecosystem components to be most susceptible to increased snowfall: (1) snowbank situations at elevations above treeline; (2) elk herds (in other mountain ranges other big game species may be similarly affected); and (3) some small mammal populations, especially the deer mouse. Not all of these impacts are necessarily deleterious; an increase in the area of snowbank edge habitats in alpine areas may, for example, increase the niches available for rare plant species.

Finally, even in the small areas where we predict greatest impacts from increased snowfall, the changes involved are unlikely to approach the magnitude of other man-made impacts on mountain ecosystems.

However, it should be remembered that they may act in phase with other man-made impacts and with natural climatic changes, in which case the total effect could be much greater than our studies suggest.

SEVERE STORM ABATEMENT

Essentially synonymous with hurricane control, this technology offers some promise of mitigating the onshore impacts of such major storms by reducing their intensity and/or altering their paths, both through judicious seeding of the storm while still well out at sea. The "state of the art" is such that few answers of the long-term ecological effects of applying such a technology are available. Cooper and Jolly⁴³ sketched a number of possible implications and speculated about some of the effects. More recently, Cooper identified a number of specific questions he felt should be addressed before hurricane modification research is carried out on an extensive scale:⁴⁴

1. What is the importance of hurricanes in bringing precipitation to continental areas such as eastern U.S.? Will this delivery be affected by hurricane modification? What fraction of hurricane precipitation is actually useful and effective, and what fraction is primarily flood-producing? Will this ratio be affected?

2. What is the role of hurricanes in the biology of coral reefs and in the productivity of tropical marine fisheries? There is evidence that hurricanes improve fishing in the Caribbean (Florida) and in the Pacific. How would control affect the livelihood of subsistence fishermen in the Pacific?

3. How important are hurricanes as determinants of forest structure and growth? Influences are known from St. Vincent, New England, and the Solomon Islands, among others.

Clearly there may be significant ecological ramifications on several scales if severe storm abatement technology is applied. Yet, good research answers are seemingly still a ways off.

⁴¹ Weisbecker, "The Impact of Snow Enhancement," p. xii, 299-352 (note 16).

⁴² Howell, "Environmental Impacts of Precipitation Management: Results and Inferences From Project Skywater," p. 494 (note 17).

⁴³ Cooper and Jolly, Ecological effects of weather modification: a problem analysis, pp. 85-88 (Note 1).

⁴⁴ Cooper, Ecological Implications of weather modification (Note 9).

FOG DISPERSAL

Cold fog dispersal is now rather easily effected locally, principally over airports, although warm fog dispersal remains more difficult and expensive. Cooper and Jolly foresaw no significant ecological effect from the expected kinds of fog dispersal in the 1969 report⁴⁵ and that conclusion was more recently restated by Cooper.⁴⁶

HAIL SUPPRESSION

An interdisciplinary assessment of hail suppression in the past, present, and future has been recently reported.⁴⁷ The authors concluded the technology is currently scientifically uncertain but potentially beneficial, and one which would be widely adopted in the Great Plains with benefits to agriculture and the American consumer.⁴⁸ As recently as 1977, Cooper concluded that hail suppression technology offers no likely ecological implications beyond those associated with the effects on precipitation which would presumably attend its applications.⁴⁹

ALTERATION OR ARREST OF LIGHTNING DISCHARGES

As is the case with hail suppression technology, there does not seem to be reason to anticipate any significant ecological effects from applying lightning alteration efforts beyond those to be associated with precipitation affects. Again, Cooper and Jolly largely dismissed any grounds for significant ecological concern with respect to lightning modification in 1969⁵⁰ and Cooper in 1977 reiterated that position.⁵¹

INADVERTENT WEATHER MODIFICATION

Inadvertent weather modification can be defined to include both unintended effects on nontarget areas of deliberate modifications aimed at target areas, and of totally unintended modifications as a result of man's activities not related to planned weather influences or operations. Regardless of the category, however, there are ecological ramifications involved.

EXTRA-AREA EFFECTS

Concern with extra area, usually downwind, effects is almost as old as weather modification efforts themselves. The most common public concern has been of the "rob Peter to pay Paul" variety wherein it is alleged or at least feared that increased moisture for A's benefit through cloud seeding must come from a B, at some point. Howell has written the following summary conclusions about effects of cloud seeding on precipitation in nearby areas; "the assumption that augmentation of precipitation in one place must result in its diminution some-

⁴⁵ Cooper and Jolly, "Ecological Effects of Weather Modification: A Problem Analysis," p. 83 (Note 1).

⁴⁶ Cooper, "Ecological Implications of Weather Modification," p. 15 (Note 9).

⁴⁷ Changnon, et al., "Hail Suppression: Impacts and Issues" (Note 12); Stanley Changnon, Barbara C. Farhar, and Earl R. Swanson, "Hail Suppression and Society," *Science* 200 (4340) (28 April 1978): p. 387.

⁴⁸ Changnon, Farhar, and Swanson, "Hail Suppression and Society," p. 387 (Note 47).

⁴⁹ Cooper, "Ecological Implications of Weather Modification," p. 14 (Note 9).

⁵⁰ Cooper and Jolly, "Ecological Effects of Weather Modification: A Problem Analysis" (Note 1).

⁵¹ Cooper, "Ecological Implications of Weather Modification," p. 14 (Note 9).

where else is plausible but fallacious." He continues, "The fallacy lies in failure to appreciate (1) the role of natural atmospheric disturbances in causing the convergence and ascent of moist air as the dominant mechanism that makes moisture available for cloud formation and (2) the potential of cloud seeding both for increasing the dynamic energy of such disturbances and for increasing the efficiency with which the storm clouds are converted to precipitation. * * * Model studies of convective rain clouds are not far enough advanced to predict the outcomes with high confidence, but at least they offer no encouragement to the notion that cloud seeding robs Peter to pay Paul."⁵²

Howell adds: "Studies of rainfall downwind from actual summer-convective cloud seeding operations have been inconclusive, with the evidence tending to favor some increase out to distances of 400 kilometers or so. However, the types of operations involved have been so disparate that no general conclusions are possible. Studies of precipitation downwind of winter-orographic cloud-seeding operations confirm the presence of increases at distances of approximately 250 kilometers. The evidence, therefore, does not support the notion that stimulation of precipitation in one area deprives another area but suggests that seeding may strengthen existing precipitation systems."⁵³

A fuller treatment of extra area effects is provided in chapter 3 of this CRS weather modification report.

LONG-TERM, CLIMATIC AND GLOBAL IMPLICATIONS

Finally, it is desirable to point out that alteration of weather brought about by cloud seeding or other deliberate interference with atmospheric processes will necessarily be superimposed against the record of long-term, natural changes of climate and the ubiquitous, year-to-year variability of climate and, in addition, any inadvertent effects attributable to human activities. The evolution of natural climatic change and variability and the possibility that society, through its own actions, may be altering the climate by pushing on certain leverage points make it more difficult to assess the reality of planned weather modification, because claimed results may in fact be due to other causes. Furthermore, the ecological effects of a planned weather change may be partially masked by unanticipated changes in other climatic variables.⁵⁴

While man has become generally aware of some of the environmental effects of his polluting the air and waters of the planet, he has barely begun to credibly study the global implications of long-term climatic change which may be exacerbated or even caused by his inadvertent impacts on global atmospheric and oceanic processes. While no solid ecological answers are yet demonstrable, the implications of industrially caused acid rains, impacts on the carbon dioxide cycle of deforestation as well as the burning of fossil fuels and similar scale concerns are all terribly serious. Cooper has recently articulated some of these concerns, too.⁵⁵

⁵² Howell, "Environmental Impacts of Precipitation Management: Results and Inferences From Project Skywater," pp. 491-492 (Note 17).

⁵³ *Ibid.*, p. 492.

⁵⁴ Cooper and Jolly, "Ecological Effects of Weather Modification: A Problem Analysis," p. 17 (Note 1).

⁵⁵ Cooper, "What Might Man-Induced Climate Change Mean?" (Note 9).

A comprehensive and detailed discussion of inadvertent weather and climate modification appears in chapter 4 of this CRS text on weather modification.

SUMMARY AND CONCLUSIONS

This chapter seeks to review a number of recent studies aimed at addressing and answering questions about the ecological effects of various kinds of weather modification activity. In general, the body of directed research with respect to these concerns is still limited but significantly greater than was the case a decade or even less ago.

Economically significant weather modification will always have an eventual ecological effect, although appearance of that effect may be delayed or hidden by system resilience and/or confounded by system complexity.

It will never be possible to predict "the ecological effects of weather modification." However, the more precisely the weather modifier can specify the effects he will produce in terms of average percentage increase or decrease in precipitation (or other climatic variable), expected seasonal distribution of the change, expected year-to-year distribution of the change, geographic distribution of the change, changes in relative form of precipitation, and the like, the more precise can be the ecologist's prediction of likely ecological effects.

Ecological effects of weather modification will be the result of moderate shifts in rates of reproduction, growth, and mortality of species of plants and animals which are sensitive to weather. Effects will rarely, if ever, be sudden or catastrophic because plant and animal communities react to changes in climate much more than changes in weather. Accordingly, those modifications in the weather which occur with significant regularity over time—eventually constituting at least a micro-climatic shift of some degree—are the ones to which biological communities will react.

Animal populations will rarely be affected directly by weather modification activities but will rather be indirectly affected as their habitat is altered as vegetative changes occur.

Weather modification, being a change imposed on an already variable climate, will nevertheless have an inexorable, if subtle, effect on long-term structure of plant and animal communities as they respond to average climatic conditions.

Such adjustments of plants and animal communities will usually occur more slowly in regions of highly variable weather than in those of relatively uniform weather conditions. Similarly, deliberate precipitation change is likely to have greater ecological impact in semi-arid systems and less in humid ones.

Widespread cloud seeding could result in local, temporary concentrations of silver in precipitation which are of the same order of magnitude as the natural concentration in surface waters, though the rates of exchange would remain more than an order of magnitude smaller than principal exchanges for the aquatic environment. Exchange rates would be many orders of magnitude smaller than those affecting plants and soil, even in localized areas of precipitation management.

It is still a reality that our level of ignorance of ecological effects of changes in weather and climate exceeds our level of knowledge.

APPENDIXES

APPENDIX A

STATEMENT ON WEATHER MODIFICATION IN CONGRESSIONAL RECORD OF JUNE 17, 1975, BY CONGRESSMAN GILBERT GUDE, CONTAINING WHITE HOUSE STATEMENT ON FEDERAL WEATHER MODIFICATION POLICY

WEATHER MODIFICATION

(Mr. Gude asked and was given permission to extend his remarks at this point in the Record and to include extraneous matter.)

Mr. GUDE. Mr. Speaker, I would like to bring to my colleagues' attention an exchange of correspondence Senator Pell, Congressman Fraser, and I have recently had with the White House concerning Federal weather modification activities. On April 23, we wrote the President the following letter urging the creation of a lead agency to coordinate Federal work on weather modification and urging that such research be conducted by civilian agencies rather than the Defense Department:

HOUSE OF REPRESENTATIVES,
Washington, D.C., April 23, 1975.

THE PRESIDENT,
The White House.

DEAR MR. PRESIDENT: As authors of several resolutions for outlawing environmental modification as a weapon of war, we now write recommending government work in the peaceful uses of such modification that could help to promote energy conservation, safeguard the environment and stabilize agricultural production. In sending these recommendations, we wish to make clear that we support continued research, particularly into weather modification for peaceful purposes, regarding which we believe there currently exist numerous opportunities for its applications.

The role of weather modification in energy conservation was sharply outlined in a recent example which came to our attention. Coming from Boston to Washington, a recent flight was delayed by bad weather and according to one passenger's calculations, as much fuel was exhausted around Washington while the plane waited to land as was consumed during the entire flight from Boston. This is only one example of the energy costs of bad weather, but weather conditions being what they are, it is a frequent case. Research into fog dissipation is precisely the kind of work which can reduce those costs.

We are only beginning to research and understand how our own industrial development has inadvertently modified weather and environment. Studies are beginning to show differences in temperature and air quality over urban and industrial areas, which affected the immediate environment as well as influence weather downwind. There is sufficient growing suspicion that inadvertent environmental modification can help produce extremes of weather, such as drought, to warrant further investigation and research.

The implications of weather modification for agriculture are obvious and various efforts to enhance rainfall have been going on for years. These efforts, however, need coordination and careful study to help determine what approaches are productive, what types of weather formation are most susceptible to modification and how modification in one area affects weather elsewhere. Clearly, the potential for increased agriculture output—both domestically and worldwide—is great.

Given these opportunities, it is unfortunate that civilian directed research has been diffused. The fiscal 1975 budget shows weather modification projects in six agencies and a division by function as follows:

	Fiscal year—		
	1973	1974	1975
Department of Agriculture.....	366	270	150
Department of Commerce.....	4, 779	4, 673	4, 575
Department of Defense.....	(1, 209)	(1, 161)	(1, 300)
Army.....	150	96	-----
Navy.....	404	399	555
Air Force.....	645	666	745
Department of the Interior.....	6, 370	3, 900	3 445
Department of Transportation.....	1, 067	1, 397	1, 520
National Science Foundation.....	5, 790	4, 000	4, 270
Total.....	19, 581	15, 401	15, 270

DIVISION BY FUNCTION

	Fiscal year—			Agencies
	1973	1974	1975	
Precipitation modification.....	5, 472	3, 735	3, 279	DOC, DOI.
Fog and cloud modification.....	1, 541	1, 194	1, 264	DOD, DOT.
Hail suppression.....	2, 860	2, 000	2, 100	NSF.
Lightning modification.....	624	330	356	DOA, DOD, NSF
Hurricane and severe storm modification.....	1, 818	1, 741	1, 816	DOC
Social, economic, legal, and ecological studies.....	1, 740	1, 310	1, 110	DOI, NSF.
Inadvertent modification of weather and climate.....	3, 252	3, 643	4, 398	DOC, DOT, NSF.
Support and services.....	2, 274	1, 475	937	DOC, DOI, NSF.
Total.....	19, 581	15, 401	15, 270	

Although in some respects the National Oceanographic and Atmospheric Administration gathers data on all these projects, it does not really function as a lead agency or exert sufficient direction, coordination or control over the civilian or military projects. It is clear from the second chart, furthermore, that considerable overlap and possible duplication exists. We believe, however, that in a field as diverse and speculative as this, a greater degree of centralization is desirable. This same recommendation has been made on a number of occasions by the National Advisory Committee on Oceans and Atmosphere:

NACOA finds that, although we appear to stand on the threshold of practical weather modification, and some facets are operational, in other applications a great deal of complex research still needs to be done. Unless the scientific manpower and funding are better directed, we assuredly will continue to make very slow progress towards weather control. NACOA therefore reiterates its recommendations of last year that:

"The many small programs in weather modification now scattered widely through the Federal agencies be focused and coordinated under NOAA's head; basic cloud physics and dynamics be given higher priority; and that the legal, social, and economic impact of weather modification be thoroughly examined and appropriate regulatory and licensing legislation be sought." (*A Report to the President and the Congress*, NACOA, June 29, 1973, page viii.)

We also believe it is particularly important that any such coordination should be in the hands of a civilian agency; indeed, that all such research should be conducted by civilian agencies.

Considerable doubt has been raised in the past over the nature of some of the research conducted by the Defense Department in the area of weather modification. You will recall the not too successful efforts to increase rainfall over the Ho Chi Minh Trail several years ago at a cost of \$21.6 million. We have grave doubts about the merits of any project such as this, but we are also concerned about the way in which the incident was handled by the Government. The project was at first flatly—and repeatedly—denied publicly and before Congress by the Department of Defense, but the basic facts were ultimately conceded some

years later by former Defense Secretary Laird in a letter to the Senate Foreign Relations Committee, which confirmed the allegations that had been made.

Such incidents have given rise to continuing concern on our part over the scope of federal research and development on environmental and weather modification. What is significant about these incidents is that they continue to occur in respect to Defense Department research, even though DOD asserts such research has only peaceful applications, such as airport fog dispersal. If this is the case, then it would seem both logical and appropriate to place such research in civilian agencies where it can be carried on with the same degree of precision and success, since weapons' applications are not involved, and where it would not cause new suspicions about the real nature of the work.

Weather modification is a field of great potential, promising considerable benefits to agriculture and transportation, to mention only two prime areas of research. At the same time the potential military applications of weather modification research are serious. Last summer's agreement with the Soviet Union to meet to discuss a ban on weather warfare is most encouraging. We hope that in the light of that agreement, you will be able to give favorable consideration to our recommendations.

Sincerely,

GILBERT GUDE,

Member of Congress.

CLAIBORNE PELL,

U.S. Senator.

DONALD M. FRASER,

Member of Congress.

On June 5, we received the following response from Norman E. Ross, Jr., Assistant Director of the Domestic Council:

THE WHITE HOUSE,
Washington, June 5, 1975.

HON. GILBERT GUDE,
House of Representatives,
Washington, D.C.

DEAR MR. GUDE: The President has asked me to respond to your letter of April 23, 1975, in which you recommended a coordinated program of governmental work in the peaceful uses of weather modification.

A considerable amount of careful thought and study has been devoted to the subject of weather modification and what the Federal role and, in particular, the role of various agencies should be in this area. As a result of this study, we have developed a general strategy for addressing weather modification efforts which we believe provides for an appropriate level of coordination.

For the most part, as your letter points out, we are just beginning to understand the possibilities for weather modification and the complexities that are involved. Inadvertent modification of weather and environment through industrial development is indeed a prime example.

There are many problems generated by various weather phenomena such as loss of crops through hail damage and destruction of property caused by hurricanes and flooding. In many cases the approaches to solving the problems may or may not be best met through weather modification techniques. Other solutions such as community preparedness, better land use planning, and protective measures may more effectively and realistically achieve the objectives.

For this reason, we believe that the agency which is charged with a particular national problem should be given the latitude to seek the best approach or solution to the problem. In some instances this may involve a form of weather modification, while in other instances other approaches may be more appropriate.

While we would certainly agree that some level of coordination of weather modification research efforts is logical, we do not believe that a program under the direction of any one single agency's leadership is either necessary or desirable. We have found from our study that the types of scientific research conducted by agencies are substantially different in approach, techniques, and type of equipment employed, depending on the particular weather phenomena being addressed. For example, there is very little in common between hurricane suppression and attempting to increase rain or snow. Fog dispersal efforts have almost nothing in common with any other weather modification. Each type of weather modification requires a different form of program management and there are few common threads which run among all programs.

To the extent that there are common problems and solutions among the programs, the Interagency Committee on Atmosphere Sciences (ICAS) is bringing together agency representatives who are involved in weather modification research, for the purpose of sharing their ideas and approaches to various problems. In addition, a series of lead agencies have been established to concentrate efforts in particular areas: Interior in precipitation; Agriculture in lightning suppression; Commerce in severe storms, including hurricanes; NSF in hail research; and Transportation in fog suppression. These lead roles provide for coordination in areas with common characteristics and have gone a long way toward eliminating duplicative efforts. Although more than one agency is involved in a general area such as inadvertent modification, their efforts are keyed toward particular objectives.

I hope this information will be helpful to you and I would like to thank you for sharing your views with us. We would be happy to provide you any additional information you may need concerning current efforts in the weather modification area.

Sincerely,

NORMAN E. ROSS, JR.,
Assistant Director, Domestic Council.

The administration's response is disappointing that it rejects the recommendation of a lead agency, despite the fact that the National Advisory Committee on Oceans and Atmosphere has regularly recommended it. The reply ignores completely the crucial second point of military involvement in weather modification research. I commented on this problem in some detail in my testimony of September 24, 1974, before the Foreign Affairs Subcommittee on International Organizations and Movements:

"DANGERS OF WEATHER MODIFICATION—CONTROL

"Why should we be so alarmed about a technique that is not nearly as lethal as other forms of warfare? First, there are distinct control and command problems associated with geophysical warfare and weather modification in particular. We simply do not have effective short or long term control over the climates of the world. We can create certain disturbances, but as civilian experiments have shown, control is not precise. In a military environment, control over the results of weather experimentation is even more uncertain in respect to military targets, and there is practically no hope of preventing military efforts from spilling over into civilian life with devastating effect, particularly in developing agricultural countries. Here, wind changes, rainfall changes, or even changes in the composition of rain could seriously disrupt the livelihood of most of the country's citizens and create severe food supply problems, all far distant from the chosen military target. This is partly due to the so-called downwind effect, carrying weather changes with weather movements. But weather unpredictability—enhanced by modification efforts themselves—may make it impossible to determine where 'downwind' will be at any given time. This means that the use of weather modification is inevitably indiscriminate. We cannot flood only military targets or cause drought in areas producing only military rations. The technology will be used against people regardless of their uniform or occupation and will inevitably strike civilians harder than nearby military objectives.

"The command problem is no less acute. Since the technology to date does not involve great expense or sophisticated equipment, it is not difficult to imagine the use of weather modification by many different military subunits. In fact, there have been reports that we have trained the South Vietnamese to use weather modification. There are no double-key safing mechanisms here, no exclusive possession as with nuclear weapons.

"DANGERS OF WEATHER MODIFICATION—IDENTIFICATION AND DETECTION

"These issues of command and control highlight another disturbing characteristic of weather modification, the difficulty of detection. Unlike other weapons, it may be possible to initiate military weather modification projects without being detected. In other words, the military results may not be visibly tied to the initiating party. This raises the possibility of the clandestine use of geophysical warfare where a country does not know if it has been attacked. The uncertainty of this situation, the fear of not knowing how another country may be altering you

climate is highly destabilizing. This feeding of national paranoia—a pervading suspicion of the motives and actions of a neighboring country—could well be amplified into the laying of blame for any adverse climate conditions or weather disasters on one's neighbors.

"This was clearly brought home by the recent admission of the Department of Defense that it had indeed been involved in weather modification activities in Southeast Asia from 1967 to 1972, even at a time when Department witnesses were denying such involvement in their congressional testimony.

"In a January 28, 1974, letter to the Senate Foreign Relations Committee, former Defense Secretary Laird corrected his testimony of April 18, 1972, in which he stated, 'We have never engaged in that type of activity over North Vietnam.' Laird admitted that just such activities were conducted over North Vietnam in 1967 and 1968. It was clearly one of the most useless programs ever conceived by the Government. This rainmaking effort accomplished nothing except washing \$21.6 million down the drain, and it was undertaken with no thought as to the very dangerous situations which could evolve from such a policy.

"EFFECTS OF WEATHER MODIFICATION RESEARCH

"There is no question that much valuable research is now being done under the heading of weather modification. Airport fog dispersal operations, cloud seeding in farm areas threatened by drought, efforts to increase the winter snow pack, and experiments in hurricane control are all legitimate scientific efforts that can meet important domestic and international needs. This work into peaceful applications of environmental modification technology should continue. Unfortunately, Pentagon involvement in weather modification research—whether classified or for peaceful purposes—has serious consequences for the U.S. civilian scientific community, the American public, and the international community.

"Geophysical warfare, to use a figure of speech, can poison the atmosphere surrounding legitimate international programs such as the global atmospheric research program, the international hydrological decade and meteorology in general. We have already seen that it caused the U.S. delegation at the Stockholm Conference to water down a recommendation on climate changes. The potential for embarrassment is great.

"Our scientific community could come under suspicion or attack at these international meetings. The fine work and trust built up over the years by our excellent atmospheric scientists could be dispelled in one stroke of Pentagon experimentation.

"But it is not only our scientists who lose credibility—it is the Defense Department itself. Through its involvement in research which may have military applications, even though it is intended for peaceful purposes, the Pentagon has laid itself open to allegations of a variety of clandestine activities.

"Two cases will illustrate the point. The Defense Department engages in considerable medical research, some of which is related exclusively to military needs, while some parallel research carried out by civilian institutions. The Navy, for example, has had a research unit in Egypt studying equatorial diseases for many years. By conducting such research 'in-house,' so to speak, instead of obtaining it through civilian research agencies, the Navy leaves itself open to charges that it is actually studying or developing germ warfare or the like. As unfounded as such charges may be, they are very difficult to combat, especially in the current climate of suspicion about many Pentagon activities. Yet, there is no reason why this kind of research could not be conducted by the civilian agencies of Government and its results made available to the Defense Department. In cases where Defense required information on subjects not currently under investigation, it could levy requirements on the National Science Foundation which would in turn conduct or contract for the needed research, thus reducing the opportunities for controversy to develop, controversy which might itself hamper research, especially abroad.

"In the area of weather modification, I have been assured that Air Force interest in these techniques is limited to developing methods for airfield fog dispersal or suppression and other life-saving measures. These techniques are just as important to business and civil aviation and the general public, and there is no reason why such research cannot be conducted by a civilian agency.

"As a general principle, therefore, I would urge that wherever an adequate scientific base exists for conducting specific types of applied research outside of the Department of Defense and associated agencies, it would be wise policy

to conduct all such research through non-defense agencies, such as NOAA, NIH, NSF or private institutions. In addition to helping resolve Pentagon credibility problems, such a procedure will tend to reduce duplication of effort and may therefore produce some cost savings.

"Thus, although the subject of this hearing is an international treaty banning the use of weather modification techniques as weapons, it is important that we go beyond that and deal directly with the development of such research within our own Government, so as to clearly divorce all weather modification activities from the military and leave no doubt that American interest in this field is strictly peaceful and humanitarian."

This administration and its predecessor have made progress toward an international treaty banning the use of weather modification as a weapon of war, but neither administration has really understood the important link between banning weather warfare and taking weather modification research out of the hands of the military. We cannot credibly negotiate a weather warfare treaty at the same time we are funding classified Defense Department research projects in weather modification. Since the Defense Department has maintained that its research only involves peaceful applications, it is difficult to understand why such research cannot be placed in civilian hands. The administration is unwilling to move in that direction, and legislative action may be necessary. I am in the process of preparing just that, and I plan shortly to submit my proposals for House consideration.

APPENDIX B

DEPARTMENT OF DEFENSE STATEMENT ON POSITION ON WEATHER MODIFICATION

POSITION ON WEATHER MODIFICATION¹

Based on extant theories and demonstrated technology, weather modification has little utility as a weapon of war. Conventional arms are more effective instruments of warfare. While weather modification experiments in Vietnam demonstrated the technical ability to increase rainfall, its military payoff was nil. Unless there is a major scientific breakthrough which would allow the use of weather modification as a weapon, we see little value in continued weather modification development toward this end. However, DoD must continue to have the option to conduct reesarch and development to exploit emerging technology and to avoid technological surprise.

Weather modification can enhance the effectiveness of conventional weapons, particularly aircraft and helicopter forces. The primary impediment to aircraft operations is the visibility at airfields and visibility over target. The DoD should pursue technology to dissipate fog and clouds for the purposes of increasing visibility, and thus conventional weapons effectiveness. We employ operationally cold fog dissipators at those military airfields affected by cold fog and fund a significant development program in airfield warm fog dissipation. At the same time, we continue to work on technology to clear fog and clouds in a battlefield area.

The future direction of the DoD weather modification program is influenced not only by our perceptions of the usefulness of the technology, but also by the Environmental Modification Convention. The Environmental Modification Convention constrains the use of military weather modification activities to those not having widespread, long-lasting, or severe effects. The effect of the Environmental Modification Convention, when superimposed on our present perceptions of technology, is to further devalue the development of weather modification as a weapon of war. As a result, our present efforts are directed solely at fog and cloud dissipation.

Insights into the future directions and potential of weather modification will derive from fundamental research in atmospheric physics and atmospheric processes, and not from applied technology experiments in weather modification. DoD will continue to support a vigorous program in basic research in cloud physics and atmospheric dynamics. We are jointly funding with NASA experiments to be conducted in the NASA cloud physics laboratory to be flown on the space shuttle. DoD laboratories and contract programs fund a broad spectrum of fundamental research into the atmosphere.

¹ Provided April 5, 1978, by Col. Elbert W. Friday, Office of the Under Secretary of Defense for Research and Engineering, in a briefing to representatives of the Weather Modification Advisory Board and from several Federal agencies.

APPENDIX C

TEXT OF UNITED NATIONS CONVENTION ON THE PROHIBITION OF MILITARY OR ANY OTHER HOSTILE USE OF ENVIRONMENTAL MODIFICATION TECHNIQUES

TEXT OF RESOLUTION¹

The General Assembly,

Recalling its resolutions 3264 (XXIX) of 9 December 1974 and 3475 (XXX) of 11 December 1975,

Recalling its resolution 1722 (XVI) of 20 December 1961, in which it recognized that all States have a deep interest in disarmament and arms control negotiations,

Determined to avert the potential dangers of military or any other hostile use of environmental modification techniques,

Convinced that broad adherence to a convention on the prohibition of such action would contribute to the cause of strengthening peace and averting the threat of war,

Noting with satisfaction that the Conference of the Committee on Disarmament has completed and transmitted to the General Assembly, in the report of its work in 1976, the text of a draft Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques,

Noting further that the Convention is intended to prohibit effectively military or any other hostile use of environmental modification techniques in order to eliminate the dangers to mankind from such use,

Bearing in mind that draft agreements on disarmament and arms control measures submitted to the General Assembly by the Conference of the Committee on Disarmament should be the result of a process of effective negotiations and that such instruments should duly take into account the views and interests of all States so that they can be joined by the widest possible number of countries,

Bearing in mind that article VII of the Convention makes provision for a conference to review the operation of the Convention five years after its entry into force, with a view to ensuring that its purposes and provisions are being realized,

Also bearing in mind all relevant documents and negotiating records of the Conference of the Committee on Disarmament on the discussion of the draft Convention,

Convinced that the Convention should not affect the use of environmental modification techniques for peaceful purposes, which could contribute to the preservation and improvement of the environment for the benefit of present and future generations,

Convinced that the Convention will contribute to the realization of the purposes and principles of the Charter of the United Nations,

Anxious that during its 1977 session the Conference of the Committee on Disarmament should concentrate on urgent negotiations on disarmament and arms limitation measures,

1. *Refers the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, the text of which is annexed to the present resolution, to all States for their consideration, signature and ratification:*

2. *Requests the Secretary-General as depositary of the Convention, to open it for signature and ratification at the earliest possible date:*

¹ A/RES/31/72 (text from U.N. doc. A/31/382, report of the First Committee on agenda item 45, Convention on the prohibition of military or any other hostile use of environmental modification techniques); adopted by the committee on Dec. 3 by a recorded vote of 89 (U.S.) to 11, with 25 abstentions, and by the Assembly on Dec. 10 by a recorded vote of 96 (U.S.) to 8, with 30 abstentions.

3. *Expresses its hope* for the widest possible adherence to the Convention ;
4. *Calls upon* the Conference of the Committee on Disarmament, without prejudice to the priorities established in its programme of work, to keep under review the problem of effectively averting the dangers of military or any other hostile use of environmental modification techniques ;
5. *Requests* the Secretary-General to transmit to the Conference of the Committee on Disarmament all documents relating to the discussion by the General Assembly at its thirty-first session of the question of the prohibition of military or any other hostile use of environmental modification techniques.

ANNEX

CONVENTION ON THE PROHIBITION OF MILITARY OR ANY OTHER HOSTILE USE OF ENVIRONMENTAL MODIFICATION TECHNIQUES

The States Parties to this Convention,

Guided by the interest of consolidating peace, and wishing to contribute to the cause of halting the arms race, and of bringing about general and complete disarmament under strict and effective international control, and of saving mankind from the danger of using new means of warfare,

Determined to continue negotiations with a view to achieving effective progress towards further measures in the field of disarmament,

Recognizing that scientific and technical advances may open new possibilities with respect to modification of the environment,

Recalling the Declaration of the United Nations Conference on the Human Environment, adopted at Stockholm on 16 June 1972,

Realizing that the use of environmental modification techniques for peaceful purposes could improve the interrelationship of man and nature and contribute to the preservation and improvement of the environment for the benefit of present and future generations,

Recognizing, however, that military or any other hostile use of such techniques could have effects extremely harmful to human welfare,

Desiring to prohibit effectively military or any other hostile use of environmental modification techniques in order to eliminate the dangers to mankind from such use, and affirming their willingness to work towards the achievement of this objective,

Desiring also to contribute to the strengthening of trust among nations and to further improvement of the international situation in accordance with the purposes and principles of the Charter of the United Nations,

Have agreed as follows :

Article I

1. Each State Party to this Convention undertakes not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party.

2. Each State Party to this Convention undertakes not to assist, encourage or induce any State, group of States or international organization to engage in activities contrary to the provisions of paragraph 1 of this article.

Article II

As used in article I, the term "environmental modification techniques" refers to any technique for changing—through the deliberate manipulation of natural processes—the dynamics, composition or structure of the earth, including its biota, lithosphere, hydrosphere, and atmosphere, or of outer space.

Article III

1. The provisions of this Convention shall not hinder the use of environmental modification techniques for peaceful purposes and shall be without prejudice to generally recognized principles and applicable rules of international law concerning such use.

2. The States Parties to this Convention undertake to facilitate, and have the right to participate in, the fullest possible exchange of scientific and technological information on the use of environmental modification techniques for peaceful purposes. States Parties in a position to do so shall contribute, alone

or together with other States or international organizations, to international economic and scientific co-operation in the preservation, improvement, and peaceful utilization of the environment, with due consideration for the needs of the developing areas of the world.

Article IV

Each State Party to this Convention undertakes to take any measures it considers necessary in accordance with its constitutional processes to prohibit and prevent any activity in violation of the provisions of the Convention anywhere under its jurisdiction or control.

Article V

1. The States Parties to this Convention undertake to consult one another and to co-operate in solving any problems which may arise in relation to the objectives of, or in the application of the provisions of, the Convention. Consultation and co-operation pursuant to this article may also be undertaken through appropriate international procedures within the framework of the United Nations and in accordance with its Charter. These international procedures may include the services of appropriate international organizations, as well as of a consultative committee of experts as provided for in paragraph 2 of this article.

2. For the purposes set forth in paragraph 1 of this article, the Depositary shall, within one month of the receipt of a request from any State Party, convene a consultative committee of experts. Any State Party may appoint an expert to this committee whose functions and rules of procedure are set out in the annex, which constitutes an integral part of this Convention. The committee shall transmit to the Depositary a summary of its findings of fact, incorporating all views and information presented to the committee during its proceedings. The Depositary shall distribute the summary to all States Parties.

3. Any State Party to this Convention which has reasons to believe that any other State Party is acting in breach of obligations deriving from the provisions of the Convention may lodge a complaint with the Security Council of the United Nations. Such a complaint should include all relevant information as well as all possible evidence supporting its validity.

4. Each State Party to this Convention undertakes to co-operate in carrying out any investigation which the Security Council may initiate, in accordance with the provisions of the Charter of the United Nations, on the basis of the complaint received by the Council. The Security Council shall inform the States Parties to the Convention of the results of the investigation.

5. Each State Party to this Convention undertakes to provide or support assistance, in accordance with the provisions of the Charter of the United Nations, to any Party to the Convention which so requests, if the Security Council decides that such Party has been harmed or is likely to be harmed as a result of violation of the Convention.

Article VI

1. Any State Party may proposed amendments to this Convention. The text of any proposed amendment shall be submitted to the Depositary, who shall promptly circulate it to all States Parties.

2. An amendment shall enter into force for all States Parties which have accepted it, upon the deposit with the Depositary of instruments of acceptance by a majority of States Parties. Thereafter it shall enter into force for any remaining State Party on the date of deposit of its instrument of acceptance.

Article VII

This Convention shall be of unlimited duration.

Article VIII

1. Five years after the entry into force of this Convention, a conference of the State Parties to the Convention shall be convened by the Depositary at Geneva. The conference shall review the operation of the Convention with a view to ensuring that its purposes and provisions are being realized, and shall in particular examine the effectiveness of the provisions of article I, paragraph 1, in eliminating the dangers of military or any other hostile use of environmental modification techniques.

2. At intervals of not less than five years thereafter, a majority of the States Parties to this Convention may obtain, by submitting a proposal to this effect to the Depositary, the convening of a conference with the same objectives.

3. If no review conference has been convened pursuant to paragraph 2 of this article within 10 years following the conclusion of a previous review conference, the Depositary shall solicit the views of all States Parties to this Convention on the holding of such a conference. If one third or 10 of the States Parties, whichever number is less, respond affirmatively, the Depositary shall take immediate steps to convene the conference.

Article IX

1. This Convention shall be open to all States for signature. Any State which does not sign the Convention before its entry into force in accordance with paragraph 3 of this article may accede to it at any time.

2. This Convention shall be subject to ratification by signatory States. Instruments of ratification and instruments of accession shall be deposited with the Secretary-General of the United Nations.

3. This Convention shall enter into force upon the deposit with the Depositary of instruments of ratification by 20 Governments in accordance with paragraph 2 of this article.

4. For those States whose instruments of ratification or accession are deposited after the entry into force of this Convention, it shall enter into force on the date of the deposit of their instruments of ratification or accession.

5. The Depositary shall promptly inform all signatory and acceding States of the date of each signature, the date of deposit of each instrument of ratification or of accession and the date of the entry into force of this Convention and of any amendments thereto, as well as of the receipt of other notices.

6. This Convention shall be registered by the Depositary in accordance with Article 102 of the Charter of the United Nations.

Article X

This Convention of which the Arabic, Chinese, English, French, Russian, and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations who shall send certified copies thereof to the Governments of the signatory and acceding States.

IN WITNESS WHEREOF, the undersigned, duly authorized thereto, have signed this Convention.

Done at ----- On -----

ANNEX TO THE CONVENTION

Consultative Committee of Experts

1. The Consultative Committee of Experts shall undertake to make appropriate findings of fact and provide expert views relevant to any problem raised pursuant to article V, paragraph 1, of this Convention by the State Party requesting the convention of the Committee.

2. The work of the Consultative Committee of Experts shall be organized in such a way as to permit it to perform the functions set forth in paragraph 1 of this annex. The Committee shall decide procedural questions relative to the organization of its work, where possible by consensus, but otherwise by a majority of those present and voting. There shall be no voting on matters of substance.

3. The Depositary or his representative shall serve as the Chairman of the Committee.

4. Each expert may be assisted at meetings by one or more advisers.

5. Each expert shall have the right, through the Chairman, to request from States, and from international organizations, such information and assistance as the expert considers desirable for the accomplishment of the Committee's work.

APPENDIX D

STATE STATUTES CONCERNING WEATHER MODIFICATION

Twenty-nine States were found which have some type of statute discussing weather modification. These state statutes were found by an examination of the indices to the state codes under the topics weather modification, climate control and cloud seeding. Statutes which have been repealed are not included.¹

The following chart divides the types of weather modification statutes into three main categories: comprehensive, licensing and other. The comprehensive category would include those statutes which include provisions relating not only to licensing but also to general policy, liability, etc. State statutes put in the licensing category are entirely, or almost entirely, concerned with the licensing of weather modifiers. The "other" category would include States like Hawaii which discuss weather modification in some manner but have neither a comprehensive statute nor one concerning licensing. States for which no provisions concerning weather modification were found contain a notation of "no provisions" on the chart. The exact text of those provisions follows the chart.

It should be noted that in most cases the State codes were current through the 1976 sessions, however, in some cases the most current material available was from the 1975 sessions.

States	Types of weather modification statutes		
	Comprehensive	Licensing	Other
Alabama.....	No provisions.....		
Alaska.....	No provisions.....		
Arizona.....		Arizona Rev. Stat. §§ 45-2401—45-2405.	
Arkansas.....	No provisions.....		
California.....	California Water Code §§ 400-415; § 235. California Government Code § 53063. California Pub. Res. Code § 5093.36.		
Colorado.....	Colorado Rev. Stat. §§ 36-20-101—36-20-126.		
Connecticut.....			Connecticut Gen. Stat., Ann. § 24-5—24-8.
Delaware.....	No provisions.....		
Florida.....		Florida Stat. Ann. §§ 403.281-403.411.	
Georgia.....	No provisions.....		
Hawaii.....			Hawaii Rev. Stat. § 174-5(8).
Idaho.....			Idaho Code §§ 22-3201—22-3202; 22-4301—22-4302.
Illinois.....	Illinois Ann. Stat. ch. 146 3/4, §§ 1-32.		
Indiana.....	No provisions.....		
Iowa.....			Iowa Code Ann. §§ 361.1-361.7.
Kansas.....	Kansas Stat. §§ 19-212f; 82a-1401—82a-1425.		
Kentucky.....	No provisions.....		
Louisiana.....		Louisiana Rev. Stat. Ann. §§ 2201-2208.	
Maine.....	No provisions.....		
Maryland.....	No provisions.....		
Massachusetts.....	No provisions.....		
Michigan.....	No provisions.....		
Minnesota.....	Minnesota Stat. Ann. §§ 42.01-42.14.		
Mississippi.....	No provisions.....		
Missouri.....	No provisions.....		
Montana.....	Montana Rev. Codes Ann. §§ 89 310—89-331.		
Nebraska.....	Nevada Rev. Stat. §§ 2-2401—2-2449; 81-829.45.		

¹ This search was completed in May 1977.

States	Types of weather modification statutes		
	Comprehensive	Licensing	Other
Nevada.....	Nevada Rev. Stat. §§ 544.010-544.240; 244.190.		
New Hampshire.....			New Hampshire Rev. Stat. Ann. § 432:1.
New Jersey.....	No provisions.		
New Mexico.....	New Mexico Stat. Ann. §§ 75-37-1—75-31-15.		
New York.....			New York Gen. Mun. Law § 119-p.
North Carolina.....	No provisions.		
North Dakota.....	North Dakota Cent. Code §§ 2-07-01—2-07-13; 37-17.1-15; 58-03-07.		
Ohio.....	No provisions.		
Oklahoma.....	Oklahoma Stat. Ann., title 2, §§ 1401-1432.		
Oregon.....	Oregon Rev. Stat. §§ 558.010-558.990; 451.010; 451.420.		
Pennsylvania.....	Pennsylvania Stat. Ann., title 3, §§ 1101-1118.		
Rhode Island.....	No provisions.		
South Carolina.....	No provisions.		
South Dakota.....	South Dakota Compiled Laws Ann. §§ 38-9-1—38-9-22; 1-40-8; 10-12-18.		
Tennessee.....	No provisions.		
Texas.....	Texas Water Code, title 2, §§ 14.001-14.112; Texas Civil Code, title 120A, § 6889-7(16).		
Utah.....			Utah Code Ann. §§ 73-15-3—73-15-8.
Vermont.....	No provisions.		
Virginia.....	No provisions.		
Washington.....	Washington Rev. Code Ann. §§ 43.37.010-43.37.200; 43.27A.080(6); 43.27A.180(1).		
West Virginia.....	West Virginia Code §§ 29-2B-1—29-2B-15.		
Wisconsin.....			Wisconsin Stat. Ann. § 195.40.
Wyoming.....		Wyoming Stat. §§ 10-4—10-6; §§ 9-267-9-276.	

ARIZONA

Ariz. Rev. Stat. §§ 45-2401-45-2405

§ 45-2401. License required

No person or corporation, other than the United States and its administrative agencies or the state shall, without having first received a license from the Arizona water commission, conduct any weather control or cloud modification operations or attempt artificially to produce rainfall. As amended Laws 1971, Ch. 49, § 25.

§ 45-2402. Application for license

Any individual or corporation who proposes to operate weather control or cloud modification projects or attempts to artificially induce rainfall shall, before engaging in any such operation, make application to the Arizona water commission for a license to engage in the particular weather control or cloud modification operation contemplated. As amended Laws 1971, Ch. 49, § 26.

Effective April 13, 1971.

§ 45-2403. Application fee; statement accompanying application

At the time of applying for the license, the applicant shall pay to the Arizona water commission a fee of one hundred dollars, and shall file an application in the form prescribed by the Arizona water commission and furnish a statement showing:

1. The name and address of the applicant.
2. The names of the operating personnel, and if unincorporated all individuals connected with the organization, or if a corporation the names of each of the officers and directors thereof, together with the address of each.

3. The scientific qualifications of all operating or supervising personnel.

4. A statement of all other contracts completed or in process of completion at the time the application is made, giving the names and addresses of the persons to whom the services were furnished and the areas in which such operations have been or are being conducted.

5. Methods of operation the licensee will use and the description of the aircraft, ground and meteorological services to be utilized.

6. Names of the contracting parties within the state, including :

(a) The area to be served.

(b) The months in which operations will be conducted.

(c) The dates when evaluations will be submitted. As amended Laws 1971,

Ch. 49, § 27.

§ 45-2404. *Reports required from licensees; failure to file; revocation of license*

Each licensee shall within ninety days after conclusion of any weather control or cloud modification project, file with the Arizona water commission a final evaluation of the project. Each six months during the operation of any project which has not been completed, each licensee shall file a report evaluating the operations for the preceding six months in the project. Failure to file such reports constitutes grounds for immediate revocation of the license. As amended Laws 1971, Ch. 49, § 28.

§ 45-2405. *Equipment license; fee; application; reports required; revocation of license*

A. Any individual or corporation engaging in manufacturing, selling or offering for sale, leasing or offering to lease, licensing or offering to license equipment and supplies designed for weather control or cloud modification shall, before engaging in such manufacture, sale or offering for sale, procure a license from the Arizona water commission. The license shall be issued upon payment of a license fee of ten dollars and the filing of an application which shall show :

1. The name and address of the applicant.

2. The full description of the type and design of the equipment and supplies manufactured and sold by the applicant.

3. The operating technique of the equipment or supplies.

B. Within sixty days after issuance of an equipment license and semi-annually thereafter, the licensee shall file with the commission a copy of all advertising material used in selling or offering for sale, leasing or offering for lease, licensing or offering for license the equipment and supplies manufactured or sold by it.

C. The holder of a license shall within ten days after each sale of equipment or supplies report to the commission, in writing, the exact character and quantity of equipment or supplies sold, the date of the sale and the persons to whom the sale was made.

D. Failure to file a copy of advertising material or reports required in this section constitutes grounds for immediate revocation of the equipment license. As amended Laws 1971, Ch. 49, § 29.

Effective April 13, 1971.

CALIFORNIA

Cal. Water Code §§ 400-415; 235

REGULATION OF RAIN-MAKING AND RAIN-PREVENTION

Sec.

400. Legislative finding.

401. Department; person.

402. License; necessity.

403. License; application; fee.

404. License; contents of application.

405. License; issuance; duration.

406. License; renewal; fee.

407. Notice of intention.

408. Notice of intention; contents.

409. Notice of intention; publication.

410. Notice of intention; proof of publication.

411. Record of operations.

412. Evaluation statement.

413. Emergency nucleation project; fire fighting.

413.5 Drought emergency.

414. License; revocation or suspension; procedure.

415. Violation; offense.

Chapter 4 was added by Stats. 1953, c. 139, p. 903, § 1.

§ 400. *Legislative finding*

The public interest, health, safety, welfare, and necessity require that scientific experimentation in the field of artificial nucleation, and that scientific efforts to develop, increase, and regulate natural precipitation be encouraged, and that means be provided for the regulation and control of interference by artificial means with natural precipitation of rain, snow, moisture, or water in any form contained in the atmosphere, within the State, in order to develop, conserve, and protect the natural water resources of the State and to safeguard life and property.

(Added by Stats. 1953, c. 139, p. 903, § 1.)

§ 401. *Department; person*

As used in this chapter:

(a) "Department" means the Department of Water Resources.

(b) "Person" means any person, firm, association, organization, partnership, company, corporation, private or public, county, city, city and county, district, or other public agency.

(Added by Stats. 1953, c. 139, p. 903, § 1. Amended by Stats. 1959, c. 1269, p. 3415, § 2.)

§ 402. *License; necessity*

No person, without first securing a license from the department, shall cause or attempt to cause condensation or precipitation of rain, snow, moisture, or water in any form contained in the atmosphere, or shall prevent or attempt to prevent by artificial means the natural condensation or precipitation of rain, snow, moisture, or water in any form contained in the atmosphere.

(Added by Stats. 1953, c. 139, p. 903, § 1.)

§ 403. *License; application; fee*

Any person desiring to do any of the acts specified in Section 102 may file with the department an application in writing for a license. Each application shall be accompanied by a filing fee fixed by the department with the approval of the Department of General Services but not to exceed fifty dollars (\$50) and shall be on a form to be supplied for such purpose by the department.

(Added by Stats. 1953, c. 139, p. 904, § 1. Amended by Stats. 1965, c. 371, p. 1599, § 292.)

§ 404. *License; contents of application*

Every application shall set forth all of the following:

(a) The name and post-office address of the applicant.

(b) The previous education, experience, and qualifications of the applicant, or, if the applicant is other than an individual, the previous education, experience, and qualifications of the persons who will be in control of and charged with the operations of the applicant.

(c) A general description of the operation which the applicant intends to conduct and the method and type of equipment that the applicant proposes to use.

(d) Such other pertinent information as the department may require.

(Added by Stats. 1953, c. 139, p. 904, § 1.)

§ 405. *License; issuance; duration*

Upon the filing of the application upon a form supplied by the department and containing the information prescribed by this chapter and accompanied by the required filing fee the department shall issue a license to the applicant entitling the applicant to conduct the operations described in the application for the calendar year for which the license is issued, unless the license is sooner revoked or suspended.

(Added by Stats. 1953, c. 139, p. 904, § 1.)

Derivation: Stats. 1951, c. 1677, p. 3868, § 6.

§ 406. *License; renewal; fee*

A license may be renewed annually upon application to the department, accompanied by a renewal fee fixed by the department with the approval of the Depart-

ment of General Services but not to exceed twenty-five dollars (\$25), on or before the last day of January of the calendar year for which the license is renewed.

(Added by Stats.1953, c. 139, p. 904, § 1. Amended by Stats.1965, c. 371, p. 1599, § 293.)

Derivation : Stats.1951, c. 1677, p. 3868, § 6.

§ 407. *Notice of intention*

Prior to undertaking any operation authorized by the license the licensee shall file with the department and cause to be published a notice of intention. The licensee shall then confine his activities for that operation substantially within the time and area limits set forth in the notice of intention.

(Added by Stats.1953, c. 139, p. 904, § 1.)

Derivation : Stats.1951, c. 1677, p. 3868, § 7.

§ 408. *Notice of intention; contents*

The notice of intention shall set forth all of the following :

- (a) The name and address of the licensee.
- (b) The nature and object of the intended operation and the person or persons on whose behalf it is to be conducted.
- (c) The area in which and the approximate time during which the operation will be conducted.
- (d) The area which will be affected by the operation as near as the same may be determined in advance.

(Added by Stats.1953, c. 139, p. 904, § 1.)

Derivation : Stats.1951, c. 1677, p. 3868, § 8.

§ 409. *Notice of intention; publication*

The licensee shall cause the notice of intention to be published pursuant to Section 6063 of the Government Code in a newspaper having a general circulation and published within any county wherein the operation is to be conducted and in which the affected area is located, or, if the operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the operation is to be conducted, then such notice shall be published in like manner in a newspaper having a general circulation and published within each of such counties. In case there is no newspaper published within the appropriate county, publication shall be made in a newspaper having a general circulation within the county.

(Stats.1953, c. 139, p. 904, § 1. Amended by Stats.1955, c. 482, p. 953, § 1; Stats. 1957, c. 448, p. 1302, § 1.)

§ 410. *Notice of intention; proof of publication*

Proof of publication shall be filed by the licensee with the department within 15 days from the date of the last publication of the notice. Proof of publication shall be by copy of the notice as published attached to and made a part of the affidavit of the publisher or foreman of the newspaper publishing the notice.

(Added by Stats.1953, c. 139, p. 905, § 1.)

Derivation : Stats.1951, c. 1677, p. 3868, § 10.

§ 411. *Record of operations*

Every licensee shall keep and maintain a record of all operations conducted by him pursuant to his license showing the method employed, the type of equipment used, the times and places of operation of the equipment, the name and post-office address of each person participating or assisting in the operation other than the licensee, and such other information as may be required by the department, and shall report the same to the department immediately upon the completion of each operation.

(Added by Stats.1953, c. 139, p. 905, § 1.)

Derivation : Stats.1951, c. 1677, p. 3869, § 11.

§ 412. *Evaluation statement*

Each licensee shall further prepare and maintain an evaluation statement for each operation which shall include a report as to estimated precipitation, defining the gain or loss occurring from nucleation activities, together with supporting data therefor. This statement, together with such other pertinent information as

the department may require, shall be sent to the department upon request by the department.

(Added by Stats. 1953, c. 139, p. 905, § 1.)

Derivation: Stat. 1951, c. 1677, p. 3869, § 11.

§ 413. *Emergency nucleation project; fire fighting*

Notwithstanding any provision of this chapter to the contrary, the department may grant a licensee permission to undertake an emergency nucleation project, without compliance by the licensee with the provisions of Sections 407 to 410, inclusive, if the same appears to the department to be necessary or desirable in aid of extinguishment of fires.

(Added by Stats. 1953, c. 139, p. 905, § 1.)

Derivation: Stats. 1951, c. 1677, p. 3869, § 12.

§ 413.5 *Drought emergency*

Notwithstanding any provision of this chapter to the contrary, upon request of the board of supervisors of a county or of the governing body of a city or a public district of the State, and upon the submission of such supporting evidence as the department may require, the department may grant a licensee permission to undertake a nucleation project for the purpose of alleviating a drought emergency, without prior compliance by the licensee with the provisions of Section 407 requiring publication of notice of intention, if such project appears to the department to be necessary or desirable. Nothing contained in this section shall be construed as to relieve the licensee in such case from compliance with the provisions of Sections 407 to 410, inclusive, requiring publication of notice of intention and filing of proof of such publication, as soon after the granting of permission by the department as is practicable.

(Added by Stats. 1955, c. 1399, p. 2512, § 1.)

§ 414. *License; revocation or suspension; procedure*

Any license may be revoked or suspended if the department finds, after due notice to the licensee and a hearing thereon, that the licensee has failed or refused to comply with any of the provisions of this chapter. The proceedings herein referred to shall be conducted in accordance with the provisions of the Administrative Procedure Act, Chapter 5, Part 1, Division 3, Title 2 of the Government Code and the department shall have all the powers granted therein.

(Added by Stats. 1953, c. 139, p. 905, § 1.)

Derivation: Stats. 1951, c. 1677, p. 3869, § 13.

§ 415. *Violation; offense*

Any person who violates any provision of this chapter is guilty of a misdemeanor.

(Added by Stats. 1953, c. 139, p. 905, § 1.)

Derivation: Stats. 1951, c. 1677, p. 3869, § 14.

§ 235. *Weather modification; artificial rainfall; research contracts*

The department, either independently or in co-operation with any person or any county, state, federal, or other agency, to the extent that funds are allocated therefor, may conduct a program of study, research, experimentation, and evaluation in the field of weather modification, including the production and control of rainfall by artificial means, and it may contract with public and private organizations and persons for research relative thereto.

(Added by Stats. 1959, c. 2115, p. 4932, § 1.)

Cal. Gov't Code § 53063

§ 5306. *Rainfall control*

Any county, city, city and county, district, authority or other public corporation or agency which has the power to produce, conserve, control or supply water for beneficial purposes shall have the power to engage in practices designed to produce, induce, increase or control rainfall or other precipitation for the general benefit of the territory within it. (Formerly § 53062, added Stats. 1955, c. 1823, p. 3265, § 1. Renumbered § 53063, and amended Stats. 1957, c. 65, p. 634, § 4.)

Library references: Waters and Water Courses ⇔ 121; C.J.S. Waters § 124; Waters and Water Courses, ⇔ 180, 183 (1, 2), 190, 198, 202; C.J.S. Waters § 228.

Cal. Pub. Res. Code § 5093.36

§ 5093.36 *Management and preservation of wilderness areas*

(a) Except as otherwise provided in this chapter, each state agency with jurisdiction over any area designated as a wilderness area shall be responsible for preserving the wilderness character of the wilderness area and shall so administer such area for such other purposes for which it may have been established as also to preserve its wilderness character. Except as otherwise provided in this chapter, wilderness areas shall be devoted to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use.

(b) Except as specifically provided * * * in this chapter, and subject to private rights existing as of January 1, 1975, there shall be no commercial enterprise and no permanent road within any wilderness area and, except as necessary in emergencies involving the health and safety of persons within the wilderness area, there shall be no temporary road, no use of motor vehicles, motorized equipment, or motorboats, no landing or hovering aircraft, no flying of aircraft lower than * * * 2,000 feet above the ground, no other form of mechanical transport, and no structure or installation within any wilderness area.

(c) The following special provisions are hereby made:

(1) Within wilderness areas, such measures may be taken as may be necessary for the control of fire, insects, and diseases, subject to such conditions as the state agency or agencies having jurisdiction over such wilderness areas may deem desirable.

(2) Nothing in this chapter shall prevent any activity by any public agency within a wilderness area, including prospecting, for the purpose of gathering information about mineral or other resources, which the state agency or agencies having jurisdiction over such wilderness area have determined will be carried on in a manner compatible with the preservation of the wilderness environment.

(3) The state agency or agencies having jurisdiction over wilderness areas may authorize the collection of hydrometeorological data and the conduct of weather modification activities, including both atmospheric and surface activities and environmental research, which are within, over, or may affect wilderness areas and for such purposes may permit access, installation, and use of equipment which is specifically justified and unobtrusively located. Maximum practical application of miniaturization, telemetry, and camouflage shall be employed in conducting weather modification activities. In granting permission for the conduct of data collection and weather modification activities, the appropriate state agency may prescribe such operating and monitoring conditions as it deems necessary to minimize or avoid long-term and intensive local impact on the wilderness character of the wilderness areas affected.

(4) Within wilderness areas, the grazing of livestock, where established prior to January 1, 1975, may be permitted to be continued by the present lessee or permittee subject to * * * limitation * * * by such terms and regulations as are deemed necessary by the state agency or agencies having jurisdiction over such wilderness areas.

(5) The provisions of this chapter shall not apply to the aerial stocking of fish or to the conduct of aerial surveys of wildlife species.

(Added by Stats. 1974, c. 1196, p. 2581, § 2. Amended by Stats. 1975, c. 26, p. —, § 1; Stats. 1976, c. 592, p. —, § 1.)

COLORADO

Colo. Rev. Stat. § 36-20-101-36-20-126

WEATHER MODIFICATION

ARTICLE 20

Weather Modification

EDITOR'S NOTE.—The substantive provisions of this article, formerly article 1 of chapter 151, C.R.S. 1963, were repealed and reenacted in 1972, causing some addition, relocation, and elimination of sections as well as subject matter. (Compare historical record prior to 1972 of article 1 of chapter 151, C.R.S. 1963, as amended through L. 71.)

- 36-20-101. Short title.
- 36-20-102. Legislative declaration.
- 36-20-103. Declaration of rights.
- 36-20-104. Definitions.
- 36-20-105. Administration.
- 36-20-106. Advisory committee—appointment—duties.
- 36-20-107. Duties of the director.
- 36-20-108. Powers of the director.
- 36-20-109. License and permit required—exemptions.
- 36-20-110. Issuance of license.
- 36-20-111. License fee—expiration.
- 36-20-112. Permit required—when issued.
- 36-20-113. Permit fee.
- 36-20-114. Limits of permit.
- 36-20-115. Modification of permit.
- 36-20-116. Scope of activity.
- 36-20-117. Reports of licensee.
- 36-20-118. Operations affecting weather in other states.
- 36-20-119. Suspension—revocation—refusal to renew.
- 36-20-120. Operation under permit.
- 36-20-121. Hearing required.
- 36-20-122. Immunity of state or public employees.
- 36-20-123. Legal recourse—liability—damages.
- 36-20-124. License or permit as defense in actions.
- 36-20-125. Judicial review.
- 36-20-126. Penalty.

36-20-101. *Short title.*—This article shall be known and may be cited as the "Weather Modification Act of 1972".

Source: R & RE, L. 72, p. 632, § 1; C.R.S. 1963, § 151-1-1.

36-20-102. *Legislative declaration.*—The general assembly declares that the state of Colorado recognizes that economic benefits can be derived for the people of the state from weather modification. Operations, research, experimentation, and development in the field of weather modification shall therefore be encouraged. In order to minimize possible adverse effects, weather modification activities shall be carried on with proper safeguards, and accurate information concerning such activities shall be made available for purposes of regulation. While recognizing the value of research and development of weather modification techniques by governmental agencies, the general assembly finds and declares that the actual practice of weather modification, whether at public or private expense, is properly a commercial activity which the law should encourage to be carried out, whenever practicable, by private enterprise.

Source: R & RE, L. 72, p. 632, § 1; C.R.S. 1963, § 151-1-2.

36-20-103. *Declaration of rights.*—The general assembly declares that the state of Colorado claims the right to all moisture suspended in the atmosphere which falls or is artificially induced to fall within its borders. Said moisture is declared to be the property of the people of this state, dedicated to their use pursuant to sections 5 and 6 of article XVI of the Colorado constitution and as otherwise provided by law. It is further declared that the state of Colorado also claims the prior right to increase or permit the increase of precipitation by artificial means for use in Colorado. The state of Colorado also claims the right to modify weather as it affects the people of the state of Colorado and to permit such modification by activity within Colorado.

Source: R & RE, L. 72, p. 632, § 1; C.R.S. 1963, § 151-1-3.

36-20-104. *Definitions.*—As used in this article, unless the context otherwise requires:

(1) "Advisory committee" or "committee" means the advisory committee appointed pursuant to this article.

(2) "Director" means the executive director of the department of natural resources, as created by article 33 of title 24, C.R.S. 1973.

(3) "License" means a certification issued by the director indicating that a specific person has met the standards for certification as a weather modifier and is approved to direct weather modification operations in the state.

(4) "Operation" means the performance in Colorado of any activity to attempt to modify or having the effect of modifying natural weather conditions other than usual and customary activities not conducted primarily for weather modification and having only a minor effect on natural weather conditions.

(5) "Permit" means a certification of project approval to conduct a specific weather modification operation within the state under the conditions and within the limitations required and established under the provisions of this article.

(6) "Person" means an individual, partnership, or public or private corporation or agency, except where the context indicates that "person" is used in the sense of a living individual.

(7) "Publication" or "publish" means a minimum of at least two consecutive weekly legal notices in at least one newspaper of general circulation in the county or counties, or portions thereof, included within the proposed operation. It shall not be necessary that notice be made on the same day of the week in each of the two weeks, but not less than one week shall intervene between the first publication and the last publication, and notice shall be complete on the date of the last publication. If there is no such newspaper, notice shall be by posting in at least three public places within the county, or portions thereof, included within a proposed operation. Publication of notices provided for in this article may be made, at the discretion of the director, by notices broadcast over any or all standard radio, FM radio, television stations, and cable television. Such broadcast notices shall make reference to locations or publications wherein details of the subject matter of the notices are located.

(8) "Research and development" means theoretical analysis, exploration, experimentation, and the extension of investigative findings and theories of a scientific or technical nature into practical application for experimentation and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials, and processes both in the laboratory and in the atmosphere.

(9) "Research and development operation" or "research and development project" means an operation which is conducted solely to advance scientific and technical knowledge in weather modification. Research and development operations may be conducted by state or federal agencies, state institutions of higher education, and bona fide nonprofit research corporations, or by commercial operators under contracts with such entities solely for research purposes.

(10) "Weather modification" means any program, operation, or experiment intended to induce changes in the composition, behavior, or dynamics of the atmosphere by artificial means.

36-20-105. *Administration.*—(1) The executive director of the department of natural resources is hereby charged with administration of this article.

(2) The director shall issue all licenses and permits provided for in this article. He is hereby empowered to issue rules and regulations he finds necessary to facilitate the implementation of this article, and he is authorized to execute and administer all other provisions of this article pursuant to the powers and limitations contained in this article.

Source: R & RE, L. 72, p. 634, § 1; C.R.S. 1963, § 151-1-5.

36-20-106. *Advisory committee—appointment—duties.*—(1) (a) The governor shall appoint an advisory committee to assist the director in developing licensing standards and report forms, in conducting studies, in establishing minimum operation requirements, and to advise the director on such other technical and general matters as the director may request. The director may designate subcommittees from the advisory committee to assist him in carrying out the purposes of this paragraph (a).

(b) The advisory committee shall be composed of ten persons chosen by the governor, five of whom shall have appropriate scientific, technical, industrial, and water resources background and who may reside anywhere within the state; and five of whom shall be farmers or ranchers who derive the major portion of their income from agricultural enterprises located within Colorado: One farmer or rancher shall reside in and be chosen from each of the following river basins in Colorado:

(I) One person representing the Gunnison, White, Yampa, and Colorado river basins;

(II) One person representing the San Juan river basin;

(III) One person representing the Rio Grande river basin;

(IV) One person representing the Arkansas river basin; and

(V) One person representing the Republican, South Platte, and North Platte river basins.

(c) At the first meeting of the committee subsequent to the passage of this section, the ten appointed members of the committee shall draw lots to determine which four shall hold office for a period of three years, which three shall hold office for a period of two years, and which three shall hold office for a period of one year. Thereafter, appointed members to the committee shall hold office for a period of three years. Any six members of the committee shall constitute a quorum.

(2) (a) When any person shall file a verified complaint alleging damages as a result of an operation or that an operation is being conducted in violation of the

requirements of a permit or in violation of this article, the director shall either convene the advisory committee, which shall investigate the complaint and shall conduct a hearing or he may appoint a hearing officer pursuant to section 36-20-108(3)(b). Thereafter a decision shall be issued in accordance with article 4 of title 24, C.R.S. 1973. Such decision shall not include any determination as to the amount of damages, if any.

(b) The record of the hearing, including all evidence, exhibits, and other papers presented or considered, together with all findings of fact and conclusions of law, shall be available to any part in interest for use in any action for judicial review or a trial for damages, subject to applicable rules of evidence.

(3) Members of the advisory committee shall not be paid for their services but they may be reimbursed for any actual and necessary expenses they incur in the performance of their duties.

Source: R & RE, L. 72, p. 634, § 1; C.R.S. 1963, § 151-1-6.

36-20-107. *Duties of the director.*—(1) The director shall establish rules and regulations, in accordance with article (4) of title 24, C.R.S. 1973, necessary to effectuate the purposes of this article and shall consult with the advisory committee with respect thereto.

(2)(a) The director shall establish qualifications, procedures, and conditions for the issuance of licenses for the purpose of conducting weather modification activities within the state. Such qualifications, procedures, and conditions shall be developed in consultation with the advisory committee appointed pursuant to section 36-20-106.

(b) The qualifications so established shall insure that the licensee demonstrates knowledge, skill, and experience reasonably necessary to accomplish weather modification without actionable injury to person or property, but the licensee shall be limited to the exercise of such license to the method of weather modification within his area of expertise. At a minimum each such application shall meet requirements at least as stringent as one or more of the following:

(I) Demonstrates that he has at least eight years' experience at the professional level in weather modification field research or operations, at least three of those year as a project director; or

(II) Has obtained a baccalaureate degree in engineering, mathematics, or the physical sciences plus three years' experience in weather modification field research or operations; or

(III) Has obtained a baccalaureate degree in meteorology, or a degree in engineering or the physical sciences which includes, or is an addition to, the equivalent of at least twenty-five semester hours of meteorological course work and two years' practical experience in weather modification operations or research.

Source: R & RE, L. 72, p. 635, § 1; C.R.S. 1963, § 151-1-7; L. 73, p. 1535, § 2.

36-20-108. *Powers of the director.*—(1) The director may issue permits applicable to specific weather modification operations. For each operation, said permit shall describe the specific geographic area authorized to be affected and shall provide a specific time period during which the operation may continue, which period may be discontinuous but may not have a total duration exceeding one calendar year from the day of its issuance. A separate permit shall be required for each operation. The director shall issue a permit only after it is established that the project is conceived to provide economic benefits or that it will advance or enhance scientific knowledge. The director shall issue only one active permit for activities in any geographic area if two or more projects therein might adversely interfere with each other. The director shall ask the advisory committee to review each request for a permit and offer him its advice on issuance.

(2) The director shall, by regulation or order, establish standards instructions to govern the carrying out of research and development or commercial operations in weather modification that he considers necessary or desirable to minimize danger to land, health, safety, people, property, or the environment.

(3)(a) The director may make any studies or investigations, obtain any information, and hold any hearings he considers necessary or proper to assist him in exercising his power or administering or enforcing this article or any regulations or orders issued under this article.

(b) All hearings conducted under this article shall be conducted pursuant to the provisions of this article and article 4 of title 24, C.R.S. 1973, and the

director may by his own action, or at the request of the advisory committee, appoint a hearing officer to conduct any hearing required by this article: said hearing to be conducted under the provisions and within the limitations of article 4 of title 24, C.R.S. 1973, and this article.

(4) (a) The director may, upon approval of the governor, represent the state in matters pertaining to plans, procedures, or negotiations for interstate compacts relating to weather modification, but, before any such compacts may be implemented, the consent of the general assembly must be obtained.

(b) The director may represent the state, and assist counties, municipalities, and public agencies in contracting with commercial operators for the performance of weather modification or cloud seeding operations. Counties, municipalities, and other public agencies of this state are hereby granted the authority to contribute to and participate in weather modification.

(5) In order to assist in expanding the theoretical and practical knowledge of weather modification the director may participate in and promote continuous research and development in:

(a) The theory and development of weather modification, including processes, materials, ecological effects, and devices related to such matters;

(b) The utilization of weather modification for agricultural, industrial, commercial, municipal, recreational, and other purposes;

(c) The protection of life and property and the environment during research and operational activities.

(6) The director may conduct and may contract for research and development activities relating to the purposes of this article.

(7) The director, subject to limits of the department of natural resources' appropriation, may hire any technical or scientific experts or any staff deemed necessary to carry out the provisions of this article.

(8) Subject to any limitations imposed by law, the department of natural resources, acting through the director, may accept federal grants, private gifts, and donations from any other source. Unless the use of the money is restricted, or subject to any limitations provided by law, the director may:

(a) Spend it for the administration of this article:

(b) By grant, contract, or cooperative arrangement, use the money to encourage research and development by a public or private agency; or

(c) Use the money to contract for weather modification operations.

(9) The director, in cooperation with the advisory committee, shall prescribe those measurements reasonably necessary to be made prior to and during all operations to determine the probable effects of an operation.

Source: R & RE L. 72, p. 636, § 1; C.R.S. 1963, § 151-1-8.

36-20-109. *License and permit required—exemptions.*—(1) No person may engage in activities for weather modification and control without a weather modification license and a weather modification permit issued by the director: nor may any person engage in any activities in violation of any term or condition of the license or the permit.

(2) The director, to the extent he considers exemptions practical, may provide by regulation for exempting the following activities from the fee requirements of this article:

(a) Research, development, and experiments conducted by state and federal agencies, state institutions of higher education, and bona fide nonprofit research organizations;

(b) Laboratory research and experiments; and

(c) Activities of an emergency nature for protection against fire, frost, hail, sleet, smog, fog, or drought.

Source: R & RE, L. 72, p. 637, § 1; C.R.S. 1963, § 151-1-19.

36-20-110. *Issuance of license.*—(1) The director, in accordance with applicable regulations, shall issue a weather modification license to each applicant who:

(a) Pays the license fee, if applicable; and

(b) Meets the qualifications for licensure established by the director pursuant to section 36-20-107 (2).

Source: R & RE, L. 72, p. 637, § 1; C.R.S. 1963, § 151-1-10.

36-20-111. *License fee—expiration.*—A license shall be issued under this article only upon the payment to the state of Colorado the sum of one hundred dollars for such license. Each such license shall expire at the end of the calendar year in which it is issued.

Source: R & RE, L. 72, p. 638, § 1; C.R.S. 1963, § 151-1-11.

36-20-112. *Permit required—when issued.*—(1) The director, in accordance with his regulations, shall issue a weather modification permit to each applicant who:

(a) Holds, or if the applicant is a corporation, the corporation demonstrates that the person in control of the project holds, a valid weather modification license.

(b) Pays the permit fee, if applicable.

(c) Furnishes proof of financial responsibility adequate to meet obligations reasonably likely to be attached to or result from the proposed weather modification operation. Such proof of financial responsibility may, but at the discretion of the director shall not be required to, be shown by presentation of proof of a prepaid insurance policy with an insurance company licensed to do business in Colorado, which insurance policy shall insure liabilities in an amount set by the director and provide a cancellation clause with a thirty-day notice to the director, or by filing with the director an individual, schedule, blanket, or other corporate surety bond in an amount approved by the director.

(d) Submits a complete operational plan for each proposed project prepared by the licensed operator in control which includes a specific statement of objectives, a map of the proposed operating area which specifies the primary target area and shows the area reasonably expected to be affected, the name and address of the licensee, the nature and object of the intended operation, the person or organization on whose behalf it is to be conducted, a statement showing any expected effect upon the environment and methods of determining and evaluating the same, and such other detailed information as may be required to describe the operation and its proposed method of evaluation. This operational plan shall be placed on file with the director and with any other agent as he may required.

(e) Publishes a notice of intent to modify weather in the counties to be affected by the weather modification program before the licensee secures a permit and before beginning operations. The published notice shall designate the primary target area and indicate the general area which might be affected. It shall also indicate the expected duration and intended effect and state that complete details are available on request from the licensee or the director or from the other agent specified by the director. The publication shall also specify a time and place, not more than one week following the completion of publication, for a hearing on the proposed project. Proof of publication shall be furnished to the director by the licensee.

(f) Receives approval under the criteria set forth in subsection (3) of this section.

(2) Before a permit may be issued, the director or his authorized agents shall hold a public hearing on the proposed project. Said hearing shall be held in a place within a reasonable proximity of the area expected to be affected by the proposed operation.

(3) No permit may be issued unless the director determines, based on the information provided in the operational plan and on the testimony provided at the public hearing:

(a) That, if it is a commercial project, the proposed weather modification operation is conceived to provide, and offers promise of providing, an economic benefit to the area in which the operation will be conducted;

(b) That the project is reasonably expected to benefit the people in said area or benefit the people of the state of Colorado;

(c) That the project is, if it is a commercial project, scientifically and technically feasible;

(d) That the project is, if it is a scientific or research project, designed for and offers promise of expanding the knowledge and the technology of weather modification;

(e) That the project does not involve a high degree of risk of substantial harm to land, people, health, safety, property, or the environment;

(f) That the project is designed to include adequate safeguards to prevent substantial damage to land, water rights, people, health, safety, or to the environment;

(g) That the project will not adversely affect another project; and

(h) That the project is designed to minimize risk and maximize scientific gains or economic benefits to the residents of the area or the state.

Source: R & RE, L. 72, p. 638, § 1; C.R.S. 1963, § 151-1-12.

36-20-113. *Permit fee.*—The fee for each permit or the renewal thereof under section 36-20-114 shall be at a minimum of one hundred dollars. If the operation is a commercial project an additional amount equal to two percent of the value of the contract for such commercial project shall be required and paid before a permit may be issued. Said fees are intended to provide at least a portion of the moneys necessary to administer this article.

Source: R & RE, L. 72, p. 639, § 1; C.R.S. 1963, § 151-1-13.

36-20-114. *Limits of permit.*—(1) A separate permit is required annually for each operation. If an operation is to be conducted under contract, a permit is required for each separate contract. Subject to the provisions of subsection (2) of this section, a permit may be granted for more than one year's duration.

(2) The director may conditionally approve a project for a continuous time period in excess of one year's duration. Permits for such operations must be renewed annually. In approving the renewal of a permit for a continuous program, the director may waive the procedures for initial issuance of a permit in section 36-20-112 and, upon his review and approval of the project's operational record, or, if at his request, the advisory committee reviews and subsequently approves the project's operational record, he may issue a renewed permit for the operation to continue. In such instances, the fees, based upon the value of the contract pursuant to section 26-20-113 may be prorated and paid on an annual basis.

(3) A project permit may be granted by the director without prior publication of notice by the licensee in case of fire, frost, hail, sleet, smog, fog, drought, or other emergency. In such cases, publication of notice shall be performed as soon as possible and shall not be subject to the time limits specified in this article 4 of title 24, C.R.S. 1973.

Source: R & RE, L. 72, p. 639, § 1; C.R.S. 1963, § 151-1-14.

36-20-115. *Modification of permit.*—(1) The director may revise the terms and conditions of a permit if:

(a) The licensee is first given notice and a reasonable opportunity for a hearing on the need for a revision; and

(b) It appears to the director that a revision is necessary to protect the health or property of any person or to protect the environment.

(2) If it appears to the director that an emergency situation exists or is impending which could endanger life, property, or the environment, he may, without prior notice or a hearing, immediately modify the conditions of a permit, or order temporary suspension of the permit on his own order. The issuance of such order shall include notice of a hearing to be held within ten days thereafter on the question of permanently modifying conditions or continuing the suspension of the permit. Failure to comply with an order temporarily suspending an operation or modifying the conditions of a permit shall be grounds for immediate revocation of the permit and the operator's license.

(3) It shall be the responsibility of the licensee conducting any operation to notify the director of any emergency which can reasonably be foreseen or of any existing emergency situations in subsection (2) of this section which might in any way be caused or affected by the weather modification operation. Failure by the licensee to so notify the director of any such existing emergency, or any impending emergency which should have been foreseen, may be grounds, at the discretion of the director, for revocation of the license and revocation of the permit for operation.

Source: R & RE, L. 72, p. 640, § 1; C.R.S. 1963, § 151-1-15.

36-20-116. *Scope of activity.*—Once a permit is issued, the licensee shall confine his activities within the limits of time and area specified in the permit, except to the extent that the limits are modified by the director. He shall also comply with any terms and conditions of the permit as originally issued or as subsequently modified by the director.

Source: R & RE, L. 72, p. 640, § 1; C.R.S. 1963, § 151-1-16.

36-20-117. *Reports of licensee.*—(1) In order to aid in research and development in weather modification and to aid in the protection of life and property or the environment, any person conducting any weather modification operation in Colorado or elsewhere where by undertaking operations within Colorado shall

file such reports at such time and in the manner and form as shall be required by regulation of the director.

(2) Report forms may be developed by the director on the advice of the advisory committee and shall include basic records showing: The method employed, the type of equipment used, the kind and amount of each material used, the times and places the equipment is operated, the name and address of each individual, other than the licensee, who participates or assists in the operation, any environmental effects realized or suspected to have occurred, and any other necessary data he may require.

(3) The director shall require written biweekly reports summarizing the project's activities and intended results while the project is actually in operation, and he shall require a written final operational report and a written final report evaluating the project, or an annual operational report and an annual project evaluation, as the case may be. A final operational report along with a preliminary scientific evaluation of the project shall be filed no later than thirty days after the completion of the project. A final complete scientific evaluation of the project shall be filed no later than one hundred eighty days after the completion of the project. An annual summary report shall be filed sixty days prior to the renewal of a permit under the provisions of section 36-20-114(2). All such reports are declared to be public records subject to the provisions and limitations of part 2 of article 72 of title 24, C.R.S. 1973.

Source: R & RE, L. 72, p. 640, § 1; C.R.S. 1963, § 151-1-17; L. 73, p. 1536, § 3.

36-20-118. *Operations affecting weather in other states.*—Weather control operations may not be carried on in Colorado for the purpose of affecting weather in any other state if that state prohibits such operations to be carried on in that state for the benefit of Colorado or its inhabitants.

Source: R & RE, L. 72, p. 641, § 1; C.R.S. 1963, § 151-1-18.

36-20-119. *Suspension—revocation—refusal to renew.*—(1) The director may suspend or revoke a license or permit if it appears that the licensee no longer has the qualifications necessary for the issuance of an original license or permit or has violated any provision of this article.

(2) The director may refuse to renew the license of, or to issue another permit to, any applicant who has failed to comply with any provision of this article.

Source: R & RE, L. 72, p. 641; § 1; C.R.S. 1963, § 151-1-19.

36-20-120. *Operation under permit.* Operations under permit may only be carried forward by or under the immediate direction and supervision of a licensee.

Source: R & RE, L. 72, p. 641; § 1; C.R.S. 1963, § 151-1-20.

36-20-21. *Hearing required.*—(1) Except as provided in section 36-20-115, the director may not suspend or revoke a license or permit without first giving the licensee notice and a reasonable opportunity to be heard with respect to the grounds for his proposed action.

(2) Said hearing shall be conducted by the advisory committee in the manner provided in section 36-20-106(2) or in the same manner by a hearing officer.

Source: R & RE, L. 72, p. 641; § 1; C.R.S. 1963, § 151-1-21.

36-20-22. *Immunity of state or public employees.*—Officers or employees of the state or any agency thereof, or officers or employees of any county or municipality or other public agency of the state, are immune from liability resulting from any weather modification operations approved or conducted by them under the provisions and limitations of this article.

Source: R & RE, L. 72, p. 641; § 1; C.R.S. 1963, § 151-1-22.

36-20-123. *Legal recourse—liability—damages.*—(1) The mere dissemination of materials and substances into the atmosphere pursuant to an authorized project shall not give rise to the contention or concept that such use of the atmosphere constitutes trespass or involves an actionable or enjoined public or private nuisance.

(2) (a) Failure to obtain a license or permit before conducting an operation, or any actions which knowingly constitute a violation of the conditions of a permit, shall constitute negligence per se.

(b) The director may order any person who is found to be conducting a weather modification operation without a license and permit to cease and desist from said operation. Failure to obey said order shall constitute a misdemeanor and is punishable as provided in section 36-20-126.

Source: R & RE, L. 72, p. 641, § 1; C.R.S. 1963, § 151-1-23.

36-20-124. *License or permit as defense in actions.*—The fact that a person holds a license or was issued a permit under this article, or that he has complied with the requirements established by the director pursuant to this article, is not admissible as a defense in actions for damages or injunctive relief brought against him.

Source: R & RE, L. 72, p. 642, § 1; C.R.S. 1963, § 151-1-24.

36-20-125. *Judicial review.*—Judicial review of any action of the director or findings of the advisory committee may be had in accordance with the provisions of section 24-4-106, C.R.S. 1973.

Source: R & RE, L. 72, p. 642, § 1; C.R.S. 1963, § 151-1-25.

36-20-126. *Penalty.*—Any person conducting a weather modification operation without first having procured a required license and permit, or who makes a false statement in the application for a license or permit, or who fails to file any report as required by this article, or who conducts any weather modification operation after revocation of a license or denial, revocation, modification, or temporary suspension of a permit for operation, or who violates any other provisions of this article is guilty of a misdemeanor and, upon conviction thereof, shall be punished by a fine of not more than five thousand dollars, or by imprisonment in the county jail for not more than six months, or by both such fine and imprisonment. Each such violation shall be a separate offense.

Source: R & RL, L. 72, p. 642, § 1; C.R.S. 1963, § 151-1-26.

CONNECTICUT

Conn. Gen. Stat. Ann. §§ 24-5-24-8

WEATHER CONTROL BOARD

Sec.

24-5. Weather control board.

24-6. Duties.

24-7. Advisory committees, standards, representation of state in interstate matters.

24-8. Receipt of funds.

§ 24-5. *Weather control board*

There shall be a weather control board, consisting of the commissioner of agriculture, the commissioner of environmental protection or his designated representative, the dean of the college of agriculture of The University of Connecticut, the director of the Connecticut Agricultural Experiment Station and a meteorologist, whose education and experience qualify him for professional membership in the American Meteorological Society and who shall be appointed by the governor for a term of six years. The members of the board shall serve without compensation but shall be reimbursed for then necessary expenses. The commissioner of agriculture shall be chairman of the board and shall furnish such supplies, materials and clerical assistance as the duties of the board may require. The board shall meet on call of the chairman at the offices of the department of agriculture.

(1959, P.A. 668, § 1; 1961, P.A. 16; 1971, P.A. 872, § 206, eff. Oct. 1, 1971.)

§ 24-6. *Duties*

The board may conduct, and promote the conduct of, research and development activities relating to:

- (1) The theory and development of methods of weather modification and control, including processes, materials and devices related thereto;
- (2) the utilization of weather modification and control for agricultural, industrial, commercial and other purposes, and
- (3) the protection of life and property during research and operational activities.

(1959, P.A. 668, § 2.)

§ 24-7. *Advisory committees, standards, representation of state in interstate matters*

In the performance of its functions the board may:

- (1) Establish advisory committees to advise with and make recommendations to the board concerning legislation, policies, administration, research and other matters;

(2) establish standards and instructions to govern research in weather modification and control, and

(3) represent the state in all matters pertaining to plans, procedures or negotiations for interstate compacts relating to weather modification and control.

(1959, P.A. 668, § 3.)

§ 24-8. *Receipt of funds*

The board may, subject to any limitations otherwise imposed by law, receive and accept on behalf of the state any funds which may be offered or which may become available from federal grants or appropriations, private gifts, donations or bequests or any other source and may expend such funds, unless their use is restricted or subject to any limitations otherwise provided by law, for the administration of this chapter and for the encouragement of research and development by a state, public or private agency by direct grant, by contract or by cooperative means.

(959, P.A. 668, § 4.)

FLORIDA

Fla. Stat. Ann. §§ 403.281-403.411

403.281 *Definitions; weather modification law*

As used in this chapter relating to weather modification:

(1) "Department" is the Department of [Environmental Regulation]¹.

(2) "Person" includes any public or private corporation.

403.291 *Purpose of weather modification law*

The purpose of this law is to promote the public safety and welfare by providing for the licensing, regulation and control of interference by artificial means with the natural precipitation of rain, snow, hail, moisture or water in any form contained in the atmosphere.

403.301 *Artificial weather modification operation; license required*

No person without securing a license from the department, shall cause or attempt to cause by artificial means condensation or precipitation of rain, snow, hail, moisture or water in any form contained in the atmosphere, or shall prevent or attempt to prevent by artificial means the natural condensation or precipitation of rain, snow, hail, moisture or water in any form contained in the atmosphere.

403.311 *Application for licensing; fee*

(1) Any person desiring to do or perform any of the acts specified in § 403.301 may file with the department an application for a license on a form to be supplied by the department for such purpose setting forth all of the following:

(a) The name and post office address of the applicant.

(b) The education, experience and qualifications of the applicant, or if the applicant is not an individual, the education, experience and qualifications of the persons who will be in control and in charge of the operation of the applicant.

(c) The name and post office address of the person on whose behalf the weather modification operation is to be conducted if other than the applicant.

(d) The nature and object of the weather modification operation which the applicant proposes to conduct, including a general description of such operation.

(e) The method and type of equipment and the type and composition of materials that the applicant proposes to use.

(f) Such other pertinent information as the department may require.

(2) Each application shall be accompanied by a filing fee in the sum of one hundred dollars and proof of financial responsibility as required by § 403.321.

403.321 *Proof of financial responsibility*

(1) No license shall be issued to any person until he has filed with the department proof of ability to respond in damages for liability on account of

¹ Bracketed words substituted by the division of statutory revision for the words "Pollution Control." See Laws 1975, c. 75-22, § 8.

Republished to conform to Fla. St. 1975.

accidents arising out of the weather modification operations to be conducted by him in the amount of ten thousand dollars because of bodily injury to or death of one person resulting from any one incident, and subject to said limit for one person, in the amount of one hundred thousand dollars because of bodily injury to or death of two or more persons resulting from any one incident, and in the amount of one hundred thousand dollars because of injury to or destruction of property of others resulting from any one incident.

(2) Proof of financial responsibility may be given by filing with the department a certificate of insurance or a bond in the required amount.

403.331 Issuance of license; suspension or revocation; renewal

(1) The department shall issue a license to each applicant who :

- (a) By education, skill and experience appears to be qualified to undertake the weather modification operation proposed in his application.
- (b) File proof of his financial responsibility as required by § 403.321.
- (c) Pays filing fee required in § 403.311.

(2) Each such license shall entitle the licensee to conduct the operation described in the application for the calendar year for which the license is issued unless the license is sooner revoked or suspended. The conducting of any weather modification operation or the use of any equipment or materials other than those described in the application shall be cause for revocation or suspension of the license.

(3) The license may be renewed annually by payment of a filing fee in the sum of fifty dollars.

403.341 Filing and publication of notice of intention to operate; limitation on area and time

Prior to undertaking any operation authorized by the license, the licensee shall file with the department and cause to be published a notice of intention. The licensee shall then confine his activities substantially within the time and area limits set forth in the notice of intention.

403.351 Contents of notice of intention

The notice of intention shall set forth all of the following :

- (1) The name and post office address of the licensee.
- (2) The name and post office of the persons on whose behalf the weather modification operation is to be conducted if other than the licensee.
- (3) The nature and object of the weather modification operation which licensee proposes to conduct, including a general description of such operation.
- (4) The method and type of equipment and the type and composition of the materials the licensee proposes to use.
- (5) The area in which and the approximate time during which the operation will be conducted.
- (6) The area which will be affected by the operation as nearly as the same may be determined in advance.

403.361 Publication of notice of intention

The licensee shall cause the notice of intention to be published at least once a week for two consecutive weeks in a newspaper having general circulation and published within any county wherein the operation is to be conducted and in which the affected area is located, or if the operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the operation is to be conducted, then such notice shall be published in like manner in a newspaper having a general circulation and published within each of such counties. In case there is no newspaper published within the appropriate county, publication shall be made in a newspaper having a general circulation within the county.

403.371 Proof of publication

Proof of publication shall be filed by the licensee with the department fifteen days from the date of the last publication of notice. Proof of publication shall be by copy of the notice as published, attached to and made a part of the affidavit of the publisher or foreman of the newspaper publishing the notice.

403.381 Record and reports of operations

(1) Each licensee shall keep and maintain a record of all operations conducted by him pursuant to his license showing the method employed, the type and composition of materials used, the times and places of operation, the name and

post office address of each person participating or assisting in the operation other than licensee and such other information as may be required by the department and shall report the same to the department at such times as it may require.

(2) The records of the department and the reports of all licensees shall be available for public examination.

403.391 Emergency licenses

Notwithstanding any provisions of this act to the contrary, the department may grant a license permitting a weather modification operation without compliance by the licensee with the provisions of §§ 403.351-403.371, and without publication of notice of intention as required by § 403.341 if the operation appears to the department to be necessary or desirable in aid of the extinguishment of fire, dispersal of fog or other emergency.

403.401 Suspension or revocation of license; appeal

(1) Any license may be revoked or suspended if the department finds, after due notice to the licensee and a hearing therein, that the licensee has failed or refused to comply with any of the provisions of this act.

(2) Any licensee may apply to the circuit court for the county of Leon to review any order of the department within the time provided by the Florida appellate rules. The review shall be by certiorari in the manner prescribed by the Florida appellate rules.

(3) Either the department or the licensee may appeal from the order or decree of the circuit court to the appropriate district court of appeal in the same manner appeals may be taken in suits in equity.

403.411 Penalty

Any person conducting a weather modification operation without first having produced a license, or who shall make a false statement in his application for license, or who shall fail to file any report or reports as required by this act, or who shall conduct any weather modification operation after revocation or suspension of his license, or who shall violate any other provision of this act, shall be guilty of a misdemeanor of the second degree, punishable as provided in § 775.082 or § 775.083; and if a corporation, shall be guilty of a misdemeanor of the second degree, punishable as provided in § 775.083. Each such violation shall be a separate offense.

HAWAII

Haw. Rev. Stat. § 174-5(8)

§ 174-5 Powers

In addition to all the powers granted to the board of land and natural resources in chapter 171 for the purpose of carrying out all of its functions and duties, the board shall have the following powers for the purposes of this chapter:

(8) To investigate and make surveys of water resources, including the possibility and feasibility of inducing rain by artificial or other means;

IDAHO

Idaho Code §§ 22-3201-23-3202; 22-4301-22-4302

RAINFALL—ARTIFICIAL PRODUCTION

Sec.

22-3201. Registration of producers of artificial rainfall.

22-3202. Log of activities filed with department of agriculture.

22-3201. *Registration of producers of artificial rainfall.*—Any person, persons, association, firm, or corporation conducting or intending to conduct within the state of Idaho operations to assist artificially in production of or to produce artificially rainfall shall register with the department of agriculture of the state of Idaho.

Such registration shall require the filing of the name of the person, association, or corporation, its residence, or principal place of business in the state of Idaho and the general nature of the business to be conducted. [1957, ch. 106, § 1, p. 184.]

22-3202. *Log of activities filed with department of agriculture.*—Such person, persons, association, firm or corporation shall thereafter file with the said

department of agriculture a log of all its activities in the production, artificially, within this state, of rainfall. [1957, ch. 106, § 2, p. 184.]

CHAPTER 43—WEATHER MODIFICATION DISTRICTS

Sec.

2-4301. Establishment—Petition—Election.

22-4302. Weather modification fund—Creation—Administration.

22-4301. *Establishment—Petition—Election.*—(1) The county commissioners of any county shall, upon petition signed by not less than fifty (50) resident real property holders of said county, or any portion thereof, which may exclude incorporated cities, undertake the following procedure to determine the advisability of resolving to establish and maintain a weather modification district within the county as may be designated in the petition.

(a) A petition to form a weather modification district shall be presented to the county clerk and recorder. The petition shall be signed by not less than fifty (50) of the resident real property holders within the proposed district.

(b) The petition shall be filed with the county clerk and recorder of the county in which the signers of the petition are located. Upon the filing of the petition the county clerk shall examine the petition and certify whether the required number of petitioners have signed the petition. If the number of petition signers is sufficient, the clerk shall transmit the petition to the board or county commissioners.

(c) Upon receipt of a duly certified petition the board of county commissioners shall give notice of an election to be held in such proposed district for the purpose of determining whether or not the proposed district shall be organized and to elect the first board of trustees for the district. Such notice shall include the date and hours of the election, the polling places, the maximum number of mills which the proposed district will be permitted to levy, the general purposes of the proposed district, a description of lands to be included in the proposed district, a statement that a map of the proposed district is available in the office of the board of county commissioners, and the names and terms of the members to be elected to the first board of trustees. The notice shall be published once each week for three (3) consecutive weeks prior to such election, in a newspaper of general circulation within the county.

(d) The election shall be held and conducted as nearly as may be in the same manner as general elections in this state, except that electors need not be registered in order to vote in such election. The board of county commissioners shall appoint three (3) judges of election, one (1) of whom shall act as clerk for the election. Each elector may be required to take an oath that he is a resident of the proposed district, and otherwise possesses all the qualifications of an elector before casting his vote. At such election the electors shall vote for or against the organization of the district, and the members of the first board of trustees.

(e) The judges of election shall certify the returns of the election to the board of county commissioners. If a majority of the votes cast at said election are in favor of the organization, the board of county commissioners shall declare the district organized and give it a name by which, in all proceedings, it shall thereafter be known, and shall further designate the first board of trustees elected, and thereupon the district shall be a legal taxing district.

(f) On the second Tuesday of January, in the second calendar year after the organization of any district, and on the second Tuesday of January every year thereafter an election shall be held, which shall be known as the annual election of the district.

At the first annual election in any district hereafter organized, and each third year thereafter, there shall be elected by the qualified electors of the district, one (1) member of the board to serve for a term of three (3) years; at the second annual election and each third year thereafter, there shall be elected one (1) member of the board to serve for a term of three (3) years, and at the third annual election, and each third year thereafter, there shall be elected one (1) member of the board to serve for a term of three (3) years.

Not later than thirty (30) days before any such election, nominations may be filed with the secretary of the board and if a nominee does not withdraw his

name before the first publication of the notice of election, his name shall be placed on the ballot. The board shall provide for holding such election and shall appoint judges to conduct it. The secretary of the district shall give notice of election by publication, and shall arrange such other details in connection therewith as the board may direct. The returns of the election shall be certified to and shall be canvassed and declared by the board. The candidate or candidates receiving the most votes shall be elected. [1975, ch. 145, § 1, p. 334.]

22-4302. *Weather modification fund—Creation—Administration.*—The board of trustees of a weather modification district shall conduct the affairs of the district. The board of trustees shall certify a budget to the board of county commissioners to fund the operations of the district. The budget preparation, hearings and approval shall be the same as required for any county budget. The certification of the budget to the board of county commissioners shall be as required for other taxing districts. The board of county commissioners may levy annually upon all taxable property in the weather modification district, a tax not to exceed four (4) mills, to be collected and paid into the county treasury and apportioned to a fund to be designated the "weather modification" fund, which is hereby created. Such fund shall be used by the district for the gathering of information upon, aiding in or conducting programs for weather control or modification, and such activities related to weather modification programs as are necessary to insure the full benefit of such programs. Moneys in the fund may be paid out only on order of the board of trustees. [1975, ch. 145, § 2, p. 334.]

ILLINOIS

Ill. Ann. Stat. ch. 146 $\frac{3}{4}$, §§ 1-32CHAPTER 146 $\frac{3}{4}$

WEATHER [NEW]

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|------|---|
| Sec. | |
| 1. | Short title. |
| 2. | Declaration of purpose. |
| 3. | Definitions. |
| 3.01 | Department. |
| 3.02 | Director. |
| 3.03 | Board. |
| 3.04 | Weather modification. |
| 3.05 | Person. |
| 3.06 | Operation. |
| 3.07 | Research and Development. |
| 3.08 | License. |
| 3.09 | Licensee. |
| 3.10 | Permit. |
| 3.11 | Permittee. |
| 4. | Administration. |
| 5. | Weather Modification Board. |
| 6. | Regulations. |
| 7. | Investigations. |
| 8. | Hearings. |
| 9. | Interstate compacts. |
| 10. | License and permit required. |
| 11. | Exemptions. |
| 12. | Issuance of license. |
| 13. | License fee. |
| 14. | Expiration date. |
| 15. | Renewal of license. |
| 16. | Suspension, revocation, refusal to renew a license. |
| 17. | Issuance of permit. |
| 18. | Permit fee. |
| 19. | Scope of permit. |
| 20. | Proof of financial responsibility. |
| 21. | Modification of permit. |
| 22. | Renewal of permit. |
| 23. | Suspension, revocation, refusal to renew permit. |
| 24. | Recreation of license or permit. |
| 25. | Review under Administrative Review Act—Venue—Costs. |
| 26. | Records and reports. |
| 27. | State immunity. |
| 28. | Liability. |
| 29. | Penalty for violations. |
| 30. | Suits to recover fines, penalties or fees. |
| 31. | Injunction to restrain violations. |
| 32. | Partial invalidity. |

WEATHER MODIFICATION CONTROL ACT

The Weather Modification Control Act was enacted as Article I of P.A. 78-674; Article II consisted of amendments of related acts.

§ 1. *Short title*

This Act shall be known and may be cited as the "Weather Modification Control Act". (P.A. 78-674, Art. I, § 1, eff. Oct. 1, 1973.)

TITLE OF ACT

An Act to regulate weather modification in this State and amending certain Acts therein named in connection therewith. Approved by P.A. 78-674, eff. Oct. 1, 1973.

§ 2. *Declaration of purpose*

(a) The General Assembly hereby declares that weather modification affects the public health, safety and welfare and the environment, and is subject to regulation and control in the public interest. Properly conducted weather modification operations can improve water quality and quantity, reduce losses from weather hazards and provide economic benefits for the people of the State. Therefore weather modification operations and research and development shall be encouraged. In order to minimize possible adverse effects, weather modification activities shall be carried on with proper safeguards, and accurate information concerning such activities shall be recorded and reported to the Department of Registration and Education.

(b) This Act shall be liberally construed to carry out these objectives and purposes. (P.A. 78-674, Art. I, § 2, eff. Oct. 1, 1973.)

§ 3. *Definitions*

As used in this Act unless the context otherwise requires, the terms specified in Sections 3.01 through 3.11 have the meanings ascribed to them in those Sections. (P.A. 78-674, Art. I, § 3, eff. Oct. 1, 1973.)

§ 3.01. *Department*

"Department" means the Department of Registration and Education. (P.A. 78-674, Art. I, § 3.01, eff. Oct. 1, 1973.)

§ 3.02 *Director*

"Director" means the Director of Registration and Education. (P.A. 78-674, Art. I § 3.02, eff. Oct. 1, 1973.)

§ 3.03 *Board*

"Board" means the Weather Modification Board appointed pursuant to this Act. (P.A. 78-674, Art. I, § 3.03, eff. Oct. 1, 1973.)

§ 3.04 *Weather modification*

"Weather modification" means any activity performed with the intention of producing artificial changes in the composition, motions and resulting behavior of the atmosphere. (P.A. 78-674, Art. I, § 3.04, eff. Oct. 1, 1973.)

§ 3.05 *Person*

"Person" means any individual, corporation, company, association, firm, partnership, society, joint stock company, any State or local government or any agency thereof, or any other organization, whether commercial or non-profit, who is performing weather modification operations or research and development, except where acting solely as an employee, agent or independent contractor of the United States of America or any agency thereof. "Person" does not include the United States of America or any agency thereof. (P.A. 78-674, Art. 1, § 3.05, eff. Oct. 1, 1973.)

§ 3.06 *Operation*

"Operation" means the performance of any weather modification activity undertaken for the purpose of producing or attempting to produce any form of modifying effect upon the weather within a specified geographical area over a specified time interval. (P.A. 78-674, Art. I, § 3.06, eff. Oct. 1, 1973.)

§ 3.07 *Research and Development*

"Research and Development" means exploration, field experimentation and extension of investigative findings and theories of a scientific or technical

nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials and processes. (P.A. 78-674, Art. I, § 3.07, eff. Oct. 1, 1973.)

§ 3.08 License

"License" means a professional license issued by the Director indicating that a specified person has met the standards for certification as a weather modifier and is approved to conduct weather modification operations for which permits have been issued under this Act. (P.A. 78-674, Art. I, § 3.08, eff. Oct. 1, 1973.)

§ 3.09 Licensee

"Licensee" means a person who holds a professional weather modification license issued under this Act. (P.A. 78-674, Art. I, § 3.09, eff. Oct. 1, 1973.)

§ 3.10 Permit

"Permit" means an operational permit issued by the Director indicating that approval has been given for conducting a specified weather modification operation within the State subject to the conditions and within the limitations established under the provisions of this Act. (P.A. 78-674, Art. I, § 3.10, eff. Oct. 1, 1973.)

§ 3.11 Permittee

"Permittee" means a person who holds an operational permit issued under this Act. (P.A. 78-674, Art. I, § 3.11, eff. Oct. 1, 1973.)

§ 4. Administration

(a) The powers and duties enumerated in this Act shall be exercised by the Director.

(b) The Director shall exercise the powers and duties enumerated in this Act, except those enumerated in Section 5, only upon the recommendation and report in writing of the majority of the members of the Board (P.A. 78-674, Art. I, § 4, eff. Oct. 1, 1973.)

§ 5. Weather Modification Board

There is created the Weather Modification Board to be composed of 5 residents of the State who shall be appointed by the Director. In selecting members of the Board the Director shall include individuals with qualifications and practical experience in agriculture, law, meteorology and water resources.

The Director shall appoint one member of the Board to a term of one year, 2 members to terms of 2 years and 2 members to terms of 3 years, commencing January 1, 1974. After expiration of the terms of the members first appointed pursuant to this Act, each of their respective successors shall hold office for a term of 3 years and until their successors are appointed and qualified. Members of the Board shall be eligible for re-appointment.

In the event a member of the Board shall be disqualified from considering business before the Board because of a conflict of interest, the Director may appoint a resident of the State to serve temporarily on the Board. After the Board decides upon its recommendation to the Director concerning such business the member will resume his position on the Board.

The chairman of the Board shall be designated by the Director from among the members.

Each member of the Board shall be paid the sum of \$25 for every day he is actually engaged in its services, and shall be reimbursed for such actual and necessary expenses as he may incur in performance of the functions of the Board.

The Board shall hold an annual meeting at Springfield, Illinois, and such other meetings at such times and places and upon such notice as the Board may determine. Three members of the Board shall constitute a quorum for performance of its function. (P.A. 78-674, Art. I, § 5, eff. Oct. 1, 1973.)

§ 6. Regulations

The Department shall make reasonable rules and regulations necessary to the exercise of its powers and the performance of its duties under this Act.

In order to effectuate the objectives and purposes of this Act, the Department shall make reasonable rules and regulations establishing qualifications, procedures and conditions for issuance, renewal, revocation, suspension, refusal to renew, refusal to issue, restoration and modification of licenses and permits.

In order to minimize possible adverse effects to the public health, safety and welfare and the environment, the Department shall make reasonable rules and regulations establishing standards and instructions to govern weather modification operations and research and development.

In order to make accurate information available concerning weather modification operations and research and development in the State, the Department shall make reasonable rules and regulations requiring record keeping and reporting and shall establish procedures and forms for such record keeping and reporting. (P.A. 78-674, Art. I, § 6, eff. Oct. 1, 1973.)

§ 7. *Investigations*

The Department shall have the power to investigate the weather modification operations and research and development of any person holding or claiming to hold a license or a permit issued under this Act.

Duly authorized agents of the Department shall have the power to enter and inspect any place in which there is reasonable belief that weather modification operations or research and development is taking place, in which weather modification operations or research and development is in fact taking place and the premises of any person holding a permit issued under this Act. (P.A. 78-674, Art. I, § 7, eff. Oct. 1, 1973.)

§ 8. *Hearings*

Except for emergency modifications of operational permits as provided for in Section 21(b) of this Act, before suspending, revoking, refusing to renew or modifying a license or a permit, the Department shall issue a citation notifying the licensee or permittee of the time and place when and where a hearing of the matter shall be had. Such citation shall contain a statement of the reasons for the proposed action. Such citation shall be served on the licensee or permittee at least 10 days prior to the date therein set for the hearing, either by delivery of the citation personally to the licensee or permittee or by mailing it by registered mail to his last known place of business.

The Department shall hear the matter at the time and place fixed in such citation unless the licensee or permittee waives his right to a hearing. Both the Department and the licensee or permittee shall be accorded ample opportunity to present, in person or by counsel, such statements, testimony, evidence and argument as may be pertinent to the matter.

The Department may continue such hearing from time to time. If the Department shall not be sitting at the time and place fixed in the citation or at the time and place to which a hearing shall have been continued, the Department shall continue such hearing for a period not to exceed 30 days.

Any circuit court or any judge thereof, upon the application of the licensee or permittee or of the Department, may by order duly entered, require the attendance of witnesses and the production of relevant books, records, documents and instruments before the Department in any hearing relative to refusal to renew, suspension, revocation or modification of a license or a permit, and the court or judge may compel obedience to its or his order by proceedings for contempt.

In conducting any hearing, the Department or a representative designated by it may administer oaths and examine witnesses.

The Department, at its expense, shall provide a stenographer to record the testimony and preserve a record of all proceedings at the hearing of any case wherein a license or permit is revoked, suspended, not renewed or modified. The notice of hearing and all other documents in the nature of pleadings and written motions filed in the proceedings, the transcript of testimony, the report of the Board and the orders of the Department constitute the record of such proceedings. (P.A. 78-674, Art. I, § 8, eff. Oct. 1, 1973.)

§ 9. *Interstate compacts*

The Department may represent the State in matters pertaining to plans, procedures or negotiations for interstate compacts related to weather modification. (P.A. 78-674, Art. I, § 9, eff. Oct. 1, 1973.)

§ 10. *License and permit required*

Except as provided in Section 11 of this Act, no person may engage in weather modification activities:

(a) Without both a professional weather modification license issued under Section 12 of this Act and a weather modification operational permit issued under Section 18 of this Act; or

(b) In violation of any term, condition or limitation of such license or permit. (P.A. 78-674, Art. I, § 10, eff. Oct. 1, 1973.)

§ 11. Exemptions

(a) The Department may provide by rules and regulations for exemption of the following activities from the license and permit requirements of this Act:

- (1) Research and development conducted by the State, its subdivisions and agencies of the State and of its subdivisions, institutions of higher learning and bona fide research corporations;
 - (2) Activities for protection against fire, frost or fog; and
 - (3) Activities normally conducted for purposes other than inducing, increasing, decreasing or preventing hail, precipitation, or tornadoes.
- (b) Exempted activities shall be so conducted as not to interfere with weather modification operations conducted under a permit issued in accordance with this Act. (P.A. 78-674, Art. I, § 11, eff. Oct. 1, 1973.)

§ 12. Issuance of license

(a) The Department shall provide by rules and regulations the procedure and criteria for issuance of licenses. Criteria established by rules and regulations shall be consistent with the qualifications recognized by national or international professional and scientific associations concerned with weather modification and meteorology, and shall be designed to carry out the objectives and purposes of this Act.

(b) The Department, in accordance with its rules and regulations, shall issue a weather modification license to each applicant who:

- (1) Pays the license fee established by Section 13 of this Act; and
- (2) Demonstrates, to the satisfaction of the Department, competence necessary to engage in weather modification operations.

(c) If an applicant for a license does not pay the license fee established by Section 13 of this Act or does not demonstrate, to the satisfaction of the Department, competence necessary to engage in weather modification operations, the Department shall deny the application for the license. (P.A. 78-674, Art. I, § 12, Eff. Oct. 1, 1973.)

§ 13. License fee

The fee for an original license is \$100. The fee for a renewal license is \$20. (P.A. 78-674, Art. I, § 13, eff. Oct. 1, 1973.)

§ 14. Expiration date

Each original or renewal license shall expire on October 31 of each year. (P.A. 78-674, Art. I, § 14, eff. Oct. 1, 1973.)

§ 15. Renewal of license

At the expiration of the license period, the Department shall issue a renewal license to each applicant who pays the renewal license fee established by Section 13 of this Act, and who has the qualifications then necessary for issuance of an original license. (P.A. 78-674, Art. I, § 15, eff. Oct. 1, 1973.)

§ 16. Suspension, revocation, refusal to renew a license

The Department may suspend, revoke or refuse to renew a license for any one or combination of the following causes:

- (a) Incompetency;
- (b) Dishonest practice;
- (c) False or fraudulent representation in obtaining a license or permit under this Act;
- (d) Failure to comply with any of the provisions of this Act or any of the rules and regulations of the Department made under this Act; and
- (e) Aiding other persons to fail to comply with any of the provisions of this Act or any of the rules and regulations of the Department made under this Act.

(P.A. 78-674, Art. I, § 16, eff. Oct. 1, 1973.)

§ 17. Issuance of permit

(a) The Department shall provide by rules and regulations the procedure and criteria for issuance of permits. Criteria established by rules and regulations shall be designed to carry out the objectives and purposes of this Act.

(b) A person applying for a weather modification operational permit shall file with the Department an application which shall contain such information as the Department by rules and regulations may require and which in addition shall:

(1) List the name and address of the applicant;

(2) List the name and address of the person on whose behalf the operation is to be conducted;

(3) Indicate that the applicant holds, or if the applicant is an organization rather than an individual, demonstrates that the individual in control of the project holds a valid professional weather modification license issued under Section 12 of this Act;

(4) Furnish proof of financial responsibility in accordance with Section 20 of this Act; and

(5) Set forth a complete operational plan for the project which includes a specific statement of its nature and object, a map of the proposed operating area which specifies the primary target area and shows the area reasonably expected to be affected, a statement of the approximate time during which the operation is to be conducted, a list of the materials and methods to be used in conducting the operation, an emergency shut down procedure which states conditions under which operations must be suspended because of possible danger to the public health, safety and welfare or to the environment, and such other detailed information as may be required to describe the operation.

(c) The Department may give public notice by newspaper, radio or television announcement in the area of the State reasonably expected to be affected by operations conducted under a permit that it is considering an application for a permit, and may hold a public hearing for the purpose of obtaining information from the public concerning the effects of issuing or refusing to issue the permit.

(d) The Department may issue the operational permit if it determines that:

(1) The applicant holds, or if the applicant is an organization rather than an individual, demonstrates that the individual in control of the project holds a valid professional weather modification license issued under section 12 of this Act;

(2) The applicant has furnished proof of financial responsibility in accordance with Section 20 of this Act;

(3) The project is reasonably conceived to improve water quality or quantity, reduce losses from weather hazards, provide economic benefits for the people of the State, advance or enhance scientific knowledge or otherwise carry out the objectives and purposes of this Act;

(4) The project is designed to include adequate safeguards to minimize possible damage to the public health, safety or welfare or to the environment;

(5) The project will not adversely affect another operation for which a permit has been issued;

(6) The applicant has complied with the permit fee requirement established by Section 18 of this Act; and

(7) The applicant has complied with and the project conforms to such other criteria for issuance of permits as have been established by rules and regulations of the Department made under this Act.

(e) In order to carry out the objectives and purposes of this Act, the Department may condition and limit permits as to primary target area, time of the operation, materials and methods to be used in conducting the operation, emergency shut down procedure and such other operational requirements as may be established by the Department.

(f) A separate permit shall be required for each operation.

(g) The Department shall issue only one permit at a time for operations in any geographic area if 2 or more operations conducted within the conditions and limits of the permits might adversely interfere with each other. (P.A. 78-674, Art. I, § 17, eff. Oct. 1, 1973.)

§ 18. Permit fee

(a) The fee for each permit or renewal thereof shall be a minimum of \$100.

(b) If the operation will be conducted under contract and the value of the contract is more than \$10,000, the fee for the permit or renewal thereof shall be equivalent to one per cent of the value of the contract.

(c) If the operation will not be conducted under contract and the estimated costs of the operation are more than \$10,000, the fee for the permit or renewal thereof shall be equivalent to one per cent of the estimated costs of the opera-

tion. The costs of the operation shall be estimated by the Department from information given to it by the applicant for the permit or renewal thereof and such other information as may be available to the Department.

(d) The permit fee is due and payable to the Department prior to issuance of the permit or renewal thereof. (P.A. 78-674, Art. I, § 18, eff. Oct. 1, 1973.)

§ 19. *Scope of permit*

(a) A separate permit is required for each operation. When an operation is conducted under contract, a permit is required for each separate contract.

(b) Except as provided in subsection (c) of this Section, each permit or renewal permit shall expire one year from the date of its issuance.

(c) The Department may conditionally approve a project for a continuous time period in excess of one year's duration. Permits for such operations must be renewed annually. In approving the renewal of a permit for a continuous program, the Department shall review and approve the permittee's operational record, and then may issue a renewal of the permit for the operation to continue.

(d) The permittee shall confine his activities within the limits specified in the permit, except to the extent that the limits are modified by the Department. The permittee shall comply with any conditions of the permit as originally issued or as subsequently modified by the Department. (P.A. 78-674, Art. I, § 19, eff. Oct. 1, 1973.)

§ 20. *Proof of financial responsibility*

Proof of financial responsibility is made by showing to the satisfaction of the Department that the permittee has the ability to respond in damages to liability which might reasonably result from the operation for which the permit is sought. Such proof of financial responsibility may, but shall not be required to, be shown by:

(a) Presentation to the Department of proof of a prepaid noncancellable insurance policy against such liabilities in an amount set by the Department; or

(b) Filing with the Department a corporate surety bond, cash or negotiable securities in an amount approved by the Department. (P.A. 78-674, Art. I, § 20, eff. Oct. 1, 1973.)

§ 21. *Modification of permit*

(a) The Department may revise the conditions and limits of a permit if:

(1) The permittee is given notice and a reasonable opportunity for a hearing on the need for a revision in accordance with Section 8 of this Act; and

(2) It appears to the Department that a modification of the conditions and limits of a permit is necessary to protect the public health, safety and welfare or the environment.

(b) If it appears to the Department that an emergency situation exists or is impending which could endanger the public health, safety or welfare or the environment, the Department may, without prior notice or a hearing, immediately modify the conditions and limits of a permit, or order temporary suspension of the permit. The issuance of such an order shall include notice of a hearing to be held within 10 days thereafter on the question of permanently modifying the conditions and limits or continuing the suspension of the permit. Failure to comply with an order temporarily suspending an operation or modifying the conditions and limits of a permit shall be grounds for immediate revocation of the permit and of the license of the person controlling the operation.

(c) It shall be the responsibility of the permittee to notify the Department of any emergency which can reasonably be foreseen, or of any existing emergency situations which might be caused or affected by the operation. Failure by the permittee to so notify the Department of any such existing emergency, or any impending emergency which should have been foreseen, may be grounds, at the discretion of the Department, for revocation of the permit and of the license of the person controlling the operation. (P.A. 78-674, Art. I, § 21, eff. Oct. 1, 1973.)

§ 22. *Renewal of permit*

At the expiration of the permit period, the Department shall issue a renewal permit to each applicant who pays the permit fee and whose operational record

indicates that an original permit would be issuable for the operation. (P.A. 78-674, Art. I, § 22, *eff. Oct. 1, 1973.*)

§ 23. *Suspension, revocation, refusal to renew permit*

(a) The Department may suspend or revoke a permit if it appears that the permittee no longer has the qualifications necessary for the issuance of an original permit or has violated any provision of this Act or of any of the rules and regulations issued under this Act.

(b) The Department may refuse to renew a permit if it appears from the operational records and reports of the permittee that an original permit would not be issuable for the operation, or if the permittee has violated any provision of this Act or of any of the rules and regulations issued under this Act. (P.A. 78-674, Art. I, § 23, *eff. Oct. 1, 1973.*)

§ 24. *Restoration of license or permit*

(a) At any time after the suspension or revocation of a license or permit the Department may restore it to the licensee or permittee upon a finding that the requirements for issuance of an original license or permit have been met by the licensee or permittee.

(b) At any time after the refusal to renew a license or permit the Department may renew it upon a finding that the requirements for issuance of an original license or permit have been met by the licensee or permittee. (P.A. 78-674, Art. I, § 24, *eff. Oct. 1, 1973.*)

§ 25. *Review under Administrative Review Act—Venue—Costs*

(a) All final administrative decisions of the Department are subject to judicial review pursuant to the provisions of the "Administrative Review Act", approved May 8, 1945, and all amendments and modifications thereof, and the rules adopted pursuant thereto.¹ The term "administrative decision" is defined as in Section 1 of the "Administrative Review Act".²

(b) Such proceedings for judicial review shall be commenced in the circuit court of the county in which the party applying for review resides; but if such party is not a resident of this State, the venue shall be in Sangamon County.

(c) The Department shall not be required to certify any record to the circuit court or file any answer in the circuit court or otherwise appear in any court in a judicial review proceeding, unless there is filed in the court with the complaint a receipt from the Department acknowledging payment of the costs of furnishing and certifying the record. The costs shall be computed at the rate of fifty cents per page. Failure on the part of the plaintiff to file such receipt in court shall be grounds for dismissal of the action. (P.A. 78-674, Art. I, § 25, *eff. Oct. 1, 1973.*)

§ 26. *Records and reports*

(a) In order to aid in research and development of weather modification and to aid in the protection of the public health, safety and welfare and the environment, any person conducting any weather modification in Illinois or elsewhere by undertaking operations within Illinois, shall keep such records and file such reports at such time or times and in the manner and form as may be required by the rules and regulations made under this Act.

(b) Record and report forms may be developed by the Department showing the method of weather modification employed in the operation, the type of equipment used, the kind and amount of each material used, the times and places the equipment was operated, the times when there was modifiable weather but the permittee did not operate and the reasons therefor, the name and address of each individual, other than the licensee, who participates or assists in the operation, the manner in which operations do not conform to the conditions and limits of the permit as established according to Section 17(e) or as modified under Section 21, weather observations and records specified by the Department and any other necessary data the Department may require under its rules and regulations.

(c) The records and reports which are the custody of the Department and which have been filed with it under this Act or under the rules and regulations made under this Act shall be kept open for public examination as public documents. (P.A. 78-674, Art. I, § 26, *eff. Oct. 1, 1973.*)

¹ Chapter 110, § 264 et seq.

² Chapter 110, § 264.

§ 27. *State immunity*

Nothing in this Act shall be construed to impose or accept any liability or responsibility by the State, its agencies and the officers and employees thereof for any injury caused by any persons who conduct weather modification operations. (P.A. 78-674, Art. I, § 27, eff. Oct. 1, 1973.)

§ 28. *Liability*

(a) An operation conducted under the license and permit requirements of this Act is not an ultrahazardous or an abnormally dangerous activity which makes the licensee or permittee subject to liability without fault.

(b) Dissemination of materials and substances into the atmosphere by a permittee acting within the conditions and limits of his permit shall not give rise to the contention that such use of the atmosphere constitutes trespass.

(c) Except as provided in subsections (a) and (b) of this Section, and in Section 27 of this Act, nothing in this Act shall prevent any person adversely affected by a weather modification operation from recovering damages resulting from intentional harmful actions or negligent conduct by a permittee.

(d) Failure to obtain a license and permit before conducting an operation, or operational activities which knowingly constitute a violation of the conditions or limits of a permit, shall constitute negligence per se.

(e) The fact that a person holds a license or was issued a permit under this Act, or that he has complied with the rules and regulations made by the Department pursuant to this Act, is not admissible as a defense in any legal action which may be brought against him. (P.A. 78-674, Art. I, § 28, eff. Oct. 1, 1973.)

§ 29. *Penalty for violations*

Any person violating any of the provisions of this Act or of any valid rule or regulation issued under this Act is guilty of a Class B misdemeanor, and each day such violation continues constitutes a separate offense. (P.A. 78-674, Art. I, § 29, eff. Oct. 1, 1973.)

§ 30. *Suits to recover fines, penalties or fees*

All suits for the recovery of any of the fines, penalties or fees prescribed in this Act shall be prosecuted in the name of the "People of the State of Illinois", in any court having jurisdiction, and it shall be the duty of the State's Attorney of the county where such offense is committed to prosecute all persons violating the provisions of this Act upon proper complaint being made. All fines, penalties and fees collected under the provisions of this Act shall inure to the Department. (P.A. 78-674, Art. I, § 30, eff. Oct. 1, 1973.)

§ 31. *Injunction to restrain violations*

The Department may, in its discretion, in addition to the remedy set forth in the preceding Section, apply to a court having competent jurisdiction over the parties and subject matter, for a writ of injunction to restrain repetitious violations of the provisions of this Act. (P.A. 78-674, Art. I, § 31, eff. Oct. 1, 1973.)

§ 32. *Partial invalidity*

If any portion of this Act is held invalid, such invalidity shall not affect any other part of this Act which can be given effect without the invalid portion. (P.A. 78-674, Art. I, § 32, eff. Oct. 1, 1973.)

IOWA

Iowa Code Ann. §§ 361.1-361.7

CHAPTER 361. WEATHER MODIFICATION [NEW]

Sec.	
361.1	Definitions.
361.2	Modification board.
361.3	Program—contract.
361.4	Fund.
361.5	Election on question.
361.6	Budget request.
361.7	Cancellation of program.

Chapter 361, Code 1958, Township Licenses, consisting of sections 361.1 to 361.7, was repealed by Acts 1959 (58 G.A.) ch. 254, § 9.

For provisions relating to county business licenses, see § 332.23 et seq.

Provisions constituting chapter 361, Code 1973, Weather Modification, consisting of sections 361.1 to 361.7, were added by Acts 1972 (64 G.A.) ch. 1086, §§ 1 to 7.

361.1 Definitions

As used in this chapter, unless the context otherwise requires:

1. "Agricultural land" means any tract of land of ten acres or more used for agricultural or horticultural purposes.
2. "Public agency" means public agency as defined in section 28E.2.
3. "Private agency" means private agency as defined in section 28E.2. (Acts 1972 (64 G.A.) ch. 1086, § 1.)

361.2 Modification board

The county board of supervisors shall, upon receipt of a petition signed by at least one hundred owners and tenants of agricultural land located in the county, establish a weather modification board consisting of five members appointed by the board of supervisors for three-year terms, except that two members of the initial board shall be appointed for two-year terms. In the case of a vacancy, the appointment shall be made for the unexpired term. The members of the board shall organize annually by the election of a chairman and vice-chairman. Meetings shall be held at the call of the chairman or at the request of the majority of the members of the board. A majority vote of the members of the board shall be required to determine any matter relating to their duties. (Acts 1972 (64 G.A.) ch. 1086, § 2.)

361.3 Program—contract

The weather modification board may:

1. Investigate and study the feasibility of artificial weather modification for the county.
2. Develop and administer an artificial weather modification program.
3. Contract with any public or private agency as provided in chapter 28E to carry out an artificial weather modification program.
4. Request the county board of supervisors to conduct a referendum authorizing the levy and collection of a tax, not to exceed two cents per acre on agricultural land in the county, for the administration of an artificial weather modification program.
5. Accept, receive, and administer grants, funds, or gifts from public or private agencies to develop or administer an artificial weather modification program. (Acts 1972 (64 G.A.) ch. 1086, § 3.)

361.4 Fund

There is created in the office of county treasurer of each county having a weather modification board a weather modification fund. Any taxes or other funds received by the weather modification board shall be placed in the fund and used exclusively for the purpose of artificial weather modification as provided in this chapter. (Acts 1972 (64 G.A.) ch. 1086, § 4.)

361.5 Election on question

Upon request of the weather modification board, the county board of supervisors shall submit to the owners and tenants of agricultural land in the county at any general election or special election called for that purpose, the question of whether a tax not to exceed two cents per acre shall be levied annually on agricultural land. Notice of the election shall be published each week for two consecutive weeks in a newspaper of general circulation throughout the county. The notice shall include the date and time of the election and the question to be voted upon. A majority of the agricultural landowners and tenants voting shall determine the question. (Acts 1972 (64 G.A.) ch. 1086, § 5.)

361.6 Budget request

The weather modification board annually submit a budget request to the county board of supervisors. If the annual tax levy is approved as provided in section 361.5, the weather modification board shall determine the tax levy needed, not to exceed two cents per acre on agricultural land, to meet the budget request. The tax shall be levied by the board of supervisors and collected at the same time and in the same manner as other property taxes. (Acts 1972 (64 G.A.) ch. 1086, § 6.)

361.7 Cancellation of program

If a tax levy has been authorized under section 361.5, the county board of supervisors shall, upon receipt of a petition signed by at least one hundred owners and tenants of agricultural land located in the county, submit to the owners and tenants of agricultural land at any general election or special election called for that purpose the following question: "Shall the power to levy a tax for the administration of an artificial weather modification program be canceled?" Notice of the date and time of election and the question to be voted upon shall be published each week for two consecutive weeks in a newspaper or general circulation throughout the county. If a majority of the agricultural landowners and tenants voting favor the question, no further tax levy as provided in section 361.6 shall be made. (Acts 1972 (64 G.A.) ch. 1086, § 7.)

KANSAS

Kan. Stat. §§ 19-212f; 82a-1401-82a-1425

19-212f. Establishment or participation in weather modification programs; expenditures; definition of weather modification. The board of county commissioners of any county is hereby authorized to establish or participate in weather modification programs and for the purpose of paying the costs thereof are hereby authorized to expend moneys from the county general fund, moneys derived from taxes levied therefor or any other funds of the county available for such purpose and in addition to receive and expend any and all funds which may be offered or become available from federal or state grants or appropriations, private gifts, donations or bequests or from any other source. As used in this act "weather modification" means and extends to the control, alteration, amelioration of weather elements including man-caused changes in the natural precipitation process, hail suppression or modification and alteration of other weather phenomena including temperature, wind direction and velocity, and the initiating, increasing, decreasing and otherwise modifying by artificial methods precipitation in the form of rain, snow, hail, mist or fog through cloud seeding, electrification or by other means to provide immediate practical benefits. [L. 1975, ch. 74, § 2; July 1.]

ARTICLE 14.—KANSAS WEATHER MODIFICATION ACT

Cross references to related sections

Powers of boards of county commissioners, see 19-212f.

Interlocal agreements, see 12-2904.

82a-1401. Citation of act. This act may be cited as the "Kansas weather modification act." [L. 1974, ch. 321, § 1; July 1.]

82a-1402. Kansas weather modification act; definitions. As used in this act, unless the context otherwise requires: (a) "Board" means the Kansas water resources board;

(b) "Director" means the executive director of the Kansas water resources board;

(c) "Person" means and includes a natural person, a partnership, an organization, a corporation, a municipality and any department or agency of the state;

(d) "Research and development operation" or "research and development project" means an operation which is conducted solely to advance scientific and technical knowledge; and

(e) "Weather modification activity" means any operation or experimental process which has as its objective inducing change, by artificial means, in the composition, behavior, or dynamics of the atmosphere. [L. 1974, ch. 321, § 2; July 1.]

82a-1403. Same; administration of act; rules and regulations; powers of board and director. The board is hereby vested with responsibility for the implementation of this act. Within the authority granted to the board, the director shall be the chief administrative officer for carrying out the powers and duties provided for in this act. The board may adopt rules and regulations, issue licenses and permits, conduct hearings, enter into contracts for weather modification activities and to do all other things provided for in this act for the achievement of its purposes, subject to the powers and limitations contained herein. [L. 1974, ch. 321, § 3; July 1.]

82a-1404. Same; advisory committee; membership, duties and compensation. (a) The board shall appoint an advisory committee to assist the director in developing licensing standards and report forms, in conducting studies, in establishing minimum operation requirements for weather modification activities, and to advise the board and the director on such other matters, both technical and general, as the board may deem appropriate.

(b) The advisory committee shall be composed of seven (7) persons designated by the board who have the appropriate scientific, technical, legal, industrial, agricultural or water resources background to serve in an advisory capacity relative to weather modification activities and may include such other persons from the public sector as the board may deem capable of contributing assistance. Four (4) members of the advisory committee shall be actively engaged in agriculture and shall derive a major portion of their income from agriculture.

(c) Members of the advisory committee shall serve without compensation but they shall receive subsistence allowances, mileage and other expenses as provided in section 1 of 1974 House bill No. 1624 [75-3223], while attending meetings of such committee. [L. 1974, ch. 321, § 4; July 1.]

82a-1405. Same; licenses, issuance and limitations; permits, issuance and conditions; studies, hearings and investigations, research and development programs; expenditure of funds; representation of state in matters relating to weather modification. (a) At the direction of the board, the director may issue licenses for weather modification activities, as hereinafter provided for in this act but any licensee shall be limited in the exercise of activities under his license to the specified method or methods of weather modification activity within his area of expertise.

(b) At the direction of the board, the director may issue a permit for each specific weather modification project, which may be comprised of one or more weather modification activities. Every such permit shall describe (1) the geographic area within which such activities are to be carried out, (2) the geographic area to be affected, and (3) duration of the weather modification activities of the project which period may be non-continuous but which may not have a total duration exceeding one calendar year from the day of its issuance. The director shall issue a permit only after it has been established that the project, as conceived, will provide substantial benefits or that it will advance scientific knowledge. The director may ask the advisory committee to review each request for a permit and to advise him thereon.

(c) The director shall make any studies or investigations, obtain any information, and hold any hearings that he considers necessary or proper to assist him in exercising his powers or administering or enforcing the provisions of this act.

The director may by his own action, or at the request of the advisory committee, appoint a hearing officer to conduct any hearings required by this act; said hearings to be conducted under the provisions and within any limitations of rules and regulations adopted by the board.

(d) In order to assist in expanding the theoretical and practical knowledge of weather modification, the board may, to the extent that funds are available therefor, participate in and promote research and development in:

(1) The theory and development of weather modification, including those aspects relating to procedures, materials, ecological effects, and the attendant legal and social problems;

(2) The utilization of weather modification for domestic, municipal, agricultural, industrial, recreational, and other beneficial purposes;

(3) The protection of life, health, property, and the general environment.

(e) Subject to any limitations imposed by law, the board in furthering the purposes of this act may utilize available funds from the state and may accept federal grants, private gifts, and donations from any source. Except as otherwise provided by law, the board may use any such moneys:

(1) For the administration of this act;

(2) To encourage research and development projects by public or private agencies through grants, contracts, or cooperative arrangements;

(3) To contract for weather modification activities to seek relief from or to avoid droughts, hail, storms, fires, fog, or other undesirable conditions.

(f) Under the direction of the board, the director shall represent the state in matters pertaining to plans, procedures, or negotiations for cooperative agree-

ments, or intergovernmental arrangements relating to weather modification. [L. 1974, ch. 321, § 5; July 1.]

82a-1406. Same; engaging in weather modification without, or in violation of license or permit; exemption from payment of fees. (a) No person may engage in any activity for weather modification or control without a weather modification license and a weather modification permit issued by the director. No person may engage in any activity in violation of any term or condition of a license or permit issued under this act.

(b) The board, to the extent it considers exemptions appropriate and desirable, may exempt the following weather modification activities from the fee requirements of this act:

(1) Research and development operations and experiments conducted by or under authority of any state or federal department or agency, state institution of higher education, or nonprofit research organization;

(2) Laboratory research and experiments; and

(3) Activities of an emergency nature for protection of public health, safety, and welfare including but not limited to fire, frost, hail, sleet, smog, fog, and drought. [L. 1974, ch. 321, § 6; July 1.]

82a-1407. Same; license; application; requirements. The director shall issue a weather modification license to each person who: (a) Applies in writing to the board in such form as the board shall require;

(b) Pays the license fee, if applicable; and

(c) Meets at least one of the following requirements:

(1) The applicant shall demonstrate that he (or his official representative) has had at least eight years of professional experience in weather modification field research or activities, and has served for at least three years as a project director of weather modification activities;

(2) The applicant shall demonstrate that he has obtained a baccalaureate degree from a recognized institution of higher learning in engineering, mathematics, or the physical sciences and has had at least three years of experience in weather modification field research or activities; or

(3) The applicant shall demonstrate that he has obtained a baccalaureate degree from a recognized institution of higher learning in engineering, mathematics, or the physical sciences and has satisfactorily completed the equivalent of at least twenty-five (25) semester hours of meteorological studies at a recognized institution of higher learning and has had at least two years of practical experience in weather modification research or activities; and

(d) Demonstrates that he possesses the knowledge, skill, and experience necessary to conduct weather modification activities without unreasonable risk of injury to persons or property. [L. 1974, ch. 321, § 7; July 1.]

82a-1408. Same; license fee; license year; renewal, fee; deposit of fees in general fund. A license shall be issued under this act only upon payment to the board of a fee of one hundred dollars (\$100). Each license shall expire at the end of the calendar year for which it is issued.

Subject to the limitation of this act, any person licensed under the provisions of this act may, on or before January 1, each year, renew his license by payment to the board of an annual fee of one hundred dollars (\$100). The board shall remit all moneys received pursuant to this section to the state treasurer and the state treasurer shall deposit the same in the state treasury to the credit of the state general fund. [L. 1974, ch. 321, § 8; July 1.]

82a-1409. Same; license; suspension or revocation; conditions and procedures. Any license issued under this act may be suspended or revoked by the board after notice and hearing, when (1) the licensee is found to have engaged in any activity prohibited by or under this act, (2) he has practiced fraud or deceit in obtaining a license, (3) he has been negligent or guilty of incompetence in engaging in any weather modification activity, or (4) he has violated any requirement of this act. In addition to the board, any interested person may make a formal complaint to the board against any licensee. All formal complaints shall be in writing, shall be signed by the complainant, and shall specify the charges against the licensee. Upon receipt of a formal complaint, the board shall make a preliminary examination thereof, and if it determines that there are reasonable grounds to believe that the licensee has committed any of the acts for which his license may be suspended or revoked under this section, it shall set the matter for hearing, shall give the licensee concerned at least thirty (30) days written

notice prior to the time set for the hearing, and shall furnish the licensee a true and correct copy of the complaint at the time of such notice. Service upon such licensee shall be deemed to have been made when the notice and a copy of the complaint are deposited by the board in the United States mail, addressed to the licensee at the last known address shown in the records and files of the board. At any hearing before the board, any party may appear either in person or by counsel, except that the person bringing the complaint shall have the burden of proof. When authorized by a majority of the board, any member of the board shall have the authority to administer oaths to witnesses and to issue subpoenas in connection with any hearing authorized by this section. A transcript shall be kept of the hearing before the board. The costs of notice and hearing may be borne by the board or assessed at the discretion of the board. [L. 1974, ch. 321, § 9; July 1.]

82a-1410. Same; appeals to district court. Any party who deems himself aggrieved by any decision of the board may appeal to the district court as provided in K.S.A. 60-2101. [L. 1974, ch. 321, § 10; July 1.]

82a-1411. Same; permit; application; requirements; financial responsibility.

(a) The director shall issue a weather modification permit to each person who:

(1) Applies in writing to the director for a permit in such form as the director shall require;

(2) Holds a valid weather modification license issued under this act;

(3) Pays the permit fee, if applicable;

(4) Files with the director proof of ability to respond in damages for liability on account of accidents arising out of any weather modification activities to be conducted by him in an amount of not less than fifty thousand dollars (\$50,000) because of bodily injury to or death of one person resulting from any one accident and, subject to said limit for one person, in an amount of not less than one hundred thousand dollars (\$100,000) because of bodily injury to or death of two or more persons resulting from any one accident, and in an amount of not less than one hundred thousand dollars (\$100,000) because of injury to or destruction of the property of others resulting from any one accident, or in such increased amounts as the board may require hereunder upon determining that the circumstances of the particular weather modification project require additional proof of financial responsibility, except that municipalities and departments or agencies of the state shall be exempt from the requirements of this paragraph; proof of financial responsibility required hereunder may be given by a certificate of insurance or a bond or a certificate of deposit of money;

(5) Submits a complete and satisfactory operational plan for the proposed weather modification project which includes a map of the proposed operating area which specifies the primary target area and shows the area reasonably expected to be affected, the name and address of the licensee, the nature and object of the intended weather modification activities, the person or organization on whose behalf it is to be conducted, a statement showing any expected effect upon the environment, the methods that will be used in determining and evaluating the proposed weather modification project, and such other information as may be required by the director;

(6) Meets the preceding requirements for a permit and before beginning operations under the proposed weather modification project, publishes a notice of intent to engage in weather modification activities in a newspaper of general circulation in the county or counties to be affected by the proposed project. The published notice shall designate the primary target area and indicate the general area which might be affected. It shall also indicate the expected duration and intended effect and state that complete details are available on request from the licensee or the director. In accordance with information furnished by the director, the notice shall also specify a time and place for a hearing on the proposed weather modification project, which will be conducted by the board; and

(7) Furnishes to the director proof of the publication of the notice required by the foregoing provision.

(b) Before a permit is issued, the director, or a hearing officer appointed by him, shall hold the public hearing on the proposed weather modification project in a place or places within a reasonable proximity of the area expected to be affected by the proposed weather modification activities.

(c) No permit may be issued unless the director determines, based on the information provided in the operational plan for the proposed weather modification project and on the testimony and information provided at the public hearing, that:

(1) If the project is one for profit, the proposed weather modification activities are designed to provide, and are reasonably expected to provide, an economic benefit to the people of the area in which the operation will be conducted, or will benefit the people of the state of Kansas, and is scientifically and technically feasible;

(2) If the project is a scientific or research project, the proposed weather modification activities offer promise of expanding the knowledge and the technology of weather modification;

(3) The project includes adequate safeguards for the protection of property, health, safety and welfare; and

(4) The project is designed to minimize risk and maximize scientific gains or economic benefits to the people of the state.

(d) The operational plan for the proposed project shall be placed on file with the director and will be available for public inspection during regular office hours. [L. 1974, ch. 321, § 11; July 1.]

82a-1412. Same; conduct of operations under permit under supervision of licensee. Operations under weather modification permits may be executed only by or under the immediate direction and supervision of a licensee or licensees. [L. 1974, ch. 321 § 12; July 1.]

82a-1413. Same; permit fees, renewal; deposit in general fund. The fee for each weather modification permit under this act or any renewal thereof shall be one hundred dollars (\$100) and shall be paid to the board which shall remit all such moneys to the state treasurer and the state treasurer shall deposit the same in the state treasury to the credit of the state general fund. [L. 1974, ch. 321, § 13; July 1.]

82a-1414. Same; permit for calendar year; emergency. (a) A separate weather modification permit shall be required annually on a calendar year basis for each weather modification project.

(b) The director may grant a weather modification permit on an emergency basis without prior publication of any required notice in instances, of fire, frost, hail, sleet, smog, fog drought, or other emergency. In such situations, publication of notice shall be made as soon as possible but shall not be subject to the time limits specified elsewhere in this act. [L. 1974, ch. 321, § 14; July 1.]

82a-1415. Same; permit; revision, suspension or modification of terms and conditions; procedure; licensee to notify director of emergencies. (a) The director may revise, suspend, or modify the terms and conditions of a permit if:

(1) He first notifies the licensee and affords the licensee a reasonable opportunity for a hearing on the need for a revision, suspension, or modification and, after such hearing, he finds that revision, suspension, or modification is necessary to protect the health, safety, or property of any person or to protect the environment; or

(2) He finds that an emergency situation exists, or is impending, which would endanger life, property, or the environment, in which case he may, on his own initiative, without giving prior notice or conducting a hearing, immediately modify the conditions of a permit, or order the temporary suspension of the permit.

(b) Upon ordering revision, suspension or modification under paragraph (2) of subsection (a) of this section, the director shall within ten (10) days thereafter hold a hearing on the question of permanently revising, suspending, or modifying the terms and conditions of the permit and shall notify the licensee at the time of ordering the revision, suspension, or modification of the time and place that he will hear the matter. A licensee's failure to comply with an order of the director to temporarily suspend or change the authorized activity shall be grounds for immediate revocation of the permit and of the operator's license.

(c) It shall be the responsibility of the licensee conducting any weather modification activity to notify the director of any emergency that the licensee could be expected to reasonably foresee, including any existing emergency situations described in paragraph (2) of subsection (a) of this section that might in any way be caused or affected by weather modification activities. Failure by the licensee to so notify the director of any such existing emergency, or any

impending emergency that the licensee should have reasonably foreseen, may be grounds for revocation of the permit and the operator's license. [L. 1974, ch. 321, § 15; July 1.]

82a-1416. Same; licensee confined to terms and conditions of permit. When a weather modification permit has been issued, the licensee shall confine his weather modification activities within the limits of time and area specified in the permit, except to the extent that the limits are modified by the director. He shall also comply with any terms and conditions of the permit as originally issued or as subsequently revised or modified by the director. [L. 1974, ch. 321, § 16; July 1.]

82a-1417. Same; reports of activities; form and content. (a) Any person conducting weather modification activities in Kansas or operations that affect conditions within Kansas shall file reports at such time or times and in the manner and form as the board may require.

(b) The director shall develop report forms that shall provide for reporting the methods employed, the type of equipment used, the kind and amount of each material used, the times and places the equipment was operated, the name and address of each individual other than the licensee who participated or assisted in the activities, any environmental effects that have or are believed to have occurred, and any other data as the board may require. [L. 1974, ch. 321, § 17; July 1.]

82a-1418. Same; suspension or revocation of permit; refusal to renew license or issue additional permit. (a) The director shall suspend or revoke a permit if he finds that the licensee no longer meets the qualifications or conditions of the original permit or has violated any provision of this act.

(b) At the direction of the board, the director may refuse to renew the license of, or to issue another permit to, any applicant who has failed to comply with any provision of this act. [L. 1974, ch. 321, § 18; July 1.]

82a-1419. Same; suspension or revocation of license or permit; notice of hearing. (a) Except as provided in section 15 [82a-1415] of this act relating to the director, the board or the director shall not suspend or revoke a license or permit without first giving the licensee reasonable notice and a reasonable opportunity to be heard with respect to the ground for possible suspension or revocation.

(b) Hearings under this section shall be conducted by the board or the director in the manner provided for in section 9 [82a-1409] of this act. [L. 1974, ch. 321, § 19; July 1.]

82a-1420. Same; state and local officers immune from liability; issuance of permit not state endorsement. Officers and employees of the state or any department or agency thereof, and officers and employees of any county or municipality or other public agency of the state, shall be immune from liability resulting from any weather modification activity approved or conducted by them or under their authority under the provisions and limitations of this act. The issuance of a permit to conduct weather modification activities does not constitute state endorsement of any weather modification activities conducted with respect to that permit. [L. 1974, ch. 321, § 20; July 1.]

82a-1421. Same; operation without license or permit; order to cease; enforcement. The director may order any person who is found to be conducting weather modification activity without a license and permit to cease and desist from said operation. Any such order shall be enforceable in any court of competent jurisdiction. [L. 1974, ch. 321, § 21; July 1.]

82a-1422. Same; license or permit no defense in action for damages or injunctive relief. The fact that a person holds a license or a permit under this act, or that he has complied with all requirements established pursuant to this act, shall not be a defense in actions for damages or injunctive relief brought against him. [L. 1974, ch. 321, § 22; July 1.]

82a-1423. Same violations of act, misdemeanor. Any person conducting a weather modification activity without first having procured a required license and permit, or who shall knowingly make a false statement in an application for a license or permit, or who shall fail to file any report or reports as required by this act, or who shall conduct any weather modification activity after a revocation of his license or the denial, revocation, modification, or temporary suspension of his weather modification permit therefor, or who shall violate any other provisions of this act, shall be guilty of a class B misdemeanor. Each day that any such unauthorized weather modification activity is conducted shall constitute a separate offense. [L. 1974, ch. 321, § 23; July 1.]

82a-1424. Severability of act. If any word, phrase, sentence, or provision of this act is determined to be invalid, such invalidity shall not affect the other provisions of this act and they shall be given effect without the invalid provision, and to this end the provisions of this act are declared to be severable. [L. 1974, ch. 321, § 24; July 1.]

82a-1425. Participation by counties in weather modification programs; tax levy; procedure; protest petitions. The board of county commissioners of any county is hereby authorized to establish or participate in weather modification programs and for the purpose of paying the costs thereof is authorized to levy a tax of not to exceed two (2) mills upon the assessed tangible valuation of property in the county and to expend such moneys for weather modification purposes; *Provided*, In counties of this state having a population of more than one hundred eighty thousand (180,000) and not more than two hundred twenty thousand (220,000) and an assessed tangible valuation of more than three hundred fifty million (350,000,000) and not more than three hundred sixty-five million (365,000,000) shall be excluded. No such levy shall be made until a resolution authorizing the same shall be adopted by the board of county commissioners stating the specific purpose for which such levy is made, the amount of the proposed levy and the number of years such tax levy shall be made and until such resolution has been published once each week for three (3) consecutive weeks in the official county newspaper. Whereupon any such levy may be made unless a petition requesting an election upon the proposition signed by electors equal in number to not less than five percent (5%) of the qualified electors of such county is filed in the office of the county election officer within sixty (60) days following the last publication of such resolution. In the event any such petition is filed, no levy shall be made without the same having been approved by a majority of the electors of such county voting at an election called and held thereon within ninety (90) days after the last publication of such resolution or at the next general election if held within such time. Such election shall be noticed, called and held in the manner provided for by the provisions of K. S. A. 1976 Supp. 10-120. Such tax levy shall be in addition to all other tax levies authorized or limited by law and shall not be subject to nor within the limitations upon the levy of taxes imposed by K. S. A. 1976 Supp. 79-5001 to 79-5016, inclusive, and amendments thereto.

The board of county commissioners is authorized to expend any other funds of the county available for any such purpose and, in addition, to receive and expend any and all funds which may be offered or become available for any such purpose. [L. 1976, ch. 114, § 1; July 1.]

LOUISIANA

La. Rev. Stat. Ann. §§ 2201-2208

CHAPTER 25. WEATHER MODIFICATION

Sec.

- 2201. Sovereign right to use of moisture.
- 2202. Definitions.
- 2203. Necessity for license; application.
- 2204. Licenses: fees; expiration; revocation.
- 2205. Disposition of fees.
- 2206. Penalty.
- 2207. Qualifications and requirements; conditions.
- 2208. Evaluation of operations; reports.

§ 2201. *Sovereign right to use of moisture*

It is hereby declared that the state of Louisiana claims its sovereign right to the use for the best interest of its people of the moisture contained in the clouds and atmosphere within its state boundaries. (Acts 1956, No. 350, § 1.)

§ 2202. *Definitions*

The term "weather modification", as used in this Chapter, means the changing or controlling by chemical, mechanical, or physical methods the occurrence of lightning or the precipitation of rain, hail, mist, sleet, or snow.

The term "Commissioner", as used in this chapter, means the commissioner of the Louisiana State Department of Agriculture and Immigration. (Acts 1956, No. 350, §§ 2, 3.)

§ 2203. *Necessity for license; application*

Any person who engages in weather modification shall prior to engaging in such activity obtain a license from commissioner in accordance with the pro-

cedure established the commissioner. Each application for a license shall be accompanied by a fee of twenty-five dollars. (Acts 1956, No. 350, § 4.)

§ 2204. *Licenses; fees; expiration; revocation*

A license fee of one hundred dollars shall be paid by any person issued a weather modification license, in addition to the application fee provided in R.S. 37:2203. Each such license shall expire one year after the date such license is issued and shall be revocable at any time, by the Commissioner, in accordance with such procedure as the commissioner may establish. (Acts 1956, No. 350, § 5.)

§ 2205. *Disposition of fees*

The money collected from fees provided in R.S. 37:2203 and R.S. 37:2204 shall be deposited with the state treasurer to be credited to the general fund of the state of Louisiana. (Acts 1956, No. 350, § 6.)

§ 2206. *Penalty*

Any person engaging in weather modification without a license shall be guilty of a misdemeanor and shall be fined not exceeding five hundred dollars for each separate offense. (Acts 1956, No. 350, § 7.)

§ 2207. *Qualifications and requirements; conditions*

The commissioner shall determine the qualifications and requirements which applicants must meet in order to receive a license to engage in weather modification and shall establish the conditions under which weather modification operations may be carried out. (Acts 1956, No. 350, § 8.)

§ 2208. *Evaluation of operations; reports*

The commissioner shall evaluate each weather modification operation and publish the results of such evaluation in an annual report. (Acts 1956, No. 350, § 9.)

MINNESOTA

Minn. Stat. Ann. §§ 42.01-42.14

1977 SESSION—WEATHER MODIFICATION

CHAPTER 426

S. F. No. 73 [Coded]

AN ACT relating to weather modification; prescribing powers and duties for the commissioner of agriculture; providing for weather modification research; requiring the obtaining of licenses and permits prior to engaging in weather modification; prohibiting the use of cloud seeding apparatus located on the ground; prescribing penalties; appropriating money

Be it enacted by the Legislature of the State of Minnesota:

SECTION 1

42.01 *Policy*

The legislature finds that it is necessary for the state to regulate weather modification to protect its citizens, but nothing in sections 42.01 to 42.14 shall be construed to encourage or promote weather modification.

SECTION 2

42.02 *Definitions*

Subdivision 1. For the purposes of sections 42.01 to 42.14, the terms defined in this section have the meanings given them.

Subdivision 2. "Weather modification" means any activity performed in connection with placing or attempting to place any substance in the atmosphere or clouds within the atmosphere, including fog, with the intention of and for the purpose of producing artificial changes in the composition, motions, and resulting behavior of the atmosphere or clouds within the atmosphere, including fog.

Subdivision 3. "Person" means any person, firm, association, organization, partnership, company, corporation, private or public, county, city, trust or other public agency.

Subdivision 4. "Operation" means the performance of weather modification activities entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding one year.

Subdivision 5. "Commissioner" means the commissioner of agriculture.

SECTION 3

42.03 Sovereign right claimed by state

It is declared that the state of Minnesota claims its sovereign right to use for the best interest of its residents the moisture contained in the clouds and atmosphere within its sovereign state boundaries.

SECTION 4

42.04 Commissioner; powers and duties

Subdivision 1. Powers. The commissioner of agriculture may :

(a) pursuant to Minnesota Statutes, Chapter 15, adopt rules necessary to implement the license and permit program established pursuant to sections 42.01 to 42.14 ;

(b) enter into contracts or memoranda of agreement and do all things necessary to cooperate with the United States government, and to qualify for, accept and disburse any private grant intended for the administration of sections 42.01 to 42.14 ;

(c) cooperate with other states to jointly carry out research and planning in weather modification ;

(d) advise persons, groups, and local units of government on weather modification and distribute informational material relating to weather modification and review and comment on all county programs of weather modification ; and

(e) carry on research related to weather modification including evaluation of the effects of weather modification activities within the state by staff members, or by contract. Evaluation of weather modification programs shall, if practical and within limits of available funding, including components of economic and environmental analysis which delineate the economic and environmental implications of the programs.

Subdivision 2. Duties. The commissioner of agriculture shall :

(a) utilize to the extent possible the facilities and technical resources of public and private institutions in the state ;

(b) by rule adopted pursuant to Minnesota Statutes, Chapter 15, require persons engaged in weather modification to submit reports of their activities and operations and any other information deemed necessary ;

(c) on or before January 15 of each year, submit a report to the legislature and governor describing the weather modification operations within the state during the preceding year and the social, economic and environmental impact of the operations. The report shall also include recommendations for legislative action and any other information useful to the legislature.

SECTION 5

42.05 County programs of weather modifications

Counties may, only after approval of the commissioner and subject to the requirements of sections 42.01 to 42.14, conduct programs of weather modification and expend money therefor. At least two weeks published notice in a newspaper of general circulation within the county must be given before the program of weather modification may begin. If, within 30 days of a decision by a county to expend funds for weather modification, a petition signed by voters in the county equal in number to ten percent of the votes cast in the county in the last general election or 2,000 voters, whichever is less, requesting a referendum on the proposed expenditure is filed with the county auditor, the funds shall not be expended until it has been submitted to the voters at a general or special election and a majority of votes cast on the question of the expenditure of the funds are affirmative. No program may be conducted within the county without prior approval by the county board.

SECTION 6

42.06 Licenses

Subdivision 1. No person shall engage in weather modification without a license issued by the commissioner. Applications for weather modification licenses shall be on forms prescribed and furnished by the commissioner. The applicant shall pay a fee of \$100. The license shall be valid for one year.

The commissioner may waive the license fee in situations he deems appropriate.

Subdivision 2. The commissioner shall issue licenses only to applicants who demonstrate good character, adequate education and sufficient competence in the field of meteorology and cloud physics to engage in weather modification. At a minimum, each applicant shall meet at least one of the following:

(1) demonstrate that he has at least eight years of experience at the professional level in weather modification field research or operations, at least three of these years as a professional director; or

(2) has obtained a baccalaureate degree in engineering, mathematics, or the physical sciences plus three years experience in weather modification field research or operations; or

(3) has obtained a baccalaureate degree in meteorology, or a degree in engineering or the physical sciences which includes, or is in addition to, the equivalent of at least 25 semester hours of meteorological course work and two years practical experience in weather modification operations or research.

If the applicant is an organization, the competence must be demonstrated by the individuals who are to supervise and conduct the weather modification

Subdivision 3. The commissioner may renew a license annually if the applicant by the individuals who are to supervise and conduct the weather modification. fee of \$100.

Subdivision 4. The moneys collected as fees shall be deposited with the state treasurer in the general fund.

SECTION 7

42.07 Suspension; revocation; refusal to renew license

The commissioner shall, subject to the provisions of chapter 15, suspend, revoke or refuse to renew a license for any one or any combination of the following causes:

(1) Incompetency;

(2) Dishonest practice;

(3) False or fraudulent representation in obtaining a license or permit under sections 42.01 to 42.14 or rules promulgated thereunder;

(4) Failure to comply with any of the provisions of sections 42.01 to 42.14 or of rules promulgated thereunder; or

(5) Aiding other persons who fail to comply with any of the provisions of sections 42.01 to 42.14 or rules promulgated thereunder.

SECTION 8

42.08 Investigation

The commissioner may investigate any operation or research and development activities of any person applying for a license and of any person holding or claiming to hold a license or permit.

SECTION 9

42.09 Permits

Subdivision 1. No person shall conduct an operation without a permit issued by the commissioner. Applications for permits shall be on forms prescribed and furnished by the commissioner. Permits shall be issued only to applicants who hold a valid weather modification license, pay a fee of \$100 and furnish proof of financial responsibility pursuant to subdivision 2. Prior to conducting an operation, the permittee shall publish notice of the operation as the commissioner shall require and shall give written notice to the county boards of the counties over which the operation is to be conducted and counties contiguous thereto. The permit shall be valid for one year or until the operation terminates, whichever first occurs.

Subdivision 2. The applicant shall demonstrate to the satisfaction of the commissioner that he has the ability to respond to damages for liability which might reasonably result from the operation for which the permit is sought.

Subdivision 3. The fees collected for permits shall be deposited with the state treasurer in the general fund.

Subdivision 4. To the extent the commissioner deems necessary, emergency weather modification operations for the purpose of controlling fire, frost, sleet, hail, fog, or wind shall be exempt from the permit requirements.

Subdivision 5. The commissioner may renew a permit annually if the applicant has the qualifications necessary for issuance of an original permit and pays a fee of \$100.

Subdivision 6. No permit shall be issued to use a cloud seeding apparatus which emits cloud seeding material into the air when located on or in contact with the ground.

Subdivision 7. Before a permit is issued, the commissioner may hold an informal hearing on the permit, at a location within the same geographic area as the proposed operation will be conducted.

Subdivision 8. No more than one weather modification permit shall be issued for a given geographic area.

Subdivision 9. The applicant must submit a complete operational plan for each proposed project prepared by the licensee who shall conduct the operation, which shall include, but not be limited to:

(a) a specific statement of the nature and objectives of the intended operation,

(b) a map of the proposed operating area which specifies the primary target area and shows the area reasonably expected to be affected and a rain gauge system for both seeded and downwind areas,

(c) an estimate of the amount of cloud seeding material expected to be placed in the clouds,

(d) a statement of the types of clouds to be seeded and identification of a procedure for random selection of at least a portion of the clouds to be seeded during the operation,

(f) the name and address of the licensee,

(g) the person or organization on whose behalf it is to be conducted,

(h) a statement showing any expected effect upon the environment and results of weather modification operations, and methods of determining and properly evaluating that operation, and any other detailed information as may be required to describe the operation and its proposed method of evaluation.

SECTION 10

42.10 Suspension; revocation and refusal to renew permit

Subdivision 1. The commissioner shall, subject to chapter 15, suspend or revoke a permit if it appears that the permittee no longer has the qualifications necessary for the issuance of an original permit or has violated any provision of sections 42.01 to 42.14 or of any rules promulgated thereunder.

Subdivision 2. The commissioner shall, subject to chapter 15, refuse to renew a permit if it appears from the operational records and reports of the permittee that an original permit would not be issuable for the operation, or if the permittee has violated any provision of sections 42.01 to 42.14 or of any rules promulgated thereunder.

SECTION 11

42.11 Modification of permit

Subdivision 1. The commissioner may revise the conditions and limits of a permit if:

(a) The permittee is given notice and a hearing, pursuant to chapter 15, on whether there is a need for the revision and the commissioner finds that a modification of the conditions and limits of a permit is necessary to protect the public health, safety or welfare, or the environment.

(b) If it appears to the commissioner that an emergency situation exists or is impending which could endanger the public safety, health or welfare, or the environment, the commissioner may, without prior notice or a hearing, immediately modify the conditions and limits of a permit, or order temporary suspension of the permit. The order shall include notice of a hearing to be held pursuant to chapter 15 within ten days thereafter on the question of permanently modifying the conditions and limits, continuing the suspension of the permit, removing the changes or lifting the suspension.

Subdivision 2. Failure to comply with an order temporarily suspending an operation or modifying the conditions and limits of a permit shall be grounds for immediate revocation of the permit and of the license of the person controlling the operation.

Subdivision 3. The permittee shall notify the commissioner of any emergency which can reasonably be foreseen, or of any existing emergency situations

which might be caused or affected by the operation. Failure by the permittee to so notify the commissioner may be grounds, at the discretion of the commissioner, for revocation of the permit and of the license of the person controlling the operation.

SECTION 12

42.12 Penalty for violations

Any person violating any of the provisions of sections 42.01 to 42.14 or of any rule promulgated thereunder is guilty of a misdemeanor, and each day such violation continues constitutes a separate offense.

SECTION 13

42.13 Legal action

Other than in legal actions charging failure to obtain a license and permit, the fact that a person holds a license or was issued a permit under sections 42.01 to 42.14, or that a person has complied with the rules made by the commissioner pursuant to sections 42.01 to 42.14, is not admissible as a defense in any legal action which may be brought under this section against such person.

SECTION 14

42.14 Injunction

The commissioner may, in addition to the other remedies provided in sections 42.01 to 42.14 apply to a district court having venue and jurisdiction, for an injunction to restrain repetitious violations of the provisions of sections 42.01 to 42.14 and of any rule promulgated thereunder.

SECTION 15. APPROPRIATION

There is appropriated from the general fund to the commissioner the sum of \$75,000 for the biennium ending June 30, 1979 for administrative expenses incurred in fulfilling the provisions of this act.

SECTION 16. EFFECTIVE DATE

Section 5 of this act is effective on the day following its final enactment. Sections 1 to 4 and sections 6 to 16 are effective January 1, 1978.

Approved June 2, 1977.

MONTANA

Mont. Rev. Code Ann. §§ 89-310-89-331

CHAPTER 3—WEATHER MODIFICATION ACTIVITIES

Sec.

- 89-310. Definitions.
- 89-312. Acquisition of property—acceptance and expenditure of funds—research and development authority.
- 89-312.1. Standards for research in weather modification control.
- 89-313. License and permit required for weather modification and control.
- 89-314. Department to review applications—exemptions.
- 89-315. Issuance of license—qualifications of licensees.
- 89-316. Term of license—renewal.
- 89-317. License fee.
- 89-318. Issuance of permits—requirements for permit—hearing.
- 89-319. Separate permit for each operation.
- 89-320. Notice of intention to apply for permit—activities limited by terms of permit.
- 89-321. Contents of notice of intention.
- 89-322. Publication of notice of intention.
- 89-323. Proof of financial responsibility by applicant.
- 89-324. Permit fee—time of payment.
- 89-325. Earmarked revenue fund.
- 89-326. Records of operations maintained by licensees.
- 89-327. Reports of operations.
- 89-328. Records and reports open to public.
- 89-329. Termination of licenses and permits by board.
- 89-330. State and agents not liable for acts of private persons.
- 89-331. Violation as misdemeanor—continuing violations.
- 89-301 to 89-309. (349.54 to 349.62) Repealed.

REPEAL

These sections (Secs. 1 to 9, Ch. 176, L. 1935), relating to development of state resources by the state planning board, were repealed by Sec. 10, Ch. 19, Laws 1967.

89-310. *Definitions.* Unless the context requires otherwise, in this chapter:

(1) "Weather modification and control" means changing or controlling, or attempting to change or control, by artificial methods, the natural development of atmospheric cloud forms or precipitation forms which occur in the troposphere.

(2) "Research and development" means theoretical analysis, exploration and experimentation, and the extension of investigative findings and theories of a scientific and technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials, and processes.

(3) "Department" means the department of natural resources and conservation provided for in Title 82A, chapter 15.

(4) "Board" means the board of natural resources and conservation provided for in section 82A-1509.

89-312. *Acquisition of property—acceptance and expenditure of funds—research and development authority.* In addition to any other acts authorized by law the department may:

(1) acquire materials, equipment and facilities as are necessary to perform its duties under this act;

(2) receive any funds which may be offered or become available from federal grants or appropriations, private gifts, donations, bequests, or any other source and unless their use is restricted, may expend the funds for the administration of this act;

(3) make such studies and investigations, and obtain such information as the department may deem necessary in exercising its authority in the administration or enforcement of this act;

(4) co-operate with public or private agencies in the performance of the department's functions or duties and in furtherance of the purposes of this act;

(5) represent the state in any and all matters pertaining to plans, procedures or negotiations for interstate compacts relating to weather modification and control;

(6) enter into co-operative agreements with the United States government or any of its agencies, or with the various counties and cities of this state or with any private or public agencies for conducting weather modification or cloud seeding operations;

(7) act for and represent the state and the counties, cities and private or public agencies in contracting with private concerns for the performance of weather modifications or cloud seeding operations; and

(8) conduct and may make arrangements including contracts and agreements for the conduct of, research and development activities relating to:

(a) the identification and evaluation of meteorological, environmental, ecological, agricultural, economic, hydrological and sociological impacts of weather modification in Montana;

(b) the theory and development of methods of weather modification and control, including processes, materials and devices relating thereto;

(c) the utilization of weather modification and control for agricultural, industrial, commercial, recreational and other purposes;

(d) the protection of life and property during research and operational activities.

89-312.1. *Standards for research in weather modification control.* The board may establish by rule standards and instruction to govern the carrying out of research and development or projects in weather modification and control as it deems necessary or desirable to minimize danger to health, safety, welfare or property.

89-313. *License and permit required for weather modification and control.* No person shall engage in activities for weather modification and control except under, and in accordance with, a license and a permit issued by the board authorizing such activities.

89-314. *Department to review applications—exemptions.* The department shall review all applications for weather modification activities, and the board may provide by rule for exempting from the license and permit requirements of this act:

(1) research, development, and experiments by state and federal agencies, institutions of higher learning and bona fide nonprofit research organizations and their agents;

(2) laboratory research and experiments;

(3) activities of an emergency character for protection against fire, frost, sleet, or fog; and

(4) activities normally engaged in for purposes other than those of inducing, increasing, decreasing, or preventing precipitation or hail.

89-315. *Issuance of license—qualifications of licensees.* The license to engage in the field of meteorology to the satisfaction of the board. If the applicant is an individual and subject to conditions the board may by rule establish to effectuate the provisions of this act, to applicants who demonstrate competence in the field of meteorology to the satisfaction of the board. If the applicant is an organization, these requirements must be met by the individual who will be in charge of the operation for the applicant.

89-316. *Term of license—renewal.* The license shall be issued for a period to expire at the end of the calendar year in which it is issued and, if the licensee possesses the qualifications necessary for the issuance of a new license, shall upon application be renewed at the expiration of the period.

89-317. *License fee.* A license shall be issued or renewed only upon the payment to the department of one hundred dollars (\$100) for the license or renewal.

89-318. *Issuance of permits—requirements for permit—hearing.* (1) The permits shall be issued in accordance with procedures and subject to conditions the board may by rule establish to effectuate this chapter, only:

(a) if the applicant is licensed pursuant to this chapter;

(b) if sufficient notice of intention is published and proof of publication is filed as required in section 89-322;

(c) if an applicant furnishes proof of financial responsibility in an amount to be determined by the board as required in section 89-323;

(d) if the fee for the permit is paid as required in section 89-324;

(e) if the weather modification and control activities to be conducted are determined by the board to be for the general welfare and the public good.

(2) The department shall hold a public hearing in the area to be affected by the issuance of the permit, if the board determines that a hearing is necessary. The department may in its discretion assess the permit applicant for the costs incurred by the department in holding the hearing.

89-319. *Separate permit for each operation.* "Operation" means the performance of weather modification and control activities entered into for the purpose of producing or attempting to produce, a certain modifying effect within one (1) geographical area over one continuing time interval not exceeding one (1) year.

89-320. *Notice of intention to apply for permit—activities limited by terms of permit.* Before undertaking any weather modification and control activities, the applicant for a permit shall file with the department, and also have published, a notice of intention. If a permit is issued, the holder of the permit shall confine his activities to the time and area limits set forth in the notice of intention, unless modified by the board. His activities shall conform to any conditions imposed by the board. The permit may not be sold or transferred.

89-321. *Contents of notice of intention.* The notice of intention shall set forth at least the following:

(1) the name and address of the applicant;

(2) the nature, purpose, and objective of the intended operation and the person or organization on whose behalf it is to be conducted;

(3) the area in which, and the approximate time during which, the operation will be conducted;

(4) the area which is intended to be affected by the operation;

(5) the materials and methods to be used in conducting the operation.

(History: En. Sec. 12, Ch. 20, L. 1967.)

89-322. *Publication of notice of intention.* (1) The applicant shall have notice of intention, or that portion thereof including the items specified in section 89-321, published at least once a week for two (2) consecutive weeks in a newspaper having a general circulation and published within any county in which the operation is to be conducted and in which the affected area is located, or, if the operation is to be conducted in more than one (1) county or if the affected area is located in more than one (1) county or is located in a county other than the one in which the operation is to be conducted, then in newspapers having a general circulation and published within each of the counties.

(2) Proof of publication, made in the manner provided by law, shall be filed by the applicant with the department sooner than the sixteenth day after the date of the last publication of the notice.

89-323. *Proof of financial responsibility by applicant.* Proof of financial responsibility may be furnished by an applicant by his showing, to the satisfaction of the board, ability to respond in damages for liability which might reasonably be attached to, or result from, his weather modification and control activities.

(History: En. Sec. 14, Ch. 20, L. 1967.)

89-324. *Permit fee—time of payment.* The fee to be paid by each applicant for a permit shall be equivalent to one per cent (1%) of the estimated cost of such operation, the estimated cost to be computed by the department from the evidence available to it. The fee is due and payable to the department as of the date of issuance of the permit by the board; however, if the applicant is able to give satisfactory security for the payment of the balance he may be permitted to commence the operation, and a permit may be issued therefor, upon the payment of not less than fifty per cent (50%) of the fee. The balance due shall be paid within three (3) months from the date of termination of the operation as prescribed in the permit.

89-325. *Earmarked revenue fund.* All license and permit fees and fines collected under this chapter shall be deposited in the earmarked revenue fund for use by the department in the administration of this chapter.

89-326. *Records of operations maintained by licensees.* Every licensee shall keep and maintain a record of all operations conducted by him under his license and each permit, showing:

- (1) The method employed;
- (2) Type of equipment used;
- (3) Kinds and amounts of material used;
- (4) Times and places of operation of the equipment;
- (5) Names and addresses of all individuals participating or assisting in the operation;
- (6) Any other general information as the department may require.

89-327. *Reports of operations.* The department shall require written reports, in a manner as it provides, of each operation for which a permit is issued. The department shall also require reports from any organization that is exempt from license and permit requirements as provided in section 89-314.

89-328. *Records and reports open to public.* The records and reports in the custody of the department shall be open for public examination.

89-329. *Termination of licenses and permits by board.* After notice to the licensee and a reasonable opportunity for a hearing, the board may modify, suspend, revoke, or refuse to renew, any license or permit issued if it appears that the licensee no longer possesses the qualifications necessary or if it appears that the licensee has violated any of the provisions of this act; or in the case of a modification, that it is necessary for the protection of the health or the property of any person.

(History: En. Sec. 20, Ch. 20, L. 1967.)

89-330. *State and agents not liable for acts of private persons.* Nothing in this act shall be construed to impose or accept any liability or responsibility on the part of the state, the board, the department or any state officials or employees for any weather modification and control activities of any private person or group.

89-331. *Violation as misdemeanor—continuing violations.* A person violating any provision of this act is guilty of a misdemeanor, and a continuing violation is punishable as a separate offense for each day during which it occurs.

NEBRASKA

Neb. Rev. Stat. §§ 2-2401—2-2449; 81-829.45

ARTICLE 24—WEATHER CONTROL

(a) Weather Control Commission

Sec.

2-2401. Weather control; declaration of policy.

2-2402. Weather control; terms, defined.

2-2403. Weather Control Commission; administration of act; Department of Agriculture.

2-2404. Weather Control Commission; establishment; composition; appointment; term; no salary; expenses.

2-2405. Weather Control Commission; duties.

2-2406. Weather control; modification activities; license; issuance; expiration; revocation.

2-2407. Weather control; artificial precipitation; application; license; fees; payment to State Treasurer; credited to General Fund.

2-2408. Weather Control Commission; cooperation with other agencies.

2-2409. Weather control; engaging in artificial weather modification without license; violation; penalty.

(b) Weather Control Districts

Sec.

- 2-2410 to 2-2427. Repealed. Laws 1959, c. 9, § 24.
 2-2428. Weather control districts; authorization.
 2-2429. Weather control districts; initiation; petition; signatures required.
 2-2430. Weather control districts; petition; contents.
 2-2431. Weather control districts; examination of petition; order for hearing; notice.
 2-2432. Weather control districts; hearing; change of boundaries.
 2-2433. Weather control districts; hearing; order; appeal.
 2-2434. Weather control districts; Secretary of State; election; fix date.
 2-2435. Weather control districts; notice to election commissioner or county clerk; statement of question to be submitted.
 2-2436. Weather control districts; election commissioner or county clerk; notice of election; publication.
 2-2437. Weather control district; election; how conducted; certification of results; resubmission of question.
 2-2438. Weather control district; body politic; sue and be sued; directors not liable for debts.
 2-2439. Weather control district; board of directors; oath; bond; vacancies.
 2-2440. Weather control district; board of directors; election of successors; no filing fee required.
 2-2441. Weather control district; board of directors; no compensation; expenses.
 2-2442. Weather control district; officers; election; books; records; audit.
 2-2443. Weather control district; board of directors; general powers.
 2-2444. Weather control district; taxes; levy; limit of levy; certification; collection.
 2-2445. Weather control district; warrants; issuance; payment; registration; interest.
 2-2446. Weather control district; program for weather control; contact; seeding outside of boundaries of district; violation; penalty.
 2-2447. Weather control district; dissolution of district; election; how conducted; disposal of funds; debts; tax; levy.
 2-2448. Weather control district; act; how cited.
 2-2449. Weather control district; formed under prior act; validation.

(a) Weather Control Commission

2-2401. *Weather control; declaration of policy.* (1) It is hereby declared that the State of Nebraska claims its sovereign right to the use, for the best interests of its residents, of the moisture contained in the clouds and atmosphere within its sovereign state boundaries.

(2) While weather modification is at present a reality, the ultimate extent to which it may be utilized is speculative. The application of such measures should have proper safeguards and supply sufficient data and accurate information in order to protect life, property and the public interest.

Source: Laws 1957, c. 7, § 1, p. 101.

2-2402. *Weather control; terms, defined.* When used in sections 2-2401 to 2-2409, unless the context otherwise requires:

(1) Commission shall mean the Weather Control Commission created by sections 2-2401 to 2-2409;

(2) Department shall mean the Department of Agriculture;

(3) Experimentation and research and development, shall mean theoretical exploration and experimentation and the extension of investigative findings and theories of a scientific or technical nature in the practical application for experimental and demonstrative purposes, including the experimental producing and testing of model devices, equipment, materials, and processes; and

(4) Weather modification shall mean initiating, changing, or controlling the course or effects of the forces, measures, and other factors constituting weather phenomena, including temperature, wind direction and velocity, and the inducing, increasing, decreasing, and preventing by artificial methods, of precipitation in the form of rain, snow, hail, sleet, mist, or fog.

Source: Laws 1957, c. 7, § 2, p. 101.

2-2403. *Weather Control Commission; administration of act; Department of Agriculture.* The department shall administer and enforce the provisions of sections 2-2401 to 2-2409 and shall have and may exercise any or all of the administrative powers conferred hereinafter by sections 2-2401 to 2-2409.

Source: Laws 1957, c. 7, § 3, p. 101.

2-2404. *Weather Control Commission; establishment; composition; appointment; term; no salary; expenses.* There is hereby established a Weather Control Commission, composed of the Director of Agriculture, the Dean of the College of Agriculture of the University of Nebraska, the Director of the Conservation and Survey Division of the University of Nebraska, the head of the physics department of the University of Nebraska, and four additional members, interested in weather modification, who shall be appointed annually by the Governor for a one-year term commencing January 1. The members of the commission

shall serve without salary, but shall be reimbursed for their actual and necessary expenses while in the performance of their duties.

Source: Laws 1957, c. 7, § 4, p. 102.

2-2405. *Weather Control Commission; duties.* The Commission shall perform the following duties:

(1) Elect annually from its membership a chairman, vice-chairman, and secretary;

(2) Determine the procedures, requirements, conditions, and professional standards under which licenses to applicants to conduct artificial weather modification operations may be issued;

(3) Determine who shall be issued a license, and make recommendations to the department which shall issue the license;

(4) Approve the areas in which each operator is to work; and

(5) The commission, in order to carry into effect the provisions of sections 2-2401 to 2-2409, is authorized and empowered: (a) To promulgate and enforce such rules and regulations as may be deemed proper and necessary; (b) to appoint a qualified individual, organization, or institution to evaluate and publish the effects of all operations conducted in the state, and employ such clerical help as is necessary; (c) to recommend to the department the revocation of licenses, for cause, if, after holding hearing, they so determine; (d) to enter into any contracts or memoranda of agreement as are necessary; and (e) to authorize the department to expend such funds as may be made available to it.

Source: Laws 1957, c. 7, § 5, p. 102.

2-2406. *Weather control; modification activities; license; issuance; expiration; revocation.* (1) It shall be unlawful for any private person or persons, corporation, institution, or individual group to engage in activities for artificial weather modification except under and in accordance with a license issued by the department. The department shall issue such license only upon the recommendation of the Weather Control Commission.

(2) Each such license shall expire on December 31 of each year and shall be revocable at any time prior to such date by the department upon recommendation of the commission, in accordance with such procedure as the commission may establish.

Source: Laws 1957, c. 7, § 6, p. 103.

2-2407. *Weather control; artificial precipitation; application; license; fees; payment to State Treasurer; credited to General Fund.*

(1) Any person desiring to cause, or attempting to cause, condensation of precipitation of rain, snow, moisture, or water in any form contained in the atmosphere, or who shall prevent or attempt to prevent by artificial means the natural condensation or precipitation of rain, snow, moisture, or water in any form contained in the atmosphere shall make application to the department in writing, on forms supplied by the department, to do so. Each application shall be accompanied by a fee of fifty dollars.

(2) Any person issued a license to do any of the acts specified in subsection (1) of this section shall pay a fee of two hundred dollars.

(3) No fee shall be charged for experimental or research work.

(4) The money collected from such fees shall be deposited with the state treasury and by the State Treasurer credited to the General Fund.

Source: Laws 1957, c. 7, § 7, p. 103; Laws 1965, c. 8, § 6, p. 91

2-2408. *Weather Control Commission; cooperation with other agencies.* The commission shall cooperate with the federal government and its agents and contractors, and with other states, in the conduct of artificial weather modification operations.

Source: Laws 1957, c. 7, § 8, p. 104.

2-2408. *Weather Control Commission; cooperation with other agencies. The license; violation; penalty.* Any private person engaging in any type of artificial weather modification without having first procured a license as required by sections 2-2401 to 2-2409 shall be guilty of a misdemeanor and shall, upon conviction thereof, be fined not less than three hundred dollars nor more than eight hundred dollars.

Source: Laws 1957, c. 7, § 9, p. 104.

(b) Weather Control Districts

2-2410 to 2-2427. *Repealed.* Laws 1959, c. 9, § 24.

Weather Control Act of 1957 was unconstitutional as unlawful delegation of legislative powers. *Summerville v. North Platte Valley Weather Control Dist.*, 170 Neb. 46, 101 N.W. 2d 748.

2-2428. *Weather control districts; authorization.* Weather control districts may be formed in the manner, and having the power, provided in section 2-2428 to 2-2449.

Source: Laws 1959, c. 9, § 1, p. 107.

2-2429. *Weather control districts; initiation; petition; signatures required.* Proceedings for the establishment of a weather control district may be initiated only by the filing of a petition with the Department of Agriculture. The petition shall be signed by not less than twelve resident owners of land in each of a majority of the precincts lying wholly or partly within the proposed district.

Source: Laws 1959, c. 9, § 2, p. 107.

2-2430. *Weather control districts; petition; contents.* (1) The petition referred to in section 2-2429 shall set forth:

(a) The proposed name of the district;

(b) A description of the territory proposed to be included in the district, together with the proposed boundaries of such district and the divisions thereof for the purpose of election of directors; a map showing such boundaries; and that property within the proposed district will be benefited by the organization of such district;

(c) A recommendation as to the number and terms of directors that the district shall have if formed, together with the name, address, terms of office, and division to be represented of each of the proposed directors, who shall serve until their successors are elected and qualified, designating their terms so that not more than one-third shall terminate every two years;

(d) Where the offices of such proposed district are to be maintained; and

(e) A prayer that the organization of the district be submitted to a vote of the electors who own taxable property except intangible property within such district.

(2) No petition for the organization of a district under sections 2-2428 to 2-2449 with the requisite signatures shall be declared null and void on account of minor defects, but the department may at any time, prior to final determination of the sufficiency thereof, permit the petition to be amended in form and substance to conform to the facts. Several similar petitions or duplicate copies of the same petition for the organization of the same district may be filed and shall together be regarded as one petition. All petitions filed prior to the determination of the sufficiency of such petition, shall be considered as though filed with the first petition placed on file.

Source: Laws 1959, c. 9, § 3, p. 108.

2-2431. *Weather control districts; examination of petition; order for hearing; notice.* The Department of Agriculture shall examine the petition and if it finds that the same bears the requisite number of signatures and otherwise meets the requirements of sections 2-2428 to 2-2449, it shall fix a time and place for hearing upon such petition and cause notice thereof to be given to all persons having any interest in the organization of the proposed district by publication in each of the counties lying wholly or partly within the proposed district once each week for two consecutive weeks in a legal newspaper or newspapers of general circulation in such counties. Such notice shall state (1) the fact of filing of the petition; (2) in summary form, the information required by subsection (1) of section 2-2430 to be included in the petition; (3) the purpose of the formation of such proposed district; (4) the time and place of hearing such petition; and (5) the purpose of such hearing. Such hearing shall be held at such time and place as designated by the department, not less than twenty days nor more than forty days after the filing of the petition.

Source: Laws 1959, c. 9, § 4, p. 109.

2-2432. *Weather control districts; hearing; change of boundaries.* At the time of the hearing, the Department of Agriculture shall receive any competent and relevant evidence which may be produced by any person interested in the organization of such district in support of or against the petition. If the department finds that the boundaries proposed by the petitioners should be changed, it shall change the same and fix the boundaries where the same, in the judgment of the department, should be fixed with a view to doing justice and equity to all persons; *Provided*, that if the department deems it proper to include in the district any territory not included in the boundaries proposed by the petitioners, it shall first cause notice of its intention to do so to be mailed to each owner of land within the territory proposed to be included. Such notice shall describe the territory so proposed to be included in the proposed district and fix a time

and place, not less than one week nor more than three weeks from the date of mailing thereof, when all persons interested may appear and be heard.

Source: Laws 1959, c. 9, § 5, p. 109.

2-2433. *Weather control districts; hearing order; appeal.* If the Department of Agriculture determines that the organization of such district would be desirable and necessary in the interest of the public welfare, it shall within ten days after the final hearing enter an order (1) approving the petition and amendments thereto, if made; and (2) fixing the boundaries of the proposed district and the divisions thereof for the purpose of election of directors, which order shall be deemed a final order for purposes of review to the district court on appeal. Any person owning taxable property, except intangible property, within the proposed district aggrieved by the order of the department approving the petition or fixing the boundaries, may appeal from such order to the district court of the county wherein the office of the district is maintained. The procedure for and upon such appeal shall be nearly as possible the same as is provided for appeals from final orders on claims presented to the county board of such county.

Source: Laws 1959, c. 9, § 6, p. 110.

2-2434. *Weather control districts; Secretary of State; election; fix date.* If no appeal is taken from the order of the Department of Agriculture, or upon final determination by the court, the department shall deliver to the Secretary of State a copy of the order or orders of the department or court and the petitions as approved by the department, along with a request that the question of the organization of the district be submitted to a vote of the electors who own taxable property, except intangible property, within such district as prayed for in the petition. Upon receipt of such request, the Secretary of State shall fix the date of such election, which may be held either as a special election or at any general election. Such election shall be so scheduled that the notice required by section 2-2435 can be given.

Source: Laws 1959, c. 9, § 7, p. 110.

2-2435. *Weather control districts; notice to election commissioner or county clerk; statement of question to be submitted.* The Secretary of State shall give notice of the scheduling of such election to the election commissioners, or county clerks in those counties not having an election commissioner, of each county to be embraced in whole or in part within such district. Such notice shall contain a statement of the question to be submitted at such election, the area in which such election is to be held, and the date thereof.

Source: Laws 1959, c. 9, § 8, p. 110.

2-2436. *Weather control districts; election commissioner or county clerk; notice of election; publication.* The election commissioner or county clerk, whichever is appropriate, shall publish a notice once each week, three consecutive weeks, in a legal newspaper having general circulation in his county, which notice shall state: (1) The fact of filing of the petition; (2) in summary form, the information required by subsection (1) of section 2-2430 to be included in the petition; (3) that an election will be held to decide the question of organization of the proposed district; (4) the date of such election; (5) the polling places at which such election is to be held; (6) a statement that all electors who own taxable property, except intangible property, within such district shall be entitled to vote at such election; and (7) the specific question to be submitted.

Source: Laws 1959, c. 9, § 9, p. 110.

2-2437. *Weather control district; election; how conducted; certification of results; resubmission of question.* The ballots cast at such election shall be counted and canvassed as nearly as practicable in the same manner as for elections generally. Not later than one week after the holding of such election, the election commissioners or county clerks, whichever is appropriate, shall certify the results thereof to the Secretary of State. The Secretary of State shall tabulate the results so certified to him, and if he finds fifty-five per cent of those voting in such election voted in favor of the organization of the proposed district, he shall so certify to the county clerk in each of the counties lying in whole or in part within such district, and the district shall thereupon be fully organized; *Provided*, that if the ballots cast in any precinct, or part of a precinct when the entire precinct is not included in the proposed district, in favor of the organization of the proposed district are less than fifty-five per cent of the total ballots cast, then such precinct or part thereof shall not be included in the proposed district. If the proposition to form such district is defeated at the election, the proposition may again be submitted after the lapse of one year from the rejection thereof upon

the filing of a new petition therefor. If the proposition to form a district is approved by fifty-five per cent of those voting on the proposition as provided in this section, then the Secretary of State shall annually submit the proposition to electors of the district for three consecutive years as to whether the district shall be continued or dissolved. If the electors vote to dissolve, the district shall be dissolved as provided in section 2-2447.

Source: Laws 1959, c. 9, § 10, p. 111.

2-2438. *Weather control district; body politic; sue and be sued; directors not liable for debts.* A district formed under the provisions of sections 2-2428 to 2-2449 shall be a body politic, and may sue and be sued in its own name, and no liability shall result to its directors on account of debts or other obligations of the district.

Source: Laws 1959, c. 9, § 11, p. 112.

2-2439. *Weather control district; board of directors; oath; bond; vacancies.* Each member of the board of directors shall be a resident landowner in such district. He shall take an oath of office, and shall give bond in the sum of five thousand dollars conditioned that he shall faithfully perform the duties of director and of such further office to which he may be elected in such district, and shall account for all funds or property coming into his hands as such director or other officer. The treasurer of the district shall also give a corporate surety bond in an amount sufficient to cover all money coming into his possession or control. Each such bond shall run to the district, be signed by a surety or sureties approved by the Secretary of State and shall be filed and recorded in the office of the Secretary of State. When such bond is so filed and approved, such person so elected shall take and hold office until his successor is elected and qualified. When a vacancy occurs on the board, such vacancy shall be filled by the remaining members of the board.

Source: Laws 1959, c. 9, § 12, p. 112.

2-2440. *Weather control district; board of directors; election of successors; no filing fee required.* As the terms of members of the board of directors expire, their successors shall be elected in the manner provided for election of directors of public power districts. No filing fee shall be required of candidates filing for the office of director of a weather control district.

Source: Laws 1959, c. 9, § 13, p. 112.

2-2441. *Weather control district; board of directors; no compensation; expenses.* The members of the board of directors shall receive no compensation, but shall be paid their actual expenses while engaged in the business of such district.

Source: Laws 1959, c. 9, § 14, p. 112.

2-2442. *Weather control district; officers; election; books; records; audit.* The board of directors shall annually elect a president, vice president, secretary, treasurer, and such other officers as may be necessary. Such board shall hold regular meetings in its office at least once each calendar quarter and such special meetings as may be required for the proper transaction of business. Notice of all meetings of the board must be published in a newspaper of general circulation in the district not less than seven nor more than fourteen days prior to the holding of such meeting, which notice shall state the time, date, and place thereof, and, in case of a special meeting, the purpose thereof. The board shall cause to be kept accurate minutes of its meetings and accurate records and books of account, conforming to approved methods of bookkeeping, clearly setting out and reflecting the operation, management, and business of the district. Such books and records shall be kept at the offices of the district and shall be open to public inspection during normal business hours. The board shall cause to be published at the close of each regular or special meeting a brief statement of the proceedings thereof in a newspaper of general circulation in the district. At the close of each year's business, the board shall cause an audit of the books, records, and financial affairs of the district to be made by a certified public accountant or firm of such accountants, who shall be selected by the board, and the report of such audit shall be kept on file at the district's office for inspection by any interested party.

Source: Laws 1959, c. 9, § 15, p. 112.

2-2443. *Weather control district; board of directors; general powers.* The board of directors shall have authority to: (1) Maintain and equip an office, and employ such persons as may be needed; (2) gather information concerning weather control; (3) aid or conduct, alone or in conjunction with other districts, any program of weather control; (4) contract with any private individual, association, or corporation, or with any governmental agency, engaged in weather control, for performance of the activities mentioned in subdivisions (2) and (3) of this section; (5) disseminate, by publication, or by press, radio, or television release, or other-

wise, information concerning weather control; (6) participate in any federal grant-in-aid program which has been or which might be established; and (7) levy a tax as provided in section 2-2444.

Source: Laws 1959, c. 9, § 16, p. 113.

2-2444. Weather control district; taxes; levy; limit of levy; certification; collection. The board of directors shall, prior to August 1 of each year, prepare an estimate showing the amount of money required to finance the activities of the district for the ensuing year and may levy and collect each year the taxes necessary to finance the activities of such district for the ensuing year to the amount of not more than one mill on the dollar of the assessed value of all taxable property, except intangible property, within such district. It shall, on or before the first day of August in each year, certify its mill levy to the county clerks of the counties wholly or partially within the district, who shall extend the same on the county tax list, and the same shall be collected by the county treasurer in the same manner as state and county taxes. It shall be the duty of the board to apply for and to receive from the county treasurers all money to the credit of the district. The county treasurers shall disburse the same to the order of the treasurer of the district.

Source: Laws 1959, c. 9, § 18, p. 113.

2-2445. Weather control district; warrants; issuance; payment; registration; interest. All claims against weather control districts may be paid by warrants or orders, duly drawn on the treasurer of such district, signed by the president and countersigned by the secretary. When such warrants or orders have been issued and delivered, they may be presented to the treasurer of the district, and if such be the fact, endorsed Not paid for want of funds. Such warrants or orders shall be registered by the treasurer in the order of presentation, shall draw interest at the rate of seven per cent per annum from the date of registration thereof, and shall be received by the county treasurers in payment of weather control district taxes levied pursuant to section 2-2444.

Source: Laws 1959, c. 9, § 19, p. 114.

2-2446. Weather control district; program for weather control; contract; seeding outside of boundaries of district; violation; penalty. The board of directors shall not be required to conduct, or contract for, any program of weather control for any year in which it does not appear that such program would be of substantial benefit to the district. In the event any program of weather control is conducted within any such weather control district organized under sections 2-2428 to 2-2449 it shall be unlawful for any aircraft of such district or its contractor to fly outside the boundaries of such district during any seeding operations or to seed any cloud formation situated outside the boundaries of such district. Any person, partnership, association, or corporation violating the provisions of this section shall, upon conviction thereof, be fined in any sum not to exceed five thousand dollars.

Source: Laws 1959, c. 9, § 20, p. 114.

2-2447. Weather control district; dissolution of district; election; how conducted; disposal of funds; debts; tax; levy. The board of directors may, on its own motion, or the board shall, on a written request signed by not less than twelve resident owners of land in each of a majority of the precincts lying wholly or partly within the district, request of the Secretary of State that the question of dissolution of such district be submitted to a vote of the electors, as set forth in sections 2-2428 to 2-2449, of the district, and the Secretary of State shall fix the date of such election, notice of which shall be given and which shall be conducted in the same manner as elections for the formation of such districts. If a majority of those voting on such question vote in favor of dissolution, the Secretary of State shall certify such result to the board of directors of such district. If the district has no debts outstanding at the time such result is certified to the board by the Secretary of State, such district shall thereupon stand dissolved. If the district has debts outstanding at the time such result is certified to the board by the Secretary of State and there are not sufficient funds in the hands of the treasurer of the district or in the hands of the county treasurer or treasurers to the credit of the district, to pay such debts, or if at the time of such certification, the district is under contract for any program of weather control as authorized herein, the board of directors of such district shall have authority to: (1) Levy the taxes necessary to pay such outstanding debts; (2) complete, in accordance with the contract, any program of weather control, or in the alternative, to negotiate and enter into a settlement of such contract with the contractor or contractors; (3) levy the taxes necessary to pay any obligations due or to become due

under any such contract for any such program of weather control or to pay the cost of settlement thereof; and (4) wind up the affairs of the district and levy the taxes necessary to pay the cost thereof, and upon payment of such debts, the completion or settlement of such contract or contracts for any such program of weather control and the payment of the obligations due under any such contract or the settlement thereof, and the payment of the costs incurred in winding up the affairs of the district, the district shall thereupon stand dissolved. In case a district is dissolved, any funds on hand or to be collected, in excess of the funds necessary to pay the outstanding obligations of the district and the costs of winding up the affairs of the district, shall be held by the treasurer of the district, and the directors shall petition the district court of the county in which the main office is located for an order approving the distribution of funds to the taxpayers of the district on the same basis as collected. The question of dissolution shall not be submitted more often than once every twelve months.

Source: Laws 1959, c. 9, § 21, p. 114.

2-2448. *Weather control district; act, how cited.* Sections 2-2428 to 2-2449 may be cited as the Weather Control Act of Nebraska.

Source: Laws 1959, c. 9, § 22, p. 116.

2-2449. *Weather control district; formed under prior act; validation.* In all cases in which weather control districts were established in accordance with laws heretofore existing, all acts and proceedings taken for the purpose of creating such district are hereby legalized, validated, and declared to be sufficient, and such weather control district is hereby declared to be duly incorporated, and as such, said weather control district under its corporate name shall have all the rights and privileges and be subject to all of the duties and obligations of a duly incorporated weather control district.

Source: Laws 1959, c. 9 § 23, p. 116.

ARTICLE 24—WEATHER MODIFICATION COMMISSION

(a) Weather Modification Commission

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| Sec.
2-2404. | Weather Modification Commission; created; membership; appointment; term; no salary; expenses. |
| 2-2407. | Weather control; artificial precipitation; application; license; fees; payment to State Treasurer; credited to special funds and accounts. |
| 2-2408.01. | Department of Agriculture; authority to accept funds; purpose. |
| 2-2408.02. | State Treasurer; custodian of weather modification funds or accounts; duties; investment. |

(a) Weather Modification Commission

2-2404. *Weather Modification Commission; created; membership; appointment; term; no salary; expenses.* There is hereby established a Weather Modification Commission, composed of the Director of Agriculture, the Vice Chancellor of the Institute of Agriculture and Natural Resources of the University of Nebraska or his representative, the chairman of the physics department of the University of Nebraska, and four additional members, interested in weather modification, who shall be appointed annually by the Governor for a one-year term commencing January 1. The members of the commission shall serve without salary, but shall be reimbursed for their actual and necessary expenses while in the performance of their duties.

Source: Laws 1957, c. 7, § 4, p. 102; Laws 1975, LB 247, § 1. Effective date August 24 1975.

2-2407. *Weather control; artificial precipitation; application; license; fees; payment to State Treasurer; credited to special funds and accounts.* (1) Any person desiring to cause or attempting to cause, condensation or precipitation of rain, snow, moisture, or water in any form contained in the atmosphere, or who shall prevent or attempt to prevent by artificial means the natural condensation or precipitation of rain, snow, moisture, or water in any form contained in the atmosphere, shall make application to the department in writing, on forms supplied by the department, to do so. Each application shall be accompanied by a fee of fifty dollars.

(2) Any person issued a license to do any of the acts specified in subsection (1) of this section shall pay a fee of two hundred dollars.

(3) No fee shall be charged for experimental or research work.

(4) The money collected from such fees shall be deposited with the state treasury and by the State Treasurer credited to the special funds and accounts established by section 2-2408.02.

Source: Laws 1957, c. 7, § 7, p. 103; Laws 1965, c. 8, § 6, p. 91; Laws 1975 LB 247, § 2. Effective date August 24, 1975.

2-2408.01. *Department of Agriculture; authority to accept funds; purpose.* The department may accept funds or fees from any source, federal, state, public or private, to be used by the commission in the performance of its duties.

Source: Laws 1975, LB 247, § 3. Effective date August 24, 1975.

2-2408.02. *State Treasurer; custodian of weather modification funds or accounts; duties; investment.* The State Treasurer is hereby designated as the custodian of all funds or fees received by the department from any source, federal, state, public or private, to be used by the commission in the performance of its duties. The State Treasurer is authorized to receive and provide for the proper custody of such funds or fees and establish such special weather modification funds and accounts as may be necessary to carry out the intent and purposes of sections 2-2404 2-2407, 2-2408.01, and 2-2408.02. The Director of Administrative Services shall draw warrants upon such funds or accounts upon presentation of proper vouchers by the department. Any money in the special weather modification funds or accounts available for investment shall be invested by the state investment officer pursuant to the provisions of Chapter 72, article 12.

Source: Laws 1975, LB 247, § 4. Effective date August 24, 1975.

81-829.45. *State Civil Defense Agency; weather condition; continuously apprise; permits; issue; suspend.* The state Civil Defense Agency shall keep continuously apprised of weather conditions which present danger of precipitation or other climatic activity severe enough to constitute a disaster. If the agency determines that precipitation that may result from weather modification operations, either by itself or in conjunction with other precipitation or climatic conditions or activity, would create or contribute to the severity of a disaster, it shall direct the officer or agency empowered to issue permits for weather modification operations to suspend the issuance of the permits, and thereupon no permits may be issued until the agency informs the officer or agency that the danger has passed.

Source: Laws 1973, LB 494, § 10. Effective date May 12, 1973.

NEVADA

Nev. Rev. Stat. §§ 544.010-544.240; 244.190

CHAPTER 544--WEATHER MODIFICATION

Weather Modification Research Law

Sec.	Short title.
544.010	Short title.
544.020	Definitions.
544.030	State department of conservation and natural resources authorized to conduct research programs.
544.040	County financial participation in research; conditions.
544.050	Agreements between counties and state department of conservation and natural resources; term of agreements.
544.060	Utilization of facilities, technical resources of desert research institute, University of Nevada System.

Regulations of Weather Modification Operations

544.070	Definitions.
544.080	Powers of the director of the state department of conservation and natural resources.
544.090	Promotion of research and development activities relating to weather modification.
544.100	Hearings; Record of proceedings; examination of witnesses; subpoenas.
544.110	Acceptance of gifts and grants; weather modification fund.
544.120	License and permit required for weather modification and control activities.
544.130	Exemptions from license, permit and liability requirements.
544.140	Qualifications of licensees; issuance, renewal of licenses; license fee.
544.150	Conditions for issuance of permits.
544.160	Separate permit required for each operation; notice of intention; conditions, modification of permit.
544.170	Notice of intention: Contents.
544.180	Notice of intention: Publication; filing of proof of publication.
544.190	Proof of financial responsibility.
544.200	Permit fees.
544.210	Records and reports of licensees, exempt organizations.
544.220	Suspension, revocation of licenses and permits: Grounds; modification of permit terms.
544.230	Construction of NRS 544.070 to 544.240, inclusive.
544.240	Penalties.

WEATHER MODIFICATION RESEARCH LAW

544.010 *Short title.* NRS 544.010 to 544.060, inclusive, may be cited as the Weather Modification Research Law.

(Added to NRS by 1961, 668)

544.020 Definitions. As used in NRS 544.010 to 544.060, inclusive, unless the context otherwise requires:

1. "Department" means the state department of conservation and natural resources.

2. "Director" means the director of the state department of conservation and natural resources.

(Added to NRS by 1961, 668)

544.030 State department of conservation and natural resources authorized to conduct research programs. The department may conduct weather modification research programs.

(Added to NRS by 1961, 668)

544.040 County financial participation in research; conditions. In areas where weather modification research is to be carried on, the counties involved may give such financial assistance as the director and the board of county commissioners shall determine, but such financial assistance shall aggregate for the counties involved an amount not less than 25 percent of the amount paid by the state for such program.

(Added to NRS by 1961, 668)

544.050 Agreements between counties and state department of conservation and natural resources; term of agreements. Counties in cooperating with the director in conducting any weather modification program in fulfillment of the purposes of NRS 544.010 to 544.060, inclusive, are authorized to enter into 5-year agreements with the director.

(Added to NRS by 1961, 669; A 1975, 576)

544.060 Utilization of facilities, technical resources of desert research institute, University of Nevada System. In carrying out the purposes of NRS 544.010 to 544.060, inclusive, the director shall utilize to the fullest possible extent the facilities and technical resources of the desert research institute of the University of Nevada System.

(Added to NRS by 1961, 669; A 1969, 1443)

REGULATIONS OF WEATHER MODIFICATION OPERATIONS

544.070 Definitions. As used in NRS 544.070 to 544.240, inclusive, unless the context requires otherwise:

1. "Director" means the director of the state department of conservation and natural resources.

2. "Operation" means the performance of weather modification and control activities pursuant to a single contract entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding 1 year, or, if the performance of weather modification and control activities is to be undertaken individually or jointly by a person or persons to be benefited and not undertaken pursuant to a contract, "operation" means the performance of weather modification and control activities entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding 1 year.

3. "Research and development" means theoretical analysis, exploration and experimentation and the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials and processes.

4. "Weather modification and control" means changing or controlling, or attempting to change or control, by artificial methods the natural development of any or all atmospheric cloud forms or precipitation forms which occur in the troposphere.

(Added to NRS by 1961, 691)

544.080 Powers of the director of the state department of conservation and natural resources. In the performance of his functions the director may, in addition to any other acts authorized by law:

1. Establish advisory committees to advise with and make recommendations to the director concerning legislation, policies, administration, research and other matters.

2. Establish by regulation or order such standards and instructions to govern the carrying out of research or projects in weather modification and control as he may deem necessary or desirable to minimize danger to health or property,

and make such regulations as are necessary in the performance of his powers and duties.

3. Make such studies, investigations, obtain such information and hold such hearings as he may deem necessary or proper to assist him in exercising his authority or in the administration or enforcement of NRS 544.070 to 544.240, inclusive, or any regulations or orders issued thereunder.

4. Appoint and fix the compensation of such personnel, without compliance with the provisions of chapter 284 of NRS, including specialists and consultants, as are necessary to perform his duties and functions.

5. Acquire, in the manner provided by law, such materials, equipment and facilities as are necessary to perform his duties and functions.

6. Cooperate with public or private agencies in the performance of his functions or duties and in furtherance of the purposes of NRS 544.070 to 544.240, inclusive.

7. Represent the state in any and all matters pertaining to plans, procedures or negotiations for interstate compacts relating to weather modification and control.

8. With approval of the governor, enter into cooperative agreements with the various counties and cities of this state or with any private or public agencies for conducting weather modification or cloud seeding operations.

9. Act for and represent the state and the counties, cities and private or public agencies in contracting with private concerns for the performance of weather modifications or cloud seeding operations.

(Added to NRS by 1961, 692)

544.090 Promotion of research and development activities relating to weather modification. The director shall exercise his powers in such manner as to promote the continued conduct of research and development activities in the fields specified below by private or public institutions or persons and to assist in the acquisition of an expanding fund of theoretical and practical knowledge in such fields. To this end the director may conduct, and make arrangements including contracts and agreements for the conduct of, research and development activities relating to:

1. The theory and development of methods of weather modification and control, including processes, materials and devices related thereto.

2. Utilization of weather modification and control for agricultural, industrial, commercial and other purposes.

3. The protection of life and property during research and operational activities.

(Added to NRS by 1961, 693)

544.100 Hearings: Record of proceedings; examination of witnesses; subpoenas. In the case of hearings held pursuant to NRS 544.220, the director shall, and in other cases may, cause a record of all proceedings to be taken and filed with the director, together with his findings and conclusions. For any hearing, the director or a representative designated by him is authorized to administer oaths and affirmations, examine witnesses and issue, in the name of the director, notice of the hearing or subpoenas requiring any person to appear and testify, or to appear and produce documents, or both, at any designated place.

(Added to NRS by 1961, 693)

544.110 Acceptance of gifts and grants; weather modification fund.

1. The director may, subject to any limitations otherwise imposed by law, receive and accept for and in the name of the state any funds which may be offered or become available from federal grants or appropriations, private gifts, donations or bequests, or from any other source, and may expend such funds, unless their use is restricted and subject to any limitations otherwise provided by law, for the administration of NRS 544.070 to 544.240, inclusive, and for the encouragement of research and development by a state or public or private agency, either by direct grant, by contract or other cooperative means.

2. There is hereby established a continuing fund in the general fund in the state treasury to be known as the weather modification fund. All license and permit fees paid to the director shall be deposited in such fund. Any accumulation in such fund in excess of \$5,000 shall revert immediately to the general fund.

(Added to NRS by 1961, 693)

544.120 License and permit required for weather modification and control activities. Except as provided in NRS 544.130, no person shall engage in activ-

ities for weather modification and control except under and in accordance with a license and a permit issued by the director authorizing such activities.

(Add to NRS by 1961, 693)

544.130 Exemptions from license, permit and liability requirements. The director, to the extent he deems practical, shall provide by regulation for exempting from the license, permit and liability requirements of NRS 544.070 to 544.240, inclusive:

1. Research and development and experiments by state and federal agencies, institutions of higher learning and bona fide nonprofit research organizations.
2. Laboratory research and experiments.
3. Activities required in emergencies for protection against fire, frost, sleet or fog.

4. Activities normally engaged in for purposes other than those of inducing, increasing, decreasing or preventing precipitation or hail.

(Added to NRS by 1961, 693; A 1967, 159)

544.140 Qualifications of licensees; issuance, renewal of licenses; license fee. 1. Licenses to engage in activities for weather modification and control shall be issued to applicants therefor who pay the license fee required and who demonstrate, to the satisfaction of the director, competence in the field of meteorology reasonably necessary to engage in activities for weather modification and control. If the applicant is an organization, these requirements shall be met by the individual or individuals who are to be in control and in charge of the operation for the applicant.

2. The director shall issue licenses in accordance with such procedures and subject to such conditions as he may by regulation establish to effectuate the provisions of NRS 544.070 to 544.240, inclusive. Each license shall be issued for a period to expire at the end of the calendar year in which it is issued and, if the licensee possesses the qualifications necessary for the issuance of a new license, such license shall upon application be renewed at the expiration of such period. A license shall be issued or renewed only upon the payment to the director of \$100 for the license or renewal thereof.

(Added to NRS by 1961, 694)

544.150. Conditions for issuance of permits. The director shall issue permits in accordance with such procedures and subject to such conditions as he may by regulation establish to effectuate the provisions of NRS 544.070 to 544.240, inclusive, only:

1. If the applicant is licensed pursuant to NRS 544.070 to 544.240, inclusive.
2. If a sufficient notice of intention is published and proof of publication is filed as required by NRS 544.180.
3. If the applicant furnishes proof of financial responsibility, as provided in NRS 544.190, in an amount as may be determined by the director but not to exceed \$20,000.

4. If the fee for a permit is paid as required by NRS 544.200.

(Added to NRS by 1961, 694)

544.160. Separate permit required for each operation; notice of intention; condition, modification of permit. A separate permit shall be issued for each operation. Prior to undertaking any weather modification and control activities the licensee shall file with the director and also cause to be published a notice of intention. The licensee, if a permit is issued, shall confine his activities for the permitted operation substantially within the time and area limits set forth in the notice of intention, unless modified by the director, and his activities shall also substantially conform to any conditions imposed by the director upon the issuance of the permit or to the terms of the permit as modified after issuance.

(Added to NRS by 1961, 694)

544.170.—Notice of intention: Contents. The notice of intention shall set forth at least all the following:

1. The name and address of the licensee.
2. The nature and object of the intended operation and the person or organization on whose behalf it is to be conducted.
3. The area in which and the approximate time during which the operation will be conducted.
4. The area which is intended to be affected by the operation.
5. The materials and methods to be used in conducting the operation.

(Added to NRS by 1961, 694)

544.180. Notice of intention: Publication; filing of proof of publication. 1. The applicant shall cause the notice of intention, or that portion thereof including

the items specified in NRS 544.170, to be published at least once a week for 3 consecutive weeks in a newspaper having a general circulation and published within any county in which the operation is to be conducted and in which the affected area is located, or, if the operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the operation is to be conducted, then in a newspaper having a general circulation and published within each of such counties. In case there is no newspaper published within the appropriate county, publication shall be made in a newspaper having a general circulation within the county.

2. Proof of publication, made in the manner provided by law, shall be filed by the licensee with the director within 15 days from the date of the last publication of the notice.

(Added to NRS by 1961, 695)

544.190 Proof of financial responsibility. Proof of financial responsibility may be furnished by an applicant by his showing, to the satisfaction of the director, his ability to respond in damages for liability which might reasonably be attached to or result from his weather modification and control activities in connection with the operation for which he seeks a permit; but the applicant need not show ability to respond in damages for liability resulting from precipitation caused by weather modification experiments.

(Added to NRS by 1961, 695; A 1967, 159)

544.200 Permit fees. The fee to be paid by each applicant for a permit shall be equivalent to 1½ percent of the estimated cost of such operation, such cost to be estimated by the director from the evidence available to him. The fee is due and payable to the director as of the date of the issuance of the permit, but if the applicant is able to give to the director satisfactory security for the payment of the balance, he may be permitted to commence the operation, and a permit may be issued therefor, upon the payment of not less than 50 percent of the fee. The balance due shall be paid within 3 months from the date of the termination of the operation as prescribed in the permit. Failure to pay a permit fee as required is grounds for suspension or revocation of the license of the delinquent permit holder and grounds for refusal to renew his license or to issue any further permits to such person.

(Added to NRS by 1961, 695)

544.210 Records and reports of licensees, exempt organizations. 1. Each licensee shall keep and maintain a record of all operations conducted by him pursuant to his license and each permit, showing the method employed, the type of equipment used, materials and amounts thereof used, the times and places of operation of the equipment, the name and post office address of each individual participating or assisting in the operation other than the licensee, and such other general information as may be required by the director, and shall report the same to the director at the time and in the manner required by the director.

2. The director shall require written reports in such manner as he provides but not inconsistent with the provisions of NRS 544.070 to 544.240, inclusive, covering each operation for which a permit is issued. The director shall also require written reports from such organizations as are exempt from the license, permit and liability provisions of NRS 544.130.

3. All information on an operation shall be submitted to the director before any information on such operation may be released to the public.

4. The reports and records in the custody of the director shall be open for public examination.

(Added to NRS by 1961, 695)

544.220 Suspension, revocation of licenses and permits: Grounds; modification of permit terms. 1. The director may suspend or revoke any license or permit issued if it appears that the licensee no longer possesses the qualifications necessary for the issuance of a new license or permit. The director may suspend or revoke any license or permit if it appears that the licensee has violated any of the provisions of NRS 544.070 to 544.240, inclusive. Such suspension or revocation shall occur only after notice to the licensee and a reasonable opportunity granted such licensee to be heard respecting the grounds for the proposed suspension or revocation. The director may refuse to renew the license of, or to issue another permit to, any applicant who has failed to comply with any provisions of NRS 544.070 to 544.240, inclusive.

2. The director may modify the terms of a permit after issuance thereof if the licensee is first given notice and a reasonable opportunity for a hearing

respecting the grounds for the proposed modification and if it appears to the director that it is necessary for the protection of the health or the property of any person to make the modification proposed.

(Added to NRS by 1961, 696)

544.230 Construction of NRS 544.070 to 544.240, inclusive. Nothing in NRS 544.070 to 544.240, inclusive, shall be construed to impose or accept any liability or responsibility on the part of the state or any state officials or employees for any weather modification and control activities of any private person or group, or to affect in any way any contractual, tortious or other legal rights, duties or liabilities between any private persons or groups.

(Added to NRS by 1961, 696)

544.240 Penalties. Any person violating any of the provisions of NRS 544.070 to 544.240, inclusive, or any lawful regulation or order issued pursuant thereto shall be guilty of a misdemeanor and a continuing violation is punishable as a separate offense for each day during which it occurs.

(Added to NRS by 1961, 696)

244.187 Franchises for garbage collection, disposal services; fire protection, suppression; ambulance service. 1. Any board of county commissioners may grant exclusive franchises to operate any of the following services outside the limits of incorporated cities within the county:

(a) Garbage and disposal.

(b) Fire protection and suppression.

(c) Ambulance service to pick up patients outside the limits of such incorporated cities.

2. Nothing in paragraph (c) of subsection 1 shall prevent any ambulance service from transporting patients from any county in which it is franchised to another county.

3. The board of county commissioners may, by ordinance, regulate such services and fix fees or rates to be charged by the franchise holder.

4. A notice of the intention to grant any franchise shall be published once in a newspaper of general circulation in the county, and the franchise may not be granted until 30 days after such publication. The board of county commissioners shall give full consideration to any application or bid to supply such services, if received prior to the expiration of such 30-day period, and shall grant the franchise on terms most advantageous to the county and the persons to be served.

5. The provisions of chapter 709 of NRS shall not apply to any franchise granted under the provisions of this section.

6. Nothing in this section shall be construed to prevent any individual, partnership, corporation or association from hauling his or its own garbage subject to the regulations of the board of county commissioners promulgated under the provisions of this section.

(Added to NRS by 1960, 433; A 1971, 1372; 1975, 569)

244.190 Weather modification cooperative agreements. 1. The boards of county commissioners of the various counties are empowered to enter into cooperative agreements with the State of Nevada, other counties of this state, or any private or public organization, and with private concerns engaged in weather modification (cloud seeding) operations.

2. The expenses incident and necessary for the participation of counties in such cooperative program, as provided in subsection 1, shall be paid out of the general funds of such counties, and the board of county commissioners of any county acting under the terms of this section shall annually, at the time of making its budget, make an estimate of the expenses necessary to carry out its agreement, under the provisions of this section, and budget the same, in all respects, as other items of the budget may be made.

3. All agreements for cooperation between the State of Nevada and the counties, and with any private organization as set forth in subsection 1, shall be evidenced by written agreements made and entered into by the boards of county commissioners interested, and the same shall be spread upon the minutes of each of the boards at the time of the adoption thereof.

4. All action taken and all proceedings adopted prior to March 2, 1955, by the boards of county commissioners of Pershing, Lander, Eureka, Humboldt, Elko and White Pine counties, relating to weather modification (cloud seeding), are ratified, approved and confirmed.

[1:26:1955]+[2:26:1955]+[3:26:1955]+[4:26:1955]

244.194 Voting machines: Rental, lease, acquisition. Boards of county commis-

sioners may rent, lease or otherwise acquire voting machines in whatever manner will best serve local interests.

(Added to NRS by 1965, 615; A 1975, 570)

244.195 Other powers. The boards of county commissioners shall have power and jurisdiction in their respective counties to do and perform all such other acts and things as may be lawful and strictly necessary to the full discharge of the powers and jurisdiction conferred on the board.

[Part 8:80:1865; A 1871, 47; 1931, 52; 1933, 203; 1953, 681]

NEW HAMPSHIRE

N.H. Rev. Stat. Ann. § 432:1

WEATHER MODIFICATION EXPERIMENTATION

432:1 Weather Modification Experimentation. Any department or agency of the state may, with the approval of the governor and council and within the limits of appropriated funds or by means of gifts, donations or grants, engage in and undertake experimentation in the techniques and methods for weather modification, and may cooperate therein with the federal government, with authorized agencies of other states, and with interested persons and organizations.

NEW MEXICO

N.M. Stat. Ann. §§ 75-37-1-75-31-15

ARTICLE 37—WEATHER CONTROL AND CLOUD MODIFICATION

Sec.

- 75-37-1. Short title.
- 75-37-2. Definitions.
- 75-37-3. Declaration of rights.
- 75-37-4. Attempt to control precipitation—License required.
- 75-37-5. Application for license.
- 75-37-6. Application for license—Contents—Annual license fee—Statement.
- 75-37-7. Issuance of license.
- 75-37-8. License fee—Expiration.
- 75-37-9. Reports required from licensees.
- 75-37-10. Revocation of license.
- 75-37-11. Judicial review.
- 75-37-12. Operations affecting weather in other states.
- 75-37-13. Enforcement.
- 75-37-14. Powers and duties of commission.
- 75-37-15. Violations of act—Penalty.

75-37-1. Short title.—This act [75-37-1 to 75-37-15] may be cited as the “Weather Control Act.”

75-37-2. Definitions.—As used in the Weather Control Act [75-37-1 to 75-37-15] “commission” means the weather control and cloud modification commission.

History: Laws 1965, ch. 235, § 2.

75-37-3. Declaration of rights.—It is declared that the state of New Mexico claims the right to all moisture in the atmosphere which would fall so as to become a part of the natural streams or percolated water of New Mexico, for use in accordance with its laws.

75-37-4. Attempt to control precipitation—License required.—No person or corporation shall, without having first received a license from the commission, conduct any weather control or cloud modification operations or attempt to control precipitation.

History: Laws 1965, ch. 235, § 4.

75-37-5. Application for license.—Any individual or corporation who proposes to operate weather control or cloud modification projects or who attempts to induce precipitation, shall, before engaging in any such operation, make application to the commission for a license to engage in the particular weather control or cloud modification operation contemplated.

History: Laws 1965, ch. 235, § 5.

75-37-6. Application for license—Contents—Annual license fee—Statement.—At the time of applying for the license, the applicant shall pay to the commission a fee of one hundred dollars (\$100), and shall file an application in the form prescribed by the commission which shall be accompanied by a statement showing:

- A. The name and address of the applicant;
- B. The names of the operating personnel, and, if unincorporated, all individuals connected with the organization, or, if a corporation, the names of each of the officers and directors thereof, together with the address of each;
- C. The scientific qualifications of all operating and supervising personnel;

D. A statement of all other contracts completed or in process of completion at the time the application is made, giving the names and addresses of the persons to whom the services were furnished and the areas in which such operations have been or are being conducted;

E. The objective of the operation, methods of operation the licensee will use, and the description of the aircraft, ground and meteorological services to be used;

F. Names of the contracting parties within the state; including:

- (1) the area to be served;
- (2) the months in which operations will be conducted;
- (3) the methods to be used in evaluating the operation; and

G. Any other information the commission deems necessary.

History: Laws 1965, ch. 235, § 6.

75-37-7. *Issuance of license.*—The commission may issue a license to any applicant who demonstrates sufficient financial responsibility, to the satisfaction of the board, necessary to meet obligations reasonably likely to be attached to or result from weather control or cloud modification activities, and skill and experience reasonably necessary to accomplishment of weather control without actionable injury to property or person.

History: Laws 1965, ch. 235, § 7.

75-37-8. *License fee—Expiration.*—A license shall expire at the end of the calendar year in which it is issued and may be renewed upon payment of the annual license fee.

History: Laws 1965, ch. 235, § 8.

75-37-9. *Reports required from licenses.*—Each licensee shall, within ninety [90] days after conclusion of any weather control or cloud modification project, file with the commission a final evaluation of the project. Each three [3] months, during the operation of any project which has not been completed, each licensee shall file a report evaluating the operations for the preceding three [3] months in the project. Failure to file such reports constitute[s] grounds for immediate revocation of the license. Each evaluation report shall contain such information as required by the commission in order to aid in research and development in weather modification and to aid in the protection of life and property.

History: Laws 1965, ch. 235, § 9.

75-37-10. *Revocation of license.*—The commission shall revoke any license if it shall appear that the licensee no longer possesses the qualifications necessary for the issuance of a new license, or is guilty of a violation of any of the provisions of the Weather Control Act [75-37-1 to 75-37-15]. Such revocation shall occur only after notice to the licensee, and a reasonable opportunity has been granted the licensee to be heard respecting the grounds of the proposed revocation.

History: Laws 1965, ch. 235, § 10.

75-37-11. *Judicial review.*—Rulings by the commission on the issuance, refusal or revocation of a license are subject to review only in the district court for Santa Fe County and the state Supreme Court.

History: Laws 1965, ch. 235, § 11.

75-37-12. *Operations affecting weather in other states.*—Weather control or cloud modification operations may not be carried on in New Mexico for the purpose of affecting weather in any other state which prohibits such operations, or which prohibits operations in that state for the benefit of New Mexico or its inhabitants.

History: Laws 1965, ch. 235, § 12.

75-37-13. *Enforcement.*—Enforcement of the Weather Control Act [75-37-1 to 75-37-15] is vested in the board of regents of New Mexico Institute of Mining and Technology. The board of regents shall appoint a three-member weather control and cloud modification commission for the purpose of administering the provisions of the Weather Control Act. Technical assistance, research, evaluation, and advice to the commission shall be furnished by the institute at the direction of the board of regents. The commission shall elect from among its members a chairman and other officers it deems necessary. All fees collected by the commission shall be placed in a fund to be used by the commission for the purposes of carrying out the provisions of the Weather Control Act.

History: Laws 1965, ch. 235, § 13.

75-37-14. *Powers and duties of commission.*—The commission may:

A. Make all rules and regulations necessary to carry out the provisions of the Weather Control Act [75-37-1 to 75-37-15];

B. Make any field investigations and inspections necessary to the enforcement of the Weather Control Act;

C. Make periodic reports on weather control and cloud modification activities in this state together with evaluations of the results of such activities; and

D. Make recommendations to the legislature through the board of regents on needed legislation in the regard to weather control and cloud modification.

History: Laws 1965, ch. 235, § 14.

75-37-15. *Violations of act—Penalty.*—Any person conducting weather control or cloud modification operations without first having procured a license, or who makes a false statement in the application for a license, or who fails to file any report or evaluation required by the Weather Control Act [75-37-1 to 75-37-15], or who conducts any weather control or cloud modification operation after revocation of his license, or who violates any provision of the Weather Control Act is guilty of a misdemeanor.

History: Laws 1965, ch. 235, § 15.

NEW YORK

N.Y. Gen. Mun. Law § 119-p

ARTICLE 5-H—PROJECTS RELATING TO THE USE OF ATMOSPHERIC WATER RESOURCES [New]

Sec.
119-p. Projects relating to the use of atmospheric water resources.

Article added L.1965, c. 661, eff. July 2, 1965.

§ 119-p. *Projects relating to the use of atmospheric water resources*

Every municipal corporation is, and any two or more municipal corporations are, hereby authorized and empowered to conduct or engage in projects, experiments and other activities designed to develop the use of atmospheric water resources, and to make scientific evaluations of such projects, experiments and other activities, or to contract therefor, and to appropriate and expend moneys therefor. In the case of a joint project by two or more municipal corporations, the share of the cost of such project or activity to be borne by each such municipal corporation shall be fixed by contract. The expenditure of moneys for such purpose by a municipal corporation shall be deemed a lawful municipal purpose and the moneys appropriated therefor shall be raised by tax upon the taxable real property within the municipal corporation in the same manner as moneys for other lawful municipal purposes. Each municipal corporation is hereby authorized to accept and disburse grants of public or private money or other aid paid or made available by the state or federal government for any such purpose. Added L.1965, c. 661, eff. July 2, 1965.

NORTH DAKOTA

N.D. Cent. Code §§ 2-07-01—2-07-13; 37-17.1-15; 58-03-07

CHAPTER 2-07—WEATHER MODIFICATION

- Sec.
- 2-07-01 Ownership of water
 - 2-07-01.1 Declaration of policy and purpose.
 - 2-07-02 Definitions.
 - 2-07-02.1 North Dakota weather modification board—Created—Membership.
 - 2-97-02.2 Weather modification board—Districts created.
 - 2-07-02.3 Direction and supervision by aeronautics commission—Independent functions retained by board.
 - 2-07-02.4 Weather modification board—Officers—Compensation.
 - 2-07-02.5 Powers and duties of weather modification board.
 - 2-07-03 License and permit required.
 - 2-07-03.1 Exemptions.
 - 2-07-03.2 Operator deemed to be doing business within state—Resident agent.
 - 2-07-03.3 Issuance of license—Fee.
 - 2-07-03.4 Revocation or suspension of license.
 - 2-07-04 Permit required—Issuance of permit—Fee.
 - 2-07-04.1 Hearings.
 - 2-07-04.2 Revocation, suspension, or modification of permit.
 - 2-07-04.3 Proof of financial responsibility.
 - 2-07-05 Board may create operating districts—Representation of noncontracting counties.
 - 2-07-05.1 District operations advisory committees created—Duties.
 - 2-07-05.2 Weather modification authority may suspend operations.
 - 2-07-06 Weather modification authority created by petition.
 - 2-07-06.1 Petition contents.

Sec.

2-07-06.2	Commissioners—Compensation—Meetings—Officers.
2-07-06.3	Tax levy may be certified by weather modification authority.
2-07-06.4	Creation of weather modification authority and its powers by resolution.
2-07-06.5	Procedure for abolishment of weather modification authority and all its powers by recall initiated petition.
2-07-06.6	Creation of weather modification authority by election.
2-07-06.7	Abolishment of weather modification authority by election.
2-07-06.8	Creation of weather modification authority by vote after resolution of county commissioners.
2-07-07	County budget may be waived for first appropriation—Conditions.
2-07-08	Bids required—When.
2-07-09	Performance bond required.
2-07-09.1	Bid bond required.
2-07-10	State immunity.
2-07-10.1	Liability of controller.
2-07-11	Weather modification board may receive and expend funds.
2-07-11.1	County appropriations—State to provide matching funds.
2-07-12	Aeronautics commission—Compensation—Expenses.
2-07-13	Penalty.

58-03-07. *Powers of electors.*—The electors of each township have the power at the annual township meeting:

1. To establish one or more pounds within the township, to determine the location of the pounds, to determine the number of poundmasters and to choose the poundmasters, and to discontinue pounds which have been established;

2. To select the township officers required to be chosen;

3. To direct the institution or defense of actions in all controversies where the township is interested;

4. To direct the raising of such sums of as they may deem necessary to prosecute or defend actions in which the township is interested;

5. To make all rules and regulations for the impounding of animals;

6. To make such bylaws, rules, and regulations as may be deemed necessary to carry into effect the powers granted to the township;

7. To impose penalties not exceeding ten dollars for each offense on persons offending against any rule or regulation established by the township;

8. To apply penalties when collected in such manner as they deem most conducive to the interests of the township;

9. To ratify or reject recommendations offered by the board of township supervisors for the expenditure of funds for the purpose of purchasing building sites and for the purchase, location, erection, or removal of any building or erection for township purposes. No recommendation shall be adopted except by a two-thirds vote of the electors present and voting at any annual township meeting;

10. To authorize and empower the board of township supervisors to purchase liquids, compounds, or other ingredients for the destruction of noxious weeds, and sprinklers to be used in spraying said liquids or compounds. No township shall purchase more than two such sprinklers in any one year;

11. Repealed by S.L. 1949, ch. 343, § 1;

12. To authorize aid to a district fair association within the limits provided in title 4, Agriculture;

13. To authorize the levy of township taxes for the repair and construction of roads and bridges and for other township charges and expenses within the limits prescribed in title 57, Taxation;

14. To direct the expenditure of funds raised for the repair and construction of roads within the limits provided in title 24, Highways, Bridges, and Ferries;

15. To authorize the dissolution of the township in the manner provided in this title;

16. To authorize the purchase and maintenance of dipping tanks as provided in title 36,* Livestock;

17. To authorize the purchase of township firefighting equipment in the manner provided in title 18.** Fires; and to authorize the entering into a contract for fire protection as provided for in section 18-06-10; and

18. To establish a fund for the eradication of gophers, prairie dogs, crows, and magpies.

19. To authorize the expenditure of township funds for weather modification activities.

37-17.1-15. *Weather modification.*—The division of disaster emergency services shall keep continuously apprised of weather conditions which present danger of precipitation or other climatic activity severe enough to constitute a disaster. If the division determines that precipitation that may result from weather modification operations, either by itself or in conjunction with other precipitation or climatic conditions or activity, would create or contribute to the severity of a

disaster, it shall direct the officer or agency empowered to issue permits for weather modification operations to suspend the issuance of the permits. Thereupon, no permits may be issued until the division informs the officer or agency that the danger has passed.

Source: S. L. 1973, ch. 281, § 15.

2-07-01. Ownership of water.—In order that the state may share to the fullest extent in the benefits already gained through fundamental research and investigation on new and improved means for predicting, influencing, and controlling the weather, for the best interest, general welfare, health, and safety of all the people of the state, and to provide proper safeguards in applying the measures for use in connection therewith in order to protect life and property, it is deemed necessary and hereby declared that the state of North Dakota claims its sovereign right to use the moisture contained in the clouds and atmosphere within the sovereign state boundaries. All water derived as a result of weather modification operations shall be considered a part of North Dakota's basic water supply and all statutes, rules, and regulations applying to natural precipitation shall also apply to precipitation resulting from cloud seeding.

Source: S. L. 1965, ch. 71, § 1; 1975, ch. 50, § 1.

2-07-01.1. Declaration of policy and purpose.—The legislative assembly finds that weather modification affects the public health, safety, and welfare, and that, properly conducted, weather modification operations can improve water quality and quantity, reduce losses from weather hazards, and provide economic benefits for the people of the state. Therefore, in the public interest, weather modification shall be subject to regulation and control, and research and development shall be encouraged. In order to minimize possible adverse effects, weather modification operations shall be carried on with proper safeguards, and accurate information shall be recorded concerning such operations and the benefits obtained therefrom by the people of the state.

Source: S. L. 1975, ch. 50, § 2.

2-07-02. Definitions.—As used herein, unless the context or subject matter otherwise requires:

1. "Weather modification" means and extends to the control, alteration, amelioration of weather elements including man-caused changes in the natural precipitation process, hail suppression or modification and alteration of other weather phenomena including temperature, wind direction and velocity, and the initiating, increasing, decreasing and otherwise modifying by artificial methods of precipitation in the form of rain, snow, hail, mist or fog through cloud seeding, electrification or by other means to provide immediate practical benefits;

2. "Initiating precipitation" refers to the process of causing precipitation from clouds that could not otherwise or inducing precipitation significantly earlier than would have occurred naturally;

3. "Increasing precipitation" refers to the activation of any process which will actually result in greater amounts of moisture reaching the ground in any area from a cloud or cloud system than would have occurred naturally;

4. "Hail suppression" refers to the activation of any process which will reduce, modify, suppress, eliminate or soften hail formed in clouds or storms;

5. "Person" means any person, firm, association, organization, partnership, company, corporation, private or public, county, city, trust or other public agencies;

6. "Controller" refers to any licensee duly authorized in this state to engage in weather modification activities;

7. "Board" means the North Dakota weather modification board which, in the exercise of the powers granted herein, shall have all of the powers of an administrative agency as defined in chapter 28-32;

8. "Research and development" means exploration, field experimentation, and extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production of models, devices, equipment, materials, and processes; and

9. "Operation" means the performance of any weather modification activity undertaken for the purpose of producing or attempting to produce any form of modifying effect upon the weather within a limited geographical area or within a limited period of time.

Source: S. L. 1965, ch. 71, § 2; 1975, ch. 50, §§ 3, 4.

2-07-02.1. North Dakota weather modification board—Created—Membership.—There is hereby created a North Dakota weather modification board which shall

be a division of the state aeronautics commission. The board shall be composed of the director of the state aeronautics commission, a representative of the environmental section of the state department of health, state engineer of the state water conservation commission, and seven additional board members; one member from each of seven districts established by section 2-07-02.2. The governor shall appoint one board member for each of the seven districts from a list of three candidates given to him by weather modification authorities in each such district:

1. When the entire board is to be initially appointed, provided that such appointments shall be made within thirty days after July 1, 1975.

2. When the term of office of any board member from any district is about to expire.

3. When a vacancy has occurred, or is about to occur, in the term of office of a board member from any district for any reason other than expiration of term of office.

Board members from each district shall serve for a four-year term of office except in the event the governor shall appoint a member for an unexpired term, in which case the member shall serve only for the unexpired term. In the event any district fails to furnish a list to the governor, or if there are no weather modification authorities under this chapter within a district, then the governor shall appoint a board member of his choice residing within such district.

Source: S. L. 1975, ch. 50, § 5.

2-07-02.2. *Weather modification board—Districts created.*—Members of the weather modification board shall be appointed from districts containing the following counties: District I—Burke, Divide, McKenzie, Mountrail, and Williams; District II—Bottineau, McHenry, McLean, Renville, Sheridan, and Ward; District III—Benson, Cavalier, Eddy, Foster, Griggs, Nelson, Pierce, Ramsey, Rollette, Steele, Towner, and Wells; District IV—Cass, Grand Forks, Pembina, Richland, Traill, and Walsh; District V—Barnes, Dickey, Kidder, LaMoure, Logan, McIntosh, Ransom, Sargent, and Stutsman; District VI—Burleigh, Emons, Grant, Mercer, Morton, Oliver, and Sioux; District VII—Adams, Billings, Bowman, Dunn, Golden Valley, Hettinger, Slope, and Stark.

Source: S. L. 1975, ch. 50, § 6.

2-07-02.3. *Direction and supervision by aeronautics commission—Independent functions retained by board.*—The powers, functions, and duties of the North Dakota weather modification board shall be administered under the direction and supervision of the North Dakota aeronautics commission, but the board shall retain the quasi-judicial, quasi-legislation, advisory, and other nonadministrative and budgetary functions otherwise vested in it.

Source: S. L. 1975, ch. 50, § 7.

2-07-02.4. *Weather modification board—Officers—Compensation.*—All members of the weather modification board, with the exception of the chairman, shall be voting members. The board shall elect annually from its membership a chairman, vice chairman, and secretary. A majority of the members shall constitute a quorum for the purpose of conducting the business of the board. Board members who are not full-time salaried employees of this state shall receive compensation in the amount provided in subsection 1 of section 54-35-10, and shall be reimbursed for their mileage and expenses in the amounts provided by sections 44-08-04 and 54-06-09. All other members of the board shall be reimbursed for necessary travel and other expenses incurred in the performance of the business of the board in the amounts provided in sections 44-08-04 and 54-06-09.

Source: S. L. 1975, ch. 50, § 8.

2-07-02.5. *Powers and duties of weather modification board.*—The board may exercise the following powers and shall have the following duties:

1. The board shall appoint an executive director to serve at its discretion, and perform such duties as assigned by the board.

2. The board shall authorize the employment of whatever staff it deems necessary to carry out the provisions of this chapter. The executive director shall hire the staff, subject to the approval of the board.

3. The board shall make reasonable rules and regulations concerning: qualifications, procedures and conditions for issuance, revocation, suspension, and modification of licenses and permits; standards and instructions governing weather modification operations, including monitoring and evaluation; record-keeping and reporting, and the board shall establish procedures and forms for such recordkeeping and reporting. The board may adopt all other reasonable

rules and regulations necessary to the administration of this chapter. The provisions of chapter 28-32 shall apply to this chapter.

4. The board may contract with any person, association, partnership, or corporation, with the federal government, and with any county or groups of counties, as provided in section 2-07-05, to carry out weather modification operations and shall, in connection with regulated weather modification operations, carry on monitoring and evaluation activities.

5. The board may order any person who is conducting weather modification operations in violation of this chapter, or any rules and regulations promulgated pursuant to it, to cease and desist from such operations and such order shall be enforceable in any court of competent jurisdiction within this state.

6. The board may cooperate and contract with any private person or any local, state, or national commission, organization, or agency engaged in activities similar to the work of the board and may make contracts and agreements to carry out programs consistent with the purpose and intent of this chapter. The board may also, in accordance with law, request and accept any grants of funds or services from any such commission, organization, person, or agency, and expend such funds or use such services to carry out the provisions of this chapter.

7. The board shall administer and enforce the provisions of this chapter and do all things reasonably necessary to effectuate the purposes of this chapter.

Source: S. L. 1975, ch. 50, § 9.

2-07-03. *License and permit required.*—Except as provided in section 2-07-03.1, no person may engage in weather modification activities without both a professional weather modification license issued under section 2-07-03.2 and a weather modification permit issued under section 2-07-04. Licenses shall expire on December thirty-first of the year of issuance.

2-07-03.1. *Exemptions.*—The board may provide by rules and regulations for exemption of the following activities from the permit and license requirements of section 2-07-03:

1. Research and development conducted by the state, political subdivisions of the state, colleges and universities of the state, agencies of the federal government, or bona fide research corporations.
2. Weather modification operations of an emergency nature taken against fire, frost, or fog.

Exempted activities shall be so conducted so as not to unduly interfere with weather modification operations conducted under a permit issued in accordance with this chapter.

Source: S. L. 1975, ch. 50, § 11.

2-07-03.2. *Operator deemed to be doing business within state—Resident agent.*—A person shall be deemed doing business within this state when engaged in weather modification operations within the boundaries of this state, and shall, if not already qualified to do business within this state under chapter 10-22, prior to conducting such operation, file with the secretary of state an authorization designating an agent for the service of process.

Source: S. L. 1975, ch. 50, § 12.

2-07-03.3. *Issuance of license—Fee.*—The board shall provide, by rules and regulations, the procedure and criteria for the issuance of a license. The board, in accordance with its rules and regulations, shall issue a weather modification license to each applicant who:

1. Pays a license fee of fifty dollars.
2. Demonstrates, to the satisfaction of the board, competence to engage in weather modification operations.
3. Designates an agent for the purpose of service of process pursuant to section 2-07-03.2 or chapter 10-22.

Each license issued by the board shall be nontransferable and shall expire on December thirty-first of the year of issuance. A license shall be revocable for cause at any time prior to such date if, after holding a hearing pursuant to due notice thereof, the board shall so determine. License fees collected by the board shall be paid into the general fund of the state treasury.

Source: S. L. 1975, ch. 50, § 13.

2-07-03.4. *Revocation or suspension of license.*—The board may suspend or revoke a license for any of the following reasons:

1. Incompetency.
2. Dishonest practice.
3. False or fraudulent representations made in obtaining a license or permit under this chapter.

4. Failure to comply with any provisions of this chapter, or any rules or regulations of the board made pursuant to this chapter.

Source: S. L. 1975, ch. 50, § 14.

2-07-04. Permit required—Issuance of permit—Fee.—

1. A Weather modification permit shall be required for each geographical area, as set out in the operational plan required by subsection 2 of this section, in which a person intends to conduct weather modification operations. Each permit issued by the board shall expire on December thirty-first of the year of issuance. A person applying for a weather modification operational permit shall file an application with the board, in such form as the board shall prescribe, which application shall be accompanied by an application fee of twenty-five dollars and contain such information as the board, by rule or regulation, may require, and in addition, each applicant for a permit shall:

a. Furnish proof of financial responsibility as provided by section 2-07-04.3.

b. Set forth a complete operational plan for the proposed operation which shall include a specific statement of its nature and object, a map of the proposed operating area which specifies the primary target area for the proposed operation and shows the area that is reasonably expected to be affected by such operation, a statement of the approximate time during which the operation is to be conducted, a list of the materials and methods to be used in conducting the operation, and such other detailed information as may be needed to describe the operation.

2. The board may issue the operational permit if it determines that:

a. The applicant holds a valid weather modification license issued under this chapter.

b. The applicant has furnished satisfactory proof of financial responsibility in accordance with section 2-07-04.3.

c. The applicant has paid the required application fee.

d. The operation:

(1) Is reasonably conceived to improve water quantity or quality, reduce loss from weather hazards, provide economic benefits for the people of this state, advance scientific knowledge or otherwise carry out the purposes of this chapter.

(2) Is designed to include adequate safeguards to minimize or avoid possible damage to the public health, safety, or welfare or to the environment.

(3) Will not adversely affect another operation for which a permit has been issued.

e. The applicant has North Dakota workmen's compensation insurance coverage for all employees working in North Dakota.

f. The applicant has furnished a performance bond as required by section 2-07-09.

g. The applicant has complied with such other requirements for the issuance of permits as may be required by the rules and regulations of the board.

h. The applicant has furnished a bid bond in accordance with section 2-07-09.1.

i. The applicant has registered, with the North Dakota aeronautics commission, any aircraft and pilots intended to be used in connection with the operation.

In order to carry out the objectives and purposes of this chapter, the board may condition and limit permits as to primary target areas, time of the operation, materials, equipment, and methods to be used in conducting the operation, emergency shutdown procedure, emergency assistance, and such other operational requirements as may be established by the board.

3. The board shall issue only one permit at a time for operations in any geographical area if two or more operations conducted in such an area according to permit limitations might adversely interfere with one another.

4. All permit fees collected by the board shall be paid into the general fund of the state treasury.

*2-07-04.1. Hearings.—*The board shall give public notice, in the official county newspaper or newspapers in the area of the state reasonably expected to be affected by operations conducted under a permit, that it is considering an application for such permit, and, if objection to the issuance of the permit is received by the board within twenty days, the board may hold a public hearing for the

purpose of obtaining information from the public concerning the effects of issuing the permit. The board may also hold such hearings upon its own motion.

Source: S. L. 1975, ch. 50, § 16.

2-07-04.2. Revocation, suspension, or modification of permit.—The board may suspend or revoke a permit if it appears that the permittee no longer has the qualifications necessary for the issuance of an original permit or has violated any provision of this chapter, or any of the rules and regulations issued under it.

The board may revise the conditions and limits of a permit if:

1. The permittee is given notice and a reasonable opportunity for a hearing, to be held in accordance with chapter 28-32.

2. It appears to the board that a modification of the conditions and limits of a permit is necessary to protect the public's health, safety, or welfare or the environment.

If it appears to the board that an emergency situation exists or is impending which could endanger the public's health, safety, or welfare or the environment, the board may, without prior notice or hearing, immediately modify the conditions or limits of a permit, or order temporary suspension of a permit. The issuance of such an order shall include notice of a hearing to be held within ten days thereafter on the question of permanently modifying the conditions and limits or continuing the suspension of the permit. Failure to comply with an order temporarily suspending an operation or modifying the conditions and limits of a permit shall be grounds for immediate revocation of the license and permit of the person controlling or engaged in the operation.

Source: S. L. 1975, ch. 50, § 17.

2-07-04.3. Proof of financial responsibility.—Proof of financial responsibility is made by showing to the satisfaction of the board that the permittee has the ability to respond in damages to liability which might reasonably result from the operation for which the permit is sought. Such proof of financial responsibility may be shown by:

1. Presentation to the board of proof of a prepaid noncancellable insurance policy against such liability, in an amount approved by the board.

2. Filing with the board a corporate surety bond, cash, or negotiable securities in an amount approved by the board.

Source: S. L. 1975, ch. 50, § 18.

2-07-05. Board may create operating districts—Representation of noncontracting counties.—The board shall have the authority to place any county contracting with the state for weather modification operations, in such an operational district as the board shall deem necessary to best provide such county with the benefits of weather modification. In determining the boundaries of such operating districts, the board shall consider the patterns of crops within the state, climatic patterns, and the limitations of aircraft and other technical equipment. The board may assign any county which has not created a weather modification authority under this chapter to an operating district solely for the purpose of representation on the operations committee of such district.

Source: S. L. 1965, ch. 71, § 5; 1975, ch. 50, § 19.

CROSS-REFERENCE

Suspension of issuance of weather modification permits at direction of division of disaster emergency services, see § 37-17.1-15.

2-07-05.1. District operations advisory committees created—Duties.—

1. There shall be a district operations advisory committee in each operations district created in accordance with section 2-07-05. Each committee shall be composed of one commissioner of the weather modification authority from each county within such district and one member of the board of county commissioners from the county or counties assigned to the district in accordance with section 2-07-05. Each advisory committee shall, upon majority vote, with the concurrence of the board, prescribe rules, regulations, and bylaws necessary to govern its procedures and meetings. Each committee shall evaluate weather modification operations within their respective districts and make recommendations and proposals to the board concerning such operations.

2. The weather modification authority of any county authorized to contract for weather modification operations under this chapter and not assigned to an operations district, shall assume the functions of the district operations committee and shall have and may exercise the powers and duties assigned to such

operations committees by this chapter and by the rules and regulations of the board of weather modification.

Source: S. L. 1975, ch. 50, § 20.

2-07-05.2. *Weather modification authority may suspend operations.*—Other provisions of this chapter notwithstanding, the weather modification authority in any county authorized to contract for weather modification operations under this chapter may suspend the county and state weather modification operation within that county designed to alter the weather within such county.

Source: S. L. 1975, ch. 50, § 21.

2-07-06. *Weather modification authority created by petition.*—A weather modification authority shall be created by resolution and five commissioners appointed thereto for ten-year terms of office, by the board of county commissioners after fifty-one percent of the qualified electors of a county, as determined by the vote cast for the office of governor at the last preceding general election, shall petition the board of county commissioners of their county to create a county-wide weather modification authority. The board of county commissioners shall appoint the five commissioners to the weather modification authority, who are residents of their county, and whose names are set forth in the petition and designated by the petitioner to be appointed weather modification authority commissioner is unable or refuses for any reason to accept appointment as commissioner to have met the requirements as to number of qualified electors attached to be petition as required in this chapter. In the event any one of the five candidates named in the petition to be appointed weather modification authority commissioner is unable or refuses for any reason to accept appointment as commissioner, or is disqualified by not meeting residence requirements, as an elector in the county, the board of county commissioners shall name its own appointee for a ten-year term of office in place of any disqualified candidate selected by the petitioners. If any weather modification authority commissioner submits his resignation in writing to the board of county commissioners or becomes unable or disqualified for any reason, after accepting office, the board of county commissioners shall name its appointee as a commissioner to the weather modification authority. All vacancies occurring otherwise than by expiration of term of office shall be filled for the unexpired term.

Any weather modification authority created pursuant to this section shall expire ten years after the date of the initial appointment of the commissioners thereto. Any unexpended funds remaining in the name of the weather modification authority, after all proper bills and expenses have been paid, shall be transferred into the county general fund by the officers of the weather modification authority on or before the ten-year termination date provided by this section; provided, however, that all unexpended funds remaining in the name of the weather modification authority, after all proper bills and expenses have been paid, shall remain in the name of the weather modification authority if the board of county commissioners of such county by resolution creates a weather modification authority and all its powers in accordance with section 2-07-06.4.

2-07-06.1. *Petition contents.*—The petition for petitioning the board of county commissioners in any county of this state for the creation and appointment of commissioners to a weather modification authority shall under this chapter contain:

1. A title with the heading: "Petition for Creation of (insert name of county) Weather Modifications Authority";

2. The following paragraph: We, the undersigned qualified electors of (name of county), state of North Dakota, by this initiated petition request that the (name of county) board of county commissioners of said county create by resolution a (name of county) weather modification authority and to appoint for a term of office of ten years the following five qualified electors of said county as the commissioners for the (name of county) weather modification authority: (a) The name and address of each proposed commissioner for the (name of county) weather modification authority;

3. The following paragraph: We, the undersigned qualified electors of the (name of county), state of North Dakota, are noticed herewith that the creation of (name of county) weather modification authority and the appointment of its commissioners by the (name of county) board of county commissioners will grant unto the authority by law the power to certify to the board of county commissioners a mill levy tax not to exceed two mills upon the net taxable valuation of property in said county for a weather modification fund, which tax may be levied

in excess of the mill levy limit fixed by law for taxes for general county purposes and that such fund shall be used for weather modification activities in conjunction with the state of North Dakota. We, the undersigned understand that the authority requested in this petition expires ten years after the creation of the weather modification authority, except that the board of county commissioners may be resolution create a weather modification authority and all its power, including the power to certify a tax levy as provided by section 2-07-06.3, for five-year periods in accordance with section 2-07-06.4;

4. A heading: "Committee for Petitioners", followed by this statement: The following electors of (name of county), state of North Dakota, are authorized to represent and act for us, and shall constitute the "Committee for the Petitioners" in the matter of this petition and all acts subsequent thereto;

5. Petition details: All petitions' signatures shall be numbered, and dated by month, day and year. The name shall be written with residence address and post-office address including the county of residence followed by state of North Dakota;

6. An affidavit to be attached by each petition and sworn to under oath before a notary public by the person circulating each petition attesting to the fact that he circulated the petition and that each of the signatures to said petition is the genuine signature of the person whose name it purports to be, and that each such person is a qualified elector in the county in which the petition was circulated; and

7. The petition must state the mills to be levied by the county for the purposes of this chapter.

Sources: S. L. 1969, ch. 82, § 2; 1973, ch. 49, § 2; 1975, ch. 50, § 22.

2-07-06.2. *Commissioners—Compensation—Meetings—Officers.*—A commissioner of a weather modification authority shall receive no compensation for his services, but shall be entitled to the necessary expense, as defined in section 44-08-04, incurred in the discharge of his duties. Each commissioner shall hold office until his successor has been appointed and has qualified. The certificates of the appointment shall be filed with the weather modification authority.

The powers of each weather modification authority shall be vested in the commissioners thereof. A majority of the commissioners of an authority shall constitute a quorum for the purpose of conducting business of the authority and exercising its powers and for all other purposes. Action may be taken by the authority upon a vote of not less than a majority of all the commissioners.

There shall be elected a chairman, vice-chairman, and treasurer from among the commissioners. A weather modification authority may employ an executive director, secretary, technical experts, and such other officers, agents, and employees, permanent and temporary, as it may require, and shall determine their qualifications, duties, and compensation. For such legal services as it may require, an authority may call upon the chief law officer of the county which created the authority. An authority may delegate to one or more of its agents or employees such powers or duties as it may deem proper.

Minutes shall be kept by the secretary of official meetings and shall include all official business such as contracts authorized and all authorizations for payment of weather modification authority funds to persons, organizations, companies, and corporations. All disbursements shall be approved by a majority of all the commissioners of an authority. Disbursements authorized by the authority for the payment of employee salaries, bills, contracts, services, fees, expenses, and all other obligations, shall be made by check signed by the chairman and the treasurer of the authority. Official policies shall also be entered into the minutes. An annual report shall be compiled with complete disclosure of funds expended for contracts, services, fees, salaries and all other reimbursements, a copy of which shall be filed with the county auditor. Such report shall be given at a public meeting called for such purpose.

Source: S. L. 1969, ch. 82, § 3; 1973, ch. 49, § 3.

2-07-06.3. *Tax levy may be certified by weather modification authority.*—The weather modification authority may certify annually to the board of county commissioners a tax of not to exceed two mills upon the net taxable valuation of the property in the county for a "weather modification" fund which tax shall be levied by the board of county commissioners and which tax may be levied in excess of the mill limit fixed by law for taxes for general county purposes. Such fund shall be used only for weather modification activities in conjunction with the state of North Dakota. The tax certified by the weather modification authority

is limited to the period of existence of the weather modification authority as provided for in this chapter.

Source: S. L. 1969, ch. 82, § 4; 1973, ch. 49, § 4; 1975, ch. 50, § 23.

2-07-06.4. Creation of weather modification authority and its powers by resolution.—When a weather modification authority is about to expire, the board of county commissioners of any such county may by resolution authorize the creation of such weather modification authority and all its powers, including the power to certify a tax levy as provided by section 2-07-06.3 for additional five-year periods provided, the resolution authorizing the creation of such weather modification authority is adopted by the board of county commissioners before the expiration date prescribed in the preceding resolution for its termination. Upon passing such resolution for the creation of the authority, the board of county commissioners shall appoint five weather modification authority commissioners to five-year terms of office, subsequently filling vacancies in the manner prescribed by section 2-07-06. The board of county commissioners may remove from office any weather modification commissioner, whenever it appears to them by competent evidence and after a hearing that such commissioner has been guilty of misconduct, malfeasance, crime in office, neglect of duty in office, or of habitual drunkenness or gross incompetency.

Source: S. L. 1973, ch. 49, § 5.

2-07-06.5. Procedure for abolishment of weather modification authority and all its powers by recall initiated petition.—After fifty-one percent of the qualified electors of a county, as determined by the vote cast for the office of governor at the last preceding gubernatorial election, shall petition the board of county commissioners of their county to recall the commissioners of a weather modification authority as created by section 2-07-06 and to abolish such county weather modification authority, the board of county commissioners shall adopt a resolution recalling all commissioners of such weather modification authority and abolish their appointed office and abolish such weather modification authority until such time as a weather modification authority is created by petition in accordance with section 2-07-06, provided that such recall petition has been found by the county commissioners to have met the requirements as to the number of qualified electors attached to the petition as required in this chapter. In the event the board of county commissioners certifies the sufficiency and validity of the recall petition and adopts a resolution recalling all commissioners of a weather modification authority and abolishes such authority, then all unexpended funds remaining in the name of the weather modification authority, after all proper bills and expenses have been paid, shall be transferred into the county general fund by the officers of the weather modification authority on the effective date of such recall and abolishment resolution adopted by the board of county commissioners. In the event there are outstanding valid bills unpaid after such date, the board of county commissioners is hereby authorized to pay such proper obligations from moneys in the county general fund. A recall initiated petition shall have a title with the heading: "Recall Petition for the Abolishment of (insert name of county) Weather Modification Authority". Such recall petition shall incorporate a paragraph stating its purpose in clear language and shall comply with all requirements prescribed in subsections 4, 5, and 6 of section 2-07-06.1 relating to petition contents, committee for petitioners, petition details, affidavits and persons circulating such petitions.

2-07-06.6. Creation of weather modification authority by election.—When a petition signed by not less than twenty percent of the qualified electors of the county, as determined by the vote cast for the office of governor at the last preceding gubernatorial election, requesting an election upon the establishment of such recall and abolishment resolution adopted by the board of county commissioners, the board of county commissioners shall submit the question to the electors of the county at the next county-wide election. Upon approval by a majority of the votes cast, the board of county commissioners shall establish a weather modification authority as described in section 2-07-06, with all its powers, including the power to certify a tax levy as provided by section 2-07-06.3.

Source: S. L. 1973, ch. 49, § 7.

2-07-06.7. Abolishment of weather modification authority by election.—When a petition signed by not less than twenty percent of the qualified electors of the county, as determined by the vote cast for governor in the last preceding gubernatorial election, requesting an election upon the abolishment of a weather modification authority as created in section 2-07-06.4 and section 2-07-06.6 is presented to the board of county commissioners, the board of county commis-

sioners shall submit the question to the electors of the county at the next county-wide election. Upon approval by a majority of the votes cast, the board of county commissioners shall abolish the weather modification authority as of December thirty-first following the election. All unexpended funds remaining in the name of the weather modification authority, after all proper bills and expenses have been paid, shall be deposited in the general fund of the county.

Source: S. L. 1973, ch. 49, § 8.

2-07-06.8. Creation of weather modification authority by vote after resolution of county commissioners.—The board of county commissioners of any county may, by resolution after a public hearing, submit the question of the creation of a weather modification authority to the electors of the county at the next county-wide election. Upon approval by a majority of the votes cast, the board of county commissioners shall pass a resolution creating a weather modification authority, as described in section 2-07-06, including the authority to levy a tax as provided by section 2-07-06.3.

Source: S. L. 1975, ch. 50, § 24.

2-07-07. County budget may be waived for first appropriation—Conditions.—The provisions of chapter 11-23 shall not apply to appropriations made under the provisions of this chapter, provided, however, that only after the filing and approval of the “petitions” to create a weather modification authority by the board of county commissioners and certification of a mill levy by the weather modification authority and only for the initial or first appropriation of said “weather modification” activities, such county commissioners may, at their discretion, appropriate from moneys not otherwise appropriated in the general fund, such moneys as are necessary for carrying out the provisions of this chapter, provided that said appropriation shall not exceed an amount equal to two-mill levy upon the net taxable valuation of the property in said county.

Source: S. L. 1965, ch. 71, § 7; 1969, ch. 82, § 5.

2-07-08. Bids required—When.—Whenever the board of weather modification shall undertake to contract with any licensed controller in an amount in excess of ten thousand dollars in any one year, the board shall advertise for proposals for such weather modification activities and in its proceedings with respect to bids therefor, shall substantially follow the manner and form required by the laws of this state for the purchase of supplies by the department of accounts and purchases. The board shall enter into no contract or agreement for weather modification services except with a controller, holding the permit as required by this chapter, except for the purpose of gathering technical information, and making studies or surveys.

Source: S. L. 1965, ch. 71, § 8; 1973, ch. 49, § 9; 1975, ch. 50, § 25.

2-07-09. Performance bond required.—Before the board shall contract with any controller, it shall require the controller to furnish a surety bond for the faithful performance of the contract in such amount as determined by the board, conditioned that the licensee and his agents will in all respects faithfully perform all weather modification contracts undertaken with the board and will comply with all provisions of this chapter and the contract entered into by the board and the licensee.

Source: S. L. 1965, ch. 71, § 9; 1973, ch. 49, § 10; 1975, ch. 50, § 26.

2-07-09.1 Bid bond required.—All bids submitted to the board of weather modification for operations conducted under this chapter shall be accompanied by a bidder's bond in a sum equal to five percent of the full amount of the bid, executed by the bidder as principal and by a surety company authorized to do business in this state as a guaranty that the bidder will enter into the contract if it is awarded to him.

Source: S. L. 1975, ch. 50, § 27.

2-07-10. State immunity.—Nothing in this chapter shall be construed to impose or accept any liability or responsibility on the part of the state of North Dakota or any of its agencies, or any state officials or state employees or weather modification authorities for any injury caused by weather modification operations by any person or licensed controller as defined in this chapter.

Source: S. L. 1965, ch. 71, § 10; 1973, ch. 49, § 11; 1975, ch. 50, § 28.

2-07-10.1. Liability of controller.—

1. An operation conducted under the license and permit requirements of this chapter is not an ultrahazardous or abnormally dangerous activity which makes the permittee subject to liability without fault.

2. Dissemination of materials and substances into the atmosphere by a permittee acting within the conditions and limits of his permit shall not constitute trespass.

3. Except as provided in this section and in section 2-07-10, nothing in this chapter shall prevent any person adversely affected by a weather modification operation from recovering damages resulting from negligent or intentionally harmful conduct by a permittee.

4. The fact that a person holds a license or was issued a permit under this chapter, or that he has complied with the rules and regulations made by the board pursuant to this chapter, is not admissible as a defense in any legal action which may be brought against him.

Source: S. L. 1975, ch. 50, § 29.

2-07-11. Weather modification board may receive and expend funds.—The weather modification board is hereby authorized to receive and accept for and in the name of the state any and all funds which may be offered or become available from federal grants or appropriations, private gifts, donations or bequests, county funds, or funds from any other source, except license and permit fees, and to expend said funds for the expense of administering this chapter, and, with the exception of county funds, for the encouragement of research and development in weather modification by any private person, the North Dakota state university, the university of North Dakota, or any other appropriate state, county, or public agency in this state either by direct grant, by contract, or by other means.

All federal grants, federal appropriations, private gifts, donations or bequests, county funds, or funds from any other source, except license and permit fees, received by the board shall be paid over to the state treasurer, who shall credit same to a special fund in the state treasury, who shall credit some to a special fund in the state treasury known as the "state weather modification fund". All proceeds deposited by the state treasurer in the state weather modification fund are hereby appropriated to the North Dakota weather modification board and shall, if expended, be disbursed by warrant-check prepared by the department of accounts and purchases upon vouchers submitted by the North Dakota weather modification board, and shall be used for the purpose of paying for the expense of administration of this chapter and, with the exception of county funds, for the encouragement of research and development in weather modification by any private person, the North Dakota state university, the university of North Dakota, or any other appropriate state, county, or public agency by direct grant, by contract, or by other means.

Source: S. L. 1965, ch. 71, § 11; 1975, ch. 50, § 30.

2-07-11.1. County appropriations—State to provide matching funds.—Any county weather modification authority which has contracted with the board of weather modification for weather modification operations under this chapter shall appropriate to the state weather modification fund one-half of the total amount determined by the board of weather modification as necessary to provide such county with weather modification operations. The board of weather modification may expend, from the state weather modification fund, such funds as it deems necessary to provide contracting counties with weather modification operations.

2-07-12. Aeronautics commission—Compensation—Expenses.—Each member of the North Dakota aeronautics commission shall receive the same compensation that is paid for other aeronautics commission duties for each day actually and necessarily engaged in performance of official duties in connection with the administration of this chapter, and commission members and employees shall be reimbursed for actual and necessary expenses incurred in carrying out their official duties in the same manner and at the same rates as provided by law for state employees.

2-07-13. Penalty.—Any person contracting for or conducting any weather modification activity without being licensed in accordance with the provisions of this chapter or otherwise violating the provisions thereof shall be guilty of a class B misdemeanor.

OKLAHOMA

Okl. Stat. Ann. Tit. 2, §§ 1401-1432

CHAPTER 29—OKLAHOMA WEATHER MODIFICATION ACT

Sec.

- 1401. Short title.
- 1402. Definitions.
- 1403. Powers of Board.
- 1404. Continued conduct of research and development activities.
- 1405. Hearings.

Sec.	
1406.	Gifts and grants.
1407.	Necessity for licenses and permits.
1408.	Exemptions.
1409.	Issuance of licenses.
1410.	Issuance of permits.
1411.	Separate permits—Notice of intention.
1412.	Contents of notice of intention.
1413.	Publication of notice of intention.
1414.	Proof of financial responsibility.
1415.	Permit fees.
1416.	Records and reports.
1416.1	Monitoring by United States Government.
1417.	Revocation or suspension of licenses or permits—Modification of permits.
1418.	Certain liabilities not imposed or rights affected.
1419.	Penalties.
1420.	Purpose.
1421.	Expenditure of monies.
1422.	Receipt of monies—Contracts.
1423.	Call for election on weather modification assessment—Notice—Contents.
1424.	Proposed budget—Appraisers.
1425.	Hearing of protests concerning appraisals.
1426.	Collection of assessments.
1427.	Weather modification fund—Reports.
1428.	Discontinuance of activities.
1429.	Essential function of county government—Disbursements.
1430.	Liens—Tax sales.
1431.	Contracts for joint operations.
1432.	Construction—Codification.

§ 1401. Short title

This act may be cited as the "Oklahoma Weather Modification Act."
Laws 1972, c. 228, § 1, eff. April 7, 1972.

§ 1402. Definitions

As used in this act, unless the context requires otherwise :

1. "Board" means the Oklahoma Water Resources Board ;
2. "Operation" means the performance of weather modification and control activities pursuant to weather modification and control activities pursuant to a single contract entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one specified geographical area over one continuing time interval not exceeding one (1) year, or, if the performance of weather modification and control activities is to be undertaken individually or jointly by a person or persons to be benefited and not undertaken pursuant to a contract, "operation" means the performance of weather modification and control activities entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one specified geographical area over one continuing time interval not exceeding one (1) year ;
3. "Research and development" means theoretical analysis, exploration and experimentation and the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes including the experimental production and testing of models, devices, equipment, materials and processes ; and
4. "Weather modification" or "weather modification and control" means changing or controlling, or attempting to change or control, by artificial methods the natural development of any or all atmospheric cloud forms or precipitation forms which occur in the troposphere. (Laws 1972, c. 228, § 2, eff. April 7, 1972. Laws 1973, c. 180, § 14, eff. May 16, 1973.)

§ 1403. Powers of board

In the performance of the functions authorized herein, the Board may, in addition to any other acts authorized by law :

1. Establish advisory committees to advise with and make recommendations to the Board concerning legislation, policies, administration, research and other matters ;
2. Establish by regulation or order such standards and instructions to govern the carrying out of research or projects in weather modification and control as the Board may deem necessary or desirable to minimize danger to health or property, and make such regulations as are necessary in the performance of its powers and duties ;
3. Make such studies and investigations, obtain such information, and hold such hearings as the Board may deem necessary or proper to assist it in exercising its authority or in the administration or enforcement of this act or any regulations or orders issued thereunder ;

4. Appoint and fix the compensation of such personnel, including specialists and consultants, as are necessary to perform its duties and functions hereunder ;

5. Acquire, in the manner provided by law, such materials, equipment and facilities as are necessary to perform its duties and functions hereunder ;

6. Cooperate with public or private agencies in the performance of the Board's functions or duties and in furtherance of the purposes of this act ;

7. Represent the state in any and all matters pertaining to plans, procedures or negotiations for interstate compacts or cooperative agreements relating to weather modification and control ;

8. Enter into cooperative agreements with the United States Government or any of its agencies, other states, or with the various counties and cities of this state or with any private or public agencies for conducting weather modification or cloud seeding operations ;

9. Act for and represent the state and the counties, cities and private or public agencies in contracting with private concerns for the performance of weather modifications or cloud seeding operations ; and

10. Assist and cooperate in the formation of weather modification districts within this state. (Laws 1972, c. 228, § 3, eff. April 7, 1972.)

§ 1404. *Continued conduct of research and development activities*

The Board shall exercise its powers in such manner as to promote the continued conduct of research and development activities in the fields specified below by private or public institutions or persons and to assist in the acquisition of an expanding fund of theoretical and practical knowledge in such fields. To this end the Board may conduct, and make arrangements including contracts and agreements for the conduct of, research and development activities relating to :

1. The theory and development of methods of weather modification and control, including processes, materials and devices related thereto ;

2. Utilization of weather modification and control for agricultural, industrial, commercial, municipal and other purposes ; and

3. The protection of life and property during research and operational activities. (Laws 1972, c. 228, § 4, eff. April 7, 1972.)

§ 1405. *Hearings*

In the case of hearings held pursuant to this act, the Board shall conduct such hearings in accordance with the provisions of the Administrative Procedures Act.¹ (Laws 1972 c.228, § 5, eff. April 7, 1972.)

§ 1406. *Gifts and grants*

A. The Board may, subject to any limitations otherwise imposed by law, receive and accept for and in the name of the state any funds which may be offered or become available from federal grants or appropriations, private gifts, donations or bequests, or from any other source, and may expend such funds, unless their use is restricted and subject to any limitations otherwise provided by law, for the administration of this act for operations and research and for the encouragement of research and development by a state or public or private agency, either by direct grant, by contract or other cooperative means.

B. All license and permit fees paid to the Board shall be deposited in the General Revenue Fund of the State Treasury. (Laws 1972, c. 228, § 6, eff. April 7, 1972.)

§ 1407. *Necessity for licenses and permits*

Except as provided in Section 8 of this act,² no person, corporation or institution shall engage in activities for weather modification and control except under and in accordance with a license and a permit issued by the Board authorizing such activities. (Laws 1972, c. 228, § 7, eff. April 7, 1972.)

§ 1408. *Exemptions*

The Board, to the extent it deems practical, shall provide by regulation for exempting from the license and permit requirements of this act :

1. Research and development and experiments by state and federal agencies and institutions of higher learning ;

2. Laboratory research and experiments ;

3. Activities normally engaged in for purposes other than those of inducing, increasing, decreasing or preventing precipitation ; and

¹ Section 301 et seq. of Title 75.

² Section 1408 of this title.

4. Religious ceremonies, rites or acts and American Indian or other cultural ceremonies which do not utilize chemical or mechanical means to alter weather phenomena and which are not performed for profit. (Laws 1972, c. 228, § 8, eff. April 7, 1972.)

§ 1409. *Issuance of licenses*

A. Licenses to engage in activities for weather modification and control shall be issued to applicants therefor who pay the license fee required and who demonstrate, to the satisfaction of the Board, competence in the field of meteorology and financial responsibility reasonably necessary to engage in activities for weather modification and control. If the applicant is an organization, these requirements shall be met by the individual or individuals who are to be in control and in charge of the operation for the applicant.

B. The Board shall issue licenses in accordance with such procedures and subject to such conditions as it may by regulation establish to effectuate the provisions of this act. Each license shall be issued for a period to expire at the end of the state fiscal year in which it is issued and, if the licensee possesses the qualifications necessary for the issuance of a new license, such license shall upon application be renewed at the expiration of such period. A license shall be issued or renewed only upon the payment to the Board of One Hundred Dollars (\$100.00) for the license or renewal thereof. (Laws 1972, c. 228, § 8, eff. April 7, 1972.)

§ 1410. *Issuance of permits*

The Board shall issue permits in accordance with such procedures and subject to such conditions as it may by regulation establish to effectuate the provisions of this act only:

1. If the applicant is licensed pursuant to this act;
2. If a sufficient notice of intention is published and proof of publication is filed as required by Section 13 of this act;³
3. If the fee for a permit is paid as required by Section 15 of this act;⁴ and
4. If the applicant has given bond for the faithful performance of any weather modification contract which the applicant has entered into for the weather modification operation for which application was made for the permit. The surety on any bond to guarantee the faithful performance and execution of any work shall be deemed and held, any contract to the contrary notwithstanding, to consent without notice to an extension of time to the contractor in which to perform the contract for a period of not more than thirty (30) days. (Laws 1972, c. 228, § 10, eff. April 7, 1972.)

§ 1411. *Separate permits—Notice of intention*

A separate permit shall be issued for each operation. Prior to undertaking any weather modification and control activities the licensee shall file with the Board and also cause to be published a notice of intention. The licensee, if a permit is issued, shall confine his activities for the permitted operation substantially within the time and area limits set forth in the notice of intention, unless modified by the Board, and his activities shall also conform to any conditions imposed by the Board upon the issuance of the permit or to the terms of the permit as modified after issuance. (Laws 1972, c. 228, § 11, eff. April 7, 1972.)

§ 1412. *Contents of notice of intention*

The notice of intention shall set forth at least all of the following:

1. The name and address of the licensee;
2. The nature and object of the intended operation and the person or organization on whose behalf it is to be conducted;
3. The area in which and the approximate time during which the operation will be conducted;
4. The area which is intended to be affected by the operation; and
5. The materials and methods to be used in conducting the operation. (Laws 1972, c. 228, § 12, eff. April 7, 1972.)

§ 1413. *Publication of notice of intention*

A. The applicant shall cause the notice of intention, or that portion thereof including the items specified in Section 12 of this act,⁵ to be published at least

³ Section 1413 of this title.

⁴ Section 1415 of this title.

⁵ Section 1412 of this title.

once a week for two (2) consecutive weeks in a newspaper having a general circulation and published within any county in which the operation is to be conducted and in which the affected area is located, or, if the operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the operation is to be conducted, then in a newspaper having a general circulation and published within each of such counties. In case there is no newspaper published within the appropriate county, publication shall be made in a newspaper having a general circulation within the county.

B. Proof of publication together with publisher's affidavit, shall be filed by the licensee with the Board within fifteen (15) days from the date of the last publication of the notice.

C. Provided, that upon declaration of emergency drought conditions within any county or counties of this state by proclamation by the Governor or by concurrent resolution by the Legislature, the provisions of this act requiring notice by publication of intent to perform any weather modification operation may be suspended. (Laws 1972, c. 228, § 13, eff. April 7, 1972.)

§ 1414. *Proof of financial responsibility*

Proof of financial responsibility shall be furnished by an applicant by his showing, to the satisfaction of the director, his ability to respond in damages for liability which might reasonably be attached to or result from his weather modification and control activities in connection with the operation for which he seeks a permit. (Laws 1972, c. 228, § 14, eff. April 7, 1972.)

§ 1415. *Permit fees*

The fee to be paid by each applicant for a permit shall not exceed Twenty-five Dollars (\$25.00). (Laws 1972, c. 228, § 15, eff. April 7, 1972.)

§ 1416. *Records and reports*

A. Each licensee shall keep and maintain a record of all operations conducted by him pursuant to his license and each permit, showing the method employed, the type of equipment used, materials and amounts thereof used, the times and places of operation of the equipment, the name and post office address of each individual participating or assisting in the operation other than the licensee, and such other general information as may be required by the Board, and shall report the same to the Board at the time and in the manner required by the Board.

B. The Board shall require written reports regarding methods and results, but not inconsistent with the provisions of this act, covering each operation for which a permit is issued. The Board shall also require written reports from such organizations as are exempt under Section 8⁶ from the license and permit requirements of this act.

C. All information on an operation shall be submitted to the Board before any information on such operation may be released to the public.

D. The reports and records in the custody of the Board shall be open for public examination as public documents. (Laws 1972, c. 228, § 16, eff. April 7, 1972.)

§ 1416.1 *Monitoring by United States Government*

When a permit is issued under the Oklahoma Weather Modification Act for weather modification research by the United States Government or its agent, any other operation for which a permit is issued and which is located in full or in part within the area of the permitted research operation shall submit to monitoring by the agency conducting such operation when such operation is being conducted. (Added by Laws 1973, c. 180, § 15, eff. May 16, 1973.)

§ 1417. *Revocation or suspension of licenses or permits—Modification of permits*

A. Under the provisions of the Administrative Procedures Act,⁷ the Board may suspend, revoke or refuse to renew any license or permit issued by it if the applicant no longer qualifies for such license or permit under the provisions of this act or if the applicant has violated any provisions of this act.

B. The Board may modify the terms of a permit after issuance thereof if the licensee is first given notice and a reasonable opportunity for a hearing respecting the grounds for the proposed modification and if it appears to the Board that it is necessary for the protection of the health or the property of any person to make the modification proposed. (Laws 1972, c. 228, § 17, eff. April 7, 1972.)

⁶ Section 1408 of this title.

⁷ Section 301 et seq. of Title 75.

§ 1418. *Certain liabilities not imposed or rights affected*

Nothing in this act shall be construed to impose or accept any liability or responsibility on the part of the state or any state officials or employees for any weather modification and control activities of any private person or group, or to affect in any way any contractual, tortious or other legal rights, duties or liabilities between any private persons or groups. (Laws 1972, c. 228, § 18, eff. April 7, 1972.)

§ 1419. *Penalties*

Any person violating any of the provisions of this act or any lawful regulation or order issued pursuant thereto shall be guilty of a misdemeanor and a continuing violation punishable as a separate offense for each day during which it occurs, and upon conviction shall be imprisoned in the county jail for not more than ten (10) days or by a fine of not less than One Hundred Dollars (\$100.00) nor more than One Thousand Dollars (\$1,000.00), or by both, for each such separate offense. (Laws 1972, c. 228, § 19, eff. April 7, 1972.)

§ 1420. *Purpose*

The Legislature finds that it is in the best interest of the citizens of the State of Oklahoma to establish a procedure whereby the orderly conduct of weather modification programs can be administered, controlled and financed at the local level under the licensing and permit system established by the State of Oklahoma; further determines that such programs benefit all citizens and property in areas where they are operated, and that counties are authorized to finance programs of weather modification pursuant to the provisions of Article 10, Section 7 of the Oklahoma Constitution. It is the intention of the Legislature that this act be liberally construed so as to promote the general welfare and prosperity of the citizens of this state. (Added by Laws 1973, c. 180, § 1, eff. May 16, 1973.)

§ 1421. *Expenditure of monies*

Counties, cities, towns, other local subdivisions of government, state agencies, and special purpose districts may expend monies for weather modification and control from the following sources:

1. General funds not otherwise obligated, provided that state agencies may only expend funds for weather modification on lands owned by them or under their administrative controls or as otherwise provided by law;
2. Monies received by such entities for weather modification and control; and
3. Monies received from assessments as provided in this act. (Added by Laws 1973, c. 180, § 2, eff. May 16, 1973.)

§ 1422. *Receipt of monies—Contracts*

Counties, cities, towns, other local subdivisions of government, state agencies, and special purpose districts may receive public and private donations, payments and grants for weather modification and control. Any of the foregoing entities may contract among themselves, with state and federal agencies, and with private individuals and entities for payments, grants and donations of money for weather modification and control. (Added by Laws 1973, c. 180, § 3, eff. May 16, 1973.)

§ 1423. *Call for election on weather modification assessment—Notice—Contents*

On a petition signed by qualified electors equal to at least ten percent (10%) of the total number of votes cast by county electors in the most recent general election, or on their own motion, the board of county commissioners shall call an election and submit to the electors of the county the question of whether or not an assessment shall be levied. The board of county commissioners may exempt areas within municipalities or other areas from the assessment and may contract with such areas to make payments in lieu of assessments. The county commissioners shall exclude from voting the electors in those areas exempt from assessment. The notice of election shall be published once weekly for four (4) weeks in a newspaper of general circulation in the county. The notice shall specify the election date, the proposed weather modification plan, the proposed budget, the total amount of money proposed to be assessed, the purpose for which it is intended to be used, the maximum annual assessments proposed to be levied and the number of years, not to exceed five (5) years, for which the assessment shall be authorized. The election shall be conducted by the county election board in accordance with the general election laws of this state. The ballots shall contain the words "Weather Modification-Assessment-Yes" and "Weather Modification-

Assessment-No." If a majority of votes are "Weather Modification-Yes", the county commissioners shall, at the time of the annual levy thereunder, levy the assessment. (Added by Laws 1973, c. 180, § 4, eff. May 16, 1973.)

§ 1424. *Proposed budget—Appraisers—Waiver of assessment*

Before calling the election, the board of county commissioners shall prepare a proposed budget for weather modification and control, which may include, in addition to actual cost of a weather modification program, the cost of conducting the election, any additional costs of assessments and collection, payment of appraisers of benefits, costs of publication of notice and other costs incurred by the county if it joins with other units of government in joint modification programs. The board of county commissioners shall then determine, after consideration of other funds available from all sources, the total amount needed to be raised by assessment.

The board of county commissioners shall appoint three (3) landowners who are residents of the area to be assessed, to act as appraisers to appraise and apportion the benefits and recommend the assessments to pay for such benefits. For such purpose the appraisers shall use the records of the county assessor. Immediately after the appraisals are completed, they shall file a written report with the board of county commissioners. The board of county commissioners may, on their own motion or on the report of the appraisers and after adopting a uniform policy, waive the levy of assessment, when the board or appraisers finds that the benefits and assessments are negligible, are not justifiably economical to collect or are satisfied by an in lieu payment. Such waiver of assessment shall not be considered an exemption from assessment for any purpose, including the voting provisions of the preceding section. (Amended by Laws 1975, c. 305, § 1, emerg. eff. June 7, 1975.)

§ 1425. *Hearing of protests concerning appraisals*

After an affirmative vote of electors, the commissioners shall appoint a time and place for holding a public hearing to hear any protests concerning the appraisals. The hearing shall be held after published notice for two (2) weeks in a newspaper of general circulation in the county giving the date, time and purpose of the hearing. At the hearing, the board of county commissioners shall have the authority to review and correct said appraisals and shall by resolution confirm the same as so revised and corrected by them. Any person objecting to the appraisal of benefits and assessment of his property as confirmed shall have the right of the appeal to the district court. (Added by Laws 1973, c. 180, § 6, eff. May 16, 1973.)

§ 1426. *Collection of assessments*

A. The assessment shall become due and shall be collected at the same time ad valorem taxes are due and collected. Such annual levy shall be certified not later than October 1 of each year to the county treasurer of the county in which the property is situated. The certificate shall be substantially as hereinafter provided.

B. The certificate shall set forth a table or schedule showing in properly ruled columns:

1. The names of the owners of the property to be assessed;
2. The description of the property opposite the names of the owners;
3. The total amount of the annual assessment on the property;
4. The total amount of all delinquent assessments;
5. The total assessment against the land for the year;
6. A blank column in which the county treasurer shall record the amounts collected;
7. A blank column in which the county treasurer shall record the date of payment; and
8. A blank column in which the county treasurer shall report the name of the person who paid.

C. The certificate and report shall be prepared in triplicate in a book named "Assessment Book of Weather Modification, _____ County, Oklahoma". This name shall also be printed at the top of each page.

D. Two (2) copies of the certificate shall be forwarded to the county treasurer of the county wherein the land is located. The county treasurer shall receive the certificate as a special assessment book, and shall certify it as other special assessment records and shall collect the assessment according to law. The special assessment book shall be treasurer's warrant and authority to demand and receive the assessment due; and it shall be unlawful for any county treasurer to accept payment of the ad valorem taxes levied against any property described therein

until the owner has been notified that there is a special assessment noted in the special assessment book. (Added by Laws 1973, c. 180, § 7, eff. May 16, 1973.)

§ 1427. *Weather modification fund—Reports*

The county treasurer shall establish a weather modification fund and shall deposit all monies collected from assessments, grants, donations or other sources for weather modification purposes and make monthly reports of the sums collected to the board or county commissioners. The county treasurer shall make a report to the commissioners immediately after October 31 of each year of the sums collected and of the assessments not collected. All assessments remaining unpaid after they become due and collectible shall be delinquent and bear a penalty in the same manner as ad valorem taxes. (Added by Laws 1973, c. 180, § 8, eff. May 16, 1973.)

§ 1428. *Discontinuance of activities*

If a county ceases to be involved in weather modification activities, any unexpended funds in the weather modification fund shall be invested in interest-bearing obligations of the United States Government until weather modification activities are resumed, with the interest therefrom credited to the weather modification fund. If, after five (5) years, the county has not resumed activity in weather modification, the board of county commissioners shall transfer said unexpended funds collected by assessment, with interest accrued, to a sinking fund of the county, to reduce bonded indebtedness, and the board of county commissioners shall refund, on a pro rata basis, monies from other sources. (Added by Laws 1973, c. 180, § 9, eff. May 16, 1973.)

§ 1429. *Essential function of county government—Disbursements*

The weather modification activities herein authorized shall be deemed to be an essential function of county government. All disbursements from the weather modification fund shall be made in accordance with the requirements and procedures for disbursement from the county general fund. All records required to be maintained as to disbursements from the county general fund shall likewise be maintained on disbursements from the weather modification fund. (Added by Laws 1973, c. 180, § 10, eff. May 16, 1973.)

§ 1430. *Liens—Tax sales*

All assessments and all costs and expenses of collecting delinquent assessments shall constitute a lien on the property against which the assessments have been levied. Such lien shall attach on the date which the assessment certificate is filed in the office of the county treasurer and shall continue until paid. Such lien shall have the same priority as a lien created by delinquent ad valorem taxes, all other taxes and special assessments. Delinquent assessments shall be collected by the county treasurer in the same manner and at the same time as delinquent ad valorem taxes are collected. Any tax sale shall include all costs incurred due to said sale, and such lien may be evidenced by any ad valorem tax sale certificate including said charge substantially in the form required by law.

Unless expressly declared to the contrary, no warranty deed or deed made pursuant to a judicial sale shall warrant against any portion of any assessment or assessments levied hereunder except installments due before the date of such deed. (Added by Laws 1973, c. 180, § 11, eff. May 16, 1973.)

§ 1431. *Contracts for joint operations*

Counties may contract with other counties and other local subdivisions of government and state and federal agencies to engage in joint weather modification operations. All such contracts shall be filed with and approved by the Board. (Added by Laws 1973, c. 180, § 12, eff. May 16, 1973.)

§ 1432. *Construction—Codification*

This act shall be construed as part of the Oklahoma Weather Modification Act, and Sections 1 through 12 of this act shall be codified as a part thereof. (Added by Laws 1973, c. 180, § 13, eff. May 16, 1973.)

OREGON

Oregon Rev. Stat. §§ 558.010-558.990; 451.010; 451.420

WEATHER MODIFICATION

Licensing

558.010 Definitions for ORS 558.010 to 558.140.
558.020 Purpose of ORS 558.10 to 558.140 and 558.990.

558.030	Artificial weather modification prohibited without license.
558.040	Application for license ; fee.
558.050	Applicant to file proof of financial responsibility.
558.055	Hearing an application for license.
558.060	Issuance of license ; conditions ; licensee's authority ; use of improper materials cause for suspension or revocation ; renewal.
558.066	Governmental entities conducting weather modification at airport exempted.
558.080	Contents of hearing notice.
558.090	Publication of notice of hearing.
558.100	Proof of publication.
558.110	Records and reports of operations ; public examination.
558.120	Emergency licenses.
558.135	Revocation, suspension, refusal to issue or renew license ; procedure.
558.140	Appropriation for administration and enforcement.

Weather Modification Districts (General Provisions)

558.200	"County court" defined.
558.205	Initiative and referendum.
	(Incorporation)
558.210	Incorporation for weather modification ; limitations as to area.
558.235	Forest lands not benefited property ; not included in district except upon petition.
558.245	Time for formation election.
558.255	Commissioners of first board ; qualifications.
558.270	Certificates of election for commissioners.

(Powers of District)

558.300	General powers of district.
558.310	Limitation on right to own or operate equipment.
558.315	Regulations concerning district property.
558.320	Duty to carry liability insurance.
558.325	Cooperative agreements between districts.
558.340	Tax assessment, levy and collection.
558.345	Disposal of taxes levied when organization declared invalid.
558.350	Employes' retirement system authorized.
558.355	District to budget for retirement system.
558.360	Employee contribution.
558.365	Limitation on membership.

(Board of Commissioners)

558.400	Powers of district in board ; qualifications, terms and election of commissioners.
558.410	Board meeting ; officers ; quorum ; employing assistance ; employee benefits.
558.415	Increasing number of commissioners.
558.430	Deposit and withdrawal of moneys ; annual reports ; records.
558.440	Calling special elections.

Penalties

558.990	Penalties.
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LICENSING

558.010 *Definitions for ORS 558.010 to 558.140.* As used in ORS 558.010 to 558.140 and 558.990 :

(1) "Department" means the State Department of Agriculture.

(2) "Person" includes any public or private corporation. [1953 c.654 s.1: 1955 c.61 s.4]

558.020 *Purpose of ORS 558.010 to 558.140 and 558.990.* The purpose of ORS 558.010 to 558.140 and 558.990 is to promote the public health, safety and welfare by providing for the licensing, regulation and control of interference by artificial means with the natural precipitation of rain, snow, hail, moisture or water in any form contained in the atmosphere. [1953 c.654 s.2]

558.030 *Artificial weather modification prohibited without license.* No person, without securing a license from the department, shall cause or attempt to cause by artificial means condensation or precipitation of rain, snow, hail, moisture or water in any form contained in the atmosphere, or shall prevent or attempt to prevent by artificial means the natural condensation or precipitation of rain, snow, hail, moisture or water in any form contained in the atmosphere. [1953 c.654 s.3]

558.040 *Application for license ; fee.* (1) Any person desiring to do any of the acts specified in ORS 558.030 shall file with the department an application for a license on a form to be supplied by the department for such purpose setting forth all of the following :

(a) The name and post-office address of the applicant.

(b) The education, experience and qualifications of the applicant, or if the applicant is not an individual, the education, experience and qualifications of the persons who will be in control and in charge of the operation of the applicant.

(c) The name and post-office address of the person on whose behalf the weather modification operation is to be conducted if other than the applicant.

(d) The nature and object of the weather modification operation which applicant proposes to conduct, including a general description of such operation and the manner in which the production, management or conservation of water or energy resources or agricultural or forest crops could be benefited by the operation.

(e) The method and type of equipment and the type and composition of the materials that the applicant proposes to use.

(f) Such other pertinent information as the department may require.

(2) Each application shall be accompanied by a filing fee in the sum of \$100, and proof of financial responsibility as required by ORS 558.050. [1953 c.654 s.4; 1975 c.420 s.1]

558.050 Applicant to file proof of financial responsibility. (1) No license shall be issued to any person until he has filed with the department proof of ability to respond in damages for liability on account of accidents arising out of the weather modification operations to be conducted by him in the amount of \$100,000 because of bodily injury to or death of one person resulting from any one accident, and, subject to said limit for one person, in the amount of \$300,000 because of bodily injury to or death of two or more persons resulting from any one accident, and in the amount of \$300,000 because of injury to or destruction of property of others resulting from any one accident.

(2) Proof of financial responsibility may be given by filing with the department a certificate of insurance or a bond or a certificate of deposit of money in the same manner and with the same effect as provided by ORS chapter 486. [1953 c.654 s.13; 1975 c.420 s.1a]

558.055 Hearing on application for license. Upon receipt of an application for a license, the department shall fix the time and place for a public hearing on the application. Such hearing shall be held in the county seat of any county in which the proposed operation will be conducted. The department shall notify the applicant of the time and place of hearing in sufficient time for the applicant to comply with the notice requirements of ORS 558.080 to 558.100. [1975 c.420 s.3]

558.060 Issuance of license; conditions; licensee's authority; use of improper materials cause for suspension of revocation; renewal. (1) The department shall act within 30 days, but shall only issue the license upon finding that:

(a) The applicant is qualified to undertake the weather modification operation proposed in his application;

(b) The production, management or conservation of water or energy resources or agricultural or forest crops could be benefited by the proposed weather modification operation; and

(c) The proposed weather modification operation would not be injurious to the public health or safety.

(2) Each such license shall entitle the licensee to conduct the operations described in the license for one year from the date the license is issued unless the license is sooner revoked or suspended. The conducting of any weather modification operation or the use of any equipment or materials other than those described in the license shall be cause for revocation or suspension of the license.

(3) The license may be renewed annually by payment of a filing fee in the sum of \$50. If the application for renewal proposes any change in the previously licensed operation, or if the department determines that the public health or safety may be adversely affected by continuation of the operation, the department shall conduct a hearing on the application for renewal. The provisions of ORS 558.055 and 558.080 to 558.100 shall apply to such hearing. [1953 c.654 s.5; 1975 c.420 s.4]

558.065 [1965 c.336 s.2; repealed by 1967 c.225 s.1 (558.066 enacted in lieu of 558.065)]

558.066 Governmental entities conducting weather modification at airport exempted. The State of Oregon or its agencies, counties, cities, public corporations or political subdivisions thereof or any person engaged by any of them for the purpose of removing or dispersing fog, or carrying out or performing any other weather modification at an airport owned or operated by the State of Oregon or its agencies, counties, cities, public corporations or political subdivisions thereof, are exempt from the provisions of ORS 558.010 to 558.140 and 558.990 in respect to such operations at such airport only. [1967 c.225 s.2 (enacted in lieu of 558.065)]

558.070 [1953 c.654 s.6; repealed by 1975 c.420 s.12]

558.080 Contents of hearing notice. The notice of hearing shall set forth all of the following:

(1) The name and post-office address of the applicant.

(2) The name and post-office address of the person on whose behalf the weather modification operation is to be conducted if other than the applicant.

(3) The nature and object of the weather modification operation which applicant proposes to conduct, including a general description of such operation.

(4) The method and type of equipment and the type of composition of the materials that the applicant proposes to use.

(5) The area in which the approximate time during which the operation will be conducted.

(6) The area which will be affected by the operation as near as the same may be determined in advance.

(7) The time and place of the public hearing. [1953 c.654 s.7; 1975 c.420 s.5]

558.090 Publication of notice of hearing. The applicant shall cause the notice of hearing to be published at least once a week for two consecutive weeks in a newspaper having a general circulation and published within the county wherein the proposed operation is to be conducted and in which the affected area is located, or if the proposed operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the proposed operation is to be conducted, then such notice shall be published in like manner in a newspaper having a general circulation and published within each of such counties. In case there is no newspaper published within the appropriate county, publication shall be made in a newspaper having a general circulation within the county. The date of last publication shall be not less than three nor more than 10 days prior to the date set for hearing. [1953 c.654 s.8; 1975 c. 420 s.6]

558.100 Proof of publication. Proof of publication shall be filed by the applicant with the department at the time of the hearing. Proof of publication shall be by copy of the notice as published, attached to and made a part of the affidavit of the publisher or foreman of the newspaper publishing the notice. [1953 c.654 s.9; 1975 c.420 s.7]

558.110 Records and reports of operations; public examination. (1) Each licensee shall keep and maintain a record of all operations conducted by him pursuant to his license showing the method employed, the type of equipment, the type and composition of the materials used, the times and places of operation of the equipment, the name and post-office address of each person participating or assisting in the operation other than the licensee, the estimated precipitation for each licensed project, defining the gain or loss occurring from the operations, together with supporting data therefor, and such other information as may be required by the department, and shall report the same to the department at such times as it may require.

(2) The records of the department and the reports of all licensees shall be available for public examination. [1953 c.654 s.10; 1975 c.420 s.8]

558.120 Emergency licenses. Notwithstanding any provision of ORS 558.010 to 558.140 and 558.990 to the contrary, the department may grant a license permitting a weather modification operation without compliance by the licensee with the provisions of ORS 558.055 and 558.080 to 558.100, if the operation appears to the department to be necessary or desirable in aid of extinguishment of fires, dispersal of fog, or other similar emergency. [1953 c.654 s. 11; 1975 c.430 s. 9]

558.130 [1953 c.654 s. 12; repealed by 1975 c.420 s.12]

558.135 Revocation, suspension, refusal to issue or renew license; procedure.

(1) Where the department proposes to refuse to issue or renew a license, or proposes to revoke or suspend a license, opportunity for hearing shall be accorded as provided in ORS 183.310 to 183.500.

(2) Promulgation of rules, conduct of hearings, issuance of orders and judicial review of rules and orders shall be in accordance with ORS 183.310 to 183.500. [1975 c.420 s.11]

558.140 Appropriation for administration and enforcement. All moneys received by the department under ORS 558.010 to 558.140 and 558.990, in addition to any other appropriation of funds available for the administration of ORS 558.010 to 558.140 and 558.990, hereby are continuously appropriated to the department for the purpose of defraying the costs and expenses incurred in the administration and enforcement of ORS 558.010 to 558.140 and 558.990. [1955 c.6 s.3]

WEATHER MODIFICATION DISTRICTS

(General Provisions)

558.200 "County court" defined. As used in ORS 558.200 to 558.440, "county court" includes board of county commissioners. [1969 c.698 s.1]

558.205 Initiative and referendum. In the exercise of initiative and referendum powers reserved under the Constitution of this state to the legal voters of every municipality and district as to all local, special and municipal legislation of every sort and character in and for their respective municipalities and districts, the general laws of the state as applied to cities and towns shall govern in these districts. The chairman of the commissioners shall act as mayor and perform his duties, the secretary shall perform the duties of auditor or recorder, the attorney shall perform the duties of city attorney, and if there is no attorney, the secretary shall perform the duties required of the attorney. [1969 c.698 s.35 ; 1975 c.647 s.47]

(Incorporation)

558.210 Incorporation for weather modification; limitations as to area. Any designated area within a county bordering the Columbia River and having a population of less than 21,000, according to the latest federal decennial census, or within two or more of such counties, may be incorporated as a weather modification district for the purpose of:

(1) Causing or attempting to cause by artificial means condensation or precipitation of rain, snow, hail, moisture or water in any form contained in the atmosphere; or

(2) Preventing or attempting to prevent by artificial means the natural condensation or precipitation of rain, snow, hail, moisture or water in any form contained in the atmosphere. [1969 c.698 s.3]

558.215 [1969 c.698 s.4 ; repealed by 1971 c.727 s.203]

558.220 [1969 c. 698 s.17 ; repealed by 1971 c.727 s.203]

558.225 [1969 c.698 s.5 ; repealed by 1971 c.727 s.203]

558.230 [1969 c.698 s.6a ; repealed by 1971 c.727 s.203]

558.235 Forest lands not benefited properly; not included in district except upon petition. Forest lands within a forest protection district as defined in ORS chapter 477, shall not be considered benefited property and shall not be included in a weather modification district unless the owner of the forest lands petitions, the county court having jurisdiction of the formation proceedings to have his lands included. [1969 c.698 s.6 ; 1971 c.727 s.173]

558.240 [1969 c.698 s.20 ; repealed by 1971 c.727 s.203]

558.245 Time for formation election. An election, if any is held, on formation shall be held at the same time as the next succeeding state-wide primary or general election. [1969 c.698 s.7 : 1971 c.727 s.175]

558.250 [1969 c.698 s.8 ; repealed by 1971 c.647 s.149]

558.255 Commissioners of first board; qualifications. At the election on formation, commissioners to serve as the first board of the district shall be elected. Commissioners shall be owners of the land within the district but need not reside within the district. [1969 c.698 s.9 : 1971 c.647 s.125]

558.260 [1969 c.698 ss.10, 11, 12, 16 ; repealed by 1971 c.647 s.149]

558.265 [1969 c.698 s.13 ; repealed by 1971 c.727 s.203]

558.270 Certificates of election for commissioners. The county court shall also canvass the votes for commissioners and cause the county clerk to issue certificates of election to the number named in the petition for formation who received the highest number of votes. [1969 c.698 s.14]

558.275 [1969 c.698 s.15 ; repealed by 1971 c.727 s.203]

(Powers of District)

558.300 General powers of district. After the date of formation, a district shall make all contracts, hold and receive and dispose of real and personal property within and without its described boundaries and do all other acts and things which may be requisite, necessary or convenient in carrying out the objects of the district or exercising the powers conferred upon it as in ORS 558.200 to 558.440 set out and expressed, sue and be sued, plead and beimpleaded in all actions and suits or other proceedings brought by or against it. [1969 c.698 s.18 ; 1971 c.727 s.177]

558.310 Limitation on right to own or operate equipment. No weather modification district shall own or operate airplanes, chemicals or other equipment or appliances for weather modification activities, but must when conducting weather modification activities hire a person licensed under the provisions of ORS 558.010 to 558.140 and 588.990. [1969 c.698 s.60]

558.315 Regulations concerning district property. Any weather modification district may adopt and promulgate rules and regulations concerning the use of the property of the district. [1969 c.698 s.27]

558.320 Duty to carry liability insurance. A weather modification district shall obtain not later than the 60th day after the date of the election forming such district and before beginning any weather modification activities liability insurance coverage of not less than \$500,000 bodily injury and \$500,000 property damage, to reimburse persons for damages arising from weather modification activities. [1969 c.698 s.61]

558.325 Cooperative agreements between districts. Weather modification districts organized under ORS 558.200 to 558.440 may enter into cooperative agreements or control of facilities for weather modification. [1969 c.698 s.28]

558.330[1969 c.698 s.40; repealed by 1971 c.727 s.203]

558.340 Tax assessment, levy and collection. (1) The district may assess, levy and collect taxes each year not to exceed one-fourth of one percent (.0025) of the true cash value of all taxable property within the limits of the district, computed in accordance with ORS 308.207. The proceeds the tax shall be applied by it in carrying out the objects and purposes of ORS 558.210 to 558.270, 558.300 and 558.345 and for the purpose of financing the employees' retirement system.

(2) Any such taxes needed shall be levied in each year and returned to the county officer whose duty it is to extend the tax roll by the time required by law for city taxes to be levied and returned.

(3) All taxes levied by the district shall become payable at the same time and be collected by the same officer who collects county taxes, and shall be turned over to the district according to law. The county officer whose duty it is to extend the county levy shall extend the levy of the district in the same manner as city taxes are extended.

(4) Property shall be subject to sale for nonpayment of taxes levied by the district in like manner and with like effect as in the case of county and state taxes. [1969 c.698 s.26; 1971 c.727 s.178]

558.345 Disposal of taxes levied when organization declared invalid. When an attempt has been made to organize a district under the provisions of ORS 558.200 to 558.440 and subsequently by a decree of a court of competent jurisdiction it has been declared that the organization is invalid, but prior to such decree the invalid organization has levied taxes, the funds derived from the levy shall be disposed of as follows:

(1) If the area embraced in the invalid organization is embraced in a subsequently created organization composed of unincorporated or incorporated territory, or combinations thereof, for the purpose of weather modification, the custodian of the taxes collected for the invalid organization shall turn them over to the subsequent organization to be used only for the purpose of weather modification.

(2) If the subsequent organization does not embrace all territory embraced in the invalid organization, such taxes as have been collected from the levy upon property in areas not embraced in the subsequent organization shall be refunded to the payers thereof by the custodian of the taxes before the balance is turned over to the subsequent organization.

(3) If no such subsequent organization is created for weather modification, within a period of two years after the entry of the decree of invalidation, the taxes collected shall be refunded by the custodian of them to the taxpayers who paid them. [1969 c.698 s.19]

558.350 Employes' retirement system authorized. (1) A weather modification district organized under ORS 558.200 to 558.440 may establish an employes' retirement system. The commissioners may enter into agreements necessary to establish the system and carry out the plan and may agree to modifications of such agreements from time to time.

(2) The retirement plan may provide for retirement benefits measured on the basis of services rendered or to be rendered by an employe, either before or after the date on which such employe first becomes a member of the retirement plan. The retirement plan may provide for a minimum of years of service and a minimum and maximum age of retirement for the employe. [1969 c.698 s.56]

558.355 District to budget for retirement system. The district may budget and provide for payment into the fund of the retirement plan an amount sufficient:

(1) To provide on an actuarial reserve basis the amortized level premium cost of the retirement benefits which, under the provision of the retirement system, are to be provided by the district to its employes who attain the retirement age or retire in accordance with the terms of the retirement plan.

(2) To meet the actuarially computed costs of retirement benefits measured on the basis of services rendered or to be rendered by an employe before or after

the date on which such employe becomes a member of the retirement plan. [1969 c.698 s.57]

558.360 Employee contribution. The district may collect, as a contribution from any employe, that percentage of the salary received by the employe which is necessary to fund on an actuarial reserve basis the cost of retirement benefits which the employe is required to provide pursuant to the provisions of a retirement plan. [1969 c.698 s.58]

558.365 Limitation on membership. Nothing in ORS 558.200 to 558.440 authorizes the district to budget, provide for payments or collect contributions to fund retirement benefits for an individual who is not in the employment of the district at the time of the creation of a membership status under a retirement plan. [1969 c.698 s.59]

(Board of Commissioners)

558.400 Powers of district in board; qualifications, terms and election of commissioners. (1) The power and authority given to districts organized under ORS 558.200 to 558.440 except as therein otherwise provided is vested in and shall be exercised by a board of commissioners of the number named in the petition for formation, but not more than five, each of whom shall be a qualified voter and freeholder within the district. Except as provided in subsection (2) of this section, directors shall serve for four-year terms.

(2) Within 10 days after issuance of the formation order, the number of commissioners named in the petition for formation who received the highest vote at the election for formation shall meet and organize, first taking and subscribing an oath of office to the effect that they will support the Constitutions of the United States and of this state and the laws thereof, and will discharge faithfully the duties of commissioner to the best of their ability. They shall determine by lot the length of term each shall hold office. If there is an odd number of commissioners, a majority shall have a term expiring four years after the July 1 immediately following the election and a minority shall have a term expiring two years after the July 1 immediately following the election. If there is an even number of commissioners, the commissioners shall be divided into two equal groups as to terms. One group shall have a term expiring four years after the July 1 immediately following the election and the other group shall have a term expiring two years after the July 1 immediately following the election.

(3) A general election shall be held in the district, on the date fixed by ORS 259.240, for the election of a commissioner to succeed a commissioner whose term expires the following July 1, and to elect commissioners to fill any vacancy which then may exist. At all elections the voters shall have the qualifications of electors of this state and shall have resided in the territory embraced in the district for at least 90 days preceding the election. [1969 c.698 s.29; 1971 c.727 s.179; 1973 c.796 s.71; 1975 c.647 s.48]

558.405 [1969 c.698 s.33; repealed by 1971 c.23 s.12]

558.410 Board meetings; officers; quorum; employing assistance; employe benefits. (1) The commissioners shall hold meetings at such time and place within the district as they may determine upon. Such meetings must be open to the public. They shall hold at least one regular meeting in each month on a day to be fixed by them, and may hold special meetings under such rules as they may make.

(2) The commissioners shall, at the time of their organization, choose from their number a chairman, a secretary and a treasurer, who shall hold their offices until the first regular meeting in July, or until their successors are elected and qualified. These officers shall have, respectively, the powers and shall perform the duties usual in such cases and shall be known as the president, secretary and treasurer of the district. A majority shall constitute a quorum to do business and, in the absence of the chairman, any other member may preside at any meeting.

(3) The commissioners may employ such engineers, superintendents, mechanics, clerks or other persons as they may find requisite, necessary or convenient in carrying on any work of the district and at such rate of remuneration as they may deem just.

(4) The commissioners may provide life insurance and retirement or pension plans for employes of a weather modification district, provided the insurer issuing such policy is licensed to do business in the State of Oregon. [1969 c.698 s.31; 1971 c.23 s.11; 1971 c.403 s.13; 1973 c.796 s.72]

558.415 Increasing number of commissioners. (1) If the numbers of commissioners in a particular district is less than five, then, upon receipt of petitions containing the names of not less than 25 electors in the district and requesting

that an election be held in the district on the proposition of increasing the number of commissioners to five and nominating a candidate or candidates for each additional position, each of whom shall be a qualified voter and freeholder within the district, the commissioners may, at their discretion, call a special election of the electors of the district to vote on the proposition and on the candidates. The election shall be held in accordance with ORS chapter 259. If the proposition is approved by a majority of the electors voting at such election, the number of commissioners named in the petitions requesting the election, who received the highest vote at the election, shall take office as of the next regular meeting of commissioners following the election, after first taking and subscribing the oath of office.

(2) If only one additional commissioner is so elected his first term shall be four years if immediately before the election there was an even number of commissioners or two years if immediately before the election there was an odd number of commissioners. If more than one additional commissioner is so elected, the newly elected commissioners shall at such meeting determine by lot the length of term each shall hold office in a manner so as to comply with subsection (2) of ORS 558.400.

[1969 c.698 s.32; 1973 c.796 s.73; 1975 c.647 s.49]

558.420[1969 c.698 s.34; repealed by 1971 c.23 s.12]

558.430 *Deposit and withdrawal of moneys; annual reports; records.* (1) All moneys of the district shall be deposited in one or more banks, to be designated by the commissioners; and shall be withdrawn or paid out only when previously ordered by vote of the commissioners, and upon checks signed by the treasurer and countersigned by the chairman, or in his absence or inability to act, by the secretary. A receipt or voucher, showing clearly the nature and items covered by each check drawn, shall be kept on file.

(2) Annual reports shall be made and filed by the chairman, secretary and treasurer, and at least once in each year a full and complete itemized statement of receipts and expenditures shall be published in a newspaper of general circulation, published in the county in which the district is situate.

(3) All the proceedings of the commissioners shall be entered at large in a record book. All books, maps, plans, documents, correspondence, vouchers, reports and other papers and records pertaining to the business of the district shall be carefully preserved and shall be open to inspection as public records in the office of the county clerk of the county in which the greater part of the district is located. [1969 c.698 s.36]

558.440 *Calling special elections.* The commissioners at any regular meeting of the board of commissioners may call a special election of the electors of the district. Such an election must be held at the same time as the next succeeding state-wide primary or general election. [1969 c.698 s.30; 1971 c.647 s.128]

558.445[1969 c.698 s.2; repealed by 1971 c.647 s.149]

558.500[1969 c.698 s.37; repealed by 1971 c.727 s.203]

558.510 [1969 c.698 s. 38; repealed by 1971 c.727 s.203]

558.520 [1969 c.698 s.39; repealed by 1971 c.727 s.203]

558.550[1969 c.698 s.48; repealed by 1971 c.727 s.203]

558.555[1969 c.698 s.49; repealed by 1971 c.727 s.203]

558.560[1969 c.698 s.50; repealed by 1971 c.727 s.203]

558.565[1969 c.698 s.51; repealed by 1971 c.727 s.203]

558.570[1969 c.698 s.52; repealed by 1971 c.727 s.203]

558.575[1969 c.698 s.53; repealed by 1971 c.647 s.149]

558.580[1969 c.698 s.54; repealed by 1971 c.727 s.203]

558.585[1969 c.698 s.55; repealed by 1971 c.727 s.203]

558.600[1969 c.698 s.41; repealed by 1971 c.727 s.203]

558.610[1969 c.698 s.42; repealed by 1971 c.727 s.203]

558.620[1969 c. 698 s.43; repealed by 1971 c.727 s.203]

558.630[1969 c.698 s.44; repealed by 1971 c.727 s.203]

558.650[1969 c.698 s.45; repealed by 1971 c.727 s.203]

558.660[1969 c.698 s.46; repealed by 1971 c.727 s.191]

558.670[1969 c.698 s.47; repealed by 1971 c.27 s.203]

PENALTIES

558.990 *Penalties.* Any person who violates any provision of ORS 558.010 to 558.140 and 558.990 shall be guilty of a misdemeanor.
[1953 c.654 s.14]

GENERAL PROVISIONS

450.010 Establishing master plans and service districts. (1) Master plans and service districts may be established as provided by this chapter regarding:

(a) Sewage works, including all facilities necessary for collecting, pumping, treating and disposing of sanitary or storm sewage.

(b) Drainage works, including all facilities necessary for collecting, pumping and disposing of storm and surface water.

(c) Street lighting works, including all facilities necessary for the lighting of streets and highways.

(d) Public parks and recreation facilities, including land, structures, equipment, supplies, and personnel necessary to acquire, develop, and maintain such public park and recreation facilities and to administer a program in supervised recreation services.

(e) Diking and flood control works, including all facilities necessary for diking and control of water courses.

(f) Water supply works, including all facilities necessary for tapping natural sources of domestic and industrial water, treating and protecting the quality of the water and transmitting it to the point of sale to any city, domestic water supply corporation or other public or private agency for ultimate distribution by the city, corporation or agency to water users.

(g) Solid waste disposal. This paragraph does not apply in Clackamas, Multnomah and Washington Counties.

(h) Public transportation, including public depots, public parking and the motor vehicles and other equipment necessary for the transportation of persons together with their personal property.

(i) Agricultural educational extension services.

(2) Within the geographical jurisdiction of any local government boundary commission established by or pursuant to ORS 199.410 to 199.512, master plans and service districts may be established as provided by this chapter regarding:

(a) Fire prevention and protection.

(b) Enhanced law enforcement services provided by contract with the sheriff of the county.

(c) Domestic, municipal and industrial water supply service.

(d) Hospital and ambulance services.

(e) Library services.

(f) Vector control.

(g) Cemetery maintenance.

(h) Roads.

(i) Weather modification. [1963 c.515 s.2; 1965 c.246 s.1; 1967 c.538 s.1; 1971 c.674 s.1; 1971 c.687 s.1; 1973 c.211 s.1; 1973 c.785 s.1; 1975 c.630 s.1]

451.420 District may construct and operate service facilities. When authorized as provided in ORS 451.410 to 451.600 a district may construct, maintain and operate any or all of the service facilities specified in ORS 451.010. [1955 c.685 s.2; 1963 c.515 s.8; 1973 c.785 s.6]

PENNSYLVANIA

Pa. Stat. Ann. Tit. 3, Sec. 1101-1118

CHAPTER 16—WEATHER MODIFICATION [NEW]

Sec.

- 1101. Declaration of policy.
- 1102. Definitions.
- 1103. Weather Modification Board.
- 1104. Administration by department.
- 1105. When license registration required.
- 1106. Application for license.
- 1107. Registration of equipment.
- 1108. Publication.
- 1109. Emergencies; publication.
- 1110. Records.
- 1111. Research projects; safety.
- 1112. Enforcement.
- 1113. License suspensions, revocations.
- 1114. Damage compensation.
- 1115. Acts not authorized.
- 1116. Penalties.
- 1117. Repeal.
- 1118. Effective date.

§ 1101. Declaration of policy

The public interest, health, safety, welfare and necessity require that scientific experimentation in the field of artificial nucleation, and that scientific efforts to develop and increase natural precipitation of rain, snow, moisture, or water in any form contained in the atmosphere, within the State, be encouraged in order to develop, conserve, and protect the natural water resources of the State and to safeguard life and property. 1968, Jan. 19, P.L. (1967) 1024, § 1.

§ 1102. Definitions

As used in this act—

- (1) "Board" means the Weather Modification Board.
- (2) "Department" means the Department of Agriculture.

(3) "Operation" means the performance of weather modification and control activities pursuant to a single contract entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding one year, or, if the performance of weather modification and control activities is to be undertaken individually or jointly by a person or persons to be benefited and not undertaken pursuant to a contract, "operation" means the performance of weather modification and control activities entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding one year.

(4) "Person" means any individual, firm, association, organization, partnership, company, corporation, private or public, political subdivision, or other public agency.

(5) "Research and development" means theoretical analysis, exploration and experimentation and the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials and processes.

(6) "Weather modification and control" means changing or controlling, or attempting to change or control, by artificial methods the natural development of any or all atmospheric cloud forms and precipitation forms which occur in the troposphere. 1968, Jan. 19, P.L. (1967) 1024, § 2.

Library references: Agriculture \Leftrightarrow 1. C.J.S. Agriculture § 1 et seq.

§ 1103. Weather Modification Board¹

(a) There is hereby created within the department a Weather Modification Board. Such advisory board shall be composed of seven members who shall be:

- (1) The Secretary of Agriculture.
- (2) The Secretary of Commerce.
- (3) The Secretary of Health.
- (4) The Dean of the College of Earth Sciences at the Pennsylvania State University.

(5) Three members to be appointed by the Governor with the advice and consent of the Senate.

(b) Terms of all appointed members shall be for four years. Appointed members shall receive the sum of thirty dollars (\$30) per day for each day or part thereof devoted to the committee's activities. 1968, Jan. 18, P.L. (1967) 1024, § 1 et seq.

§ 1104. Administration by department

The department shall administer this act and in so doing shall ask for and consider the recommendations of the board herein created which shall advise on all the matters regulated by this act. 1968, Jan. 19, P.L. (1967) 1024, § 4.

Library references: Agriculture \Leftrightarrow 1. C.J.S. Agriculture § 1 et seq.

§ 1105. When license registration required

(a) No person, without first securing a license from the department, shall cause or attempt to cause condensation or precipitation of rain, snow, moisture, or water in any form contained in the atmosphere.

(b) No person without registering with the board shall have in his possession any cloud seeding equipment unless he is an employe of or under contract with a person conducting a weather modification and control operation who has been granted a license by the board. 1968, Jan. 19, P.L. (1967) 1024, § 5.

Library references: Licenses \Leftrightarrow 11(1). C.J.S. Licenses § 26 et seq. P.L.E. Licenses § 8.

¹ Enrolled bill reads "Advisory Committee on Cloud Seeding".

§ 1106. *Application for license*

(a) Any person desiring to do any of the acts specified in section 5¹ may file with the board an application in writing for a license. Each application shall be accompanied by a filing fee fixed by the board but not to exceed one hundred dollars (\$100), and shall be on a form to be supplied for such purpose by the board.

(b) Every application shall set forth all of the following :

(1) The name and post-office address of the applicant.

(2) The previous education, experience, and qualifications of the applicant, or, if the applicant is other than an individual, the previous education, experience, and qualifications of the persons who will be in control of and charged with the operations of the applicant. Previous experience includes sub-contracting or counseling services.

(3) A general description of the operations which the applicant intends to conduct and the method and type of equipment including all nucleating agents, that the applicant proposes to use. Aircraft must be listed by numbers and pilots' names.

(4) A statement listing all employes, who are residents of Pennsylvania, and/or who will be directly employed in the intended operation.

(5) A bond or insurance covering any damage the licensee may cause through his operations in an amount of fifty thousand dollars (\$50,000) or other evidence of financial responsibility shall be furnished and executed at the time of the grant of the license.

(6) Every applicant shall have a resident agent within the Commonwealth.

(c) Upon the filing of the application upon a form supplied by the board and containing the information prescribed by this act and accompanied by the required filing fee and bond or insurance, the board may issue a license to the applicant entitling the applicant to conduct the operations described in the application for the calendar year for which the license is issued, unless the license is sooner revoked or suspended or modified.

(d) A license may be renewed annually upon application to the board, accompanied by a renewal fee fixed by the board but not to exceed one hundred dollars (\$100), on or before the last day of January of the calendar year for which the license is renewed. 1968, Jan. 19, P.L. (1967) 1024, § 6.

Library references : Licenses ⇨ 22. C.J.S. Licenses §§ 34, 38, 39. P.L.E. Licenses § 16.

§ 1107. *Registration of equipment*

Every person not desiring a license who owns or possesses cloud seeding equipment shall promptly register the same with the board on a form furnished by it. 1968, Jan. 19, P.L. (1967) 1024, § 7.

Library references : Licenses ⇨ 24. C.J.S. Licenses § 41. P.L.E. Licenses § 16.

§ 1108. *Publication*

(a) Prior to undertaking any operation authorized by the license, the licensee shall file with the department and cause to be published a notice of intention. The licensee shall then confine his activities for that operation substantially within the time and area limits set forth in the notice of intention.

(b) The notice of intention shall set forth all of the following :

(1) The name and address of the licensee.

(2) The nature and object of the intended operation and the person or persons on whose behalf it is to be conducted.

(3) The area in which and the approximate time during which the operation will be conducted.

(4) The area which will be affected by the operation as near as the same may be determined in advance.

(c) The licensee shall cause the notice of intention to be published once a week for three successive weeks in a newspaper having a general circulation and published within any county wherein the operation is to be conducted and in which the affected area is located, or, if the operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the operation is to be conducted, then such notice shall be published in like manner in a newspaper having a general circulation and published within each of such counties. In case there is no newspaper published within the appropriate county, publication shall be made in a newspaper having a general circulation within the county.

¹ Section 1105 of this title.

(d) Proof of publication shall be filed by the licensee with the department within fifteen days from the date of the last publication of the notice. Proof of publication shall be by copy of the notice as published attached to and made a part of the affidavit of the publisher or foreman of the newspaper publishing the notice. 1968, Jan. 19, P.L. (1967) 1024, § 8.

Library references: Licenses ⇨ 22. C.J.S. Licenses §§ 34, 38, 39. P.L.E. Licenses § 16.

§ 1109. *Emergencies; publication*

(a) Notwithstanding any provision of this act to the contrary, the board may grant a licensee permission to undertake an emergency nucleation project, without prior compliance by the licensee with the provisions of section 8(a),¹ if the same appears to the department to be necessary or desirable in aid of extinguishment of fires.

(b) Notwithstanding any provision of this act to the contrary, upon request of the county commissioners, of a county or of the governing body of a city, borough, town or townships, and upon the submission of such supporting evidence as the board may require, the board may grant a licensee permission to undertake a nucleation project for the purpose of alleviating a drought emergency, without prior compliance by the licensee with the provisions of section 8(a) requiring publication of notice of intention, if such project appears to the department to be necessary or desirable.

(c) Nothing contained in this section shall be construed as to relieve the licensee in the cases set forth in subsection (a) or (b) of this section from compliance with the provisions of section 8 requiring publication of notice of intention and filing of proof of such publication, as soon after the granting of permission by the board as is practicable. In lieu thereof the licensee may furnish equivalent transmission of notice of intention by radio or television, and proof thereof, as soon after the granting of permission by the board as is practicable. 1968, Jan. 19, P.L. (1967) 1024, § 9.

Library references: Licenses ⇨ 22. C.J.S. Licenses §§ 34, 38, 39. P.L.E. Licenses § 16.

§ 1110. *Records*

(a) Every licensee shall keep and maintain a record of all operations conducted by him pursuant to his license showing the method employed, the type of equipment used, the times and places of operation of the equipment, the names and post office address of each person participating or assisting in the operation other than the licensee, and such other information as may be required by the board, and shall report the same to the board immediately upon the completion of each operation.

(b) Each licensee shall further prepare and maintain an evaluation statement for each operation which shall include a report as to estimated precipitation, defining the gain or loss occurring from nucleation activities, together with supporting data therefor. This statement, together with such other pertinent information as the board may require, shall be sent to the board upon completion and be available to inspection by the board at all times on the licensee's premises.

(c) The board shall require written reports concerning each operation conducted by a licensee under this act.

(d) All information on an operation shall be submitted to the board before any information on such operation may be released to the public.

(e) The reports and records in the custody of the board shall be open for public examination as public documents. 1968, Jan. 19, P.L. (1967) 1024, § 10.

Library references: Licenses ⇨ 36. C.J.S. Licenses § 42. P.L.E. Licenses § 36.

§ 1111. *Research projects; safety*

(a) Research work within the province of this statute shall be permitted only when authorized by the board.

(b) Government and armed forces projects within the province of this statute must meet all the requirements of this act.

(c) No nucleating agent may be used in concentrations dangerous to man or causes environmental pollution as determined by the State Department of Health. 1968, Jan. 19, P.L. (1967) 1024, § 11.

Library references: Agriculture ⇨ 1. C.J.S. Agriculture § 1 et seq.

§ 1112. *Enforcement*

In order to enforce the provisions of this act, the Pennsylvania State Police

¹ Section 1108 of this title.

shall, on request of the board, assign at least one trooper and one investigator to an area where unlawful cloud seeding is suspected. If such police request the same, the Pennsylvania Aeronautics Commission shall assign an airplane and pilot. Air samples shall be taken by the Pennsylvania Air Pollution Commission if requested by the State Police or the board. For such enforcement purposes, the State Department of Health shall furnish such technical services as the board may request. 1968, Jan. 19, P.L. (1967) 1024, § 12.

§ 1113. *License suspensions, revocations*

Any license may be revoked, suspended or modified if the board finds, after due notice to the licensee and a hearing thereon, that the licensee has failed or refused to comply with any of the provisions of this act. The proceedings herein referred to shall be conducted in accordance with the provisions of the act of June 4, 1945 (P.L. 1388), known as the "Administrative Agency Law,"¹ and the board shall have all the powers granted therein. 1968, Jan. 19, P.L. (1967) 1024, § 13.

Library references: Licenses ⇔ 38. C.J.S. Licenses §§ 43, 44, P.L.E. Licenses § 26.

§ 1114. *Damage compensation*

Any licensee who causes a drought as determined by the board shall compensate farmers for damages. Any licensee who by causing heavy downpours or storms which cause damage to lands as determined by the board shall compensate farmers and property owners for such damages. 1968, Jan. 19, P.L. (1967) 1024, § 14.

Library references: Agriculture ⇔ 1. C.J.S. Agriculture § 1 et seq.

§ 1115. *Acts not authorized*

(a) Nothing contained in this act shall authorize any person to carry out a cloud seeding operation from Pennsylvania to seed in another state where such cloud seeding is prohibited.

(b) Nothing contained in this act shall be construed to authorize the suppression of lightning. 1968, Jan. 19, P.L. (1967), 1024, § 15.

Library references: Agriculture ⇔ 1. C.J.S. Agriculture § 1 et seq.

§ 1116. *Penalties*

(a) Any airplane pilot who flies an airplane with numbers invisible to escape identification under this act shall be guilty of a misdemeanor and upon conviction thereof, have his license revoked for a period of five years.

(b) Any airport owner or operator who boards cloud seeding planes to seed clouds or who operates as a cloud seeder without a license shall be guilty of a misdemeanor, and upon conviction thereof have his airport permit revoked for one year and be sentenced to pay a fine of ten thousand dollars (\$10,000) and for a second or subsequent offense, he shall be sentenced to pay a fine of fifty thousand dollars (\$50,000).

(c) Any person knowingly having in his possession without registering the same with the department any cloud seeding equipment shall, on conviction thereof, be sentenced to pay a fine of ten thousand dollars (\$10,000).

(d) Any person who makes any false statement to secure a license under this act shall, on conviction thereof, have his license revoked permanently.

(e) Any person who violates any other provision of this act is guilty of a misdemeanor and shall, upon conviction thereof, be sentenced to pay a fine not exceeding one thousand dollars (\$1,000) or undergo imprisonment for not exceeding one year, or both. 1968, Jan. 19, P.L. (1967) 1024, § 16.

Library references: Aviation ⇔ 123. C.J.S. Aerial Navigation §§ 11, 16. P.L.E. Aeronautics § 1.

§ 1117. *Repeal*

The act of November 9, 1965 (P.L. 677), entitled "An act prohibiting certain weather modification activities whenever the county commissioners shall adopt a resolution stating that such action is detrimental to the welfare of the county, and providing penalties," is repealed.² 1968, Jan. 19, P.L. (1967) 1024, § 17.

Library references: Agriculture ⇔ 1. C.J.S. Agriculture § 1 et seq.

§ 1118. *Effective date*

This act shall take effect immediately. 1968, Jan. 19, P.L. (1967) 1024, § 18.

¹ 71 P.S. § 1710.1 et seq.

² 18 P.S. §§ 3871 to 3874.

SOUTH DAKOTA

S.D. Compiled Laws Ann. Secs. 38-9-1-38-9-22; 1-40-8; 10-12-18

1-40-8. Administrative functions performed for weather modification commission.—Except as provided by § 38-9-4.1, the department of natural resource development shall, under the direction and control of the secretary of natural resource development, perform all administrative functions except special budgetary functions (as defined in § 1-32-1) of the weather modification commission.

CHAPTER 38-9—WEATHER MODIFICATION ACTIVITIES

Sec.	
38-9-1.	Definition of terms.
38-9-3.	Policy and purpose of regulation.
38-9-4.	Weather modification commission established—Composition.
38-9-4.1.	Direction and supervision by department of natural resource development—Independent functions retained by commission.
38-9-5.	Areas from which members of commission appointed.
38-9-6.	Repealed.
38-9-9.	Operations and research activities.
38-9-10.1.	Utilization of technical resources of schools.
38-9-11.1.	Co-operation with counties—County participation.
38-9-12.	License and permit required to engage in weather modification—Violation of terms unlawful.
38-9-12.1.	Exemption of experimental and emergency activities.
38-9-13.	Repealed.
38-9-14.	Issuance of license to competent applicant—Competence of organization—Application fee.
38-9-15.	Fee required on issuance or renewal of license—Disposition.
38-9-16, 38-9-17.	Repealed.
38-9-18.	Expiration of licenses.
38-9-18.1.	Issuance of renewal license.
38-9-18.2.	Permits issued to licensees—Fee—Publication of notice of intention—Financial responsibility.
38-9-18.3.	Means of proving financial responsibility.
38-9-18.4.	Permit fee—Disposition.
38-9-18.5.	Permit required for each operation—Maximum duration of permit.
38-9-19.	Suspension, revocation, refusal or refusal to renew license or permit.
38-9-19.1.	Modification of permit—Notice and hearing.
38-9-21.	Unlicensed weather modification activity as misdemeanor—Penalty.
38-9-22.	Administration by department—Powers retained by commission.
38-9-23.	Repealed.

38-9-1. Definition of terms.—As used in this chapter :

(1) The term "weather modification" means performing any activity with the intention of producing artificial changes in the composition, behavior, or dynamics of the atmosphere.

(2) and (3) * * * [Same as parent volume.]

(4) The term "operation" means the performance of weather modification activities entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding one year.

38-9-3. Policy and purpose of regulations.—It is hereby declared that weather modification techniques for precipitation management should be used to augment precipitation and decrease hailfall damage in South Dakota. The application of weather modification techniques shall be carried out under proper safeguards to supply sufficient data and accurate information in order to provide a net economic benefit and enhance knowledge concerning weather modification and to protect life, property and the public interest.

38-9-4. Weather modification commission established—Composition.—There is hereby established a weather modification commission, hereinafter called the commission composed of seven representatives, one from each area designated by § 38-9-5, to be appointed biennially by the Governor on July first and provided further, no more than four shall be from any one political party.

38-9-4.1. Direction and supervision by department of natural resource development—Independent functions retained by commission.—The weather modification commission shall be administered under the direction and supervision of the department of natural resource development and the secretary thereof, but shall retain the quasi-judicial, quasi-legislative, advisory, other nonadministrative and special budgetary functions (as defined in § 1-32-1) otherwise vested in it and shall exercise those functions independently of the secretary of natural resource development. The commission shall also retain the function of setting the terms of and approving the contracts with other units of government for the sharing of the costs of weather modification operations.

38-9-5. *Areas from which members of commission appointed.*—Representatives of the commission shall be appointed from areas containing the following counties:

Area I—Bennett, Custer, Fall River, Haakon, Jackson, Pennington, Shannon and Washabaugh; Area II—Butte, Harding, Lawrence, Meade and Perkins; Area III—Campbell, Corson, Dewey, Hughes, Potter, Stanley, Sully, Walworth and Ziebach; Area IV—Aurora, Brule, Buffalo, Charles Mix, Davison, Douglas, Gregory, Jerauld, Jones, Lyman, Mellette, Sanborn, Todd and Tripp; Area V—Bon Homme, Clay, Hanson, Hutchinson, Lake, Lincoln, McCook, Miner, Minnehaha, Moody, Turner, Union and Yankton; Area VI—Beadle, Brown, Edmunds, Faulk, Hand, Hyde, McPherson and Spink; Area VII—Brookings, Clark, Codrington, Day, Deuel, Grant, Hamlin, Kingsbury, Marshall and Roberts.

38-9-9. *Operations and research activities.*—The commission shall carry on operations and research on a state-wide basis, by its own staff, or by contract with approved cloud seeding organizations or in co-operation with other agencies as provided by law.

38-9-10.1. *Utilization of technical resources of schools.*—In carrying out the purposes of this chapter, the commission shall utilize to the extent possible the facilities and technical resources of the public and private educational institutions of the state.

38-9-11.1. *Co-operation with counties—County participation.*—The commission may, at its discretion, co-operate with county programs of weather modification in carrying out the purposes of this chapter, and in addition to the powers of counties specified in § 10-18, counties may contribute to and participate in any weather modification program carried out by the state.

38-9-12. *License and permit required to engage in weather modification—Violation of terms unlawful.*—It shall be unlawful for any person to engage in activities for weather modification without a weather modification license and a weather modification permit issued by the commission or in violation of any term or condition of the license or the permit except as the commission shall provide by regulation under § 38-9-12.1.

38-9-12.1 *Exemption of experimental and emergency activities.*—The commission, to the extent it considers exemptions practical, shall provide for exempting laboratory research and experiments and activities of an emergency nature against fire, frost, sleet or fog from the license and permit requirements of this chapter.

Source: SL 1973, ch 254, § 10. See Tex Vernon's Civ Code, Art 8280-12, § 8 (2), (3).

38-9-13. *Repealed by SL 1973, ch 254, § 21.*

38-9-14. *Issuance of license to competent applicant—Competence of organization—Application fee.*—The commission, in accordance with its regulations, shall issue a weather modification license to each applicant who pays the license fee and who demonstrates, to the satisfaction of the commission, competence in the field of meteorology which is reasonably necessary to engage in weather modification activities. If the applicant is an organization, the competence must be demonstrated by the individual or individuals who are to be in control and in charge of the operation for the applicant. Each application shall be accompanied by a fee of twenty-five dollars.

38-9-15. *Fee required on issuance or renewal of license—Disposition.*—Any person issued an original license or a renewal license under this chapter shall pay a fee of one hundred dollars. The money collected from such fees shall be deposited with the state treasurer in the state general fund.

38-9-16, 38-9-17. *Repealed by SL 1973, ch 254, § 21.*

38-9-18. *Expiration of licenses.*—Each original license or renewal license issued under this chapter shall expire on December thirty-first of the year for which it was issued.

38-9-18.1. *Issuance of renewal license.*—At the expiration of the license period, the commission shall issue a renewal license to each applicant who pays the license fee and who has the qualifications necessary for issuance of an original license.

Source: SL 1973, ch 254, § 14.

38-9-18.2. *Permits issued to licensees—Fee—Publication of notice of intention—Financial responsibility.*—The commission, in accordance with its regulations, shall issue a weather modification permit to each applicant who holds a valid weather modification license, pays the permit fee, publishes such notice of intention as the commission shall require by regulation and submits proof of publication, and furnishes proof of financial responsibility.

Source: SL 1973, ch 254, § 15.

38-9-18.3. *Means of proving financial responsibility.*—Proof of financial responsibility is made by showing, to the satisfaction of the commission, that the licensee has the ability to respond in damages for liability which might reasonably result from the operation for which the permit is sought.

Source: SL 1973, ch 254, § 18. See Tex Vernon's Civ Code, Art S280-12, § 14.

38-9-18.4. *Permit fee—Disposition.*—Any person issued a permit under this chapter shall pay a fee of one hundred dollars. The money collected from such fees shall be deposited with the state treasurer in the state general fund.

Source: SL 1973, ch 254, § 16.

38-9-18.5. *Permit required for each operation—Maximum duration of permit.*—A separate permit is required for each operation. The commission shall not issue a permit for operations in an area for a period to exceed one year.

Source: SL 1973, ch 254, § 17.

38-9-19. *Suspension, revocation, refusal or refusal to renew license or permit.*—The commission may suspend or revoke a license or permit if it appears that the licensee no longer has the qualifications necessary for the issuance of an original license or permit or has violated any provision of this chapter. The commission may refuse to renew the license of, or to issue another permit to, any applicant who has failed to comply with any provision of this chapter.

38-9-19.1. *Modification of permit—Notice and hearing.*—The commission may modify the terms and conditions of a permit if the licensee is first given notice and reasonable opportunity for a hearing on the need for a modification and it appears to the commission that a modification is necessary to protect the health or property of any person.

Source: SL 1973, ch 254, § 19. See Tex Vernon's Civ Code, Art S280-12, § 17(2).

38-9-21. *Unlicensed weather modification activity as misdemeanor—Penalty.*—Any person or persons engaging in any type of weather modification activities without a valid license and permit shall be guilty of a misdemeanor, and subject to a fine not to exceed one thousand dollars or by imprisonment in the county jail for a period not to exceed thirty days; for each such offense.

38-9-22. *Administration by department—Powers retained by commission.*—The department of natural resource development shall administer and enforce the provisions of this chapter, provided, however, that the commission shall retain the authority and policy powers reserved to it by § 38-9-4.1.

10-12-18. *County weather-modification levy authorized—Maximum rate—Contractors to be licensed.*—The board of county commissioners of each county may levy and collect annually a tax of not to exceed one mill upon assessed valuation of the property in said county, for a "weather-modification" fund, which levy shall be exclusive of the maximum levy provided by law. The board of county commissioners of counties which have sixteen million dollars or less in assessed valuation of property in that county may levy and collect annually a tax of not to exceed two mills on the assessed valuation of the property in that county, which levy shall be exclusive of the maximum levy provided by law. Such fund shall be used only for the gathering of information upon, aiding in or conducting any program for weather modification, as defined by law, within said county, or in conjunction with any other county or counties. The provisions of chapter 7-21, relating to county budgeting shall not apply to appropriations made under the provisions of this section. Provided, however, that for only the initial or first appropriation of said "weather-modification" activities as aforementioned, said county commissioners may, at their discretion, appropriate from moneys not otherwise appropriated in the general fund, such moneys as are necessary for carrying out the provisions of this section, provided that said appropriation shall not exceed an amount equal to one mill levy upon the assessed valuation of the property in said county. The board of county commissioners shall enter into no contract or agreement for any such purpose except with one who has been duly licensed under the provisions of chapter 38-9, except for the purpose of gathering information they may enter into a contract or agreement with a state agency not licensed.

TEXAS

Texas Water Code Tit. 2 Secs. 14.001-14.112; Texas Civil Code tit. 120A, Sec. 6889-7(16)

Weather Modification

Sec. 16. The Division of Disaster Emergency Services shall keep continuously apprised of weather conditions which present danger of precipitation or other climatic activity severe enough to constitute a disaster. If the division determines

that precipitation that may result from weather modification operations, either by itself or in conjunction with other precipitation or climatic conditions or activity, would create or contribute to the severity of a disaster, it shall request in the name of the governor that the officer or agency empowered to issue permits for weather modification operations suspend the issuance of the permits. On the governor's request, no permits may be issued until the division informs the officer or agency that the danger has passed.

CHAPTER 14. WEATHER MODIFICATION

Subchapter A. General Provisions

Sec.

- 14.001. Short Title.
 14.002. Definitions.
 [Sections 14.003 to 14.010 reserved for expansion]

Subchapter B. Powers and Duties of Board

- 14.011. Regulations—In General.
 14.012. Regulations—Licenses and Permits.
 14.013. Regulations—Safety.
 14.014. Studies; Investigations; Hearings.
 14.015. Advisory Committees.
 14.016. Personnel.
 14.017. Materials and Equipment.
 14.018. Interstate Compacts.
 14.019. Contracts, Cooperative Agreements, Etc.
 14.020. Promotion of Research and Development.
 14.021. Grants, Gifts, Etc.
 14.022. Disposition of License and Permit Fees.
 14.023. Oaths of Witnesses; Subpoenas.
 [Sections 14.024 to 14.040 reserved for expansion]

Subchapter C. Licenses and Permits

- 14.041. License and Permit Required.
 14.042. Exemptions.
 14.043. Issuance of License.
 14.044. License Fee.
 14.045. Expiration Date.
 14.046. Renewal License.
 [Sections 14.047 to 14.060 reserved for expansion]
 14.061. Issuance of Permit.
 14.062. Permit Fee.
 14.063. Scope of Permit.
 14.064. Application and Notice of Intention.
 14.065. Content of Notice.
 14.066. Publication of Notice.
 14.067. Proof of Publication; Affidavit.
 14.068. Proof of Financial Responsibility.
 14.069. Modification of Permit.
 14.070. Scope of Activity.
 14.071. Records and Reports.
 [Sections 14.072 to 14.090 reserved for expansion]

Subchapter D. Sanctions

1091. Suspension; Revocation; Refusal to Renew.
 1092. Hearing Required.
 1093. Record of Hearing.
 [Sections 14.094 to 14.100 reserved for expansion]
 1101. Immunity of State.
 1102. Private Legal Relationships.
 [Sections 14.103 to 14.110 reserved for expansion]
 1111. Penalty
 1112. Enforcement by Board.

Subchapter A. General Provisions

Section 14.001. Short Title

This chapter may be cited as the Weather Modification Act.

§ 14.002. Definitions

As used in this chapter, unless the context requires a different definition:

- (1) "board" means the Texas Water Development Board;
- (2) "weather modification and control" means changing or controlling, or attempting to change or control, by artificial methods, the natural development of atmospheric cloud forms or precipitation forms which occur in the troposphere;
- (3) "operation" means the performance of weather modification and control activities entered into for the purpose of producing, or attempting

to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding four years; and

(4) "research and development" means theoretical analysis, exploration, experimentation, and the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials, and processes.

Amended by Acts 1975, 64th Leg., p. 1394, ch. 538, § 1, eff. Sept. 1, 1975.

1975 Amendment. In subd. (3), substituted "four years" for "one year".

Subchapter B. Powers and Duties of Board

§ 14.011. *Regulations—In General*

The board may make regulations necessary to the exercise of its powers and the performance of its duties under this chapter.

§ 14.012. *Regulations—Licenses and Permits*

In order to effectuate the purposes of this chapter, the board may make regulations establishing procedures and conditions for the issuance of licenses and permits.

§ 14.013. *Regulations—Safety*

The board may, by regulation or order, establish any standards and instructions to govern the carrying out of research or projects in weather modification and control that the board considers necessary or desirable to minimize danger to health or property.

§ 14.014. *Studies; Investigations; Hearings*

The board may make any studies or investigations, obtain any information, and hold any hearings the board considers necessary or proper to assist it in exercising its power or administering or enforcing this chapter or any regulations or orders issued under this chapter.

§ 14.015. *Advisory Committees*

The board may establish advisory committees to advise the board and to make recommendations to the board concerning legislation, policies, administration, research, and other matters.

§ 14.016. *Personnel*

The board may, as provided by the general appropriations act, point and fix the compensation of any personnel, including specialists and consultants, necessary to perform its duties and functions under this chapter.

§ 14.017. *Materials and Equipment*

The board may acquire, in the manner provided by law, any materials, equipment, and facilities necessary to perform its duties and functions under this chapter.

§ 14.018. *Interstate Compacts*

The board may represent the state in matters pertaining to plan procedures, or negotiations for interstate compacts relating to weather modification and control.

§ 14.019. *Contracts, Cooperative Agreements, Etc.*

(a) The board may cooperate with public or private agencies to promote the purposes of this chapter.

(b) The board may enter into cooperative agreements with the United States or any of its agencies, or with counties and cities of this state, or with any private or public agencies, for conducting weather modification or cloud-seeding operations.

(c) The board may represent the state, counties, cities, and public and private agencies in contracting with private concerns for the performance of weather modification or cloud-seeding operations.

§ 14.020. *Promotion of Research and Development*

(a) In order to assist in expanding the theoretical and practical knowledge of weather modification and control, the board shall provide continuous research and development in:

(1) the theory and development of methods of weather modification and control, including processes, materials, and devices related to these methods ;

(2) the utilization of weather modification and control for agricultural, industrial, commercial, and other purposes ; and

(3) the protection of life and property during research and operational activities.

(b) The board may conduct and may contract for research and development activities relating to the purposes of this section.

§ 14.021. *Grants, Gifts, Etc.*

Subject to any limitations imposed by law, the board may accept federal grants, private gifts, and donations from any other source. Unless the use of the money is restricted or subject to any limitations provided by law, the board may spend it for the administration of this chapter or may, by grant, contract, or cooperative arrangement, use the money to encourage research and development by a public or private agency.

§ 14.022. *Disposition of License and Permit Fees*

The board shall deposit all license and permit fees in the state treasury.

§ 14.023. *Oaths of Witnesses; Subpoenas*

(a) In conducting any hearing, the board or a representative designated by it may administer oaths and examine witnesses.

(b) The board or a representative designated by it may issue subpoenas to compel the attendance of witnesses and the production of books, records, documents, and instruments.

Subchapter C. Licenses and Permits

§ 14.041. *License and Permit Required*

Except as provided by regulation of the board under Section 14.042 of this code, no person may engage in activities for weather modification and control :

(1) without a weather modification license and a weather modification permit issued by the board ; or

(2) in violation of any term or condition of the license or the permit.

§ 14.042. *Exemptions*

The board, to the extent it considers exemptions practical, shall provide by regulation for exempting the following activities from the license and permit requirements of this chapter :

(1) research, development, and experiments conducted by state and federal agencies; institutions of higher learning, and bona fide nonprofit research organizations ;

(2) laboratory research and experiments ;

(3) activities of an emergent nature for protection against fire, frost, sleet, or fog ; and

(4) activities normally conducted for purposes other than inducing, increasing, decreasing, or preventing precipitation or hail.

§ 14.043. *Issuance of License*

(a) The board, in accordance with its regulations, shall issue a weather modification license to each applicant who :

(1) pays the license fee ; and

(2) demonstrates, to the satisfaction of the board, competence in the field of meteorology which is reasonably necessary to engage in weather modification and control activities.

(b) If the applicant is an organization, the competence must be demonstrated by the individual or individuals who are to be in control and in charge of the operation for the applicant.

§ 14.044. *License Fee*

The fee for an original or renewal license is \$50.

§ 14.045. *Expiration Date*

Each original or renewal license expires at the end of the state fiscal year for which it was issued.

§ 14.046. *Renewal License*

At the expiration of the license period, the board shall issue a renewal license to each applicant who pays the license fee and who was the qualifications necessary for issuance of an original license.

§ 14.061. *Issuance of Permit*

(a) The board, in accordance with its regulations, and upon a finding that the weather modification and control operation as proposed in the permit application will not significantly dissipate the clouds and prevent their natural course of developing rain in the area where the operation is to be conducted to the material detriment of persons or property in that area, may issue a weather modification permit to each applicant who:

- (1) holds a valid weather modification license;
- (2) pays the permit fee;
- (3) publishes a notice of intention and submits proof of publication as required by this chapter; and
- (4) furnishes proof of financial responsibility.

(b) The Board shall, if requested by at least 25 persons, hold at least one public hearing in the area where the operation is to be conducted prior to the issuance of a permit.

Amended by Acts 1975, 64th Leg., p. 1394, ch. 538, § 2, eff. Sept. 1, 1975.

1975 Amendment. Substituted, in present subsec. (a), "and upon finding that the weather * * * persons or property in that area, may" for "shall" and added subsec. (b).

§ 14.062. *Permit Fee*

The fee for each permit is \$25.

§ 14.063. *Scope of Permit*

A separate permit is required for each operation. If an operation is to be conducted under contract, a permit is required for each separate contract. The board shall not issue a permit for a contracted operation unless it covers a continuous period not to exceed four years.

Amended by Acts 1975, 64th Leg., P. 1395, ch. 538, § 3, eff. Sept. 1, 1975.

1975 Amendment. Substituted "four years" for "one year".

§ 14.064. *Application and Notice of Intention*

Before undertaken any operation, a licensee shall file an application for a permit and shall have a notice of intention published as required by this chapter.

§ 14.065. *Content of Notice*

In the notice of intention the applicant shall include:

- (1) the name and address of the licensee;
- (2) the nature and object of the intended operation and the person or organization on whose behalf it is to be conducted;
- (3) the area in which and the approximate time during which the operation is to be conducted;
- (4) the area which is intended to be affected by the operation; and
- (5) the materials and methods to be used in conducting the operation.

§ 14.066. *Publication of Notice*

The notice of intention shall be published at least once a week for three consecutive weeks in a newspaper of general circulation published in each county in which the operation is to be conducted and in each county which includes any part of the affected area. If in any county no newspaper of general circulation is published, then publication shall be made in a newspaper having general circulation in the county.

§ 14.067. *Proof of Publication; Affidavit*

The applicant shall file proof of the publication, together with the publishers' affidavits, with the board during the 15-day period immediately following the date of the last publication.

§ 14.068. *Proof of Financial Responsibility*

Proof of financial responsibility is made by showing, to the satisfaction of the executive director of the board, that the licensee has the ability to respond in damages for liability which might reasonably result from the operation for which the permit is sought.

§ 14.069. *Modification of Permit*

The board may modify the terms and conditions of a permit if:

- (1) the licensee is first given notice and a reasonable opportunity for a hearing on the need for a modification; and
- (2) it appears to the board that a modification is necessary to protect the health or property of any person.

§ 14.070. *Scope of Activity*

Once a permit is issued, the licensee shall confine his activities substantially within the limits of time and area specified in the notice of intention, except to the extent that the limits are modified by the board. He shall also comply with any terms and conditions of the permit as originally issued or as subsequently modified by the board.

§ 14.071. *Records and Reports*

(a) A licensee shall keep a record of each operation conducted under permit, showing:

- (1) the method employed;
- (2) the type of equipment used;
- (3) the kind and amount of each material used;
- (4) the times and places the equipment is operated;
- (5) the name and post-office address of each individual, other than the licensee, who participates or assists in the operation; and
- (6) other information required by the board.

(b) The board shall require written reports covering each operation, whether it is exempt or conducted under a permit.

(c) At the time and in the manner required by the board, a licensee shall submit a written report containing the information described in subsection (a) of this section.

(d) All information on an operation shall be submitted to the board before it is released to the public.

(e) The reports and records in the custody of the board shall be kept open for public inspection.

Subchapter D. Sanctions

§ 14.091. *Suspension; Revocation; Refusal to Renew*

(a) The board may suspend or revoke a license or permit if it appears that the licensee:

- (1) no longer has the qualifications necessary for the issuance of an original license or permit; or
- (2) has violated any provision of this chapter.

(b) The board may refuse to renew the license of, or to issue another permit to, any applicant who has failed to comply with any provision of this chapter.

§ 14.092. *Hearing Required*

The board may not suspend or revoke a license or permit without first giving the licensee notice and a reasonable opportunity to be heard with respect to the grounds for the board's proposed action.

§ 14.093. *Record of Hearing*

The board shall have a record made of all proceedings at each hearing held under Section 14.092 of this code, and shall have the record filed with its findings and conclusions.

§ 14.101. *Immunity of State*

The state and its officers and employees are immune from liability for all weather modification and control activities conducted by private persons and groups.

§ 14.102. *Private Legal Relationships*

(a) This chapter does not affect private legal relationships, except that an operation conducted under the license and permit requirements of this chapter is not an ultrahazardous activity which makes the participants subject to liability without fault.

(b) The fact that a person holds a license or permit under this chapter, or that he has complied with this chapter or the regulations issued under this chapter, is not admissible as evidence in any legal proceeding brought against him.

§ 14.111. *Penalty*

(a) A person who violates any provision of this chapter or any valid regulation or order issued under this chapter is guilty of a misdemeanor and upon conviction is punishable by a fine of not less than \$100 nor more than \$1,000, or by confinement in the county jail for not more than 10 days, or by both.

(b) A separate offense is committed each day a violation continues.

§ 14.112. *Enforcement by Board*

(a) Whenever it appears that a person has violated or is violating, or is threatening to violate, any provision of this chapter or any regulation, license, permit, or order of the board, then the board, or the executive director when authorized by the board, may have a civil suit instituted in a district court for injunctive relief to restrain the person from continuing the violation or threat of violation, or for the assessment and recovery of a civil penalty of not less than \$50 nor more than \$1,000 for each act of violation and for each day of violation, or for both injunctive relief and civil penalty.

(b) Upon application for injunctive relief and a finding that a person is violating or threatening to violate any provision of this chapter or any regulation, license, permit, or order of the board, the district court shall grant the injunctive relief the facts may warrant.

(c) At the request of the board, or the executive director when authorized by the board, the attorney general shall institute and conduct a suit in the name of the State of Texas for injunctive relief or to recover the civil penalty or for both injunctive relief and penalty, as authorized in Subsection (a) of this section. Added by Acts 1971, 62nd Leg., p. 1769, ch. 518, § 11, eff. May 31, 1971.

UTAH

Utah Code Ann. §§ 73-15-3-73-15-8

CHAPTER 15—MODIFICATION OF WEATHER

Sec.

- 73-15-3. Cloud seeding to increase precipitation—Control of division of water resources—Powers and authority of division—"Cloud seeding" and "cloud-seeding project" defined.
- 73-15-4. Water from cloud seeding same as natural precipitation—Notice of intent prior to cloud-seeding project.
- 73-15-5. Transfer of records and data to division—Establishment of reporting and record keeping procedures.
- 73-15-6. Cloud-seeding contractors—Registration.
- 73-15-7. Precipitation caused by authorized project not presumed to constitute trespass or nuisance.
- 73-15-8. Cloud seeding in Utah to target area in adjoining state.

73-15-1, 73-15-2. Repealed.

Repeal: Sections 73-15-1 and 73-15-2 (L. 1953, ch. 129, §§ 1, 2), relating to reports to the department of meteorology, state school of mines, of weather modification activities, were repealed by Laws 1973, ch. 193, § 7. For present provisions, see 73-15-3 et seq.

73-15-3. *Cloud seeding to increase precipitation—Control of division of water resources—Powers and authority of division—"Cloud seeding" and "cloud-seeding project" defined.*—The state of Utah through the division of water resources shall be the only entity, private or public, that shall have authority to authorize, sponsor, and/or develop cloud-seeding research, evaluation, or implementation projects to alter precipitation, cloud forms, or meteorological parameters within the state of Utah, except cloud seeding for the suppression of fog is excluded. The division of water resources shall authorize, sponsor, and/or develop local or state-wide cloud-seeding projects that conform to over-all state water planning objectives and are determined to be feasible by the division of water resources. The division of water resources may contract with the Utah water research laboratory or any other individual or organization for consultation and/or assistance in developing cloud-seeding projects or in furthering necessary research of cloud seeding or other factors that may be affected by cloud-seeding activities. Cloud seeding as used in this act shall be construed to mean all acts undertaken to artificially distribute or create nuclei in cloud masses for the purposes of altering precipitation, cloud forms, or other meteorological parameters. A cloud-seeding project as used in this act shall be a planned project to evaluate meteorological conditions, perform cloud seeding, and evaluate results.

73-15-4. *Water from cloud seeding same as natural precipitation—Notice of intent prior to cloud-seeding project.*—All water derived as a result of cloud

seeding shall be considered as a part of Utah's basic water supply the same as all natural precipitation water supplies have been heretofore, and all statutory provisions that apply to water from natural precipitation shall also apply to water derived from cloud seeding. A notice of intent shall be filed with the division of water rights prior to the commencement of a cloud-seeding project.

History: L. 1973, ch. 193, § 2.

73-15-5. Transfer of records and data to division—Establishment of reporting and record keeping procedures.—All records and data collected by department of meteorology of the state school of mines and mineral industries of the University of Utah since the enactment of sections 73-15-1 and 73-15-2 shall be transferred to the division of water resources, there to be a permanent record. The division of water resources shall establish forms and/or criteria for reporting data and record keeping and cause that a permanent record is kept of all pertinent data related to cloud-seeding projects, cloud-seeding research projects, or research related to other factors that may be affected by cloud-seeding activities.

History: L. 1973, ch. 193, § 3.

73-15-6 Cloud-seeding contractors—Registration.—Any individual or organization that would like to become a cloud-seeding contractor in the state of Utah shall register with the division of water resources. As a part of the registration the applicant shall meet qualifications established by the division of water resources and submit proof of financial responsibility in order to give reasonable assurance of protection to the public in the event it should be established that damages were caused to third parties as a result of negligence in carrying out a cloud-seeding project.

History: L. 1973, ch. 103, § 4.

73-15-7 Precipitation caused by authorized project not presumed to constitute trespass or nuisance.—The mere dissemination of materials and substances into the atmosphere or causing precipitation pursuant to an authorized cloud-seeding project shall not give rise to any presumption that such use of the atmosphere or lands constitutes trespass or involves an actionable or enjoicable public or private nuisance.

History: L. 1973, ch. 193, § 5.

73-15-8 Cloud seeding in Utah to target area in adjoining state.—Cloud seeding in Utah to target an area in an adjoining state is prohibited except upon full compliance of the laws of the target area state the same is if the cloud-seeding operation took place in the target area state, as well as the other provisions of this act.

History: L. 1973, ch. 193, § 6.

Repealing Clause. Section 7 of Laws 1973, ch. 193 provided: "Sections 73-15-1 and 73-15-2, Utah Code Annotated 1953, as enacted by chapter 129, Laws of Utah 1953, is repealed."

WASHINGTON

Wash. Rev. Code Ann. §§ 43.37.010-43.37.200; 43-27A.080(6); 43.27A.180(1)

CHAPTER 43.37—WEATHER MODIFICATION BOARD

Sec.	
43.37.010	Definitions.
43.37.020	Board established—Composition, appointment, qualifications, compensation, quorum.
43.37.030	Powers and duties.
43.37.040	Promotion of research and development activities, contracts and agreements.
43.37.050	Hearing procedure.
43.37.060	Acceptance of gifts, donations, etc.—Weather modification board revolving account established, excess fees.
43.37.070	Staff services, materials, office space—Expenses.
43.37.080	License and permit required.
43.37.090	Exemptions.
43.37.100	Licenses—Requirements, duration, renewal, fees.
43.37.110	Permits—Requirements—Hearings as to issuance.
43.37.120	Separate permit for each operation—Filing and publishing notice of intention—Activities restricted by permit and notice.
43.37.130	Notice of intention—Contents.
43.37.140	—Publication.
43.37.150	Financial responsibility.
43.37.160	Fees—Sanctions for failure to pay.
43.37.170	Records and reports—Open to public examination.
43.37.180	Revocation, suspension, modification of license or permit.
43.37.190	Liability of state denied—Legal rights of private person not affected.
43.37.200	Penalty.

43.37.010 Definitions

¹As used in this chapter, unless the context requires otherwise:

(1) "Department" means the department of ecology;

(2) "Operation" means the performance of weather modification and control activities pursuant to a single contract entered into for the purpose of producing or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding one year; or, in case the performance of weather modification and control activities is to be undertaken individually or jointly by a person or persons to be benefited and not undertaken pursuant to a contract, "operation" means the performance of weather modification and control activities entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding one year;

(3) "Research and development" means theoretical analysis exploration and experimentation, and the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials, and processes;

(4) "Weather modification and control" means changing or controlling, or attempting to change or control, by artificial methods, the natural development of any or all atmospheric cloud forms or precipitation forms which occur in the troposphere. [Amended by Laws 1973 ch. 64 § 1, effective July 1, 1973.]

§3.37.020 Board established—Composition, appointment, qualifications, compensation, quorum

(1) There is established a weather modification board to consist of the director of conservation, who shall be the chairman and who shall exercise no vote except in case of a tie vote, nine members all appointed by the governor, including a member of the faculty of Washington State University, a member of the faculty of the University of Washington, one member to be a person experienced in, and actually engaged in the commercial production of horticultural products, three members to be persons experienced in, and actually engaged in the commercial production of other agricultural products, and three members representing the general public. Members appointed to represent horticulture, other agricultural products, and the general public, shall each represent a different congressional district in order that each congressional district of the state shall be represented by one such appointee. The term of office of each member of the board appointed prior to March 3, 1961 shall be four years, except that the first terms of office of such appointed members first taking office shall expire, as determined by the governor at the time of their appointment, one each at the end of the first, second, third and fourth years after March 3, 1957. The term of office of each member appointed to the board as an additional member because of this amendatory act [1961 c 1954 § 1] shall be four years, except that the first terms of office of such appointed members first taking office shall expire, as determined by the governor at the time of their appointment, two at the end of the first year after March 3, 1961, and one each at the end of the second, third, and fourth years after March 3, 1961. Any member appointed to fill a vacancy occurring prior to the expiration of the term for which his predecessor was appointed shall be appointed for the remainder of such term.

(2) Members of the board shall receive no compensation for the performance of their duties under the provisions of this chapter; but each member shall be reimbursed, to the extent allowed by law from funds available for the administration of this chapter, for expenses necessarily incurred in the performance of his duties.

(3) A majority of the members shall constitute a quorum for the transaction of business.

§3.37.030 Powers and duties

In the performance of its functions the department may, in addition to any other acts authorized by law:

(1) Establish advisory committees to advise with and make recommendations to the department concerning legislation, policies, administration, research, and other matters;

(2) Establish by regulation or order such standards and instructions to govern the carrying out of research or projects in weather modification and control as the department may deem necessary or desirable to minimize danger to health or property; and make such rules and regulations as are necessary in the performance of its powers and duties;

(3) Make such studies, investigations, obtain such information, and hold such hearings as the department may deem necessary or proper to assist it in exercising its authority or in the administration or enforcement of this chapter or any regulations or orders issued thereunder;

(4) Appoint and fix the compensation of such personnel, including specialists and consultants, as are necessary to perform its duties and functions;

(5) Acquire, in the manner provided by law, such materials, equipment, and facilities as are necessary to perform its duties and functions;

(6) Cooperate with public or private agencies in the performance of the department's functions or duties and in furtherance of the purposes of this chapter;

(7) Represent the state in any and all matters pertaining to plans, procedures, or negotiations for interstate compacts relating to weather modification and control. [Amended by Laws 1973 ch 64 § 2, effective July 1, 1973.]

43.37.040 Promotion of research and development activities—Contracts and agreements

The department shall exercise its powers in such manner as to promote the continued conduct of research and development activities in the fields specified below by private or public institutions or persons and to assist in the acquisition of an expanding fund of theoretical and practical knowledge in such fields. To this end the department may conduct, and make arrangements, including contracts and agreements, for the conduct of, research and development activities relating to:

(1) The theory and development of methods of weather modification and control, including processes, materials, and devices related thereto;

(2) Utilization of weather modification and control for agricultural, industrial, commercial, and other purposes;

(3) The protection of life and property during research and operational activities. [Amended by Laws 1973 ch § 3, effective July 1, 1973.]

43.37.050—Hearing procedure

In the case of hearings pursuant to RCW 43.37.180 the department shall, and in other cases may, cause a record of the proceedings to be taken and filed with the department, together with its findings and conclusions. For any hearing, the director of the department or a representative designated by him is authorized to administer oaths and affirmations, examine witnesses, and issue, in the name of the department, notice of the hearing or subpoenas requiring any person to appear and testify, or to appear and produce documents, or both, at any designated place. [Amended by Laws 1973 ch 64 § 4, effective July 1, 1973.]

43.37.060 Acceptance of gifts, donations, etc.

(1) The department may, subject to any limitations otherwise imposed by law, receive and accept for and in the name of the state any funds which may be offered or become available from federal grants or appropriations, private gifts, donations, or bequests, or any other source, and may expend such funds, subject to any limitations otherwise provided by law, for the encouragement of research and development by a state, public, or private agency, either by direct grant, by contract or other cooperative means.

(2) All license and permit fees paid to the department shall be deposited in the state general fund. [Amended by Laws 1973 ch 64 § 5, effective July 1, 1973.]

43.37.070 Staff services, materials, office space—Expenses

Repealed by Laws 1973 ch 64 § 19, effective July 1, 1973.

43.37.080 License and permit required

Except as provided in RCW 43.37.090, no person shall engage in activities for weather modification and control except under and in accordance with a license and a permit issued by the department authorizing such activities. [Amended by Laws 1973 ch 64 § 6, effective July 1, 1973.]

43.37.090 Exceptions

The department, to the extent it deems practical, shall provide by regulation for exempting from license, permit, and liability requirements, (1) research and development and experiments by state and federal agencies, institutions of higher learning, and bona fide nonprofit research organizations; (2) laboratory research and experiments; (3) activities of an emergent character for protection against fire, frost, sleet, or fog; and (4) activities normally engaged in for pur-

poses other than those of inducing, increasing, decreasing, or preventing precipitation or hail. [Amended by Laws 1973 ch § 7, effective July 1, 1973.]

43.37.100 Licenses—Requirements, duration, renewal, fees

(1) Licenses to engage in activities for weather modification and control shall be issued to applicants therefor who pay the license fee required and who demonstrate competence in the field of meteorology to the satisfaction of the department, reasonably necessary to engage in activities for weather modification and control. If the applicant is an organization, these requirements must be met by the individual or individuals who will be in control and in charge of the operation for the applicant.

(2) The department shall issue licenses in accordance with such procedures and subject to such conditions as it may by regulation establish to effectuate the provisions of this chapter. Each license shall be issued for a period to expire at the end of the calendar year in which it is issued and, if the licensee possesses the qualifications necessary for the issuance of a new license, shall upon application be renewed at the expiration of such period. A license shall be issued or renewed only upon the payment to the department of one hundred dollars for the license or renewal thereof. [Amended of Laws 1973 ch 64 § 8, effective July 1, 1973.]

43.37.110 Permits—Requirements—Hearings as to issuance

The department shall issue permits in accordance with such procedures and subject to such conditions as it may by regulation establish to effectuate the provisions of this chapter only:

(1) If the applicant is licensed pursuant to this chapter:

(2) If a sufficient notice of intention is published and proof of publication is filed as required by RCW 43.37.140;

(3) If the applicant furnishes proof of financial responsibility, as provided in RCW 43.37.150, in an amount to be determined by the department but not to exceed twenty thousand dollars;

(4) If the fee for a permit is paid as required by RCW 43.37.160;

(5) If the weather modification and control activities to be conducted under authority of the permit are determined by the department to be for the general welfare and public good;

(6) If the department has held an open public hearing in Olympia as to such issuance. [Amended by Laws 1973 ch 64 § 9, effective July 1, 1973.]

43.37.120 Separate permit for each operation—Filing and publishing notice of intention—Activities restricted by permit and notice

A separate permit shall be issued for each operation. Prior to undertaking any weather modification and control activities the licensee shall file with the department and also cause to be published a notice of intention. The licensee, if a permit is issued, shall confine his activities for the permitted operation within the time and area limits set forth in the notice of intention, unless modified by the department; and his activities shall also conform to any conditions imposed by the department upon the issuance of the permit or to the terms of the permit as modified after issuance. [Amended by Laws 1973 ch 64 § 10, effective July 1, 1973.]

43.37.130 Notice of intention—Contents

The notice of intention shall set forth at least all the following:

(1) The name and address of the licensee;

(2) The nature and object of the intended operation and the person or organization on whose behalf it is to be conducted;

(3) The area in which and the approximate time during which the operation will be conducted;

(4) The area which is intended to be affected by the operation;

(5) The materials and methods to be used in conducting the operation.

43.37.140 Notice of intention—Publication

(1) The applicant shall cause the notice of intention, or that portion thereof including the items specified in RCW 43.37.130, to be published at least once a week for three consecutive weeks in a legal newspaper having a general circulation and published within any county in which the operation is to be conducted and in which the affected area is located, or, if the operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the operation is to

be conducted, then in a legal newspaper having a general circulation and published within each of such counties. In case there is no legal newspaper published within the appropriate county, publication shall be made in a legal newspaper having a general circulation within the county.

(2) Proof of publication, made in the manner provided by law, shall be filed by the licensee with the department within fifteen days from the date of the last publication of the notice. [Amended by Laws 1973 ch 64 § 11, effective July 1, 1973.]

43.37.150 Financial responsibility

Proof of financial responsibility may be furnished by an applicant by his showing, to the satisfaction of the department, his ability to respond in damages for liability which might reasonably be attached to or result from his weather modification and control activities in connection with the operation for which he seeks a permit. [Amended by Laws 1973 ch 64 § 12, effective July 1, 1973.]

43.37.160 Fees—Sanctions for failure to pay

The fee to be paid by each applicant for a permit shall be equivalent to one and one-half percent of the estimated cost of such operation, the estimated cost to be computed by the department from the evidence available to it. The fee is due and payable to the department as of the date of the issuance of the permit; however, if the applicant is able to give to the department satisfactory security for the payment of the balance, he may be permitted to commence the operation, and a permit may be issued therefor, upon the payment of not less than fifty percent of the fee. The balance due shall be paid within three months from the date of the termination of the operation as prescribed in the permit. Failure to pay a permit fee as required shall be grounds for suspension or revocation of the license of the delinquent permit holder and grounds for refusal to renew his license or to issue any further permits to such person. [Amended by Laws 1973 ch 64 § 13, effective July 1, 1973.]

43.37.170 Records and reports—Open to public examination

(1) Every licensee shall keep and maintain a record of all operations conducted by him pursuant to his license and each permit, showing the method employed, the type of equipment used, materials and amounts thereof used, the times and places of operation of the equipment, the name and post office address of each individual participating or assisting in the operation other than the licensee, and such other general information as may be required by the department and shall report the same to the department at the time and in the manner required.

(2) The department shall require written reports in such manner as it provides but not inconsistent with the provisions of this chapter, covering each operation for which a permit is issued. Further, the department shall require written reports from such organizations as are exempted from license, permit, and liability requirements as provided in RCW 43.37.090.

(3) The reports and records in the custody of the department shall be open for public examination. [Amended by Laws 1973 ch 64 § 14, effective July 1, 1973.]

43.37.180 Revocation, suspension, modification of license or permit

(1) The department may suspend or revoke any license or permit issued if it appears that the licensee no longer possesses the qualifications necessary for the issuance of a new license or permit. The department may suspend or revoke any license or permit if it appears that the licensee has violated any of the provisions of this chapter. Such suspension or revocation shall occur only after notice to the licensee and a reasonable opportunity granted such licensee to be heard respecting the grounds of the proposed suspension or revocation. The department may refuse to renew the license of, or to issue another permit to, any applicant who has failed to comply with any provision of this chapter.

(2) The department may modify the terms of a permit after issuance thereof if the licensee is first given notice and a reasonable opportunity for a hearing respecting the grounds for the proposed modification and if it appears to the department that it is necessary for the protection of the health or the property of any person to make the modification proposed. [Amended by Laws 1973 ch 64 § 15, effective July 1, 1973.]

43.37.190 Liability of state denied—Legal rights of private persons not affected

Nothing in this chapter shall be construed to impose or accept any liability or responsibility on the part of the state, the department, or any state officials

or employees for any weather modification and control activities of any private person or group, nor to affect in any way any contractual, tortious, or other legal rights, duties, or liabilities between any private persons or groups. [Amended by Laws 1973 ch 64 § 16, effective July 1, 1973.]

43.37.900 Revolving account abolished

The weather modification board revolving account is hereby abolished. Any funds remaining in such account shall be transferred to the general fund. [Added by Laws 1973 ch 64 § 17, effective July 1, 1973.]

43.37.200 Penalty

Any person violating any of the provisions of this chapter or any lawful regulation or order issued pursuant thereto, shall be guilty of a misdemeanor; and a continuing violation is punishable as a separate offense for each day during which it occurs.

43.27A.080 Powers, duties, functions of certain state agencies transferred to department—Columbia basin division

The department shall exercise the powers, duties and functions, through divisions as provided for in RCW 43.27A.070 of the following state agencies or division of state agencies, and public officials, and all their powers, duties and functions are transferred to the department of water resources:

- (1) The division of reclamation of the department of conservation;
- (2) The division of water resources of the department of conservation;
- (3) The division of flood control of the department of conservation;
- (4) The division of power resources of the department of conservation;
- (5) The Columbia basin commission;
- (6) The weather modification board;

All other powers, duties or functions now vested in the department of conservation or the director thereof are transferred to the department of water resources, except those powers which are expressly transferred to some other agency of the state by this chapter. The director in exercising the powers, duties and functions of the Columbia basin commission as set forth in chapter 43.49 RCW may create and maintain in the department a Columbia basin division.

43.27A.180 Agencies abolished

On July 1, 1967, the following state agencies are abolished:

- (1) Weather modification board.
- (2) Columbia basin commission.
- (3) Power advisory committee.
- (4) Department of conservation.

WEST VIRGINIA

W. Va. Code §§ 29-2B-1—29-2B-15

ARTICLE 2B—WEATHER MODIFICATION

Sec.

- 29-2B-1. Declaration of policy.
- 29-2B-2. Definitions.
- 29-2B-3. Administration by director and commission.
- 29-2B-4. When license and registration of equipment required.
- 29-2B-5. Application for license.
- 29-2B-6. Registration of equipment.
- 29-2B-7. Publication of notice of intention to undertake operation.
- 29-2B-8. Permission to undertake emergency project without compliance with § 29-2B-7.
- 29-2B-9. Records and reports.
- 29-2B-10. Research projects; safety.
- 29-2B-11. Enforcement of article.
- 29-2B-12. Suspension or revocation of license.
- 29-2B-13. Compensation for damage.
- 29-2B-14. Acts not authorized.
- 29-2B-15. Offenses and penalties.

§ 29-2B-1. *Declaration of policy*

The public interest, health, safety, welfare and necessity require that scientific experimentation in the field of artificial nucleation, and that scientific efforts to develop and increase natural precipitation of rain, snow, moisture, or water in any form contained in the atmosphere, within the State, be encouraged in order to develop, conserve, and protect the natural water resources of the State and to safeguard life and property. (1969, c. 18.)

§ 29-2B-2. *Definitions*

As used in this article:

(a) "Director" means the director of aeronautics.

(b) "Commission" means the West Virginia aeronautics commission.

(c) "Operation" means the performance of weather modification and control activities pursuant to a single contract entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding one year, or, if the performance of weather modification and control activities is to be undertaken individually or jointly by a person or persons to be benefited and not undertaken pursuant to a contract, "operation" means the performance of weather modification and control activities entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding one year.

(d) "Person" means any individual, firm, association, organization, partnership, company, corporation, private or public, political subdivision, or other public agency.

(e) "Research and development" means theoretical analysis, exploration and experimentation and the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials and processes.

(f) "Weather modification and control" means changing or controlling, or attempting to change or control, by artificial methods the natural development of any or all atmospheric cloud forms and precipitation forms which occur in the troposphere. (1969, c. 18.)

§ 29-2B-3. *Administration by director and commission*

The director shall administer this article under the supervision of the commission. (1969, c. 18.)

§ 29-2B-4. *When license and registration of equipment required*

(a) No person, without first securing a license from the commission, shall cause or attempt to cause condensation or precipitation of rain, snow, moisture, or water in any form contained in the atmosphere.

(b) No person without registering with the commission shall have in his possession any cloud seeding equipment unless he is an employee of or under contract with a person conducting a weather modification and control operation who has been granted a license by the commission. (1969, c. 18.)

§ 29-2B-5. *Application for license; renewal; temporary suspension*

(a) Any person desiring to do any of the acts specified in section four [§ 29-2B-4] of this article may file with the director an application in writing for a license. Each application shall be accompanied by a filing fee fixed by the commission but not to exceed one hundred dollars, and shall be on a form to be supplied for such purpose by the director.

(b) Every application shall set forth all of the following:

(1) The name and post-office address of the applicant.

(2) The previous education, experience and qualifications of the applicant or, if the applicant is other than an individual, the previous education, experience and qualifications of the persons who will be in control of and charged with the operations of the applicant. Previous experience includes subcontracting or counseling services.

(3) A general description of the operations which the applicant intends to conduct and the method and type of equipment, including all nucleating agents, that the applicant proposes to use. Aircraft must be listed by numbers and pilots' names.

(4) A statement listing all employees who are residents of West Virginia or who will be directly employed in the intended operation, or both.

(5) A bond or insurance covering any damage the licensee may cause through his operations in an amount of fifteen thousand dollars or other evidence of financial responsibility shall be furnished and executed at the time of the grant of the license: Provided, that no bond shall be required of any person who shall cause or attempt to cause condensation or precipitation of rain, snow, moisture or water in any form contained in the atmosphere over any landing strip or runway of any airport or any approach thereto in an effort to improve the visibility above the landing strip, runway or approach.

(6) Every applicant shall have a resident agent within this State.

(c) Upon the filing of the application upon a form supplied by the director and containing the information prescribed by this article and accompanied by the required filing fee and bond or insurance, the director may issue a license to the applicant entitling the applicant to conduct the operations described in the application for the calendar year for which the license is issued, unless the license is sooner revoked, suspended or modified.

(d) A license may be renewed annually upon application to the director, accompanied by a renewal fee fixed by the commission but not to exceed one hundred dollars, on or before the last day of January of the calendar year for which the license is renewed.

(e) Any license granted under this section shall be subject to temporary suspension by the director. Such suspension may occur whenever the director is notified by the office of emergency services that, within an area defined by the office of emergency services, precipitation or other effects of weather modification operations would be likely to cause or aggravate a potential or ongoing disaster. Any such suspension shall continue until the director is notified by the office of emergency services that the disaster or threat of disaster has passed. Should any license be suspended under this subsection, the prohibitions of section four [§ 29-2B-4] and penalties of section fifteen [§ 29-2B-15] of this article shall become effective immediately. (1969, c. 18; 1973, c. 50.)

§ 29-2B-6. Registration of equipment

Every person not desiring a license who owns or possesses cloud seeding equipment shall promptly register the same with the director on a form furnished by him. (1969, c. 18.)

§ 29-2B-7. Publication of notice of intention to undertake operation.

(a) Prior to undertaking any operation authorized by the license, the licensee shall file with the director and cause to be published a notice of intention. The licensee shall then confine his activities for that operation substantially within the time and area limits set forth in the notice of intention.

(b) The notice of intention shall set forth all of the following:

(1) The name and address of the licensee.

(2) The nature and object of the intended operation and the person or persons on whose behalf it is to be conducted.

(3) The area in which and the approximate time during which the operation will be conducted.

(4) The area which will be affected by the operation as near as the same may be determined in advance.

(c) The notice of intention required by this section shall be published as a Class III legal advertisement and the publication area shall be the county where in the operation is to be conducted and in which the affected area is located, or, if the operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the operation is to be conducted, then such notice shall be published in like manner in a newspaper having a general circulation within each of such counties.

(d) Proof of publication shall be filed by the licensee with the director within fifteen days from the date of the last publication of the notice. Proof of publication shall be by copy of the notice as published, attached to and made a part of the affidavit of the publisher or foreman of the newspaper publishing the notice. (1969, c. 18.)

§ 29-2B-8. Permission to undertake emergency project without compliance with § 29-2B-7.

(a) Notwithstanding any provision of this article to the contrary, the director may grant a licensee permission to undertake an emergency nucleation project, without prior compliance by the licensee with the provisions of section seven [§ 29-2B-7], subsection (a), if the same appears to the commissioner to be necessary or desirable in aid of extinguishment of fires.

(b) Notwithstanding any provision of this article to the contrary, upon request of the county commissioners of a county or of the governing body of a city, borough, town or township, and upon the submission of such supporting evidence as the commission may require, the commission may grant a licensee permission to undertake a nucleation project for the purpose of alleviating a drought emergency, without prior compliance by the licensee with the provisions of section seven [§ 29-2B-7], subsection (a), requiring publication of notice of intention, if such project appears to the department to be necessary or desirable.

(c) Nothing contained in this section shall be construed as to relieve the licensee in the cases set forth in subsection (a) or (b) of this section from compliance

with the provisions of section seven [§ 29-2B-7], requiring publication of notice of intention and filing of proof of such publication, as soon after the granting of permission by the director as is practicable. In lieu thereof the licensee may furnish equivalent transmission of notice of intention by radio or television, and proof thereof, as soon after the granting of permission by the director as is practicable. (1969, c. 18.)

§ 29-2B-9. Records and reports

(a) Every licensee shall keep and maintain a record of all operations conducted by him pursuant to his license showing the method employed, the type of equipment used, the times and places of operation of the equipment, the name and post-office address of each person participating or assisting in the operation other than the licensee, and such other information as may be required by the commission, and shall report the same to the director immediately upon the completion of each operation.

(b) Each licensee shall further prepare and maintain an evaluation statement for each operation which shall include a report as to estimated precipitation, defining the gain or loss occurring from nucleation activities, together with supporting data therefor. This statement, together with such other pertinent information as the commission may require, shall be sent to the commission upon completion and be available to inspection by the commission or director at all times on the licensee's premises.

(c) The commission shall require written reports concerning each operation conducted by a licensee under this article.

(d) All information on an operation shall be submitted to the commission before any information on such operation may be released to the public.

(e) The reports and records in the custody of the commission shall be open for public examination as public documents. (1969, c. 18.)

§ 29-2B-10. Research projects; safety

(a) Research work within the province of this statute shall be permitted only when authorized by the commission.

(b) Government and armed forces projects within the province of this statute must meet all the requirements of this article.

(c) No nucleating agent may be used in concentrations dangerous to man or causes environmental pollution as determined by the state department of health. (1969, c. 18.)

§ 29-2B-11. Enforcement of article

In order to enforce the provisions of this article, the West Virginia state police shall, on request of the commission, assign at least one trooper and one investigator to an area where unlawful cloud seeding is suspected. If such police request the same, the commission shall assign an airplane and pilot. Air samples shall be taken by the West Virginia air pollution control commission if requested by the state police or the commission. For such enforcement purposes, the state department of health shall furnish such technical services as the commission or director may request. (1969, c. 18.)

§ 29-2B-12. Suspension or revocation of license

Any license may be revoked, suspended or modified if the commission finds, after due notice to the licensee and a hearing thereon, that the licensee has failed or refused to comply with any of the provisions of this article. The proceedings herein referred to shall be conducted in accordance with the provisions of article one [§ 29A-1-1 et seq.], chapter twenty-nine-A of the Code of West Virginia, one thousand nine hundred thirty-one, as amended, known as the "West Virginia Administrative Procedures Act" and the commission shall have all the powers granted therein. (1969, c. 18.)

§ 29-2B-13. Compensation for damage

Any licensee who causes a drought as determined by the commission shall compensate farmers for damages. Any licensee who by causing heavy downpours or storms which cause damage to lands as determined by the commission shall compensate farmers and property owners for such damages. (1969, c. 18.)

§ 29-2B-14. Acts not authorized

(a) Nothing contained in this article shall authorize any person to carry out a cloud seeding operation from West Virginia to seed in another state where such cloud seeding is prohibited.

(b) Nothing contained in this article shall be construed to authorize the suppression of lightning. (1969, c. 18.)

§ 29-2B-15. *Offenses and penalties*

(a) Any airplane pilot who flies an airplane with numbers invisible to escape identification under this article shall be guilty of a misdemeanor, and, upon conviction thereof, have his license revoked for a period of five years.

(b) Any airport owner or operator who knowingly boards cloud seeding planes to seed clouds or who operates as a cloud seeder without a license shall be guilty of a misdemeanor, and, upon conviction thereof, have his airport permit revoked for one year and be sentenced to pay a fine of not more than five hundred dollars and for a second or subsequent offense, he shall be sentenced to pay a fine of not more than one thousand dollars.

(c) Any person knowingly having in his possession without registering the same with the commission any cloud seeding equipment shall, on conviction thereof, be sentenced to pay a fine of ten thousand dollars.

(d) Any person who makes any false statement to secure a license under this article shall, on conviction thereof, have his license revoked permanently.

(e) Any person who violates any other provision of this article shall be guilty of a misdemeanor, and, upon conviction thereof, shall be fined not more than one thousand dollars, or imprisoned in the county jail not more than one year, or both fined and imprisoned. (1969, c. 18.)

WISCONSIN

Wisc. Stat. Ann. § 195.40

195.40 *Reporting operations to artificially influence precipitation*

(1) For the purpose of determining the effect of operations designed to influence precipitation of atmospheric moisture by artificial means it is hereby required that all persons engaged in such operations shall comply with the provisions of this section.

(2) Any person who enters into any contract for or engages in any activity designed or intended to affect by artificial means the precipitation of atmospheric moisture in this state shall register each proposed operation with the commission.

(3) The registration shall set forth such data as to time, place and method of each operation as the commission shall reasonably require for the purpose of making a scientific evaluation of each operation and its effect upon the public welfare.

(4) Each registrant shall within 10 days report on the conduct of each operation and shall provide such data as the commission may deem necessary in the public interest.

(5) Any person who * * * *violates* any of the provisions of this section shall forfeit for each such offense a sum * * * not to exceed \$250 together with the actual costs of all administrative and legal action necessary to collect such forfeiture. Such forfeiture shall be enforced and the proceeds disposed of as prescribed in s. * * * 30.03. Any unregistered operation shall be subject to summary abatement as a public nuisance.

WYOMING

Wyo. Stat. 1 §§ 10-4—10-9; 9-267—9-276

§ 10-4. *Aerial spraying, etc.—Annual registration required; information to be shown.*—On the first Monday in May of each year, any person or persons, firm, partnership, corporation, association, or any other organization engaged in the activity or business of aerial spraying, spreading of seeds, weather-modification or other chemicals, dusting, fertilizing, baiting, predator control or insect control of any area of this state, and all aircraft in Wyoming used for predator control or equipped with apparatus for distribution of sprays, dusts, weather-modification or other chemicals, seeds, or bait shall be registered annually with the Wyoming aeronautics commission on a printed form or forms prescribed by the Wyoming aeronautics commission, showing the name of the firm to be registered, the name and address of the owner, owners, and manager thereof, the name and address of the person to pilot such aircraft, his airman rating, number of hours flown, with airman certificate number, the make, model and type of aircraft to be used and the identification number assigned to the aircraft and type of spraying, seed or chemical spreading or dusting rig installed on the aircraft. (Laws 1951, ch. 142, § 1; 1973, ch. 57, § 1.)

§ 10-5. *Same—Unlawful unless registered.*—It is unlawful for any person, firm, partnership, corporation, association, organization or any combination thereof to engage in the activity or business of spraying, spreading of seeds, weather-modification or other chemicals, dusting, fertilizing, baiting, predator control or insect control of any area of this state by means or aircraft unless they are registered with the Wyoming aeronautics commission. (Laws 1951, ch. 142, § 2; 1973, ch. 57, § 1.)

§ 10-6. *Same—Pilot, operator or applicator qualifications.*—All pilots, operators, or applicators conducting aerial spraying, spreading of seeds, weather-modification or other chemicals, dusting, fertilizing, predator control or insect control by aircraft must have a minimum of 500 solo hours, 75 of which are in the same type aircraft used in making the application or control, and 25 hours actual spraying or predator control experience. A pilot may satisfy the requirement for actual spraying or predator control experience by taking five hours of dual simulated low flying from a qualified instructor. (Laws 1951, ch. 142, § 3; 1973, ch. 57, § 1.)

§ 10-7. *Same—Shut-off devices for aircraft required.*—That each aircraft spraying, seed or chemical spreading or dusting rig used for aerial application or dissemination of sprays, weather-modification or other chemicals and dusts shall be satisfactorily equipped with a positive shut-off device at each discharge nozzle (manually controlled shut-off valves, spring loaded valves or Ball checks acceptable) which will absolutely prevent the dissemination of material on any portion of the terrain over which flight is made other than the area being treated or sprayed. (Laws 1951, ch. 142, § 4.)

§ 10-8. *Same—Records of applications.*—That each applicator must maintain a record of each application of weather-modification or other chemicals, fertilizer or insecticides which records may be inspected by officials of the aeronautics commission on demand. Copies of said records shall be transmitted to the Wyoming aeronautics commission within ten days after the end of each calendar month during period of operation in this state and prior to departure from the State of Wyoming. The records shall contain the following minimum information: Name and address of contractee; property description; variety of crop treated; stage of crop growth; pests or weeds to be controlled; brand and type of chemical used; type of solution or seeds used; quantity of chemical used per acre; date and time sprayed or treated; wind velocity and direction. (Laws 1951, ch. 142, § 5.)

§ 10-9. *Same—Violation of §§ 10-4 to 10-8.*—Whoever shall violate any provision of this act [§§ 10-4 to 10-9] or rules and regulations thereunder shall be guilty of a misdemeanor and upon conviction shall be fined not less than twenty-five (\$25.00) dollars for the first offense and not less than fifty (\$50.00) dollars for each subsequent offense, or by imprisonment in the county jail not exceeding sixty (60) days, or both. (Laws 1951, ch. 142, § 6.)

ARTICLE 12

Weather Modification Board

§ 9-267. *Sovereign right to moisture in clouds declared; encouraging weather experimentation; proper safeguards.*—A. It is hereby declared that the State of Wyoming claims its sovereign right to the use for its residents and best interests the moisture contained in the clouds and atmosphere within its sovereign state boundaries.

B. It is hereby declared that although little is known regarding artificial weather modification, research and experimentation shall be encouraged.

C. It is hereby declared that although the ultimate use of modification methods is speculative, the application of such methods should have proper safeguards and provide sufficient data to protect life, property, and public interest. (Laws 1951, ch. 131, § 1.)

§ 9-268. *Board created; designation; composition; compensation; expenses.*—There is hereby created a board, to be known as the state weather modification board. The members of the board shall consist of the state engineer, the commissioner of agriculture, and the president of the University of Wyoming or their designated representatives. The members shall serve on the board without pay but shall be entitled to charge actual expenses incurred therewith to the department by which they are primarily employed. (Laws 1951, ch. 131, § 2.)

§ 9-269. *Function of board; "weather modification" defined.*—The primary func-

tion of the board is to procure, compile, and evaluate information relative to weather modification experiments and activities within the state boundaries. The term "weather modification" means changing, or controlling any of the weather phenomena by chemical, mechanical, or physical methods. (Laws 1951, ch. 131, § 3.)

§ 9-270. *Weather modification permit—Required to engage in modification activities; issuance; form.*—It shall be unlawful for anyone to engage in weather modification activities except under and in accordance with a permit issued by the state engineer. The state engineer may issue such permit only upon the recommendation of the weather modification board and in such form as prescribed by the board. (Laws 1951, ch. 131, § 4.)

§ 9-271. *Same—Separate permit required for each experiment or activity; permits issued for one year; revocation; fees, qualifications of permittee; authority to promulgate rules and regulations.*—A separate permit shall be issued for each experiment or activity. Permits shall be revocable by the state engineer upon recommendation of the board, in accordance with such procedures as the board shall establish. Permits are to be issued for one year from October 1 of one year to September 30 of the following year. A fee of \$25 shall be charged for each permit issued or renewed. Fees received by the board shall be deposited with the state treasurer to be placed into the general fund. A permit shall be issued only to a person, or persons, who can demonstrate to the board's satisfaction that he has or they have adequate qualifications in the atmospheric sciences. To justify issuance of a permit, the state weather modification board is hereby granted reasonable authority to promulgate the rules and regulations necessary to effectuate the purposes of the Wyoming weather modification laws. (Laws 1951, ch. 131, § 5; 1965, ch. 66, § 1; 1971, ch. 104, § 1; 1973, ch. 245, § 3.)

§ 9-272. *Same—Registration certificate to be issued; fee.*—Prior to the issuance of any permit the board shall have issued a registration certificate to the person or persons requesting such permit. A registration certificate shall be issued only after the board has considered and approved the qualifications and responsibility of the person or persons requesting a certificate. A registration fee of twenty-five dollars (\$25.00) per calendar year shall be charged for each registration certificate so issued. Registration fees so received by the board may be used by the board in paying part or all of its administrative expenses. (Laws 1951, ch. 131, § 6.)

§ 9-273. *Same—Written report of experiments required.*—The board shall be required to demand and receive a written report, in such manner as it shall provide, covering each separate experiment or activity for which a permit is issued. (Laws 1951, ch. 131, § 7.)

§ 9-274. *Same—Failure to obtain permit.*—Any person, persons, corporation, institution, or group engaging in a weather modification experiment without a permit shall be guilty of a felony and upon conviction subject to a fine not to exceed one-thousand dollars (\$1,000.00) or by imprisonment in the penitentiary for not less than one nor more than five years. (Laws 1951, ch. 131, § 10; 1955, ch. 166, § 1.)

§ 9-275. *Authority to receive and accept funds.*—Said board is hereby authorized and empowered to receive and accept for and in the name of the state any and all funds which may be offered or become available, from federal grants or appropriations, private gifts, donations or bequests, or any other source, and to expend such funds for the expenses of administering this act [§§ 9-267 to 9-276], and for the encouragement of experimentation in weather modification by the University of Wyoming or any other appropriate state or public agency, either by direct grant, by contract, or other co-operative means. (Laws 1951, ch. 131, § 8.)

§ 9-276. *Act construed; rights, duties and liabilities unchanged.*—Nothing in this act [§§ 9-267 to 9-276] shall be construed to impose or accept any liability or responsibility on the part of the State, the board, or any state officials or employees, for any weather-modification activities of any private person or group, nor to affect in any way any contractual, tortious, or other legal rights, duties or liabilities between any private persons or groups. (Laws 1951, ch. 131, § 9.)

Effective date.—Section 11, ch 131, Laws 1951, makes the act effective from and after passage. Approved February 19, 1951.

APPENDIX E

LIST OF STATE CONTACTS FOR FURTHER INFORMATION ON WEATHER MODIFICATION ACTIVITIES WITHIN THE STATES^{1, 2}

- Commissioner, Department of Agriculture and Industries, State Capitol, Montgomery, Ala. 36104.
- Commissioner, Department of Natural Resources, Pouch M, Juneau, Alaska 99811.
- Briggs, Philip C., Chief Hydrologist Arizona Water Commission 222 N. Central, Suite 800, Phoenix, Ariz. 85004.
- Division of Soil and Water Resources, Department of Commerce, 1501 N. University Avenue, Suite 364, Little Rock, Ark. 72207.
- Finlayson, Donald J., Department of Water Resources, P.O. Box 160088 Sacramento, Calif. 95816.
- Sherman, Harris, Executive Director, Department of Natural Resources, 1313 Sherman Street, Room 718, Denver, Colo. 80203.
- Commissioner Department of Agriculture and Natural Resources, State Office Building, Hartford, Conn. 06115.
- Olney, Austin P., Secretary, Department of Natural Resources and Environmental Control, Edward Tatnall Building, Dover, Del. 19901.
- Chief, Bureau of Water Resource Management, Montgomery Building, 2562 Executive Center Circle, East, Tallahassee, Fla. 32301.
- Rhinehart, John, Office of Planning and Budget, 270 Washington St., S.W., Atlanta, Ga. 30334.
- Governor, Executive Chambers, State Capitol, Honolulu, Hawaii 96813.
- Allred, Stephen, Department of Water Resources, 373 W. Franklin Street, Boise, Idaho 83720.
- Changnon, Stanley A., Jr., Head, Atmospheric Sciences Section, Illinois State Water Survey, Box 232, Urbana Ill. 61801.
- Schaal Lawrence, State Climatologist, Poultry Science Building, Purdue University, West Lafayette, Ind. 47907.
- Waite, Paul, Iowa Weather Service, Room 10, Terminal Building, Municipal Airport, Des Moines, Iowa 50321.
- Kostecki, Don, Kansas Water Resource Board, Suite 303, 503 Kansas, Topeka, Kan. 66603.
- Kimmel, Michael J., Office of Planning and Research, Department of Natural Resources and Environment, Capitol Plaza Tower, 6th Floor, Frankfort, Ky. 40601.
- Aguillard, Roy, Louisiana State Department of Public Works, Box 44155, Capitol Station, Baton Rouge, La. 70804.
- Anderson, Burton R., Water Resource Planner, State Planning Office, 184 State Street, Augusta, Me. 04333.
- Hance, Young D., Secretary, Department of Agriculture, Parole Plaza Office Building, Annapolis, Md. 21401.
- McLoughlin, Thomas F., Director, Division of Administrative Services, Executive Office of Environmental Affairs, 100 Cambridge Street, Boston, Mass. 02202.
- Nurnberger, Fred V., Department of Agriculture/Weather Services, 240 Stephen S. Nisbet Building, 1407 S. Harrison Road, East Lansing, Mich. 48823.
- Young, Randall D., Senior Management Analyst Planning, Department of Agriculture, 557 State Office Building, St. Paul, Minn. 55337.
- Pepper, Jack W., Water Engineer, Board of Water Commissioners, 416 N. State Street, Jackson, Miss. 39201.
- Ashford, Carolyn, Director, Department of Natural Resources, Box 176, 1014 Madison Street, Jefferson City, Mo. 65101.

¹ Based on information received from Conrad G. Keyes, Jr., Executive Director of the North American Interstate Weather Modification Council; information was corrected as of January 30, 1978.

² Listed alphabetically by State.

- Moy, Richard, Weather Modification Program Manager, Department of Natural Resources and Conservation, Natural Resources Building, 32 South Ewing, Helena, Mont. 59601.
- Kreuscher, Glenn W., Director, Department of Agriculture, P.O. Box 4844, Lincoln, Nebr. 68509.
- Warburton, Joseph A., Desert Research Institute, University of Nevada, Stead Campus, Reno, Nev. 89507.
- Gilman, George, Commissioner, Department of Resource and Economic Development, State House Annex, Concord, N.H. 03301.
- Chummey, Richard, Director, Division of Rural Resources, Department of Agriculture, P.O. Box 1888, Trenton, N.J. 08625.
- Holmes, Charles, Secretary, New Mexico Weather Control and Climate Modification Commission, New Mexico Institute of Mining and Technology, Socorro, N. Mex. 87801.
- Berle, Peter A., Commissioner, Department of Environmental Conservation, 50 Wolf Road, Albany, N.Y. 12233.
- Secretary, Department of Natural and Economic Resources, P.O. Box 27687, Raleigh, N.C. 27611.
- Rose, R. Lynn, Executive Director, North Dakota Weather Modification Board, P.O. Box 1833, Bismarck, N.Dak. 58505.
- Division of Water, Department of Natural Resources, Fountain Square, Columbus, Ohio 43224.
- Oklahoma Weather Modification Advisory Committee, Oklahoma Water Resources Board, Jim Thorpe Building, 5th Floor, Oklahoma City, Okla. 73105.
- Glatt, Jay, Assistant Director, Department of Agriculture, 210 Agriculture Building, Salem, Oreg. 97310.
- Wertz, Fred, Research Analyst, Pennsylvania Department of Agriculture, 2301 Cameron Street, Harrisburg, Pa. 17120.
- Russ, Robert B., Water Resources Board, Box 2772, Providence, R.I. 02907.
- Guess, Clair P., Jr., Executive Director, Water Resources Commission, Box 4515, 3838 Forest Drive, Columbia, S.C. 29204.
- Butler, Vern W., Department of Natural Resources Development, Joe Foss Office Building, Pierre, S.Dak. 57501.
- Division of Water Resources, Tennessee Department of Conservation, 6213 Charlotte Avenue, Nashville, Tenn. 37209.
- Carr, John T., Director, Weather Modification and Technology Division, Texas Department of Water Resources, Box 13087, Austin, Tex. 78711.
- Summers, Paul C., Cloud Seeding Program Coordinator, Division of Water Resources, 435 State Capitol Building, Salt Lake City, Utah 84114.
- Department of Water Resources, Environmental Conservation Agency, 5 Court Street, Montpelier, Vt. 05602.
- State Air Pollution Control Board, Room 1106, Ninth Street Office Building, Richmond, Va. 23219.
- Goodman, Duane, Department of Ecology, 335 General Administration Building, Olympia, Wash. 98504.
- Richards, William E., Executive Director, West Virginia Aeronomy Commission, Kanawha Airport, Charleston, W.Va. 25311.
- Conrad, Marlin S., Plant Industry Division, Department of Agriculture, Trades and Consumer Protection, 801 W. Badger Road, Madison, Wis. 53713.
- Christopoulos, George L., State Engineers Office, Barrett Building, Second Floor, Cheyenne, Wyo. 82002.

APPENDIX F

AGREEMENT ON EXCHANGE OF INFORMATION ON WEATHER MODIFICATION BETWEEN THE UNITED STATES OF AMERICA AND CANADA

Treaties and Other International Acts Series 8056

WEATHER MODIFICATION—EXCHANGE OF INFORMATION

Agreement Between the

UNITED STATES OF AMERICA AND CANADA

Signed at Washington March 26, 1975.

NOTE BY THE DEPARTMENT OF STATE

Pursuant to Public Law 89-497, approved July 8, 1966 (80 Stat. 271; 1 U.S.C. 113)—

The Treaties and Other International Acts Series issued under the authority of the Secretary of State shall be competent evidence of the treaties, international agreements other than treaties, and proclamations by the President of such treaties and international agreements other than treaties, as the case may be, therein contained, in all the courts of law and equity and of maritime jurisdiction, and in all the tribunals and public offices of the United States, and of the several States, without any further proof or authentication thereof.

CANADA

Weather Modification : Exchange of Information

Agreement signed at Washington March 26, 1975; entered into force March 26, 1975.

AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND CANADA RELATING TO THE EXCHANGE OF INFORMATION ON WEATHER MODIFICATION ACTIVITIES

The Government of the United States of America and the Government of Canada,

Aware, because of their geographic proximity, that the effects of weather modification activities carried out by either Party or its nationals may affect the territory of the other;

Noting the diversity of weather modification activities in both the United States and Canada by private parties, by State and Provincial authorities, and by the Federal Governments;

Believing that the existing state of knowledge warrants the expectation of further development over a period of time in the science and technology of weather modification;

Taking into particular consideration the special traditions of prior notification and consultation and the close cooperation that have historically characterized their relations;

Believing that a prompt exchange of pertinent information regarding the nature and extent of weather modification activities of mutual interest may facilitate the development of the technology of weather modification for their mutual benefit;

Recognizing the desirability of the development of international law relating to weather modification activities having transboundary effects;

Have agreed as follows:

Article I

As used in this Agreement:

(a) "Weather modification activities", means activities performed with the

intention of producing artificial changes in the composition, behavior, or dynamics of the atmosphere;

(b) "Weather modification activities of mutual interest" means weather modification activities carried out in or over the territory of a Party within 200 miles of the international boundary; or such activities wherever conducted, which, in the judgment of a Party, may significantly affect the composition, behavior, or dynamics of the atmosphere over the territory of the other Party;

(c) "Responsible agencies" means the National Oceanic and Atmospheric Administration of the United States and the Atmospheric Environment Service of Canada, or such other agencies as the Parties may designate;

(d) "Reporting requirements" means the requirements established by the domestic laws or regulations of the Parties for reporting to the responsible agencies information relating to weather modification activities by persons or entities engaged in weather modification.

Article II

(1) Information relating to weather modification activities of mutual interest acquired by a responsible agency through its reporting requirements or otherwise, shall be transmitted as soon as practicable to the responsible agency of the other Party. Whenever possible, this information shall be transmitted prior to the commencement of such activities. It is anticipated that such information will be transmitted within five working days of its receipt by a responsible agency.

(2) Information to be provided by the responsible agencies shall include copies of relevant reports received through the reporting procedures after the effective date of this Agreement, and such other information and interpretation as the responsible agency might consider appropriate.

(3) Nothing herein shall be construed to require transmission to the other responsible agency of information, the disclosure of which is prohibited by law, or of information which, in the judgment of the responsible agency, is proprietary information.

Article III

The responsible agencies shall consult with a view to developing compatible reporting formats, and to improving procedures for the exchange of information.

Article IV

In addition to the exchange of information pursuant to Article II of this Agreement, each Party agrees to notify and to fully inform the other concerning any weather modification activities of mutual interest conducted by it prior to the commencement of such activities. Every effort shall be made to provide such notice as far in advance of such activities as may be possible, bearing in mind the provisions of Article V of this Agreement.

Article V

The Parties agree to consult, at the request of either Party, regarding particular weather modification activities of mutual interest. Such consultations shall be initiated promptly on the request for a Party, and in cases of urgency may be undertaken through telephonic or other rapid means of communications. Consultations shall be carried out in light of the Parties' laws, regulations, and administrative practices regarding weather modification.

Article VI

The Parties recognize that extreme emergencies, such as forest fires, may require immediate commencement by one of them of weather modification activities of mutual interest notwithstanding the lack of sufficient time for prior notification pursuant to Article IV, or for consultation pursuant to Article V. In such cases, the Party commencing such activities shall notify and fully inform the other Party as soon as practicable, and shall promptly enter into consultations at the request of the other Party.

Article VII

Nothing herein relates to or shall be construed to affect the question of responsibility or liability for weather modification activities, or to imply the existence of any generally applicable rule of international law.

Article VIII

Each Party shall conduct an annual review of this Agreement while it remains in force, and shall inform the other of its views regarding the Agreement's operation and effectiveness and the desirability of its amendment to reflect the evolution of the science and technology of weather modification and of international law. The Parties shall meet periodically, by mutual agreement, or at the request of either, to review the implementation of this Agreement or to consider other issues related to weather modification.

Article IX

This Agreement shall enter into force upon signature. It may be amended by mutual agreement of the Parties and may be terminated by either Party upon six months written notice to the other Party.

APPENDIX G
 WEATHER MODIFICATION ACTIVITIES IN THE UNITED STATES
 DURING CALENDAR YEAR 1975¹

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
73-002.....	Irving P. Krick, Inc. of Texas, 611 South Palm Canyon Dr., Suite 216, Palm Springs, Calif. 92262.	City of Lawton, c/o Mayor Dan Whitaker, City Hall, Lawton, Okla. 73501.	Precipitation increase, Nov. 1, 1972, to July 3, 1975.	November 1972, to July 1, 1975.	Lakes Lawtonka and Ellsworth, Okla.	400.0	Ground-based dispensers	Arc-type burners,	AgI.....	0.5.
73-010.....	North American Weather Consultants, Santa Barbara Municipal Airport, Goleta, Calif. 93017.	Southern California Edison Co., P.O. Box 800, Rosemead, Calif. 91770.	Precipitation increase, Nov. 1, 1972, continuing.	November 1972, to present.	Upper San Joaquin River, Calif.	1,200.0	Ground-based.....	Propane generators (12) (AGNH1).	do.....do.....	6.
73-014.....	Los Angeles County Flood Control District, P.O. Box 2418, Terminal Annex, Los Angeles, Calif. 90051.	Los Angeles County Flood Control District, P.O. Box 2418, Terminal Annex, Los Angeles, Calif. 90051.	Precipitation increase, Dec. 5, 1972, continuing.	December 1972, to present.	Areas north of Pasadena and Glendora, Calif.	407.0	Airborne dispensers, Ground-based dispensers.	Pyrotechnics.....do.....do.....	do.....do.....	240. 6 at each generator.
73-015.....	Evergreen Air of Montana), Johnson Flying Service, P.O. Box 1366, Missoula, Mont. 59801.	Northwest Airlines, Johnson-Bell Airport, Missoula, Mont. 59801.	Cold fog dispersal, Jan. 1, 1973, continuing.	October 1972 to present.	Missoula County Airport, Mont.	5.0	Aircraft dispensers.	Dispensed by hand mounted tray mounted on aircraft floor.	CO ₂ (dry ice).	107,144.
73-029.....	Atmospherics, Inc., 5652 East Dayton, Fresno, Calif. 93727.	Kings River Conservation District, 4886 East Jensen, Fresno, Calif. 93727.	Rainfall and snowpack increase, Oct. 1, 1973, continuing.	Nov. 1, 1972, to present.	East of Fresno, Calif.	1,600.0	Aircraft (1) and ground-based generators (15).	Pyrotechnics and liquid fuel generators.	AgI smoke particles.	14 to 240.

74-062	Des Moines Flying Service, Inc., Municipal Airport, Des Moines, Iowa 50315, 60666.	United Airlines, P. O. Box 8800, O'Hare International Airport, Chicago, Ill. 60686.	Cold fog dispersal, continuing, 1973 to present.	Eppler Field, Omaha, Neb.	2.0	Aircraft dispersers.	Electric-operated, reverse auger disperser equipped with a 100-lb capacity hopper.	Dry ice..... 22,700 g/min.
74-063	do	do	do	Des Moines Municipal Airport, Des Moines, Iowa.	2.0	do	do	do
74-064	do	do	do	Cedar Rapids Municipal Airport, Cedar Rapids, Iowa.	2.0	do	do	do
74-065	do	do	do	Quad-City Airport, Moline, Ill.	2.0	do	do	do
74-066	Aviation Service, Inc., c/o Norman R. Sahn, 1880 Gentry Way, Reno, Nev. 89502.	City of Reno, Reno International Airport, Reno, Nev. 89502.	Cold fog dispersal, Dec. 10, 1973. "unknown."	Reno International Airport, Reno, Nev.	4-6.0	do	Ice crusher ejects to airstream.	Estimate 408,600.
74-075F	National Oceanic and Atmospheric Administration, 325 Broadway, Boulder, Colo. 80302.	Atmospheric Chemistry and Physics Laboratory, National Oceanic and Atmospheric Administration, 325 Broadway, Boulder, Colo. 80302.	Investigate feasibility of lightning suppression through chaff seeding Nov. 1, 1973, to September 9, 1976.	250-mile radius of Bloomfield, Colo.	100.0	Aircraft dispersers (1).	Chaff dispenser. Aluminumized nylon chaff fibers 1 mil in diameter 10 cm long.	For each operation: 2 or 3 passes made along a 2 mi track and 1,000 grams dispensed in each pass (1,000 grams equals approximately 10,800,000 fibers).
74-077	Organomic Research Foundation, Richard A. Blasband, Red Hill Rd., Box 104, Ottsville, Pa. 18942.	Richard A. Blasband, Red Hill Rd., Box 104, Ottsville, Pa. 18942.	Pollution dispersal and removal of "deadly" or gaseous radiation. Apr. 20, 1974, to Oct. 30, 1974. (Continuing).	Bucks County, Pa.	200.0	"Cloudbuster"	10 ft to 18 ft, 1 in to 3 in aluminum tubes grounded to well or stream by Greenfield cables.	do
74-091 (Continuation of 73-004)	Irving P. Krick, Inc., of Texas, 611 South Palm Canyon Dr., Suite 216, Palm Springs, Calif. 92262.	Harper County Weather, Inc., P. O. Box 441, Buffalo, Okla. 73834.	Precipitation increase, Apr. 15, 1974, to Oct. 15, 1975.	Harper County, Okla.	1,034.0	Ground-based dispersers.	Arc-type generators.	Agl..... 0.5 or 2.

See footnote at end of table.

WEATHER MODIFICATION ACTIVITY REPORTS, CALENDAR YEAR 1975—Continued

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
74-092 (continuation of 73-026).	Irving P. Krick, Inc., of Texas, 611 South Palm Canyon Dr., Suite 216, Palm Springs, Calif. 92262.	Woodward County Cloudseeding Association, Sharon, Okla. 73857.	Precipitation increase, Apr. 15, 1974, to Oct. 15, 1975.	Oct. 1, 1975, to Dec. 31, 1975.	Woodward County, Okla.	1, 235.0	Ground-based dispensers.	Arc-type generators.	AgI	0.5 or 2.
74-093 (continuation of 73-025).	do.	Ellis County Weather, Inc., Harmon, Okla., 73345.	do.	do.	Ellis County, Okla.	1, 222.0	do.	do.	do.	Do.
74-096 (continuation of 73-024).	do.	Kiowa County Weather Modification Association, E21 North Broadway, Hobart, Okla. 73651.	do.	do.	Kiowa County, Okla.	1, 032.0	do.	do.	do.	Do.
74-101F	Patrick Squires Desert Research Institute, Sage building, Stead Campus, University of Nevada, Reno, Nev. 89507.	Dr. Archie Kahan, Department for the Interior, Bureau of Reclamation, Building 67, Denver Federal Center, Denver, Colo. 80225.	Precipitation increase research, Oct. 16, 1972 to May 15, 1975.	Oct. 1, 1972 to May 15, 1975.	Lake Tahoe and Truckee River Watershed, Nev.	1, 500.0	do.	2 USBR propane generators.	AgI in acetone or Iso-propylamine solution.	42.6.
74-113F	National Hail Research Experiment, National Center for Atmospheric Research, P.O. Box 1880, Table Mesa Dr., Boulder, Colo. 80302.	National Science Foundation, 1800 G St., Washington, D.C. 20550.	Hail suppression, research, Nov. 1, 1973, to Sept. 19, 1976.	May 1, 1973 to Aug. 15, 1975.	Northwest of Sterling, Colo.	600.0	Aircraft dispensers.	4 DRI mobile propane generators. Flare racks and vertical rocket launchers.	AgI	100g/90 sec./unit, 247,000.
74-114 (continuation of 73-057).	Harlon W. Bement, Interwest Aviation, 3063 East Millcreek Rd., Salt Lake City, Utah 84109.	WAL-UAL-Frontier-Texas International-AM-Hughes AW Airlines, Salt Lake International Airport, Salt Lake City, Utah 84122.	Cold Fog Dispersal, Nov. 1, 1974 to Mar. 31, 1975.	Jan. 1, 1974 to Mar. 31, 1975.	International Airport Salt Lake City, Utah.	10.0	Aircraft dispensed.	Spreader	Dry ice	272 kg (est.).
75-115 (Continuation of 73-013 and 73-053).	Sacramento Municipal Utility District (SMUD), 6201 S St., Box 15830, Sacramento, Calif. 95813.	SMUD	Snow Pack Increase, Oct. 15, 1974, to May 15, 1975.	Oct. 15, 1974 to May 15, 1975.	Lake areas southwest of Lake Tahoe, Calif.	236.0	Ground-based dispensers.	Propane burners (6).	AgI	25 at each burner.

75-118 (Continuation of 74-059).	Alaska Air Service, Inc., P.O. box 4-469 Anchorage, Alaska 99506.	Air Facilitation Committee P.O. box 6027, Anchorage, Alaska 99502.	Cold fog dispersal, Nov. 1, 1974 to Mar. 15, 1975.	Nov. 1, 1974, to 15, 1975.	Runway Complex, Anchorage International Airport Alaska.	1.0 Aircraft dispersed.	Chute in A/c----- Dry Ice----- 545 kg (est.)
75-120 (Continuation of 74-059).	Logan and Reavis Air, Elmendorf AFB, Medford, Ore. 97501.	Air West and United Airlines, c/o United Airlines, P.O. Box 66110, Chicago, Ill. 60666.	Cold fog dispersal, Nov. 1, 1974 to Feb. 28, 1975.	Nov. 1, 1974 to Feb. 28, 1975.	Medford-Jackson County Airport, Ore.	1.0 -----do-----	Suction tube-----do----- 45.4 kg.
75-121 F (Continuation of 74-097).	11th Weather Squadron, Air Weather Service, Elmendorf AFB, Anchorage, Alaska 99506.	Alaskan Air Command, U.S. Air Force, Elmendorf AFB, Anchorage, Alaska 99506.	Cold fog dispersal, Nov. 1, 1974, to Mar. 31, 1975.	Oct. 1, 1974, to Mar. 31, 1975.	Elmendorf AFB, Runway Complex, Alaska.	50.0 Airborne dispensers.	Ice crusher and discharge chute----- Dry ice----- 820 kg (estimate).
75-122 F (Continuation of 74-097).	-----do-----	21st Composite Wing, U.S. Air Force, Elmendorf AFB, Anchorage, Alaska 99506.	Cold fog dispersal, Nov. 1, 1974, to Mar. 31, 1975.	Nov. 1, 1974, to Nov. 3, 1975.	Elmendorf AFB Runway Complex, Alaska.	50.0 Ground-based dispensers (19).	Tank, nest nozzle----- Propane----- 10 gal/hr. (approx.).
75-123 F (Continuation of 74-098).	Det. 3, 3 WW, Air Weather Service, Fairchild AFB, Spokane, Wash., 99011.	92 Bombardment Wing, USAF, Fairchild AFB, Spokane, Wash., 99011.	-----do-----	-----do-----	Fairchild AFB, Runways, Wash.	50.0 Ground-based dispensers (23).	Propane----- 10 gal/hr. (approx.).
75-124 (continuation of 74-055).	University of Wyoming, Department of Atmospheric Resources, P.O. Box 3038, Laramie, Wyo. 82070.	Eden Farson Irrigation District, Farson, Wyo. 82931.	Snow Increase, Dec. 1, 1974 to Apr. 15, 1975.	Dec. 4, 1979 to Apr. 15, 1975.	Big Sandy River drainage, Wyo.	180.0 Ground-based dispensers.	Propane dispensers----- Agl-NH ₄ I 10-15.
75-125 (continuation of 73-054).	Aero-Dyne Corp., 200 Airport Way, Renton, Wash., 98055.	Port of Seattle, Seattle-Tacoma Airport, Seattle, Wash., 98188.	Warm fog dispersal, Oct. 1, 1974, to Feb. 28, 1975.	Oct. 1, 1974 to Mar. 31, 1975.	Seattle-Tacoma Airport, Wash.	1.0 Aircraft dispensers.	Metered hopper and blower----- Poly-electrolyte 300 mg (estimate).
75-126 (Continuation of 74-067).	North American Weather Consultants, Santa Barbara Municipal Airport, Goleta, Calif., 93017.	South Utah Water Development Corp., Centerfield, Utah, 84622.	Rainfall increase, Dec. 1, 1974, to Apr. 30, 1975.	Dec. 1, 1974, to Apr. 1, 1975.	Southwest Utah.	40,000.0 Ground-based dispensers.	Propane generators----- Agl----- 6.
75-127 F (continuation of 74-061F).	E.G. & G., Inc., P.O. Box 58, Durango, Colo., 81301.	Bureau of Reclamation, Building 67, Denver Federal Center, Denver, Colo., 80225.	Research and precipitation increase, Nov. 6, 1974, to May 16, 1975.	Nov. 6, 1974, to Mar. 24, 1975.	Southeast San Juan Mountains, Colo.	1,300.0 -----do-----	Generators (15 remotely controlled, 20 manual).----- 20 to 140 each generator.

See footnote at end of table.

WEATHER MODIFICATION ACTIVITY REPORTS, CALENDAR YEAR 1975 I—Continued

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
75-128 (Continuation of 74-017).	Pacific Gas & Electric Co., 245 Market St., San Francisco, Calif., 94106.	Pacific Gas and Electric Co., 77 Beale St., San Francisco, Calif., 94106.	Snowpack increase, Nov. 1, 1974, to May 31, 1975.	Nov. 1, 1974, to May 31, 1975.	Lake Almanor, North Sierra Nevada Mountains, Calif.	500.0	Ground-based	Propane-acetone generators (8).	Agl	25.
5-129 (Continuation of 74-069).	do	do	do	do	Central Sierra Nevada Mountains, (Mokelumne) Calif.	250.0	do	Propane-acetone generators (3).	Agl	25.
75-131	North American Weather Consultants, Santa Barbara Municipal Airport, Goleta, Calif. 93017.	Portland General Electric Co., 621 South West Adler, Portland, Ore. 97205.	Precipitation increase, Dec. 16, 1974, to Mar. 30, 1975.	Dec. 16, 1974, to Mar. 25, 1975.	Deschutes River, Ore.	7,820.0	do	Propane generators.	Agl	6.
75-133	Water Resources Development Co., 611 S. Palm Canyon Dr., Palm Springs, Calif. 92262.	Benson Palmer Grand Mesa Water Users Association, Cedar-edge, Colo. 81413.	Precipitation increase, Jan. 20, 1975, to Apr. 30, 1975.	Jan. 20, 1975, to Apr. 30, 1975.	Mesa and Delta Counties, Grand Mesa National Forest, Colo.	600.0	do	Arc-type generators (10-11).	Agl	0.5 to 2.0.
75-134 (continuation of 74-058).	Executive Air Corp., P.O. Box 19187, Spokane, Wash. 19187.	Northwest Orient Airlines, Spokane International Airport, Spokane, Wash. 99219.	Warm/cold fog dispersal, Oct. 15, 1974, to Apr. 15, 1975.	Oct. 15, 1974, to Apr. 15, 1975.	Spokane Airport Runway, Wash.	4.5	Aircraft	Dispensing hopper.	CO ₂ electrolyte.	136 kg/hr; 54 kg/hr.
75-135	Weather Modification, Inc., Bowman, N. Dak. 58623.	South Dakota Division of Weather Modification, Pierre, S. Dak. 57501.	Increase rainfall, decrease hail damage, May 1, 1975, to Sept. 1, 1975.	May 1, 1975, to Sept. 1, 1975.	District 1, Tripp, Gregory etc. Counties, S. Dak.	9,112.0	Aircraft dispersed.	Lohse-acetone generators. Pyrotechnic racks.	Agl	60-120. 1,200-24,000.
75-136	do	do	do	do	District 2, McCook, Turner, etc. Counties, S. Dak.	8,828.0	do	Lohse-acetone generators.	Agl	60-120.
75-137	North American Weather Consultants, Santa Barbara Municipal Airport, Goleta, Calif. 93017.	do	do	do	District 3, Potter, Brown, etc. Counties, S. Dak.	5,135.0	do	Pyrotechnic racks. Lohse-Acetone generators. Pyrotechnic racks.	Agl	1,200-24,000. 60-120. 1,200-24,000.

75-138	do	do	do	do	District 4, Pennington, Custer, Lawrence Counties, S. Dak.	5,540.0	do	do	Do.
75-139	Weather Modification, Inc., Bowman, N. Dak. 58623.	do	do	do	District 5, Harding, Perkins, Corson Counties, S. Dak.	5,784.0	do	do	Do
75-140	do	do	do	do	District 6, Day, Beadle etc. Counties, S. Dak.	10,585.0	do	do	Do.
75-141 F	U.S. Army, CRREL, Lyme Rd., Hanover, N.H. 03755.	USACRREL and USA-FCRL Lyme Rd., Hanover, N.H. 03755.	Clear super-cooled fog continued Mar. 10, 1975, to May 1, 1976.		South of Hanover, N.H.	4.0	Groundbased	Air compressor and nozzle array.	20 ft ³ per minute.
75-142	Colorado River Municipal Water District (CRMWD), 1318 E. Fourth Street, Big Spring, Tex. 79720.	CRMWD, 1318 E. Fourth St., Big Spring, Tex. 79720.	Rain increase Apr. 15, 1975, to Oct. 15, 1975.		Northeast of Big Spring, Tex.	3,500.0	Aircraft	Flares	150.
75-143	Thomas J. Henderson, Atmospheric, Inc., 5652 East Dayton, Fresno, Calif. 93721.	Better Weather Inc., Route 1, Littlefield, Tex. 79339.	Decrease hail-fall, augment rainfall, Apr. 24, 1975, to Oct. 3, 1975.		Northwest of Lubbock, Tex.	2,200.0	Aircraft (3-4)	Pyrotechnics and Liquid-fueled generators.	30-3,000.
75-144 (continuation of 74-071),	Irving P. Krick, Inc., of Texas, 611 S. Palm Canyon Dr., Palm Springs, Calif. 92262.	H.C. Hitch, Jr., P.O. Box 1308, Guymon, Okla. 73942.	Precipitation Mar. 5, 1975, to Nov. 1, 1976.		South-central Texas County, Okla.	90.0	Groundbased	Arc-type generators.	0.5-2.0
75-145 (continuation of 74-073),	Plains Weather Improvement Association, P.O. Box 1627, Plainview, Tex. 79072.	Plains Weather Improvement Association, P.O. Box 1627, Plainview, Tex. 79072.	Decrease hail-fall, Apr. 1, 1975 to Nov. 30, 1975.		Texas High Plains, Tex.	1,500.0	Aircraft	Flares	1,020-3,000.
75-146 (continuation of 74-094).	Irving P. Krick, Inc., of Texas, 611 S. Palm Canyon Dr., Palm Springs, Calif., 92262.	John Little, president, Beaver County Weather, Inc., Knowles, Okla. 73847.	Precipitation increase, Apr. 1, 1975, to Oct. 15, 1975.		Beaver County, Okla.	1,793.0	Groundbased	Arc-type generators.	0.5-2.0.

See footnote at end of table.

WEATHER MODIFICATION ACTIVITY REPORTS, CALENDAR YEAR 1975 I—Continued

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
75-147 (Continuation of 74-070)	Irving P. Krick, Inc., of Texas, 611 S. Palm Canyon Dr., Palm Springs, Calif., 92262.	James W. Kinder, Sr., Cotton County Service, Inc., rte 1, Randlett, Okla. 73562.	Precipitation increase Apr. 1, 1975 to Mar. 15, 1976	Oct. 1, 1975, to Dec. 31, 1973	Cotton County, Okla.	629.0	Groundbased dispensers	Arc-type generators.	AgI	0.5-2.0.
75-148 (Continuation of 74-102)	do	Russell Adams, president, Woodward County Cloud Seeding Association, Sharon, Okla. 73857	Precipitation increase, Woodward County, to Oct. 15, 1975	Apr. 1, 1975, to Sept. 30, 1975, no seeding performed	Western Woods County, Okla.	450.0	do	do	AgI	0.5-2.0.
75-149	Edwin I. Boyd, 211 Ray Ann Ct., Rapid City, S. Dak. 57701	Keith Lebbin, Western Kansas Groundwater Management District, P.O. Box 604, Scott City, Kans. 67871	Increase rainfall, suppress fall, suppress hail, Apr. 15, 1975, to Sept. 15, 1975	Apr. 15, 1975 to Sept. 15, 1975	Western Kansas.	9,000.0	Aircraft (3)	Flares (24 each).	AgI	3-1,000.
75-150	(Wx Mod., Inc.) Alexander Koscielski, Route 2, P.O. Box 206, Rapid City, S. Dak., 57701	NODAK Weather Modification Association, P.O. Box 417, Valley City, N. Dak., 58072	Rain increase, hail suppression, May 15, 1975 to Sept. 15, 1975	May 15, 1975, to Sept. 1, 1975	Eastern North Dakota	10,000.0	Aircraft (5)	2 AgI-NH ₄ acetone generators, 2 flare racks (14 each rack).	AgI	300; 30-150 gm/min.
75-151	Frederick A. Andersen, Aviation Services, Inc. 2432 Second Avenue S W., Minot, N. Dak. 58701	Clark Robinson, McLean County Project, Coleharbor, N. Dak., 58531	Rain increase, hail suppression, May 15, 1975 to Aug. 31, 1975	do	McLean County, North Dakota	2,065.0	Aircraft (1)	2 AgI-NH ₄ acetone generators; pyrotechnic fuse flares.	AgI	310; 100 gm/min.
75-152	do	Walter K. Yuly, president, Ward County project, 417 N.W. 25th St., Minot, N. Dak. 58701.	do	do	Ward County, N. Dak.	2,044.0	do	do	AgI	Do.
75-153 (Continuation of 74-085).	(Weather Modification, Inc.) R. Lynn Rose, P.O. Box 905, Bowdoin, N. Dak. 58623.	Slope, Bowman, Adams, and Heltinger Counties, N. Dak.	Precipitation enhancement and hail suppression, June 1, 1975, to Aug. 31, 1975.	June 1, 1975, to Sept. 1, 1975.	Southwest North Dakota.	3,600.0	Aircraft (2)	Lohse generators.	AgI	130-160.

75-154F	Geoffrey E. Hill, Utah State University, Logan, Utah 84322.	Bureau of Reclamation, Denver, Colo. 80225.	Precipitation management technology, Feb. 7, 1975, to Mar. 31, 1975.	Feb. 7, 1975, to Mar. 25, 1975.	North Wasatch, East of Logan, Utah.	1,500.0	Ground-based generators (3).	SMUD model 300.	Ag1	25 (ea).
75-155	Water Resources Development Corp., 611 South Palm Canyon Dr., Palm Springs, Calif. 92262.	Chast H. West, Delaware Weather Modification Programs, Inc., R.D. 1, Box 417, Ellendale, Del. 19941.	Precipitation increase, June 1, 1975, to Aug. 10, 1975.	June 1, 1975, to Aug. 31, 1975.	East-central Delaware.	1,250.0	Ground-based dispensers.	Arc-type generators.	Ag1	0.5 to 2.0.
75-157 (continuation of 74-104).	Irving P. Krick, Inc., of Texas, 611 South Palm Canyon Dr., Palm Springs, Calif. 92262.	John W. Baker, Gratiot County Weather Modification, Ltd., County Courthouse, Ithaca, Mich. 48847.	Precipitation increase, June 15, 1975, to Aug. 31, 1975.	June 15, 1975, to Aug. 31, 1975.	Gratiot County, Mich.	530.0	do	do	Ag1	Do.
75-158 (continuation of 74-105).	do	James L. Crosby, M-Card, Inc., 617 North State Rd., Stanton, Mich. 48888.	do	do	Malcolm County, Mich.	856.0	do	do	do	Do.
75-159 (continuation of 74-107).	do	Warren Wooden, Michiana Weather, Inc., R5 Brownsville St., Cassopolis, Mich. 49031.	June 15, 1975, to Aug. 31, 1975, precipitation increase.	do	Cass County, Mich., and Elkhart County, Ind.	764.0	do	do	Ag1	0.5 to 2.0.
75-160 (continuation of 74-108).	do	Roger Carr, Rain Seekers Inc., Rte 2, Burr Oak, Mich. 49030.	do	do	St. Joseph and Kalamazoo Counties, Mich.	688.0	do	do	do	Do.
75-161 (continuation of 74-109).	do	Lyle Thompson, I-Card Inc., Cooperative Extension Service, Isabella County Bldg., Mt. Pleasant, Mich. 48858.	do	do	Isabella County, Mich.	288.0	do	do	do	Do.
75-162 (continuation of 74-111).	do	Arthur J. Steeby, Barry Weather Inc., 301 South Michigan Avenue, Hastings, Mich. 49058.	do	do	Berry County, Mich.	585.0	do	do	do	Do.
75-163F	W. L. Woodley, NOAA, P.O. Box 248265, Coral Gables, Fla. 33124.	NOAA, P.O. Box 248265, Coral Gables, Fla. 33124.	Rain augmentation research, June 16, 1975, to Sept. 15, 1975.	June 1, 1975, to Oct. 1, 1975.	South-central Florida.	4,800.0	Aircraft	Pyrotechnic	Ag1	15 kg/day.
75-164 (continuation of 75-124).	Eden Farson Irrigation District, Box 74, Farson, Wyo. 82932.	Eden Farson Irrigation District, Box 74, Farson, Wyo. 82932.	Snow increase, Nov. 15, 1975, to Apr. 9, 1976.	Nov. 15, 1975, to Apr. 9, 1976.	Big Sandy River drainage, Wyoming.	180.0	Ground-based generators.	AGI-NH ₄	Ag1	10-15.

See footnote at end of table.

WEATHER MODIFICATION ACTIVITY REPORTS, CALENDAR YEAR 1975 (Continued)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	App ratus	Agent	Dispensing rate (g/hr/unit)
75-165	R. Lynn Rose, Weather Modification, Inc., P.O. Box 905, Bowman, N. Dak., 58623.	Sargent County Commissioners, County Court House, For-man, N. Dak., 58032.	Precipitation enhancement and hail suppression, June 15, 1975, to Aug. 31, 1975.	June 15, 1975, to Aug. 15, 1975.	Sargent County, N. Dak.	920.0	Aircraft (1)	WMI-Lohse generators; pyrotechnic flares.	AgI	65-80; 20-200.
75-166	Ronald H. Campbell, Black Pine Precipitation Enhancement Management Association, Sublett Route, Malta, Idaho 83342.	SPDEMA (R. H. Campbell).	Rain increase July 1, 1975, to Dec. 1, 1975.	July 1, 1975, to July 29, 1975.	East of Sublett, Idaho.	198.0	Aircraft (2)	Flares, hopper, nozzles.	AgI CO ₂ Propane Hexadeca-nol.	3 per min. 0.2-1 kg per min. 0.2-1 kg per min. 0.1-0.5 kg per min.
75-167F	H. Weickmann, NOAA, ERL, Boulder, Colo., 80302.	NOAA, ERL, Boulder, Colo., 80302.	Lightning suppression investigation, June 1975 to September 1975.	June 27, 1975, to Sept. 30, 1975.	JFK Space Center, Fla.	78.5	Aircraft	Chaff dispenser	10 Cm fibers	
75-168 (continuation of 74-114).	H. W. Bement, Inter-west Aviation Corp., 3063 Millcreek Rd., Salt Lake City, Utah 84109.	AAL, WAL, Frontier, Texas International, Hughes Air West, Salt Lake City International Airport, Utah 84122.	Cold fog dispersal, Nov. 1, 1975, to Feb. 31, 1976.	Nov. 1, 1975, to Feb. 13, 1976.	Airport, Salt Lake City, Utah.	10.0	do	Spreader	CO ₂	260/kg/hr.
75-169 (continuation of 75-134)	Executive Air Corp., P.O. Box 19187, Spokane, Wash., 99219.	Northwest Orient Airlines, Spokane, Wash., 99219.	Warm/cold fog dispersal, Oct. 15, 1975, to Mar. 15, 1976.	-----	Spokane Airport, Wash.	4.5	do	Dispensing hopper.	CO ₂ Polyelectrolyte.	1,362 kg/hr; 55 kg/hr.
76-170 (continuation of 74-060).	Santa Clara County Flood Control and Water District 5750 Almaden Express-way, San Jose, Calif. 95118.	Santa Clara County Flood Control and Water District 5750 Almaden Express-way, San Jose, Calif. 95118.	Rain increase, to Apr. 15, 1976.	Dec. 1, 1973, to Apr. 15, 1976.	Part of Santa Clara County, Calif.	700.0	Ground based dispenser.	Modified Sky-fire generator.	AgI	25.
76-171 (continuation of 75-118).	Les Riskey, Aircraft Sales, P.O. Box 4-2360, Anchorage, Alaska 99509.	W. R. Borland, Air Facilitation Com-mittee, P.O. Box 6027, Anchorage, Alaska 99502.	Cold fog dispersal, Nov. 1, 1975 to Feb. 29, 1976.	-----	Anchorage International Airport, Alaska.	1.0	Aircraft dispenser.	Chute in A/C.	CO ₂	500 kg (est.).

76-172	Atmospherics, Inc., 5652 East Dayton, Fresno, Calif. 93727.	Rain and snow increase, Nov. 20, 1975 to Apr. 15, 1978.	Kaweah River Watershed, Calif.	520.0	Aircraft and ground dis- penser.	Pyrotechnics 5 ground gen- erators.	AgI----- 120-1,200, 10-20.
76-173 (continuation of 75-129).	Pacific Gas & Electric Co., 77 Beale St., San Francisco, Calif. 94106.	Increase snow- pack, Nov. 1, 1975 to May 31, 1976.	Mokelumne- Central Sierra Nevada Mts., Calif.	250.0	Groundbased dispensers.	5 generators, propane- Acetone- AgI-NH ₄ I.	AgI----- 25.
76-174 (continuation of 75-128).	do.	do.	Lake Almanor North Sierra Nevada Mts.	500.0	do.	8 generators, propane- acetone- AgI-NH ₄ I.	AgI----- 25.
76-175 (continuation of 75-126).	North American Weather Consul- tants, Santa Bar- bara Municipal Airport, Goleta, Calif. 93017.	Rainfall in- crease, Nov. 15, 1975, to Apr. 15, 1976.	Southwest Utah.	55,000.0	Groundbased	Propane operated generators.	AgI----- 6.
76-176 (continuation of 75-123).	92d Bombardment Wing (SAC), USAF, Fairchild AFB, Spokane, Wash. 99011.	Cold fog dis- persal Nov. 1, 1975 to Mar. 31, 1976.	Runways, Fairchild AFB, Wash.	50.0	do.	23 masts with tank and nozzle.	Propane---- 10 gal/hr.
76-177 (continuation of 75-122).	Det. 1, 11WS, Air Weather Service, Fairchild AFB, Anchorage, Alaska, 99506.	Cold fog dis- persal, Nov. 1, 1975 to Mar. 31, 1976.	Runways, Elmendorf AFB, Alaska.	2.0	do.	24 masts with tank and nozzle.	Propane---- 10 gal/hr.
76-178 (continuation of 75-115).	Sacramento Municipal Utility District (SMUD), 1708-59th St., Box 15830, Sacramento, Calif. 95813.	Increase snow- pack, Dec. 5, 1975, to May 15, 1976.	Lake areas southwest of Lake Tahoe, Calif.	236.0	do.	Propane operated generators with NH ₄ and acetone.	AgI----- 25.
76-179	Don Vranizan, 6105 North East Garfield, Portland, Ore., 97211.	Research on "Cloudbuster," 1975.	Portland, Ore.--	20.0	do.	Cloudbuster (metal rods grounded into water).	-----
76-181	Denver Research In- stitute, University of Denver, Denver, Colo. 80210.	Testing of seed- ing agent, June 1, 1975, to July 31, 1975.	Butte and Meade Counties, S. Dak.	5,100.0	Aircraft dis- pensed.	Experimental generator.	1.5 DN (dihy- droxy- naphtha- lene).

See footnote at end of table.

WEATHER MODIFICATION ACTIVITY REPORTS, CALENDAR YEAR 1975 (Continued)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
76-182F	Denver Research Institute, University of Denver, Denver, Colo. 80210.	National Hill Research Experiment, NCAR, P.O. Box 3000, Boulder, Colo. 80303.	Testing of seeding agent, July 22, 1975, to Aug. 8, 1975.	July 7, 1975, to Aug. 5, 1975.	Lake and Park Counties, Colo.	400.0	Aircraft dispensed.	Experimental jet-mixing type generator.	1,5 DN	1,000.
76-183F	V. R. Scheetz, Colorado State University, Fort Collins, Colo. 80523.	National Science Foundation, 1800 G St. NW, Washington, D.C. 20550.	Downwind research, Dec. 13, 1974, to Aug. 31, 1975.	Dec. 13, 1974, to Aug. 8, 1975.	Climax, Colo.	315.0	Ground-based; aircraft dispensed.	Skyfire generators. Organic nutrient generators.	Ag1 1,5 DN	15 180. 1,500.
76-186 (continuation of 75-120).	Logan & Reavis Air, Inc., Airport Rd., Medford, Oreg., 97501.	United Airlines Inc., Box 66100, Chicago, Ill. 60666.	Cold fog dispersal, Nov. 12, 1975, to Feb. 28, 1976.	Nov. 12, 1975, to Feb. 3, 1976.	Me-ford-Jackson County Airport, Oreg.	1.0	Aircraft dispensed.	Suction tube	Dry ice (CO ₂)	45.1 kg.
76-197 (continuation of 75-125).	Aero-Dyne Corp., 300 Airport Way, Renton, Wash., 98055.	Port of Seattle, Seattle-Tacoma Airport, Wash., 98188.	Warm fog dispersal, Oct 1, 1975, to Feb. 29, 1976.	Oct. 1, 1975, to Feb. 29, 1976.	Seattle-Tacoma Airport, Wash.	1.0	do	Metered hopper and blower.	Poly-electrolyte.	300 kg. (est.).
76-209F	Naval Weapons Center (Code 6022), China Lake, Calif. 93555	Naval Air Systems Command (AIR-370C), Washington, D.C. 20361	Warm fog clearance prevention, Nov. 24, 1974, to Feb. 26, 1975.	Nov. 24, 1974, to Feb. 28, 1975.	Visalia Municipal Airport, Calif.	10.0	Aircraft and groundbased	Spray nozzle and induction grid; generator; 40-foot tower and grid	H ₂ O; LiCl; Corona discharge. 90 KV.	55 gal/min; 0.16 gal/min; 90 KV.
76-210F	do	do	Warm fog clearance, evaluation, Aug. 5, 1975, to Sept. 2, 1975.	Aug. 1, 1975, to Sept. 2, 1975.	Arcata-Eureka Airport, McKinleyville, Calif.	10.0	Aircraft	Induction-charged water spray	H ₂ O	55 gal/min.

¹ Charak, Mason T. Weather Modification Activities for Calendar Year 1975. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Environmental Monitoring and Prediction, Rockville, Maryland, June 1976, p. 19-36.

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APPENDIX I

PUBLIC LAWS DEALING SPECIFICALLY WITH WEATHER MODIFICATION

August 13, 1953
[S. 285]

Public Law 256—Chapter 426

AN ACT To create a committee to study and evaluate public and private experiments in weather modification.

Weather modification.
Evaluation.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

STATEMENT OF PURPOSE AND POLICY

Research and experimentation in the field of weather modification and control have attained the stage at which the application of scientific advances in this field appears to be practical.

The effect of the use of measures for the control of weather phenomena upon the social, economic, and political structures of today, and upon national security, cannot now be determined. It is a field in which unknown factors are involved. It is reasonable to anticipate, however, that modification and control of weather, if effective on a large scale, would cause profound changes in our present way of life and would result in vast and far-reaching benefits to agriculture, industry, commerce, and the general welfare and common defense.

While the ultimate extent to which weather modification and control may be utilized is speculative, the application of such measures without proper safeguards, sufficient data and accurate information may result in inadequate or excessive precipitation; may cause catastrophic droughts, storms, floods, and other phenomena with consequent loss of life and property, injury to navigable streams and other channels of interstate and foreign commerce, injury to water supplies for municipal, irrigation, and industrial purposes, and injury to sources of hydroelectric power; may otherwise impede the production and transportation of goods and services for domestic consumption and export and for the national defense; and may otherwise adversely affect the general welfare and common defense.

Thorough experimentation and full-scale operations in weather modification and control will of necessity affect areas extending across State and possibly across national boundaries. The Congress, therefore, recognizes that experimentation and application of such measures are matters of national and international concern.

Accordingly, it is hereby declared to be the policy of the Congress, in order to effect the maximum benefit which may result from experiments and operations designed to modify and control weather, to correlate and evaluate the information derived from such activity and to cooperate with the several States and the duly authorized officials thereof with respect to such activity, all to the end of encouraging the intelligent experimentation and the beneficial development of weather modification and control, preventing its harmful and indiscriminate exercise, and fostering sound economic conditions in the public interest.

CREATION OF ADVISORY COMMITTEE ON WEATHER CONTROL

Sec. 2. There is hereby established a national committee to be known as the Advisory Committee on Weather Control (hereinafter called the "Committee").

SEC. 3. The Committee shall make a complete study and evaluation of public and private experiments in weather control for the purpose of determining the extent to which the United States should experiment with, engage in, or regulate activities designed to control weather conditions.

SEC. 4. The Committee shall be composed of the Secretary of Defense or his designee, the Secretary of Agriculture or his designee, the Secretary of Commerce or his designee, the Secretary of the Interior or his designee, the Director of the National Science Foundation or his designee, the Secretary of Health, Education, and Welfare or his designee, and five members appointed by the President, by and with the advice and consent of the Senate, from among persons in private life of outstanding ability in the fields of science, agriculture, and business. A vacancy in the Committee shall not affect its powers but shall be filled in the same manner that the original appointment was made.

SEC. 5. The President shall appoint the Chairman and Vice Chairman of the Committee. The Chairman shall be appointed from among those persons appointed to the Committee from private life.

SEC. 6. The Committee shall hold at least two meetings a year, approximately six months apart, and, on due notice, shall meet at such other times as the Committee may determine. Six members of the Committee shall constitute a quorum.

SEC. 7. The members of the Committee who are in the executive branch of the Government shall receive no additional compensation for their services on the Committee. The members from private life shall each receive \$50 per diem when engaged in the performance of duties vested in the Committee. All members of the Committee shall be reimbursed in accordance with the Travel Expense Act of 1949, as amended, for travel, subsistence, and other necessary expenses incurred by them in the performance of duties vested in the Committee.

SEC. 8. The Committee shall have power to appoint and fix the compensation of such officers and employees as may be necessary to carry out the functions of the Committee, including one executive secretary at a salary not exceeding \$12,000 per annum. Officers and employees other than the executive secretary shall be appointed in accordance with the Classification Act of 1949, as amended, except that to the extent the Committee deems such action necessary to the discharge of its responsibilities, personnel for positions requiring scientific or special qualifications may be employed and their compensation fixed without regard to such laws. The Committee shall make adequate provision for administrative review of any determination to dismiss any employee.

SEC. 9. (a) The Committee, or any member thereof, may, for the purpose of carrying out the provisions of this Act, hold such hearings and sit and act at such times and places, and take such testimony as the Committee shall deem advisable. Any member of the Committee may administer oaths or affirmations to witnesses appearing before the Committee or before such member.

(b) The Committee is authorized to secure directly from any executive department, bureau, agency, board, commission, office, independent establishment, or instrumentality information, suggestions, estimates, and statistics for the purpose of this Act; and each such department, bureau, agency, board, commission, office, establishment, or instrumentality is authorized and directed to furnish such information, suggestions, estimates, and statistics directly to the Committee, upon request made by the Chairman or Vice Chairman.

(c) The Committee may, with the consent of the agency concerned, accept and utilize, on a reimbursable basis, the personnel of any other agency of the Federal Government.

(d) (1) The Committee shall be entitled by regulation, subpoena, or otherwise, to obtain such information from, require such reports and the keeping of such records by, and make such inspection of

Members.

Meetings.

Compensation.

63 Stat. 166.
5 USC 835 note.

Officers and employees.

63 Stat. 954.
5 USC 1071 note.

Hearings.

Information, etc., from agencies.

Personnel of other agencies.

Information from persons.

the books, records, and other writings, premises or property of, any person as may be necessary or appropriate to carry out the provisions of this Act, but this authority shall not be exercised if adequate and authoritative data are available from any Federal agency. In case of contumacy by, or refusal to obey a subpoena served upon, any person referred to in this subsection, the district court of the United States for any district in which such person is found or resides or transacts business, upon application by the Committee, shall have jurisdiction to issue an order requiring such person to appear and give testimony or to appear and produce documents, or both; and any failure to obey such order of the court may be punished by such court as a contempt thereof.

(2) The production of a person's books, records, or other documentary evidence shall not be required at any place other than the place where such person usually keeps them, if, prior to the return date specified in the regulations, subpoena, or other document issued with respect thereto, such person furnishes the Committee with a true copy of such books, records, or other documentary evidence (certified by such person under oath to be a true and correct copy) or enters into a stipulation with the Committee as to the information contained in such books, records, or other documentary evidence. Witnesses shall be paid the same fees and mileage that are paid witnesses in the courts of the United States.

(3) Any person who willfully performs any act prohibited or willfully fails to perform any act required by the above provisions of this subsection, or any rule, regulation, or order thereunder, shall upon conviction be fined not more than \$500 for each offense.

(4) Information obtained under this Act which the Committee deems confidential for purposes of national security or other reasons or with reference to which a request for confidential treatment is made by the person or agency furnishing such information, shall not be published or disclosed unless the Committee determines that the withholding thereof is contrary to the purposes of this Act, and any member or employee of the Committee willfully violating this provision shall, upon conviction, be fined not more than \$5,000.

(e) The Committee shall be entitled to the free use of the United States mails in the same manner as the other executive agencies of the Government.

SEC. 10. (a) The Committee shall from time to time submit a report on its findings and recommendations to the President for submission to the Congress. At the earliest possible moment, the Committee shall submit a report to the President for submission to the Congress on the advisability of the Federal Government regulating, by means of licenses or otherwise, those who attempt to engage in activities designed to modify or control the weather. The Committee shall submit a final report to the President for submission to the Congress not later than June 30, 1956.

(b) Thirty days after the Committee has submitted such final report to the President, the Committee shall cease to exist.

SEC. 11. There are authorized to be appropriated, from any funds in the Treasury not otherwise appropriated, such sums as the Congress may from time to time deem necessary to carry out the provisions of this Act.

Approved August 13, 1953.

Witness fees.

Penalty.

Confidential information.

Use of mails.

Report.

Termination date.

Appropriation.

July 9, 1956
[S. 2913]

Public Law 664—Chapter 522

AN ACT To extend for two years the Advisory Committee on Weather Control.

15 USC 311
note.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section 10(a) of the Act entitled "An Act to create a committee to study and evaluate public and private experiments in weather modification", approved August 13, 1953 (67 Stat. 559, 561), is amended by striking out "June 30, 1956" and inserting in lieu thereof "June 30, 1958".

Approved July 9, 1956.

Public Law 85-510

AN ACT To amend the National Science Foundation Act of 1950, to provide for a program of study, research, and evaluation in the field of weather modification.

July 11, 1958
[S. 86]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That subsection (a) of section 3 of the National Science Foundation Act of 1950, as amended, is amended by striking out "and" at the end of paragraph (7), by striking out the period at the end of paragraph (8) and inserting in lieu thereof a semicolon, and by adding after paragraph (8) the following new paragraph:

National
Science
Foundation.
Weather
modification.
Research.
64 Stat. 149.
42 USC 1862.

"(9) to initiate and support a program of study, research, and evaluation in the field of weather modification, giving particular attention to areas that have experienced floods, drought, hail, lightning, fog, tornadoes, hurricanes, or other weather phenomena, and to report annually to the President and the Congress thereon."

Reports.

SEC. 2. The National Science Foundation Act of 1950, as amended, is amended by changing the designations of sections 14, 15, and 16 (and all reference to such sections in any provision of law) to 15, 16, and 17, respectively, and by inserting after section 13 the following section:

64 Stat. 154.
42 USC
1873-75.

"WEATHER MODIFICATION

"SEC. 14. (a) In carrying out the provisions of paragraph (9) of section 3 (a), the Foundation shall consult with meteorologists and scientists in private life and with agencies of Government interested in, or affected by, experimental research in the field of weather control.

"(b) Research programs to carry out the purposes of such paragraph (9), whether conducted by the Foundation or by other Government agencies or departments, may be accomplished through contracts with, or grants to, private or public institutions or agencies, including but not limited to cooperative programs with any State through such instrumentalities as may be designated by the governor of such State.

Research
contracts.

"(c) For the purposes of such paragraph (9), the Foundation is authorized to accept as a gift, money, material, or services: *Provided*, That notwithstanding section 11(f), use of any such gift, if the donor so specifies, may be restricted or limited to certain projects or areas.

Gifts.

"(d) For the purposes of such paragraph (9), other agencies of the Government are authorized to loan to the Foundation without reimbursement, and the Foundation is authorized to accept and make use of, such property and personnel as may be deemed useful, with the approval of the Director of the Bureau of the Budget.

42 USC 1870.

Loan of
property, etc.

"(e) The Director of the Foundation, or any employee of the Foundation designated by him, may for the purpose of carrying out the provisions of such paragraph (9) hold such hearings and sit and act at such times and places and take such testimony as he shall deem advisable. The Director or any employee of the Foundation designated by him may administer oaths or affirmations to witnesses appearing before the Director or such employee.

Hearings.

"(f) (1) The Director of the Foundation may obtain by regulation, subpoena, or otherwise such information in the form of testimony, books, records, or other writings, may require the keeping of and furnishing such reports and records, and may make such inspections of the books, records, and other writings and premises or property of any person or persons as may be deemed necessary or appropriate by him to carry out the provisions of such paragraph (9), but this authority shall not be exercised if adequate and authoritative data are available from any Federal agency. In case of contumacy by, or refusal to obey a subpoena served upon, any person referred to in this subsection,

Documentary
evidence.

the district court of the United States for any district in which such person is found or resides or transacts business, upon application by the Director, shall have jurisdiction to issue an order requiring such person to appear and give testimony or to appear and produce documents, or both; and any failure to obey such order of the court may be punished by such court as a contempt thereof.

"(2) The production of a person's books, records, or other documentary evidence shall not be required at any place other than the place where such person usually keeps them, if, prior to the return date specified in the regulations, subpoena, or other document issued with respect thereto, such person furnishes the Foundation with a true copy of such books, records, or other documentary evidence (certified by such person under oath to be a true and correct copy) or enters into a stipulation with the Director as to the information contained in such books, records, or other documentary evidence. Witnesses shall be paid the same fees and mileage that are paid witnesses in the courts of the United States.

Violation
and penalty.

"(3) Any person who willfully performs any act prohibited or willfully fails to perform any act required by the above provisions of this subsection, or any regulation issued thereunder, shall upon conviction be fined not more than \$500.

62 Stat. 791.

"(4) Information contained in any statement, report, record, or other document furnished pursuant to this subsection shall be available for public inspection, except (A) information authorized or required by statute to be withheld and (B) information classified in accordance with law to protect the national security. The foregoing sentence shall not be interpreted to authorize or require the publication, divulging, or disclosure of any information described in section 1905 of title 18 of the United States Code, except that the Director may disclose information described in such section 1905, furnished pursuant to this subsection, whenever he determines that the withholding thereof would be contrary to the purposes of this section and section 3(a)(9) of this Act."

Approved July 11, 1958.

Public Law 92-205—92nd Congress, H.R. 6893
December 18, 1971

AN ACT To provide for the reporting of weather modification activities to the Federal Government.

Weather
modification
reporting.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That, as used in this Act—

(1) The term "Secretary" means the Secretary of Commerce.

(2) The term "person" means any individual, corporation, company, association, firm, partnership, society, joint stock company, any State or local government or any agency thereof, or any other organization, whether commercial or nonprofit, who is performing weather modification activities, except where acting solely as an employee, agent, or independent contractor of the Federal Government.

85 STAT. 735

85 STAT. 736

(3) The term "weather modification" means any activity performed with the intention of producing artificial changes in the composition, behavior, or dynamics of the atmosphere.

(4) The term "United States" includes the several States, the District of Columbia, the Commonwealth of Puerto Rico, and any territory or insular possession of the United States.

Report
requirement.

SEC. 2. No person may engage, or attempt to engage, in any weather modification activity in the United States unless he submits to the Secretary such reports with respect thereto, in such form and containing such information, as the Secretary may by

rule prescribe. The Secretary may require that such reports be submitted to him before, during, and after any such activity or attempt.

SEC. 3. (a) The Secretary shall maintain a record of weather modification activities, including attempts, which take place in the United States and shall publish summaries thereof from time to time as he determines.

Records,
publication.

(b) All reports, documents, and other information received by the Secretary under the provisions of this Act shall be made available to the public to the fullest practicable extent.

(c) In carrying out the provisions of this section, the Secretary shall not disclose any information referred to in section 1905 of title 18, United States Code, and is otherwise unavailable to the public, except that such information shall be disclosed—

Confidential
information.
62 Stat. 791.

(1) to other Federal Government departments, agencies, and officials for official use upon request;

(2) in any judicial proceeding under a court order formulated to preserve the confidentiality of such information without impairing the proceeding; and

(3) to the public if necessary to protect their health and safety.

SEC. 4. (a) The Secretary may obtain from any person whose activities relate to weather modification by rule, subpoena, or otherwise such information in the form of testimony, books, records, or other writings, may require the keeping and furnishing of such reports and records, and may make such inspection of the books, records, and other writings and premises and property of any person as may be deemed necessary or appropriate by him to carry out the provisions of this Act, but this authority shall not be exercised to obtain any information with respect to which adequate and authoritative data are available from any Federal agency.

Authority of
Secretary.

(b) In case of contumacy by, or refusal to obey a subpoena served upon any person pursuant to this section, the district court of the United States for any district in which such person is found or resides or transacts business, upon application by the Attorney General, shall have jurisdiction to issue an order requiring such person to appear and give testimony or to appear and produce documents, or both; and any failure to obey such order of the court may be punished by such court as a contempt thereof.

Noncompliance.

SEC. 5. Any person who knowingly and willfully violates section 2 of this Act, or any rule issued thereunder, shall upon conviction thereof be fined not more than \$10,000.

Penalty.

SEC. 6. There are authorized to be appropriated \$150,000 for the fiscal year ending June 30, 1972, and \$200,000 each for the fiscal years ending June 30, 1973, and June 30, 1974, to carry out the provisions of this Act.

Appropriations.

Approved December 18, 1971.

Public Law 93-436—93rd Congress, S. 3320
October 5, 1974

AN ACT To extend the appropriation authorization for reporting of weather modification activities.

88 Stat. 1212

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section 6 of the Act entitled "An Act to provide for the reporting of weather modification activities to the Federal Government", approved December 18, 1971 (15 U.S.C. 330e), is amended by striking out "ending June 30, 1973, and June 30, 1974," and inserting in lieu thereof "1973, 1974, 1975, 1976, and 1977,".

Weather
modification
reporting.
Appropriation,
extension.

Approved October 5, 1974.

Public Law 94-490—94th Congress
October 13, 1976

Oct. 13, 1976
[S. 3383]

AN ACT To authorize and direct the Secretary of Commerce to develop a national policy on weather modification, and for other purposes.

National
Weather
Modification
Policy Act
of 1976.
15 USC 330
note.
15 USC 330
note.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "National Weather Modification Policy Act of 1976".

SEC. 2. DECLARATION OF POLICY.

(a) **FINDINGS.**—The Congress finds and declares the following:

(1) Weather-related disasters and hazards, including drought, hurricanes, tornadoes, hail, lightning, fog, floods, and frost, result in substantial human suffering and loss of life, billions of dollars of annual economic losses to owners of crops and other property, and substantial financial loss to the United States Treasury;

(2) Weather modification technology has significant potential for preventing, diverting, moderating, or ameliorating the adverse effects of such disasters and hazards and enhancing crop production and the availability of water;

(3) The interstate nature of climatic and related phenomena, the severe economic hardships experienced as the result of occasional drought and other adverse meteorological conditions, and the existing role and responsibilities of the Federal Government with respect to disaster relief, require appropriate Federal action to prevent or alleviate such disasters and hazards; and

(4) Weather modification programs may have long-range and unexpected effects on existing climatic patterns which are not confined by national boundaries.

(b) **PURPOSE.**—It is therefore declared to be the purpose of the Congress in this Act to develop a comprehensive and coordinated national weather modification policy and a national program of weather modification research and development—

(1) to determine the means by which deliberate weather modification can be used at the present time to decrease the adverse impact of weather on agriculture, economic growth, and the general public welfare, and to determine the potential for weather modification;

(2) to conduct research into those scientific areas considered most likely to lead to practical techniques for drought prevention, or alleviation and other forms of deliberate weather modification;

(3) to develop practical methods and devices for weather modification;

(4) to make weather modification research findings available to interested parties;

(5) to assess the economic, social, environmental, and legal impact of an operational weather modification program;

(6) to develop both national and international mechanisms designed to minimize conflicts which may arise with respect to the peaceful uses of weather modification; and

(7) to integrate the results of existing experience and studies in weather modification activities into model codes and agreements for regulation of domestic and international weather modification activities.

SEC. 3. DEFINITIONS.

As used in this Act:

(1) The term "Secretary" means the Secretary of Commerce.

(2) The term "State" means any State of the United States, the District of Columbia, or any Commonwealth, territory, or possession of the United States.

Policy.
Research and
development
program.

15 USC 330
note.

(3) The term "weather modification" means any activity performed with the intention and expectation of producing changes in precipitation, wind, fog, lightning, and other atmospheric phenomena.

SEC. 4. STUDY.

The Secretary shall conduct a comprehensive investigation and study of the state of scientific knowledge concerning weather modification, the present state of development of weather modification technology, the problems impeding effective implementation of weather modification technology, and other related matters. Such study shall include—

15 USC 330
note.

(1) a review and analysis of the present and past research efforts to establish practical weather modification technology, particularly as it relates to reducing loss of life and crop and property destruction;

(2) a review and analysis of research needs in weather modification to establish areas in which more research could be expected to yield the greatest return in terms of practical weather modification technology;

(3) a review and analysis of existing studies to establish the probable economic importance to the United States in terms of agricultural production, energy, and related economic factors if the present weather modification technology were to be effectively implemented;

(4) an assessment of the legal, social, and ecological implications of expanded and effective research and operational weather modification projects;

(5) formulation of one or more options for a model regulatory code for domestic weather modification activities, such code to be based on a review and analysis of experience and studies in this area, and to be adaptable to State and national needs;

(6) recommendations concerning legislation desirable at all levels of government to implement a national weather modification policy and program;

(7) a review of the international importance and implications of weather modification activities by the United States;

(8) a review and analysis of present and past funding for weather modification from all sources to determine the sources and adequacy of funding in the light of the needs of the Nation;

(9) a review and analysis of the purpose, policy, methods, and funding of the Federal departments and agencies involved in weather modification and of the existing interagency coordination of weather modification research efforts;

(10) a review and analysis of the necessity and feasibility of negotiating an international agreement concerning the peaceful uses of weather modification; and

(11) formulation of one or more options for a model international agreement concerning the peaceful uses of weather modification and the regulation of national weather modification activities; and a review and analysis of the necessity and feasibility of negotiating such an agreement.

SEC. 5. REPORT.

(a) IN GENERAL.—The Secretary shall prepare and submit to the President and the Congress, within 1 year after the date of enactment of this Act, a final report on the findings, conclusions, and recommendations of the study conducted pursuant to section 4. Such report shall include:

Submittal to
President and
Congress.
15 USC 330
note.

(1) a summary of the findings made with respect to each of the areas of investigation specified in section 4;

(2) other findings which are pertinent to the determination and implementation of a national policy on weather modifications;

(3) a recommended national policy on weather modification and a recommended national weather modification research and development program which is consistent with, and likely to contribute to, achieving the objectives of such policy;

(4) recommendations for levels of Federal funding sufficient to support adequately a national weather modification research and development program;

(5) recommendations for any changes in the organization and involvement of Federal departments and agencies in weather modification which may be needed to implement effectively the recommended national policy on weather modification and the recommended research and development program; and

(6) recommendations for any regulatory and other legislation which may be required to implement such policy and program or for any international agreement which may be appropriate concerning the peaceful uses of weather modification, including recommendations concerning the dissemination, refinement, and possible implementation of the model domestic code and international agreement developed under the specifications of section 4.

Cooperation.

Each department, agency, and other instrumentality of the Federal Government is authorized and directed to furnish the Secretary any information which the Secretary deems necessary to carry out his functions under this Act.

(b) OPERATION AND CONSULTATION.—The Secretary shall solicit and consider the views of State agencies, private firms, institutions of higher learning, and other interested persons and governmental entities in the conduct of the study required by section 4, and in the preparation of the report required by subsection (a).

SEC. 6. AUTHORIZATION FOR APPROPRIATIONS.

(a) There is authorized to be appropriated to the Secretary for the purposes of carrying out the provisions of this Act not to exceed \$1,000,000.

(b) Section 6 of the Act entitled "An Act to provide for the reporting of weather modification activities to the Federal Government", approved December 18, 1971 (85 Stat. 736; 88 Stat. 1212; 15 U.S.C. 330e), is further amended by striking out "1973, 1974, 1975, 1976, and 1977," and inserting in lieu thereof "1973 through 1980,".

Approved Oct. 13, 1976.

15 USC 330
note.

APPENDIX J

SUMMARY OF LANGUAGE IN CONGRESSIONAL DOCUMENTS SUPPORTING PUBLIC WORKS APPROPRIATIONS FOR THE BUREAU OF RECLAMATION'S ATMOSPHERIC WATER RESOURCES PROGRAM

Date	Fiscal year bill	Body	Document	Provision
Sept. 30, 1961	1962	Senate, 87th Cong., 1st sess.	Rept. No. 1097, pp. 28-29	Increased rainfall by cloud seeding, \$100,000.—The committee recommends allowances of \$100,000 to be used for research on increasing rainfall by cloud seeding. This amount would be utilized in cooperation with the National Science Foundation and the Weather Bureau, which are expected to contribute funds and participate in this research.
Oct. 4, 1962	1963	House, 87th Cong., 2d sess.	Rept. No. 2531, p. 20, conference report	The amount provided includes * * *; and up to \$100,000 for weather modification research.
Dec. 5, 1963	1964	Senate, 88th Cong., 1st sess.	Rept. No. 746, p. 32	Weather modification, \$50,000.—The committee recommends an increase of \$50,000 for a study of scientific findings and recommendations on coordination of future research by the South Dakota School of Mines at Rapid City, S. Dak.
Aug. 5, 1964	1965	Senate, 88th Cong., 2d sess.	Rept. No. 1326, p. 30	Weather modification research, \$2,000,000.—The committee recommends an increase of \$2,000,000 in the amount (\$100,000) programmed for weather modification research. The increase is to be divided between research on orographic and convective weather systems. Emphasis is to be placed on actual water production and the exploration and research is to include application of existing weather modification methods.
Aug. 13, 1964	1965	House, 88th Cong., 2d sess.	Rept. No. 1794, p. 39, conference report	The increase above the House figure includes \$50,000 for Alaskan investigations and \$1,000,000 for weather modification research.
June 17, 1965	1966	House, 89th Cong., 1st sess.	Rept. No. —, p. 43, committee print	Atmospheric water research program.—The amount recommended by the committee includes \$2,230,000 for the atmospheric research program, an increase of \$1,000,000 in the budget estimate. This program was initiated in the current fiscal year and it is believed the increase allowed is necessary to continue effectively this important research program to determine the best and most economical methods of augmenting water supplies for reclamation projects by weather modification.

APPENDIX J—Continued
SUMMARY OF APPROPRIATION LANGUAGE,¹ ATMOSPHERIC WATER RESOURCES PROGRAM, 1962-78—Continued

Date	Fiscal year bill	Body	Document	Provision
Aug. 19, 1965	1966	Senate, 89th Cong., 1st sess.	Rept. No. 632, p. 33	Atmospheric water resources.—The committee recommends an increase of \$2,500,000 over the budget estimate of \$1,230,000 for the atmospheric water resources research program. This is \$1,500,000 more than the amount allowed by the House of Representatives. The amount allowed by the House is necessary in order to maintain the program at its present level; but, in order for facilities and personnel developed during the past year to be utilized to the best advantage the amount recommended by the committee is required to permit an expansion of the current program. Of the increase recommended by the Senate, \$500,000 is to be used for the application of existing weather modification methods for the actual production of water. * * * and the increase provided over the House bill includes * * * ; and atmospheric water resources research program \$750,000. None of the latter increase is to be used for application of existing weather modification methods for the actual production of water.
Oct. 13, 1965	1966	House, 89th Cong., 1st sess.	Rept. No. 1163, p. 36, conference report	Atmospheric water resources, \$3,000,000.
Sept. 15, 1966	1967	House, 89th Cong., 2d sess.	Rept. No. 2044, p. 59	The committee recommends the following additional increases over the budget estimates: * * * Atmospheric water resources engineering research—\$1,000,000, which will provide a total program during fiscal year 1967 of \$4,000,000. It is the committee's belief that the impotence of this work warrants this proposed \$1,000,000 expansion of the program.
Oct. 3, 1966	1967	Senate, 89th Cong., 2d sess.	Rept. No. 1672, p. 32	The increase provided over the House bill includes: * * * ; and for atmospheric water resource engineering and research \$750,000 in the estimate proposed to continue the atmospheric water resources program. Although the committee strongly endorses the objectives of this program, the \$4,750,000 allowed, an increase of \$988,000, should provide for a very effective program in fiscal year 1968 considering the major increases provided in recent years.
Oct. 10, 1967	1967	House, 89th Cong., 2d sess.	Rept. No. 2216, p. 37	The committee concurs with the following increases over the budget estimates allowed by the House of Representatives: * * * atmospheric water resources research—\$5,000,000 to provide a total of \$10,000,000 to expand the budget program for atmospheric water resources research and to initiate the planned nationwide program. This will provide an increase of \$5,250,000 over the House allowance.
July 20, 1967	1968	House, 90th Cong., 1st sess.	Rept. No. 505, p. 60	The increase provided over the House bill includes: for atmospheric water resources research, \$368,000;.
Sept. 28, 1967	1968	Senate, 90th Cong., 1st sess.	Rept. No. 574, p. 30	
Oct. 24, 1967	1968	House, 90th Cong., 1st sess.	Rept. No. 820, p. 34	

June 14, 1968.....	1969 House, 90th Cong., 2d sess.....	Rept. No. 1549, p. 56.....	The committee reduction * * * includes the following: (1) a disallowance of the increase of \$900,000 proposed for the atmospheric water resources research program. The committee has allowed \$4,615,000 to continue this research, the same as the current year level. Although the committee endorses the program objectives, involving the development of a practical cloud-seeding technology to increase available water supplies; it believes it is imperative that the studies be closely coordinated with the weather research being conducted by other Federal agencies and expects that all steps necessary will be taken to assure that overlap and duplication of effort is avoided. The committee requests that a special report be submitted to the committee in this regard in connection with the appropriation request for fiscal year 1970. The committee also has included an additional \$150,000 for atmospheric water resources research in order to initiate pilot weather modification projects.
July 15, 1968.....	1969 Senate, 90th Cong., 2d sess.....	Rept. No. 1405, p. 26.....	Amendment No. * * *, and \$150,000 to initiate pilot weather modification projects in connection with the atmospheric water resources research program.
July 24, 1969.....	1969 House, 90th Cong., 2d sess.....	Rept. No. 1788, conference report, p. 30.....	Note: No specific language—Budget allowance of \$4,765,000 recommended without change within general investigations recommendation.
Oct. 2, 1969.....	1970 House, 91st Cong., 1st sess.....	Rept. No. 91-548, p. 63 and 68.....	Do.
Nov. 10, 1969.....	1970 Senate, 91st Cong., 1st sess.....	Rept. No. 91-528, p. 39.....	Do.
Dec. 2, 1969.....	1970 House, 91st Cong., 1st sess.....	Rept. No. 91-697, conference report, p. 16.....	The committee's net reduction consists of * * * and a decrease of \$300,000 made in the atmospheric water resources research program. The allowance of \$6,500,000, an increase of \$1,467,000 over the 1970 program level, should provide for adequate expansion of the program in fiscal year 1971.
June 18, 1970.....	1971 House, 91st Cong., 2d sess.....	Rept. No. 91-1219, p. 67.....	The Senate committee concurs in the House adjustments in the budget estimate for general investigations. (Note: \$6,500,000 appropriated.)
Aug. 12, 1970.....	1971 Senate, 91st Cong., 2d sess.....	Rept. No. 91-1118, p. 43.....	The committee has allowed \$6,234,000, a reduction of \$500,000 in the estimate, for continuation of the research program. Although the committee fully supports this effort on which about \$28 million has been expended to date by the Bureau, it believes that an adequate program can be carried out within the amount provided. In total, Federal agencies had available about \$15,600,000 in fiscal year 1971 for weather modification programs including \$7,600,000 for precipitation modifications.
July 30, 1971.....	1972 Senate, 92d Cong., 1st sess.....	Rept. No. 92-329, p. 34.....	The committee recommends an increase of \$675,000 for general investigations. Of this amount, \$575,000 is for atmospheric research, of which \$75,000 is for cooperation with the city of Watford, N. Dak.
July 26, 1971.....	1972 House, 92d Cong., 1st sess.....	Rept. No. 92-381, p. 59-60.....	The increase provided over the House bill amount includes \$325,000 for the atmospheric water resources management program including \$75,000 for the North Dakota pilot project.
Aug. 14, 1971.....	1972 House, 92d Cong., 1st sess.....	Rept. No. 92-479, conference report, p. 31.....	

See footnote at end of table.

APPENDIX J—Continued
SUMMARY OF APPROPRIATION LANGUAGE, ATMOSPHERIC WATER RESOURCES PROGRAM, 1962-78—Continued

Date	Fiscal year bill	Body	Document	Provision
June 19, 1972	1973	House, 92d Congress, 2d sess.	Rept. No. 92-1151, p. 52	<p>The Committee's allowance includes reductions in the following budgeted items: Atmospheric water resources management program (Project Skywater). The committee has allowed \$6,000,000 a reduction of \$200,000 in the estimate, for continuation of the research program. Although the committee continues to support this effort (on which about \$35,000,000 has been expended to date by the Bureau, it believes an adequate program can be carried out within the amount provided, considering that Federal agencies have budgeted a total of about \$21,000,000 for continuing weather modification programs in fiscal year 1973.</p> <p>The Committee believes that the Bureau's program, which has been conducted for several years under its general research authority, is now at the stage of development where specific legislative authority should be proposed by the administration and considered by the Congress to determine the future nature and scope of the effort. Within the amount allowed, the committee has made provision for \$375,000 for continuation of the contract research work at Utah State University.</p> <p>Atmospheric water resources management program. — \$1,000,000</p>
June 7, 1972	1-73	Senate, 92d Cong., 2d sess.	Rept. No. 92-923, p. 34	<p>Includes:</p> <ul style="list-style-type: none"> Extended Southern Plains..... 300,000 Sierra Cooperative pilot project..... 50,000 North Dakota pilot project..... 75,000 Winter seeding techniques..... 75,000 North Platte pilot project..... 100,000 Environmental study..... 200,000 <p>Within the funds provided for atmospheric water research management, the committee directs that contract research work at the University of Nevada, South Dakota School of Mines, University of Wyoming and Utah State University be continued at the fiscal 1972 levels.</p> <p>Atmospheric Water Resources Management Program..... \$600,000.</p> <p>The increase for the atmospheric water resources program is allocated as follows: Extended Southern Plains project, \$250,000; Sierra Cooperative pilot project, \$50,000; North Dakota pilot project, \$75,000; Winter seeding techniques, \$50,000; North Platte pilot project, \$75,000; and environmental study, \$100,000. The managers also direct that, within the funds provided, contract research work at the following universities to be continued at the 1972 funding levels: University of Nevada, South Dakota School of Mines and Technology, University of Wyoming, and Utah State University.</p>
Aug. 7, 1972	1973	House, 92d Cong., 2d sess.	Rept. No. 92-1310, conference report, pp. 28-29.	

June 25, 1973.....	1974 House, 93d Cong., 1st sess.....	Rept. No. 93-327, p. 47.....	Note: No specific language—Budget increase of \$400,000 to \$3,650,000 included.
July 20, 1973.....	1974 Senate, 93d Cong., 1st sess.....	Rept. No. 93-338, p. 35.....	Atmospheric water resources management program, +\$500,000. The committee has provided additional funds for atmospheric water research management to be allocated for the planned High Plains Cooperative experiment. The committee reaffirms its strong belief in the importance of Project Skywater, and urges the Bureau to give every consideration to and to utilize the research capabilities at the several colleges and universities located in the States covered by the High Plains program.
July 26, 1973.....	1974 House, 93d Cong., 1st sess.....	Rept. No. 93-409, conferences report, p. 28.....	The increase provided over the House bill amount includes the following: Atmospheric water resources management program, \$250,000.
June 3, 1974.....	1975 House, 93d Cong., 2d sess.....	Rept. No. 93-1077, p. 49.....	"Increase in budget" (as footnote to \$4,000,000 allowance which represents an increase from budget of \$3,454,000).
July 26, 1974.....	1975 Senate, 93d Cong., 2d sess.....	Rept. 93-1032, p. 47.....	Note: No change to House report.
Aug. 8, 1974.....	1975 House, 93d Cong., 2d sess.....	Rept. 93-1274, conference report, p. 26.....	No language (no change in House amount).
June 20, 1976.....	1976 House, 94th Cong., 1st sess.....	Rept. 94-319, p. 59.....	No language.
Dec. 4, 1975.....	1976 Senate, 94th Cong., 1st sess.....	Rept. 94-306, p. 81.....	No change of language.
Dec. 10, 1975.....	1976 House, 94th Cong., 1st sess.....	Rept. 94-711, conference report, p. 57.....	Both the House and Senate provided \$4,649,000 for fiscal year 1976 and \$1,632,000 for the atmospheric water resources management program (Project Skywater). Further, the committee of conference agrees that the Bureau of Reclamation should allocate from within the amount made available, sufficient funds (estimated at approximately \$35,000) to complete the cloud seeding and cloud physics research program under a contract with the University of Wyoming.
June 8, 1976.....	1977 House, 94th Cong., 2d sess.....	Rept. 94-1223, p. 64.....	No specific language; increase shown in table, \$4,650,000 to \$6,400,000.
June 17, 1976.....	1977 Senate, 94th Cong., 2d sess.....	Rept. 94-960, p. 73.....	No specific language; no change in House increase.
June 24, 1976.....	1977 House, 94th Cong., 2d sess. (conference report)	Rept. 94-1297, p. 30.....	No specific language; no changes.
May 29, 1977.....	1978 House, 95th Cong., 1st sess.....	Rept. No. 95-....., p. 81.....	No specific language.—Table showing \$1,850,000 increase, \$5,700,000, to \$7,550,000, specifically showing 0 to \$600,000 for Colorado River augmentation demonstration program and \$3,050,000 to \$4,000,000 for High Plains Cooperative program.
June 25, 1978.....	1978 Senate, 95th Cong., 1st sess.....	Rept. No. 95-301, pp. 65 and 70.....	"Funds in the amount of \$7,550,000 have been provided by the committee for the atmospheric water resources management program to advance verification and assessment of the benefits of cloud seeding technology. Major field research is currently underway on the Sierra Cooperative pilot project and the High Plains Cooperative program (Hiplex). The additional funds will enable the Bureau of Reclamation to undertake further downwind research and to expand cloud physics and rainfall studies under the Hiplex program; advance cloud seeding work related to the Sierra Cooperative pilot project; and prepare plans for the Colorado River augmentation demonstration program." The funding table in the House report was also repeated.

APPENDIX K

MEMBERSHIP AND CHARTER OF THE U.S. DEPARTMENT OF COMMERCE WEATHER MODIFICATION ADVISORY BOARD

WEATHER MODIFICATION ADVISORY BOARD

- Mr. Harlan Cleveland, Chairman, Director, Program in International Affairs, Aspen Institute for Humanistic Studies, P.O. Box 2820, Rosedale Rd., Princeton, N.J. 08540.
- Dr. D. Ray Booker, President, Aeromet, Inc., P.O. Box FF, Norman, OK 73070.
- Dr. Roscoe R. Braham, Jr., Director, Cloud Physics Laboratory, University of Chicago, Chicago, Illinois 60637.
- Mr. Stanley A. Changnon, Jr., Head, Atmospheric Science Section, Illinois State Water Survey, Box 232, Champaign-Urbana, Illinois 61801.
- Mr. Abram Chayes, Professor of Law, Harvard Law School, Cambridge, Mass. 02138.
- Dr. John P. Craven, Dean of Marine Programs, University of Hawaii, 2540 Maile Way, Honolulu, Hawaii 96822.
- Dr. James A. Crutchfield, Jr., Professor of Economics, Department of Economics, University of Washington, Seattle, Washington 98105.
- Mr. Robert D. Elliott, President, North American Weather Consultants, Inc., Goleta, California 93017.
- Dr. John W. Firor, Director, National Center for Atmospheric Research, P.O. Box 1470, Boulder, Colorado 80302.
- Dr. T. Keith Glennan, 11483 Waterview, Reston, VA 22070.
- Mr. Thomas L. Kimball, Executive Vice President, National Wildlife Federation, 1412 16th Street, Washington, D.C. 20036.
- Dr. Thomas F. Malone, Director, Holcomb Research Institute, Butler University, Indianapolis, Indiana 46208.
- Ms. Martha A. McInnis, President, Enviro South, Inc., 3815 Interstate Court, Suite 202, Montgomery, Alabama 36109.
- Mr. Herman Pollack, Research Professor, International Affairs, Room 714 Library, George Washington University, Washington, D.C. 20052.
- Mr. Wallace N. Robinson, III, Chairman, Western Kansas Groundwater Management District No. 1, Federal Building, Scott City, KA 67871.
- Dr. Joanne Simpson, Professor of Environmental Sciences, Center for Advanced Studies, University of Virginia, Charlottesville, VA 22903.
- Mr. S. Bryce Streibel, Fessenden, North Dakota 58438.

U.S. DEPARTMENT OF COMMERCE—CHARTER OF WEATHER MODIFICATION ADVISORY BOARD

A. ESTABLISHMENT

The Secretary of Commerce (the "Secretary"), having determined that it is in the public interest in connection with the performance of duties imposed on the Secretary by Public Law 94-490 (the "Act"), hereby establishes the Weather Modification Advisory Board (the "Board") pursuant to the Federal Advisory Committee Act, 5 U.S.C. App. I (Supp V, 1975).

B. EXPLANATION OF TERMS

The terms used in this Charter shall have the meanings that are prescribed in the Act.

C. OBJECTIVES AND DUTIES

1. The Board shall advise and make recommendations to the Secretary through the Administrator of the National Oceanic and Atmospheric Administration (the "Administrator") on matters of a national policy, a national research and development program, and other aspects of weather modification as outlined in the Act.

2. The Board may draw upon the experience and expertise of its members upon the public, and upon other bodies and individuals deemed necessary to provide advice, consultation, evaluations, and recommendations to the Secretary on the various weather modification matters relative to Sections 4 and 5 of the Act, such as: a. The present state of scientific knowledge of weather modification, its development, and technology; b. The problems impeding effective implementation of weather modification technology; c. Research needs in weather modification and the economic importance of weather modification; d. An assessment of the legal, social, and ecological implications of weather modifications; e. Development of model domestic regulatory codes; f. International implications and model agreements; g. A comprehensive and coordinated national weather modification policy; h. A national program of weather modification research and development; and i. Legislation and funding associated with such policy and program. The Board shall submit its report to the Secretary not less than 15 days prior to the date the Secretary is required to submit the report to the President and the Congress.

3. The Board functions solely as an advisory body, and will comply fully with the provisions of the Federal Advisory Committee Act.

D. MEMBERS AND CHAIRPERSON

1. The Board shall consist of not more than 25 members and not less than 7, appointed by the Secretary. The members shall possess expertise, experience, or current interest in one or more weather modification factors or related aspects such as: research, operations, agriculture, water resources, economics, law, government, business, social and environmental impact, and international relations. Members shall be appointed for up to 2 years and will serve at the discretion of the Secretary. Appointments to fill vacancies shall be for the remainder of the unexpired term of the vacancy.

2. The Chairperson of the Board shall be a nonfederal member and shall be appointed by the Secretary from among the membership.

E. ADMINISTRATIVE PROVISIONS

1. The Board shall report to the Secretary through the Administrator.

2. The Board shall have an Executive Secretary who shall be a full-time Federal officer or employee designated by the Administrator.

3. The Board generally shall meet quarterly and at such other times as may be deemed necessary by the Administrator or the Executive Secretary.

4. The National Oceanic and Atmospheric Administration shall provide clerical and other necessary support.

5. The annual cost of operating the Board is estimated at \$160,000. This includes 2 person-years of staff support.

6. The Board may establish, subject to the provisions of the Department of Commerce Committee Management Handbook (II, 1.E.), and the approval of the Administrator, an Executive Committee and such subcommittees or working groups of its members as may be necessary.

7. Members of the Board will be compensated as consultants for time spent attending Board meetings during any month in which the Board meets for more than one day. They will, upon request, be allowed travel expenses as authorized by 5 U.S.C. 5703.

F. DURATION

The Board shall terminate 2 years after its establishment unless it is earlier terminated or renewed by proper authority by appropriate action.

JANUARY 18, 1977.

JOSEPH E. KASPUTY

Assistant Secretary for Administration

Pursuant to subsection 9(c) of the Federal Advisory Committee Act, 5 U.S.C. App. 1, this charter was filed with the Assistant Secretary for Administration on January 18, 1977. On the same date, copies were filed with the Committees listed below, and a copy was furnished the Library of Congress.

Senate Committee on Commerce.

House Committee on Interstate and Foreign Commerce.

House Committee on Merchant Marine and Fisheries.

JANUARY 24, 1977.

ROBERT T. JORDAN, *Chief,*

*Information Management Division, Office of
Organization and Management Systems.*

APPENDIX L

RULES AND REGULATIONS AND REQUIRED FORMS FOR SUBMITTING INFORMATION ON WEATHER MODIFICATION ACTIVITIES TO THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, U.S. DEPARTMENT OF COMMERCE, IN ACCORDANCE WITH REQUIREMENTS OF PUBLIC LAW 92-205

CHAPTER IX—NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, DEPARTMENT OF COMMERCE

SUBCHAPTER A—GENERAL REGULATIONS

PART 908—MAINTAINING RECORDS AND SUBMITTING REPORTS ON WEATHER MODIFICATION ACTIVITIES

In a notice published in the Federal Register of February 24, 1976 (41 FR 3064), the Administrator of the National Oceanic and Atmospheric Administration proposed to amend the rules on maintaining records and submitting reports on weather modification activities (37 FR 22974 and 39 FR 1832). Interested persons were given until March 25, 1976 to submit written views, objections, recommendations, or suggestions in connection with the proposed amendments. The few comments received in response to the notice have been considered in detail, and, as a result, some revisions have been made in these amendments.

The first revision covers § 908.3(d), the amendment that allows the Administrator to waive some requirements in the reporting of certain weather modification attempts. This amendment has been clarified to provide specifically that all weather modification activities are to be reported to NOAA, that the Administrator may decide to waive some subsequent reporting requirements for certain activities after initial notification, and that the basis for such decision will be the general acceptability, from a technical or scientific viewpoint, of the apparatus and techniques to be used.

The second revision concerns the period for filing interim and final reports. Sections 908.5(a) and 908.6 now provide for such reports to be filed within 45 days, since some respondents stated that they would encounter difficulty in meeting a 30 day requirement.

The final revision is in § 908.5(a), with respect to the effective closing date for the interim report period. In reconsidering this amendment, NOAA has decided to adopt January 1 as the closing date for the interim report in order to avoid ambiguity and to prepare summary reports that more accurately reflect the status of weather modification activities during a calendar year.

The original rules on maintaining records and submitting reports on weather modification activities were published in the FEDERAL REGISTER (37 FR 22974). These rules were subsequently amended (39 FR 1832). For completeness, the revisions mentioned above and the remainder of the amendments now being effected are summarized as follows:

1. Section 908.1 (k) and (l) have been added to define sponsor and operator.
2. The last sentence in § 908.3(c) has been restated.
3. Section 908.3 (d) and (e) have been added.
4. Section 908.4(a) has been revised.
5. Section 908.5(a) has been changed.
6. Section 908.5(b) (2) has been reworded.
7. Section 908.6 has been changed.
8. Section 908.6(c) has been changed.
9. Section 906.8(a) (1) (viii) has been reworded.
10. Section 908.3(a) (2) has been reworded.

The purpose of these rules is to provide for the reporting to the Administrator of the National Oceanic and Atmospheric Administration, U.S. Department of

Commerce, of weather modification activities taking place within the United States, pursuant to the requirements of Pub. Law 92-205 as amended. The Secretary of Commerce (and by delegation the Administrator) is charged under the above law with the responsibility to assemble and retain records of such weather modification activities, to make these records publicly available to the fullest extent practicable, and to publish summaries thereof from time to time. The intent of this program is that expertise in the field of weather modification will be increased; that scientists and other concerned persons will have access to information about past and ongoing efforts toward weather modification; that concerned persons can determine whether their activities will be necessary or duplicative, can check both desirable and undesirable atmospheric changes against records of weather modification, and can be alert to possible territorial overlappings of weather modification operations. In addition, this reporting program provides information on the possibility of harm to persons, property, or the environment, or of interference with Federal research projects.

Appropriate Federal agencies also report their weather modification activities to the Secretary of Commerce. This Federal reporting complements the reporting of non-Federally sponsored projects and provides for a central source of information on all weather modification activities in the United States.

The actions of the Department of Commerce under these rules are not intended as, nor do they constitute, control or regulation of weather modification operations. Any notification that may be made to operators and State officials on the basis of information received will be advisory only.

Therefore, pursuant to the authority contained in 15 U.S.C. 330-330e and 15 U.S.C. 313, the National Oceanic and Atmospheric Administration (NOAA) has amended Title 15, Code of Federal Regulations by the addition of Part 908. These rules are administered by the Administrator, National Oceanic and Atmospheric Administration, on behalf of the Secretary of Commerce, pursuant to the Secretary's delegation of authority in section 3, subparagraph .01t of U.S. Department of Commerce Organization Order 25-5A. The current rules, including all amendments, are republished below in their entirety.

ROBERT M. WHITE,
Administrator.

JUNE 4, 1976.

Part 908 reads as follows :

Sec.

- 908.1 Definitions.
- 908.2 Persons subject to reporting.
- 908.3 Activities subject to reporting.
- 908.4 Initial report.
- 908.5 Interim reports.
- 908.6 Final report.
- 908.7 Supplemental reports.
- 908.8 Maintenance of records.
- 908.9 Retention of records.
- 908.10 Penalties.
- 908.11 Maintenance of record of related activities.
- 908.12 Public disclosure of information.
- 908.13 Address of letters.
- 908.14 Business to be transacted in writing.
- 908.15 Times for taking action : expiration on Saturday, Sunday, or holiday.
- 908.16 Signature.
- 908.17 Suspension or waiver of rules.
- 908.18 Matters not specifically provided for in rules.
- 908.19 Publication of notice of proposed amendments.
- 908.20 Effective date.
- 908.21 Report form.

AUTHORITY : Pub. L. 92-305, 85 Stat. 735, December 18, 1971.

§ 908.1 Definitions

As used in this part, terms shall have the meaning ascribed in this section.

(a) *Administrator.* The Administrator of the National Oceanic and Atmospheric Administration.

(b) *Person.* Any individual, corporation, company, association, firm, partnership, society, joint stock company, any State or local government or any agency thereof, or any other organization, whether commercial or nonprofit, except where acting solely as an employee, agent, or independent contractor of the Federal Government.

(c) *Weather modification activity.* Any activity performed with the intention of producing artificial changes in the composition, behavior, or dynamics of the atmosphere.

(d) *United States.* The several States, the District of Columbia, the Commonwealth of Puerto Rico, and any territory or insular possession of the United States.

(e) *Persons whose activities relate to weather modification.* Persons engaged in weather modification activities or engaged in the distribution or sale of weather modification apparatus or materials known by them to be destined for use in weather modification activities.

(f) *Project.* A related series of weather modification activities having a common objective.

(g) *Modification mission.* One or more airborne weather modification activities intended to affect the same target area, or one or more weather modification activities carried out by items of ground-based weather modification apparatus intended to affect the same target area. For purposes of these rules, activities that extend beyond 1 calendar day shall constitute a separate mission for each day that they continue.

(h) *Target area.* The ground area within which the effects of the weather modification activity are expected to be found.

(i) *Control area.* A preselected, untreated ground area used for comparison with a target area.

(j) *Weather modification apparatus.* Any apparatus used with the intention of producing artificial changes in the composition, behavior, or dynamics of the atmosphere. For example: Seeding generators, propane devices, flares, rockets, artillery projectiles, jet engines, etc.

(k) *Sponsor.* The primary person for whom the weather modification activity is performed.

(l) *Operator.* The person who is primarily responsible for carrying out the weather modification activity.

§ 908.2 *Persons subject to reporting*

Any person engaged or intending to engage in any weather modification activity in the United States shall be subject to the reporting provisions of this part.

§ 908.3 *Activities subject to reporting*

(a) The following, when conducted as weather modification activities, shall be subject to reporting:

(1) Seeding or dispersing of any substance into clouds or fog, to alter drop size distribution, produce ice crystals or coagulation of droplets, alter the development of hail or lightning, or influence in any way the natural development cycle of clouds or their environment;

(2) Using fires or heat sources to influence convective circulation or to evaporate fog.

(3) Modifying the solar radiation exchange of the earth or clouds, through the release of gases, dusts, liquids, or aerosols into the atmosphere;

(4) Modifying the characteristics of land or water surfaces by dusting or treating with powders, liquid sprays, dyes, or other materials;

(5) Releasing electrically charged or radioactive particles, or ions, into the atmosphere;

(6) Applying shock waves, sonic energy sources, or other explosive or acoustic sources to the atmosphere;

(7) Using aircraft propeller downwash, jet wash, or other sources of artificial wind generation; or

(8) Using lasers or other sources of electromagnetic radiation.

(b) In addition to the activities listed above, other similar activities falling within the definition of weather modification as set forth in § 908.1 are also subject to reporting.

(c) The requirement for reporting shall not apply to activities of a purely local nature that can reasonably be expected not to modify the weather outside of the area of operation. This exception is presently restricted to the use of lightning deflection or static discharge devices in aircraft, boats, or buildings, and to the use of small heat sources, fans, fogging devices, aircraft downwash, or sprays to prevent the occurrence of frost in tracts or fields planted with crops susceptible to frost or freeze damage. Also expected from the requirement for reporting are religious activities or other ceremonies, rites and rituals intended to modify the weather.

(d) All activities noted in §§ 908.3(a) and (b) are subject to initial reporting. However, after the Administrator has received initial notification of a planned activity, he may waive some of the subsequent reporting requirements. This de-

cision to waive certain reporting requirements will be based on the general acceptability, from a technical or scientific viewpoint, of the apparatus and techniques to be used.

(e) Other reporting exceptions may be made in the future by rule of the Administrator.

§ 908.4 Initial report

(a) Any person intending to engage in any weather modification project or activity in the United States shall provide a report of his intention, to be received by the Administrator at least 10 days before the commencement of such project or activity. This report shall contain at least the following:

- (1) The designation, if any, used by the operator for the project or activity;
 - (2) The following dates for weather modification activities:
 - (i) The date the first actual weather modification activity is to be undertaken;
 - (ii) The date on which the final modification activity is expected to occur;
 - (3) The following information on persons involved with the project or activity:
 - (i) The name, affiliation, and address of the sponsor;
 - (ii) The name, affiliation, and address of the operator;
 - (4) The purpose of the project or activity;
 - (5) A map showing the approximate size and location of the target and control areas, and the location of each item of ground-based weather modification apparatus, precipitation measuring device, and, for airborne operations, the airport;
 - (6) A description of the weather modification apparatus, modification agents, and the techniques to be employed;
 - (7) The name and address of the responsible individual from whom log books or other records of the project or activity may be obtained;
 - (8) Answers to the following questions on project safeguards:
 - (i) Has an Environmental Impact Statement, Federal or State, been filed: Yes----- No----- If Yes, please furnish a copy as applicable.
 - (ii) Have provisions been made to acquire the latest forecasts, advisories, warnings, etc. of the National Weather Service, Forest Service, or others when issued prior to and during operations? Yes----- No----- If Yes, please specify on a separate sheet.
 - (ii) Have any safety procedures (operational constraints, provisions for suspension of operations, monitoring methods, etc.) and any environmental guidelines (related to the possible effects of the operations) been included in the operational plans? Yes----- No----- If Yes, please furnish copies or a description of the specific procedures and guidelines; and
 - (9) Optional remarks, to include any additional items which the person deems significant or of interest and such other information as the Administrator may request the person to submit.
- (b) If circumstances prevent the signing of a contract or agreement to perform, or receipt of an authorization to proceed with, a weather modification activity at a date early enough to comply with paragraph (a) of this section, the initial report shall be provided so as to be received by the Administrator within 10 days of the date of signing of the contract or agreement, or receipt of authorization to proceed. In such cases, the report shall be accompanied by an explanation as to why it was not submitted at least 10 days prior to the commencement of the activity.
- (c) In the event that circumstances beyond the control of the person liable to report under these regulations prevent the submission of the initial report in a timely manner as described above, the report shall be forwarded as early as possible, accompanied by an explanation as to why a timely report has not been provided. If such explanation is deemed adequate, the Administrator will consider the report as timely filed.

§ 908.5 Interim reports

(a) Any person engaged in a weather modification project or activity in the United States on January 1 in any year shall submit to the Administrator, not later than 45 days thereafter, an interim report setting forth as of such date the information required below with respect to any such continuing project or ac-

tivity not previously furnished to the Administrator in a prior interim report; provided that the January 1 date shall not apply if other arrangements have previously been made with the written approval of the Administrator.

(b) The interim report shall include the file number assigned by the Administrator and shall provide a summary of the project or activity containing at least the following information for each month:

- (1) Number of days on which actual modification activities took place;
- (2) Number of days on which weather modification activities were conducted, segregated by each of the major purposes of the activities;
- (3) Number of modification missions that were carried out;
- (4) Total number of hours of operation of each type of weather modification apparatus (i.e., net hours of agent release);
- (5) Total amount of agent used. If more than one agent was used, each should be totaled separately (e.g., carbon dioxide, sodium chloride, urea, silver iodide).

(c) The totals for the items in paragraph (b) of this section shall be provided for the period covered by the interim report.

§ 908.6 *Final report*

Upon completion of a weather modification project or activity the person who performed the same shall submit a report to the Administrator not later than 45 days after completion of the project or activity. The report shall include the file number assigned by the Administrator and the following items:

(a) Information required for the interim reports (to the extent not previously reported).

(b) The total number of days on which actual modification activities took place during the project or activity.

(c) The total number of days during the project or activity on which weather modification activities were conducted, segregated by each of the major purposes of the activities.

(d) The total number of modification missions that were carried out under the project or activity.

(e) The total number of hours of operation of each type of weather modification apparatus during the project or activity (i.e., net hours of agent release).

(f) The total amount of modification agent(s) dispensed during the project or activity. If more than one agent was used, each should be totaled separately (e.g., carbon dioxide, sodium chloride, urea, silver iodide).

(g) The date on which the final weather modification activity occurred.

§ 908.7 *Supplemental reports*

Notwithstanding other regulations, a supplemental report in letter form referring to the appropriate NOAA file number, if assigned, must be made to the Administrator immediately if any report of weather modification activities submitted under § 908.4, § 908.5, or § 908.6 is found to contain any material inaccuracies, misstatements, and omissions. A supplemental report must also be made if there are changes in plans for the project or activity.

§ 908.8 *Maintenance of records*

(a) Any person engaging in a weather modification activity in the United States shall maintain a record of such activity. This record shall contain at least the following, when applicable:

(1) A chronological record of activities carried on, preferably in the form of a daily log, which shall include the NOAA file number assigned to the project, the designation of each unit of weather modification apparatus, and at least the following information for each unit:

- (i) Date of the weather modification activity.
- (ii) Position of each aircraft or location of each item of weather modification apparatus during each modification mission. Maps may be used.
- (iii) Time when weather modification activity began and ended.
- (iv) Total duration of operation of each unit of weather modification apparatus (i.e., net hours of agent release).
- (v) Type of each modification agent used.
- (vi) Rate of dispersal of each agent during the period of actual operation of weather modification apparatus.
- (vii) Total amount of agent used. If more than one agent was used, report total for each type separately.
- (viii) Number of days on which weather modification activities were conducted, segregated by each of the major purposes of the activities.

(2) The monthly totals of hours of modification activity, the amount of modification agent used, and the number of days on which weather modification activities were conducted, segregated by each of the major purposes of the activities, shall be shown on the daily log sheet for the last day of each month.

(b) When the activity involves ground-based weather modification apparatus, records of the following shall also be maintained, when applicable, but need not be made part of the daily log :

(1) The location of each item of weather modification apparatus in use and its identification such as type and manufacturer's model number. If the apparatus is not commercially available, a brief description of the apparatus and the method of operation should be recorded.

(2) The name and address of the person responsible for operating each weather modification apparatus.

(3) The altitude and type of weather phenomenon subjected to weather modification activity during each operational period (e.g., cumulus clouds between 10,000 and 30,000 feet m.s.l.; ground fog).

(c) When the activity involves airborne weather modification apparatus, records of the following shall also be maintained, when applicable, but need not be made a part of the daily log : For each airborne weather modification apparatus run : altitude, air speed ; release points of modification agents, method of modification and characteristics of flares, rockets, or other delivery systems employed ; temperature at release altitude ; and, for aircraft : the type of aircraft, its identification number, the airport or airports used, and the names and addresses of crew members and the person responsible for operating the weather modification apparatus ; and the altitude and type of weather phenomenon subjected to weather modification activity during each operational period (e.g., cumulus clouds between 10,000 and 30,000 feet m.s.l.; ground fog).

(d) The following records shall also be maintained, whenever applicable, but need not be made a part of the daily log. Only data specifically collected for the reported activity need be retained ; data available from other sources need not be included.

(1) Any descriptions that were recorded of meteorological conditions in target and control areas during the periods of operation ; for example : percent of cloud cover, temperature, humidity, the presence of lightning, hail, funnel clouds, heavy rain or snow, and unusual radar patterns.

(2) All measurements made of precipitation in target and control areas.

(3) Any unusual results.

§ 908.9 Retention of records

Records required under § 908.8 shall be retained and available for inspection by the Administrator or his designated representatives for 5 years after completion of the activity to which they relate. Such records shall be required to be produced for inspection only at the place where normally kept. The Administrator shall have the right to make copies of such records, if he deems necessary.

§ 908.10 Penalties

Knowing and willful violation of any rule adopted under the authority of section 2 of Pub. L. 92-205 shall subject the person violating such rule to a fine of not more than \$10,000, upon conviction thereof.

§ 908.11 Maintenance of records of related activities

(a) Persons whose activities relate to weather modification activities, other than persons engaged in weather modification activities, shall maintain records concerning the identities of purchasers or users of weather modification apparatus or materials, the quantities or numbers of items purchased, and the times of such purchases. Such information shall be retained for at least 5 years.

(b) In addition, persons whose activities relate to weather modification shall be required, under the authority of section 4 of Pub. L. 92-205, to provide the Administrator, on his request, with information he deems necessary to carry out the purposes of this act.

§ 908.12 Public disclosure of information

(a) Any records or other information obtained by the Administrator under these rules or otherwise under the authority of Pub. L. 92-205 shall be made publicly available to the fullest practicable extent. Such records or information may

be inspected on written request to the Administrator. However, the Administrator will not disclose any information referred to in section 1905 of title 18, United States Code, and that is otherwise unavailable to the public, except that such information shall be disclosed—

(1) To other Federal Government departments, agencies, and officials for official use upon request;

(2) In any judicial proceeding under a court order formulated to preserve the confidentiality of such information without impairing the proceeding; and

(3) To the public, if necessary to protect their health and safety.

(b) Certified copies of such reports and information, to the extent publicly disclosable, may be obtained from the Administrator at cost in accordance with the Department of Commerce implementation of the Freedom of Information Act.

(c) Persons reporting on weather modification projects or related activities shall specifically identify all information that they consider not to be subject to public disclosure under the terms of Pub. L. 92-205 and provide reasons in support thereof. A determination as to whether or not reported information is subject to public dissemination shall be made by the Administrator.

(d) When consideration of a weather modification activity report and related information indicates that a proposed project may significantly depart from the practices or procedures generally employed in similar circumstances to avoid danger to persons, property, or the environment, or indicates that success of Federal research projects may be adversely affected if the proposed project is carried out as described, the Administrator will notify the operator(s) and State officials of such possibility and make recommendations where appropriate. The purpose of such notification shall be to inform those notified of existing practices and procedures or Federal research projects known to NOAA. Notification or recommendation, or failure to notify or recommend, shall not be construed as approval or disapproval of a proposed project or as an indication that, if carried out as proposed or recommended it may, in any way, protest or endanger persons, property, or the environment or affect the success of any Federal research project. Any advisory notification issued by the Administrator shall be available to the public and be included in the pertinent activity report file.

§ 908.13 *Address of letters*

Letters and other communications intended for the Administrator, in connection with weather modification reporting or activities, shall be addressed to: The Administrator, National Oceanic and Atmospheric Administration, Environmental Modification Office, Rockville, Md. 20852.

§ 908.14 *Business to be transacted in writing*

All business transacted with the National Oceanic and Atmospheric Administration with regard to reports of weather modification activities should be transacted in writing. Actions of the National Oceanic and Atmospheric Administration will be based exclusively on the written record.

§ 908.15 *Times for taking action; expiration on Saturday, Sunday, or holiday*

Whenever periods of time are specified in these rules in days, calendar days are intended. When the day, or the last day, fixed under these rules for taking any action falls on a Saturday, Sunday, or on a Federal holiday, the action may be taken on the next succeeding day which is not a Saturday, Sunday, or Federal holiday.

§ 908.16 *Signature*

All reports filed with the National Oceanic and Atmospheric Administration must be dated and signed by or on behalf of the person conducting or intending to conduct the weather modification activities referred to therein by such person, individually or, in the case of a person other than an individual, by a partner, officer, or other person having corresponding functions and authority. For this purpose "officer" means a president, vice president, treasurer, secretary, or comptroller. Notwithstanding the foregoing, such reports may also be signed by the duly authorized agent or attorney of the person whose activities are being reported. Proof of such authorization shall be furnished to the Administrator when filing a report, unless previously furnished.

§ 908.17 *Suspension or waiver of rules*

In an extraordinary situation, any requirement of these rules may be suspended or waived by the Administrator on request of the interested party, to the extent such waiver is consistent with the provisions of Pub. L. 92-205 and subject to such other requirements as may be imposed.

§ 908.18 *Matters not specifically provided for in rules*

All matters not specifically provided for or situations not specifically addressed in these rules will be decided in accordance with the merits of each case by or under the authority of the Administrator, and such decision will be communicated in writing to all parties involved in the case.

§ 908.19 *Publication of notice of proposed amendments*

Whenever required by law, and in other cases whenever practicable, notice of proposed amendments to these rules will be published in the FEDERAL REGISTER. If not published with the notice, copies of the text of proposed amendments will be furnished to any person requesting the same. All comments, suggestions, and briefs received within the time specified in the notice will be considered before adoption of the proposed amendments, which may be modified in the light thereof. Informal hearings may be held at the discretion of the Administrator.

§ 908.20 *Effective date*

These rules are effective on June 10, 1976.

§ 908.21 *Report form*

Pub. L. 92-205 and these rules should be studied carefully prior to reporting. Reports required by these rules shall be submitted on forms obtainable on request from the Administrator, or on an equivalent format. In special situations, such alterations to the forms as the circumstances thereto may render necessary may be made, provided they do not depart from the requirements of these rules or of Pub. L. 92-205.

[FR Doc. 76-16807 Filed 6-9-76;8:45 am]

Attachment

Complete in accordance with instructions on reverse and forward copy: TO: Environmental Modification Office (EM-5) National Oceanic and Atmospheric Administration Rockville, Maryland 20852			Form Approved: OMB No. 41-2664 Expires 12-31-77 NOAA FORM 17-4 (5-76) U. S. DEPARTMENT OF COMMERCE NAT'L OCEANIC AND ATMOSPHERIC ADM.				
1. PROJECT OR ACTIVITY DESIGNATION, IF ANY			INITIAL REPORT ON WEATHER MODIFICATION ACTIVITIES (P.L. 205, 92ND. CONGRESS)				
3. PURPOSE OF PROJECT OR ACTIVITY							
4.(a) SPONSOR NAME			4.(b) OPERATOR NAME				
AFFILIATION		PHONE NUMBER	AFFILIATION		PHONE NUMBER		
STREET ADDRESS			STREET ADDRESS				
CITY	STATE	ZIP CODE	CITY	STATE	ZIP CODE		
5. TARGET AND CONTROL AREAS (See Instructions)							
TARGET AREA			CONTROL AREA				
LOCATION	SIZE OF AREA SQ. MI.		LOCATION	SIZE OF AREA SQ. MI.			
6. DESCRIPTION OF WEATHER MODIFICATION APPARATUS, MODIFICATION AGENTS AND THEIR DISPERSAL RATES, THE TECHNIQUES EMPLOYED, ETC. (See Instructions)							
7. LOG BOOKS: Enter name, affiliation, address, and telephone number of responsible individual from whom log books or other records may be obtained.			NAME				
			AFFILIATION		PHONE NUMBER		
			STREET ADDRESS				
			CITY	STATE	ZIP CODE		
8. SAFETY AND ENVIRONMENT							
<input type="checkbox"/> YES <input type="checkbox"/> NO Has an Environmental Impact Statement, Federal or State been filed? If yes, please furnish a copy as applicable.							
<input type="checkbox"/> YES <input type="checkbox"/> NO Have provisions been made to acquire the latest forecasts, advisories, warnings, etc. of the National Weather Service, Forest Service, or others when issued prior to and during operations? If yes, please specify on a separate sheet.							
<input type="checkbox"/> YES <input type="checkbox"/> NO Have any safety procedures (operational constraints, provisions for suspension of operations, monitoring methods, etc.) and any environmental guidelines (related to the possible effects of the operations) been included in the operational plans? If yes, please furnish copies or a description of the specific procedures and guidelines.							
9. OPTIONAL REMARKS (See Instructions. Use Separate Sheet.)							
NAME		CERTIFICATION: I certify that the above statements are true, complete and correct to the best of my knowledge and belief.					
AFFILIATION		SIGNATURE					
STREET ADDRESS		OFFICIAL TITLE					
CITY	STATE	ZIP CODE	DATE	PHONE NUMBER			

NOAA FORM 17-4 (5-76)

59

INSTRUCTIONS FOR INITIAL REPORT ON WEATHER MODIFICATION ACTIVITIES

"This report is required by Public Law 92-205; 85 Stat 735; 15 U.S.C. 330b. Knowing and willful violation of any rule adopted under the authority of Section 2 of Public Law 92-205 shall subject the person violating such to a fine or not more than \$10,000, upon conviction thereof."

One completed copy of this form is to be received 10 days¹ or more prior to actual modification activities. A NOAA file number will be assigned by the Administrator after receipt of the initial report for each project or activity.

¹ For exceptions, see Sections 908.4(b) and (c), Part 908 of Title 15, Code of Federal Regulations.

A supplemental report in a letter form referring to the appropriate NOAA file number must be made to the Administrator if the "Initial Report" is found to contain any material inaccuracies, misstatements, and omissions, or if there are changes in plans for the project or activity.

Item 1. Enter designation, if any, used by operator for the project or activity.

Item 2. Enter :

(a) Date first actual weather modification activity is to be undertaken ;

(b) Date on which final weather modification activity is expected to occur.

Item 3. Enter the purpose of the project or activity : e.g., rainfall increase, hail suppression, cold fog dispersal, etc.

Item 4. Enter :

(a) Name, phone number, affiliation, and address of the primary person for whom the project is to be performed (sponsor).

(b) Name, phone number, affiliation, and address of the person primarily responsible for carrying out the project (operator).

Item 5. A map should be attached showing size and location of target area, control area, coded number and location of each item of ground-based weather modification apparatus and coded number and location of key raingages, radars, or other precipitation measuring devices. Also show location of airport for airborne operations.

Item 6. Describe the weather modification apparatus, modification agents, and the techniques to be used. This would include type of ground or airborne apparatus to be used, type of modification material to be dispensed, rate of dispensing material in grams per hour or other appropriate units, type of precipitation gages to be used in target and control areas, and any other pertinent information such as type of radars, type of aircraft to be used, techniques to be employed, (e.g., cloud base seeding at 10,000 feet msl).

Item 7. List name, phone number, affiliation, and address of the responsible individual from whom log books or other records may be obtained.

Item 8. Provide applicable answers to questions as indicated.

Item 9. This item is to permit the reporting person to include any information not covered by items 1 through 8 but which he feels is significant or of interest. It is also to be used to include any information not covered elsewhere that the Administrator may request.

Attachment

FORM APPROVED O.M.B. NO. 41-R2664
APPROVAL EXPIRES 12-31-77

NOAA FORM 17-4A (6-76)		NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION					U. S. DEPARTMENT OF COMMERCE		NOAA FILE NUMBER										
INTERIM ACTIVITY REPORTS AND FINAL REPORT																			
<p><i>"This report is required by Public Law 92-205, 85 Stat 735; 15 U.S.C. 3306. Knowing and willful violation of any rule adopted under the authority of section 2 of Public Law 92-205 shall subject the person violating such rule to a fine of not more than \$10,000, upon conviction thereof."</i></p>																			
Complete in accordance with instructions on reverse and forward one copy:																			
TO: Environmental Modification Office (EM-5) National Oceanic and Atmospheric Administration Rockville, Maryland 20852																			
MONTH	(a) NUMBER OF MODIFICATION DAYS	(b) NUMBER OF MODIFICATION DAYS PER MAJOR PURPOSE					(c) NUMBER OF MODIFICATION MISSIONS	(d) HOURS OF APPARATUS OPERATION BY TYPE		(e) TYPE AND AMOUNT OF AGENT USED									
		INCREASE		ALLEVIATE				AIR-BORNE	GROUND	SILVER IODIDE	CARBON DIOXIDE	UREA	SODIUM CHLORIDE	OTHER					
		RAIN	SNOW	HAIL	FOG	OTHER													
JANUARY																			
FEBRUARY																			
MARCH																			
APRIL																			
MAY																			
JUNE																			
JULY																			
AUGUST																			
SEPTEMBER																			
OCTOBER																			
NOVEMBER																			
DECEMBER																			
TOTAL																			
TOTALS FOR FINAL REPORT																			
DATE ON WHICH FINAL WEATHER MODIFICATION ACTIVITY OCCURRED (For Final Report Only)																			
NAME OF REPORTING PERSON					CERTIFICATION: I certify that all statements in this report on this weather modification project are complete and correct to the best of my knowledge and are made in good faith.														
AFFILIATION					SIGNATURE														
STREET ADDRESS					OFFICIAL TITLE														
CITY		STATE		ZIP CODE		DATE													

NOAA FORM 17-4A

61

INSTRUCTIONS FOR INTERIM AND FINAL REPORTS

Any person engaged in any weather modification project or activity in the United States on January 1 in any year shall submit one copy of this form setting forth as of such date the information required with respect to each such continuing project or activity not previously furnished in a prior interim report. The box indicating "Interim Report" should be checked. The January 1 date shall not apply if other arrangements have previously been made with the written approval of the Administrator of NOAA. The report shall be received by NOAA not later than 45 days following the end of the reported period.

Upon completion of a project or activity one copy of this report shall be submitted and the box checked indicating "Final Report." The final report shall be

received by NOAA not later than 45 days after the completion of the project or activity.

The NOAA File Number should be filled in for any project for which the Administrator has assigned a file number.

A supplemental report in letter form referring to the appropriate NOAA file number must be made to the Administrator if the "Interim" or "Final" reports are found to contain any material inaccuracies, misstatements, and omissions.

INTERIM REPORT

The information in Items (a) through (e) on the report form should be provided as prescribed below for the months to which the report pertains. If no data are applicable for any given item in any month, enter zero.

Item (a) : Enter number of days on which actual weather modification activities took place.

Item (b) : Enter in the appropriate column number of days on which modification activities were conducted, segregated by each of the major purposes of the activities. Normally, the total of entries in (b) would equal total in (a).

Item (c) : Enter number of modification missions that were carried out.

Item (d) : Enter in the appropriate column total number of hours of operation of each type of weather modification apparatus, (i.e., net hours of agent release). If the form does not contain sufficient space, report additional types on a separate sheet.

Item (e) : Enter in the appropriate column total amount of agent used, by type. If the form does not contain sufficient space, report additional types on a separate sheet.

The totals for these items shall be provided for the period covered by the interim report.

FINAL REPORT

The final report shall contain the information required for interim reports, to the extent not previously reported. In addition, the items designated as "Totals for Final Report" should be reported. This information should pertain to the entire project or activity period, rather than only the period since the last interim report. At the space at the end of the form, enter the date on which final weather modification activity occurred.

Part 908 of Title 15, Code of Federal Regulations, the month and year of daily record, the name of the operator, and the NOAA file number. These or other logs containing the required information shall be retained for 5 years; they are not to be sent to NOAA.

Explanation of columns follows :

Column (1) : State date of the weather modification activity.

Column (2) : Give each aircraft position or location of each item of weather modification apparatus during each modification mission. Maps may be used.

Columns (3 and (4) : State local time when modification activity began and ended. Use 24-hour clock time (e.g., 0100 signifies 1:00 a.m. and 2300 signifies 11:00 p.m.). For intermittent operations, the start and end of the total sequences are acceptable.

Column (5) : Give duration of operation of each unit of weather modification apparatus, in hours and minutes. (Col. 5—Col. 4—Col. 3).

Column (6) : Describe type of modification agent used.

Column (7) : Give rate of dispersal of agent during the period of actual operation of weather modification apparatus, by hour or other appropriate time period.

Column (8) : Give total amount of modification agent used. If more than one agent was used, report total for each type separately.

Columns (9), (10), (11), (12) and (13) : Check once for each day on which modification activities were conducted, segregated by each of the major purposes of the activities.

On the daily log sheet for the last day of each month, give monthly totals, for Columns (5), (8), (9), (10), (11), (12), and (13).

APPENDIX M

SELECTED STATE RULES AND REGULATIONS FOR THE ADMINISTRATION OF STATE WEATHER MODIFICATION STATUTES

ILLINOIS

STATE OF ILLINOIS RULES AND REGULATIONS FOR THE ADMINISTRATION AND ENFORCEMENT OF THE PROVISIONS OF THE WEATHER MODIFICATION CONTROL ACT

DEPARTMENT OF REGISTRATION AND EDUCATION

(Ronald E. Stackler, Director, Springfield)

[Printed by Authority of the State of Illinois]

Foreword

These Rules are issued under the authority of Sections 6, 11, 12, 17, 20 and 26, Chapter 146 $\frac{3}{4}$, Illinois Revised Statutes, 1973, S The Weather Modification Control Act.

RULE 1—CONCEPT OF RULES

1. *Purpose of Rules.*—These Rules are adopted to promote properly conducted weather modification operations and research and development, to minimize possible adverse effects from weather modification activities and to facilitate the administration and enforcement of the Weather Modification Control Act. These Rules shall be liberally construed to carry out these objectives and purposes.

2. *Use and Effect of Rules.*—These Rules are prescribed for the performance of the statutory powers and functions vested in the Department of Registration and Education. In no event shall any Rule or Rules be construed as a limitation or restriction upon the exercise of any statutory power of the Department.

3. *Suspension or Modification of Rules.*—These Rules may be suspended or modified by the Director of the Department of Registration and Education, in whole or in part, in the interest of justice. The Department of Registration and Education by and through the Director reserves the right to waive compliance with any of these Rules whenever in the Director's judgment, no party will be injured thereby.

4. *Construction of Rules.*—These Rules should not be construed to abrogate, modify or limit any rights, privileges, or immunities granted or protected by the Constitution or laws of the United States or the Constitution or laws of the State of Illinois nor to deny any person life, liberty, or property without due process of law.

RULE 2—DEFINITIONS

As used in these Rules, unless the context otherwise requires, the terms specified herein have the meanings ascribed to them herein or by the Weather Modification Control Act, whichever shall be applicable, as same may be, at any time or from time to time, amended.

1. *Act or Weather Modification Control Act.*—"Act" or "Weather Modification Control Act" means "An Act to regulate weather modification in this State and amending certain Acts therein named in connection therewith" (P.A. 78-674, effective October 1, 1973), as same may at any time or from time to time, be amended.

2. *Weather Modification Apparatus.*—"Weather Modification Apparatus" means any apparatus used with the intention of producing artificial changes in the composition, motions and resulting behavior of the atmosphere.

3. *Sponsor.*—"Sponsor" means any person who enters into an agreement with a permittee to perform an operation.

4. *Target Area.*—"Target Area" means the surface area within which the effects of an operation are expected to be found.

5. *Operations Area*.—"Operations Area" means the area in which an operation is conducted to produce or attempt to produce the desired effect within the target area.

6. *Control Area*.—"Control Area" means a preselected, untreated surface area in which no effects are expected and which is used for comparison with a target area.

7. *Professional Level*.—"Professional Level" means a level of responsibility for direct supervision and conduct of operations or substantial parts thereof.

8. *Department's Address*.—628 East Adams Street, Springfield, Illinois 62786, or such other address as shall at any time or from time to time, be designated by the Director or his duly designated representative.

RULE 3—ADMINISTRATION

1. *Director*.—The powers and duties of the Department enumerated in the Illinois Civil Administrative Code, where applicable, the Act and these Rules shall be exercised by the Director.

2. *Board*.—Reports from the Board, except in emergencies, shall be in writing. The Chairman of the Board shall be responsible for forwarding to the Director reports from the Board promptly and for keeping other members of the Board advised of pending business of the Board. The Director shall act promptly upon receipt of reports from the Board.

RULE 4—HEARINGS

1. *Hearings Required*.—Except for emergency modifications of operational permits as provided for in Section 21(b) of the Act, before suspending, revoking, refusing to renew or modifying a license or a permit, the Department shall conduct a hearing in conformity with Section 8 of the Act.

2. *Stenographic Record*.—The stenographic record of a hearing shall be retained for at least five years. It need not be transcribed unless there is judicial review of the final administrative decision under Section 25 of the Act.

RULE 5—LICENSE AND PERMIT REQUIRED

1. *Requirement*.—Except as provided in Subsection 2 of this Rule, no person may engage in weather modification activities:

(a) Without both a professional weather modification license issued under Rule 6 and a weather modification operational permit issued under Rule 7; or

(b) In violation of any term, condition or limitation of such license or permit.

2. *Exemptions*.—The following activities are exempted from the license and permit requirements of the Act:

(a) Research and development conducted by the State, its subdivisions and agencies of the State and of its subdivisions, institutions of higher learning and bona fide research organizations;

(b) Activities for protection against fire, frost or fog; and

(c) Activities normally conducted for purposes other than inducing, increasing, decreasing or preventing hail, precipitation, clouds or tornadoes.

3. *Conduct of Exempt Activities*.—Exempted activities shall be so conducted as not to interfere with weather modification operations conducted under a permit issued in accordance with the Act and these Rules.

4. *Notice of Exempt Activities*.—Persons conducting exempted operations and research and development shall file with the Department the original of a notice form available from the Department and with the Chairman of the Board at the Department's address a copy of the form indicating their intent to engage in such activities. Information from notice forms will be used in ascertaining the extent to which records should be kept for exempted activities under Rule 8(6) and reports should be filed on such activities under Rule 9(5). Notice forms will require the following data:

(a) Name and address of the person giving notice;

(b) Name and address of the sponsor (if any) of the operation or research and development;

(c) Whether the activity is operational or research and development;

(d) Nature and object to the activity;

- (e) The legal description of and a map showing the operations area, target area and control area, if the activity involves any such areas;
- (f) The approximate starting date of the activity and its anticipated duration;
- (g) The kind of weather modification agent(s) intended for use; and
- (h) The kinds of weather modification apparatus which will be used.

RULE 6—LICENSES

1. **Criteria for Issuance:** Issuance of licenses shall be based on the applicant's character, knowledge of weather modification principles and techniques and experience in their application. The following shall be the minimum educational and experience criteria:

(a) A minimum of two years' field experience at the professional level in weather modification field operations or research; and

(b) One of the following three requirements:

(1) Six additional years' experience in weather modification field operations or research; or

(1) Six additional years' experience in weather modification field operations or research; or

(2) A degree in engineering, mathematics, or the physical sciences plus two additional years' experience in weather modification field operations or research; or

(3) A degree in meteorology, or a degree in engineering, mathematics, or the physical sciences which includes or is in addition to at least twenty-five semester hours of meteorological course work.

2. **Application for License.**—An applicant for a license shall fill out and file with the Department the original of an application form available from the Department and a copy thereof with the Chairman of the Board at the Department's address no later than thirty days before the applicant plans to use the license. The form shall require relevant information about the applicant's character, knowledge of weather modification principles and experience in their application. Among the data required is information about the applicant's:

(a) Educational background at the college and graduate level. This includes the dates of attendance and of graduation, the major and minor subjects (including the number of semester hours of meteorological course work), the degrees received, and the titles of any thesis and/or dissertation.

(b) Experience in weather modification or related activities. Attention should be given to experience with reference to meteorological conditions typical of Illinois. The applicant should list the dates of each position held, the title of the position (indicate whether it was of sub-professional or professional level), the name and address of the employer, a description of the work done (indicate both the magnitude and complexity of the work and the duties and degree of responsibility for the work), and the name and address of the supervisor.

(c) Scientific or engineering society affiliations and the grade of membership in and certification by each.

(d) Publications, patents and reports.

(e) Three references who will attest to the applicant's character, knowledge of weather modification principles and experience in their application.

(f) A list of all jurisdictions in which the applicant has previously filed application for a professional weather modification license. The outcome of such applications should be indicated.

(g) A list of all law suits relating to weather modification from any jurisdiction in which the applicant was a party or where the applicant was employed by a party thereto at the time involved therein.

(h) Indication whether a professional weather modification license issued to the applicant in any jurisdiction has ever been suspended, revoked, placed on probationary status or subjected to any other disciplinary actions or whether there has been refusal to renew such a license by any jurisdiction. If there has been any such suspension, revocation, placement on probationary status or other disciplinary action or refusal to renew, the circumstances must be explained in full.

3. **Procedure for Issuance.**—The Department shall evaluate the applications, including the responses from references, and such other relevant data about applicants as it possesses or discovers. The Department in its discretion shall also

have the right to interview any applicant. On the basis of that information the Department shall, within sixty days of receipt of an application, determine whether the applicant meets the educational and experience criteria established by Subsection 1 of this Rule and whether the applicant possesses the character, knowledge and experience necessary to engage in weather modification operations. The Director shall issue a license to each applicant who pays the license fee established by Section 13 of the Act and who demonstrates to the satisfaction of the Department the competence, by virtue of character, knowledge and experience, necessary to engage in weather modification operations. If an applicant for a license does not pay the license fee established by Section 13 of the Act or does not demonstrate to the satisfaction of the Department the competence, by virtue of character, knowledge and experience, necessary to engage in weather modification operations, the Department shall deny the application for the license.

4. *Renewal of License.*—Forty-five days before expiration of licenses the Department shall mail license application forms to all licensees and request each licensee to complete the form and file the original with the Department and a copy with the Chairman of the Board at the Department's address. The Department shall evaluate the available data about the licensee and shall issue a renewal license within thirty days of receipt of the application to each applicant who pays the renewal fee established by Section 13 of the Act and who has the qualifications necessary for issuance of an original license. The Department shall deny a renewal license within thirty days of receipt of the application of each applicant who does not pay the renewal fee or who does not possess the qualifications necessary for issuance of an original license.

RULE 7—PERMITS

1. *Criteria for Issuance.*—Issuance of permits to conduct weather modification operations shall be based on the following factors:

(a) The applicant holds, or if the applicant is an organization rather than an individual, the individual who will be physically present in Illinois in control of the operation and under whose direction on a day-by-day basis it will be carried out holds, a valid professional weather modification license issued under Section 12 of the Act and Rule 6;

(b) The applicant has furnished proof of financial responsibility in accordance with Section 20 of the Act and under Rule 7 (6);

(c) The operation has technical and scientific feasibility and is reasonably conceived to do all or any of the following: improve water quality or quantity, reduce losses from weather hazards, provide economic benefits for the people of the State, advance or enhance scientific knowledge or otherwise carry out the objectives and purposes of the Act and these Rules;

(d) The operation does not involve a high degree of substantial risk to persons or property, is designed to include adequate safeguards to minimize possible damage to the public health, safety or welfare or to the environment and includes an emergency shutdown procedure which states conditions under which operations must be suspended because of possible danger to the public health, safety and welfare or to the environment;

(e) The operation will not adversely affect another operation for which a permit has been issued;

(f) The operation will not adversely affect any existing research and development project exempted from the licensing and permit requirements by Rule 5 (2) (a);

(g) The applicant has complied with the permit fee requirement established by Section 18 of the Act.

(h) The applicant has an acceptable plan for evaluation of the operation by using available surface data from sources such as the United States Department of Agriculture county crop yield reports, the United States Geological Survey stream flow gauges, the National Weather Service temperature and precipitation gauges and reports and the hail loss insurance records for the region; and

(i) The project conforms to such other criteria as are set forth in the objects and purposes of the Act and of these Rules.

2. *Application for Permit.*—An applicant for a permit shall fill out and file with the Department the original of an application form available from the Department and a copy thereof with the Chairman of the Board at the Depart-

ment's address no later than thirty days before the applicant plans to use the permit. The form shall require relevant information about the applicant and the proposed operation from which the Department can make an informed judgment whether or not to issue the permit and, in case of issuance of the permit, what conditions and limitations should be placed upon it. Among the data required is the following information about the applicant and the project:

(a) Name and address of the applicant;

(b) Whether a weather modification operational permit issued to the applicant in any jurisdiction has ever been suspended, revoked, placed on probationary status or subjected to any other disciplinary action or whether there has been refusal to renew such a permit by any jurisdiction. If there has been any such suspension, revocation, placement on probationary status or other disciplinary action or refusal to renew, the circumstances must be explained in full;

(c) If the applicant is a corporation, whether it is licensed to do business in Illinois;

(d) Names, addresses and numbers of all professional licenses issued under Section 12 of the Act and Rule 6 of the individuals in control of the operation and under whose direction on a day-by-day basis it will be carried out;

(e) Whether professional weather modification licenses issued to such licenses in any jurisdiction have ever been suspended or revoked or placed on probationary status or subjected to any other disciplinary action or whether there has been refusal to renew such licenses by any jurisdiction. If there has been any such suspension, revocation, placement on probationary status or other disciplinary action, or refusal to renew, the circumstances must be explained in full;

(f) Whether proof of financial responsibility has been furnished in accordance with Section 20 of the Act and Rule 7 (6);

(g) If the operation will be conducted under a contract, the value of the contract;

(h) If the operation will not be conducted under a contract, an estimate of the costs of the operation and information as to how the estimate was made;

(i) A copy of any promotional and advertising material used in connection with negotiations for the contract with the sponsor (if any);

(j) A complete and detailed operational plan for the operation which includes:

(1) The nature and objects of the operation;

(2) The legal descriptions of and a map showing the operations area, the target area and the control area (if any);

(3) The approximate starting date of the operation and its anticipated duration;

(4) The kind of seeding agent(s) intended for use and the anticipated rate of their uses;

(5) The kinds of weather modification apparatus which will be used and the method(s) of seeding for which they will be used;

(6) An emergency shutdown procedure which states conditions under which operations must be suspended because of possible danger to the public health, safety and welfare or to the environment;

(7) The means by which the operation plans will be implemented and carried out, such as the location of the main operational office and any other offices used in connection with the operation, the location of such ground equipment as seeding generators, radar and evaluation instrumentation, the number and kinds of aircraft which will be used and the extent to which weather data will be made available to the licensees and other personnel carrying out the project; and

(8) How conduct of the operation will interact with other projects;

(k) An acceptable plan for evaluation of the operation prepared in compliance with Rule 7 (1) (h); and

(l) Such additional information as will assist the Department in deciding whether or not to issue the permit.

3. *Procedure for Issuance.*—The Department shall evaluate all fully executed applications, using not only information derived from the completed application forms and accompanying them, but also such other relevant data about the applicants and the proposed operations as it possesses or discovers. The Depart-

ment may give public notice by newspaper, radio or television announcement in the area of the State reasonably expected to be affected by operations conducted under a permit that it is considering an application or more than one application for a permit, and may hold a public hearing for the purpose of obtaining information from the public concerning the effects of issuing or refusing to issue the permit. The Department may issue a permit in response to an application for an operation if it determines that there has been substantial compliance with Section 17 of the Act and Rule 7(1). Otherwise it shall deny the application for the permit. The Department shall complete its action upon applications within thirty days of receiving them.

4. *Conditions and Limits of Permits.*—The permittee shall confine weather modification activities within the conditions and limits specified in the permit and those imposed by the Act and these Rules, except to the extent the conditions and limits are modified by the Department. The Department may condition and limit permits as to target area, time of the operation, materials and methods to be used in conducting the operation, emergency shutdown procedure and such other operational requirements as may be established by the Department. The Department shall condition and limit all permits in the following respects:

- (a) A permit may cover only one operation;
- (b) When an operation is conducted under contract, a separate permit is required for each contract; and
- (c) Only one permit will be issued at a time for operations in any geographical area if two or more operations conducted within the conditions and limits of the permits might adversely interfere with each other.

5. *Duration of Permit.*—Within thirty days of the end of each yearly permit period the permittee shall file a permit application form available from the Department, an original for the Department and a copy thereof for the Chairman of the Board, at the address of the Department. The Department shall complete its action upon applications within thirty days of receiving them.

6. *Proof of Financial Responsibility.*—Proof of financial responsibility is made by showing to the satisfaction of the Department that the permittee has the ability to respond in damages to liability which might reasonably result from the operation for which the permit is sought. Such proof of financial responsibility may, but shall not be required to be, shown by:

- (a) Presentation to the Department of proof of purchase of a prepaid non-cancellable insurance policy or a corporate surety bond issued by a company approved by the Department against whom service of legal process may be made in Illinois against such liabilities in an amount ten times the value of an operation conducted under contract or in an amount ten times the estimated costs of an operation not conducted under contract; or
- (b) Depositing with the Department cash or negotiable securities in an amount ten times the value of an operation conducted under contract or in an amount five times the estimated costs of an operation not conducted under contract.

7. *Renewal of Permit.*—At the expiration of the permit period, the Department shall issue a renewal permit to each applicant who:

- (a) At least thirty days before expiration of the permit period files the original of a permit application form available from the Department with the Department and a copy with the Chairman of the Board at the Department's address;
- (b) Meets the criteria for issuance of a permit under Section 17 of the Act and Rule 7(1), including payment of the permit fee; and
- (c) Has an operational record which indicates that an original permit would be issuable for the operation.

RULE 8—RECORDS

1. *Daily Log.*—Each permittee must fill in and retain a daily log of weather modification activities for each unit of weather modification apparatus used during an operation. The log form which will be available from the Department requires:

- (a) Date of the weather modification activity;
- (b) Each aircraft flight track and location of each item of weather modification apparatus during each modification mission. Maps may be used;

(c) Local time when modification activity began and ended. For intermittent operations, the start and end of the total sequence are acceptable;

(d) Duration of operation of each unit of weather modification apparatus, in hours and minutes;

(e) Description of type of modification agent used;

(f) Rate of dispersal of agent during the period of actual operation of weather modification apparatus, by hour or other appropriate time period;

(g) Total amount of modification agent used. If more than one agent was used, report total for each type separately;

(h) Local time when any radar monitoring operation was turned on and turned off;

(i) Type of clouds modified, that is whether they were stratiform, isolated cumuliform, organized cumuliform or other types of clouds;

(j) Remarks indicating such operational problems as equipment failure, weather conditions not conducive to successful performance of the operation, personnel problems and the like; and

(k) Monthly totals from daily logs listing the total:

(1) Days during month in which operation conducted;

(2) Time of operation;

(3) Amount of each kind of agent used;

(4) Average rate of dispersal of each kind of agent used;

(5) Time of operation of radar; and

(6) Days of each type of cloud treated.

2. *Weather Records*.—Each permittee must obtain and retain copies of all daily precipitation total records available from the National Weather Service stations in the target area and other sources.

3. *Summary Records*.—Each permittee must prepare a monthly summary of the monthly totals from the daily logs of all units of weather modification apparatus used during an operation.

4. *Addresses of Participants*.—Each permittee must keep a roster of the names and Illinois addresses of all employees participating in the State on an operation for which a permit has been issued.

5. *Inspection*.—Duly authorized agents of the Department shall have the power to enter and inspect the records required by this Rule and to make copies of them.

6. *Exempted Weather Modification Activities*.—The Department may in its discretion require persons operating weather modification activities exempted under Rule 5 (2) to keep all or part of the record required of permittees by this Rule. These records shall be kept in such manner as the Department may indicate.

RULE 9—REPORTS

1. *Monthly*.—Within ten days after the conclusion of each calendar month the permittee shall submit a report to the Department which shall consist of:

(a) A copy of the summary record prepared under Rule 8 (3);

(b) A copy of the roster of the names and Illinois addresses of all employees participating in the State on an operation which was prepared under Rule 8(4);

(c) A copy of the federal interim activity report form filed for that month with the National Oceanic and Atmospheric Administration in accordance with the rules adopted under the authority of Public Law 92-205; and

(d) A narrative account of the manner in which operations during the month did not conform to the operational plan filed in accordance with Rule 7 (2) (j).

2. *Final*.—Within thirty days after completion of the operation the permittee shall file with the Department a final report on the operation which shall consist of:

(a) Copies of the logs prepared in accordance with Rule 8 (1), of the weather records obtained in accordance with Rule 8 (2) and of the totals for the entire operational period from the monthly summary records prepared under Rule 8 (3);

(b) A copy of the federal final activity report form filed with the National Oceanic and Atmospheric Administration in accordance with the rules adopted under the authority of Public Law 92-205; and

(c) A narrative account of the manner in which the operation did not conform to the operational plan filed in accordance with Rule 7 (2) (j).

3. *Evaluation.*—Within sixty days after completion of the operation the permittee shall file with the Department a narrative evaluation of the operation. The data for this report should be assembled and evaluated in accordance with the evaluation plan prepared in compliance with Rule 7 (1) (h).

4. *Reports to Sponsors.*—The permittee shall file with the Department a copy of all reports made by the permittee to sponsors of the operation.

5. *Exempted Weather Modification Activities.*—The Department may in its discretion require persons operating weather modification activities exempted under Rule 5 (2) but who have been required under Rule 8 (6) to keep certain records to file all or part of the reports required of permittees by this Rule. These records shall be kept in such manner as the Department may indicate.

6. *Public Records.*—All reports which are in the custody of the Department and which have been filed with it under the Act or Rule 9 shall be kept open for public examination as public documents during regular business hours of the Department's office located at the Department's address.

RULE 10—PARTIAL INVALIDITY

If any portion of these Rules is held invalid, such invalidity shall not affect any other part of these Rules which can be given effect without the invalid portion.

KANSAS

THE KANSAS WEATHER MODIFICATION ACT

STATE STATUTES, RULES AND REGULATIONS PLUS APPLICABLE FORMS

Prepared and Published by the Kansas Water Resources Board, Suite 303,
503 Kansas Avenue, Topeka, Kans. 66603

PREFACE

While rain making has been one of man's objectives for several thousands of years, it has only been within the past half century that he has begun to grasp some of the scientific reasons for weather events which he has observed and speculated on throughout history.

With a clear recognition of the potential of weather modification for benefit or harm, and in view of the lack of hard facts with respect to the possible benefits and financial and social costs of such efforts in Kansas, it appeared wise for the state to seek to provide usable knowledge and reasonable protection to its citizens against irresponsible acts which might adversely affect them.

With this in mind, the 1974 Kansas Legislature passed H.B. 1216 which appears as Kansas Statutes Annotated 82a-1401 to 1424. This act, cited as the "Kansas Weather Modification Act," provides for licensing by the state of all qualified persons who desire to engage in weather modification activities within the state, and further requires that a permit be obtained for each specific activity. Responsibility for administering the act has been placed with the Kansas Water Resources Board.

The law also required the Board to appoint an Advisory Committee to assist the Executive Director of the Board in developing licensing standards and report forms, and to assist in other areas as directed by the Board.

This booklet contains a copy of the law, a copy of the rules and regulations prepared in cooperation with the Advisory Committee, a copy of the required forms, and instructions for preparation of the forms.

The objectives of the rules and regulations are to encourage the development and evaluation of weather modification technology, to protect the public through the requirement that operators in this field possess certain basic qualifications, to establish procedures for the issuance of permits with a minimum of delay and to clarify administrative policy.

These rules may be amended in accordance with procedures set forth in K.S.A. 77-419.

To Whom Should A Weather Modification License and Permit Be Issued?

WEATHER MODIFICATION LICENSE

The Kansas Weather Modification Act provides that a license may be issued to any qualified person. That person must be an individual. A corporation cannot

demonstrate its knowledge of meteorology and weather modification operations; that is the realm of the individual who may be a member of a corporation or political entity.

Only an individual can meet the requirements of 1976 Supp. K.S.A. 82a-1407 and 1412. If a company chooses to license several of its staff in order to meet the requirements of 1412, that is its prerogative. However, a license is not transferable since it applies to a specific individual and his capabilities.

WEATHER MODIFICATION PERMIT

In contrast to the conditions for a license, a permit may be obtained by an individual, a corporation, or any other "person" which meets the requirements of K.S.A. 82a-1411, since all activities must be under the direction of a licensed individual. In making application for a permit, the licensee who will be carrying out the provisions of the permit should be required to state in writing that he can carry out the provisions of the permit as specified in the operational plan which is to accompany the approved permit.

RULES AND REGULATIONS—GENERAL

98-4-1 PURPOSE

These rules and regulations were prepared pursuant to K.S.A. 82a-1403 by the Executive Director within the authority granted by the Kansas Water Resources Board and in consultation with the Advisory Committee appointed by the Board. The purpose of developing licensing standards and report forms and establishing minimum operating requirements for weather modification activities in Kansas is to expand knowledge, minimize conflicts, and assure the use of the most effective methods of carrying on such operations. K.S.A. 1974 Supp. 82a-1403

98-4-2 DEFINITIONS

1. "Board" means the Kansas Water Resources Board.
2. "Director" means the Executive Director of the Kansas Water Resources Board.
3. "Emergency" means an unusual condition which could not have reasonably been expected or foreseen; one in which it can be anticipated that damage can be avoided or reduced by prompt weather modification action.
4. "License" means the document issued by the Director to qualified persons who make application therefor, authorizing such persons to engage in weather modification activities in Kansas.
5. "Licensee" means an individual who has applied for and to whom a weather modification license has been issued.
6. "Permit" means the document issued by the Director authorizing weather modification activity in Kansas, which describes the objectives of the activity, the area in which the activity is to take place, the time within which the operation is to be active, and anticipated results.
7. "Primary Target Area" means the area within which weather modification activity is intended to have an effect.
8. "Research and Development" means exploration, field experimentation and/or extension of investigative findings and theories.
9. "Weather Modification Activity" means any operation or experimental process which has as its objective inducing change, by artificial means, in the composition, behavior, or dynamics of the atmosphere. K.S.A. 1974 Supp. 82a-1403.

98-4-3 LICENSING

1. No person may engage in any weather modification activity within the State of Kansas without a license and a permit.
2. In order to obtain a license under the Kansas Weather Modification Act the applicant must:
 - a. Make application for a license in Kansas to the Board on Form KWM #1. (Copy attached) To assure timely consideration, this should be submitted at least forty-five (45) days prior to the start of the proposed operational period.

b. Pay the \$100.00 license fee unless that fee is waived by a decision of the Board because of the educational or experimental nature of the work proposed. The candidate for exemption must prove to the satisfaction of the Director and the Advisory Committee, if consulted, that the nature of the work merits exemption from fees.

c. Meet one of the following professional or educational requirements :

(1) Eight (8) years of professional experience in weather modification field research or activities and at least three (3) years as a project director,

(2) A baccalaureate degree in applicable courses and three (3) years experience in application of such studies to weather modification activities.

(3) A baccalaureate degree including 25 hours of meteorological studies and two (2) years of practical experience in weather modification research or activities.

d. Demonstrate, to the satisfaction of the Director, by his knowledge of meteorology, cloud physics, and field experience, that he is qualified to conduct a weather modification project of the kind he wishes to conduct in Kansas.

3. Each license shall expire at the end of the calendar year for which it is issued.

4. Weather modification licenses may be renewed annually, effective January 1 each year. Renewal will be automatic upon the following conditions :

a. Receipt of a request for renewal by the license holder.

b. Receipt of the \$100.00 annual license fee, if applicable.

c. Verification by the Director or the Board that evidence has not become available that would raise doubts as to the qualifications of the license holder. K.S.A. 1974 Supp. 82a-1403

98-4-4 PERMITS

1. A weather modification permit shall be required annually, on a calendar year basis, for each weather modification project. In those cases when a weather modification activity will extend over more than one calendar year, a permit may be extended on a year-to-year basis upon payment of the annual fee, a review by the Director and, if desirable, his Advisory Committee, and the publication of a notice of intent to continue the operation. The Director shall determine whether a public hearing is needed.

2. A permit may not be assigned nor transferred by the holder.

3. Permit applications should, if possible, be submitted at least forty-five (45) days prior to the initial date of the proposed operational period for which the permit is sought. This will allow time to hold a public hearing, review the information presented, and permit action by the Board prior to the proposed starting date of the project.

4. In order to modify the boundaries of a project for which a permit has previously been obtained, a revised permit will be required, under conditions similar to those under which the original permit was issued, or as modified by the Director.

5. In order to obtain a permit to conduct weather modification activities in Kansas, an applicant must :

a. Submit to the Director a completed Form KWM No. 2. (Copy attached.)

b. Pay the \$100.00 permit fee, if applicable.

c. Present evidence that the applicant is, or has in its employ, a licensee.

d. Demonstrate proof of ability to meet the liability requirements of Section 1411(4) of the Kansas Weather Modification Act. This proof may be provided in the form of an insurance policy written by a company authorized to do business in Kansas or by a statement of individual worth which is satisfactory to the Director.

e. Submit a complete and satisfactory operational plan for the proposed weather modification project, which includes :

(1) A map of the proposed operating area which specifies the primary target area and shows the area reasonably expected to be affected.

(2) The name and address of the licensee.

(3) The nature and object of the intended weather modification activities.

(4) The meteorological criteria to be used to initiate or suspend modification activities.

- (5) The person or organization on whose behalf it is to be conducted.
- (6) A statement showing any expected effect upon the environment.
- (7) The methods that will be used in determining and evaluating the proposed weather modification project.

(8) Such other information as may be required by the Director.

f. Publish a "notice of intent" to engage in weather modification activities in each county of which all or part may be within the primary target area or within the areas reasonably expected to be affected, at least seven (7) days prior to the required public hearing. The time and place of the public hearing must be approved by the Director. The "notice of intent" shall include notice in a newspaper or newspapers of general circulation in the area. In addition, the use of radio and television spot announcements is encouraged. The notice shall:

- (1) Describe the primary target area.
- (2) Describe the area which might reasonably be affected.
- (3) Specify the period of operation including starting and ending dates, which operation need not be continuous.
- (4) Describe the general method of operation.
- (5) Describe the intended effect of the operation.
- (6) State the time and place of a public hearing on the application; the hearing to be in or near the primary target area.

(7) State that complete details of the application for a permit will be available for examination in the office of the Water Resources Board in Topeka and at a location within the project area as described in the public hearing notice.

g. Provide satisfactory evidence of publication of the "notice of intent" to the Director prior to the public hearing.

6. At the discretion of the Director, additional information may be required of the applicant. The additional information required may include a comprehensive environmental impact analysis similar to the statements required for federal projects.

7. Any permit issued for a weather modification activity shall be subject to revision, suspension, or modification of its terms and conditions by the Director, if necessary to protect the health, safety, or property of any person or to protect the environment. K.S.A. 1974 Supp. 82a-1403

98-4-5 EVALUATION OF PERMIT APPLICATION

Permit applications will be evaluated based on the following considerations:

1. The project can reasonably be expected to benefit the residents of the primary target area or an important segment of the state's population.

2. The testimony and information presented at the public hearing is generally favorable to the proposed activity.

3. Economic, social, or research benefits are expected:

a. If the application is for a commercial project, the project is scientifically and technically feasible.

b. If the application is for a scientific or research project, it offers promise of expanding the knowledge and technology of weather modification.

4. The applicant has provided adequate safeguards against potentially hazardous effects to health, property, or environment and has outlined a program for the implementation of these safeguards.

5. The proposed project will not have any detrimental effect on the previously authorized weather modification projects.

6. The project is to be under the personal direction, on a day-to-day basis, of an individual who holds a valid license, issued under the Kansas Weather Modification Act. K.S.A. 1974 Supp. 82a-1403

98-4-6 REPORTS

1. The permit holder will maintain at his project office a current (within 24 hours) log of all operations. This log must be available for inspection by persons

so authorized by the Director. The log will include information at least equivalent to that on Form KWM No. 3. (Copy attached)

2. Reports of weather modification activities under the permit will be made monthly to the Director for each calendar month for which the permit is valid. These should be submitted by the 15th day of the following month. Copies of all entries made on Weather Modification Form KWM No. 3 shall be submitted when making these reports unless a more detailed form is agreed to at the time the permit is granted.

3.-A preliminary report shall be made within thirty (30) days after the end of each calendar year or within thirty (30) days after the end of the project, whichever comes first, with a final report on the project submitted not later than ninety (90) days following the end of the project. These reports shall include:

a. Monthly and project period totals for information required on Form KWM No. 3.

b. The permit holder's interpretation of project effects as compared to those anticipated in the original application for the permit. K.S.A. 1974 Supp. 82a-1403

98-4-7 PROCEDURE FOR GRANTING EMERGENCY PERMITS

1. A permit may be granted on an emergency basis through the waiving of regular rules of procedure when evidence is presented that clearly identifies the situation as an emergency as defined in 98-4-2(3).

2. Upon presentation of evidence satisfactory to the Director that a condition exists or may reasonably be expected to exist in the very near future that may be alleviated or overcome by weather modification activities, the Director shall issue a permit to an individual holding a license issued under this Act. Coincident with the issuance of the permit, the Director shall also release to the news media in the area intended to be affected, the information contained in the permit.

3. Within ten (10) days after the granting of an emergency permit, and if the permittee desires to continue his activities, the Director shall set a date for a public hearing and the permittee will provide public notice of such hearing through the regular news media in the area. At the public meeting, the permittee shall describe:

- a. The objectives of the emergency action.
- b. The success to date.
- c. His future plans under the permit.

On the basis of the information presented at this public hearing and the response of the local people, the Director will then decide whether to revoke the emergency permit, modify it, or permit its continued operation under conditions specified by the Director. K.S.A. 1974 Supp. 82a-1403

98-4-8 PROCEDURE FOR SUSPENSION OR REVOCATION OF PERMITS

1. *Automatic Suspension of Permit.*—Any weather modification permit issued under the terms of the Kansas Weather Modification Act will be suspended automatically if the licensee's weather modification license expires or if the person designated as being in control of the project becomes incapacitated or leaves the employment of the permit holder and a replacement approved by the Board is not on the job site. A permit which is suspended for these reasons may be reinstated by the Board following renewal of the expired license or submission of an amended personnel statement nominating a person whose qualifications for a license are acceptable to the Board.

2. *Emergency Suspension of a Permit.*—When an emergency exists or appears imminent, or the Director has been notified of a probable impending emergency, he may order the immediate suspension of all weather modification operations within the area affected by such condition. This notification shall be given in the most expeditious manner. If the telephone is used to give this notice, it is to be followed promptly by a letter of particulars addressed to the permit holder and stating the time and place for holding a hearing on the question of taking permanent action on the permit if the Director determines such a hearing is necessary or desirable. Whether or not the permit is reinstated by the Director, and when such reinstatement may take place, will depend upon the conditions that develop within the permit area or when the requirements of the Director are met. Failure of the licensee to notify the Director of an existing or impending

emergency, which should have reasonably been foreseen may be grounds for revocation of the permit and the operator's license. K.S.A. 1974 Supp. 82a-1403

98-4-9 PROCEDURE FOR SUSPENSION OR REVOCATION OF LICENSES

1. The Board may suspend or revoke any existing license for the following reasons:

a. The licensee is found not to possess the qualifications necessary to meet the requirements of the law.

b. The licensee has violated one or more of the provisions of his license, the Kansas Weather Modification Act, or these rules.

c. It has reason to believe that the weather modification efforts of the licensee may produce undesirable effects.

2. When the Director has reason to believe that a condition exists which would be a basis for the suspension or revocation of a license, he shall so inform the Board with a recommendation for suspension or revocation. If the Board determines that the situation requires a hearing, the Director shall, at least thirty (30) days prior to the meeting of the Board at which the matter will be considered, notify the licensee and any other interested party of the pending Board action. The hearing shall be conducted as provided for in the Kansas Weather Modification Act.

The notice to the licensee shall include:

a. The Director's recommendation to the Board;

b. The reasons for the Director's recommendation; and

c. The time and place of the Board meeting at which the matter will be heard. The licensee or any other interested party may attend the Board meeting at which the Board will make its determination and may present relevant evidence to the Board concerning the revocation or suspension. K.S.A. 1974 Supp. 82a-1403

98-4-10 FIELD OPERATIONS

1. As provided under section 98-4-5, paragraph 6, there shall be the license holder or a substitute approved by the Director on duty at the project site at all times while weather modification activities are being carried out.

2. In order to supply local guidance to each weather modification project, the permit holder may seek the advice and assistance of concerned citizens within the area affected by weather modification activity. This group, which may be selected at the time of the public hearing, must be approved by the Director. This local advisory group may:

a. Assist in developing the operational plan;

b. Assist in financial arrangements; and

c. Assist the Director in the evaluation of the project.

3. The permit holder shall not conduct activities outside the limits stated in the operational plan (98-4-4(5e)). Activities planned for periods of severe weather shall be stated in the permit application and identified at the public hearing on the application for a permit. K.S.A. 1974 Supp. 82a-1403

KANSAS WATER RESOURCES BOARD FORM KWM No. 1

APPLICATION FOR LICENSE TO ENGAGE IN WEATHER MODIFICATION ACTIVITY
WITHIN THE STATE OF KANSAS

1. Name of applicant _____

2. Business address _____

3. Applicant intends to do business on an (individual, partnership, consultant, employee, corporation, other).

4. Print below the *full* name and address of all personnel to be engaged in weather modification activities who may be in control and in charge of activities for applicant.

Full Name
(Do not use initials)

Residence or Business Address

5. Has any person listed under "Personnel" been denied a license to conduct a license suspended or revoked? _____ If so, attach a detailed statement, or participate in weather modification activities in Kansas or elsewhere, or had

6. Give the name, education, experience, and qualifications of the person or persons who may be in control and in charge of weather modification activities. (If more than one, attach additional sheets).

NAME: _____

	Course of study (major)	Years or semester hours				Graduated (yes or no) and year of graduation
		1	2	3	4	
Junior College						
College or university						
University graduate study		1	2			(Degree)
Certificates of professional or vocational competence or license						(Degree)
Membership status in professional or technical associations						

EXPERIENCE IN WEATHER MODIFICATION OPERATIONS, EXPERIMENTS, OR PLANNING

[Begin with most recent experience]

From		To		Occupations and descriptions of duties (list each position separately)	Employers (name, address, and type of business)
Month	Year	Month	Year		

7. Special education and experience qualifications (publications, reports, awards).

8. Specific type(s) of weather modification activity(ies) which applicant wishes to be licensed to perform (fog dispersal, hail suppression, rain augmentation, etc.).

I certify that the information contained in this application is correct to the best of my knowledge.

Signature _____ Date _____

Subscribed and sworn to or affirmed before me—

This _____ day of _____ 19 _____

Title _____

Notary Public in and for the County of _____, State of _____

FORM KWM No. 2

APPLICATION FOR A PERMIT TO ENGAGE IN A WEATHER MODIFICATION ACTIVITY
WITHIN THE STATE OF KANSAS

1. Name of applicant _____

2. Business address _____

3. Person(s) who will be in control and in charge of activity.

4. Kansas Weather Modification License Number(s)

5. Does applicant wish to be considered exempt from fee requirements of the Kansas Weather Modification Act (K.S.A. 82a-1406(b)).

If so, give justification.

6. Primary purpose(s) of the weather modification activity to be conducted under the permit:

7. Person(s) or organization on whose behalf the proposed weather modification activity is to be conducted:

8. In accordance with the requirements, of K.S.A. 82a-1411(a) and the rules and regulations applicable thereto, the following attachments are submitted with this application:

(a) Permit fee in the form of _____

(b) Proof of financial responsibility in the form of _____

(c) Proposed operational plan _____

(d) Proposed Notice of Intent to engage in weather modification activities.

A. A separate seeding event, requiring entries in all appropriate columns, shall be logged whenever:

- (a) The cloud or cloud system being modified can reasonably be considered unaffected by previous release of seeding agents (Col. 2).
- (b) The time since the last release of seeding agent exceeds one hour (Col. 3 and 4).
- (c) The type of seeding agent used, or its rate of application, is changed (Col. 6 and 7).
- (d) The cloud form being seeded changes (Col. 9-12).

B. Explanation of column entries.

Col. (1): Give date by calendar month and day.

Col. (2): Give aircraft position or location of ground-based equipment. Aircraft position may use VOR-DME or be given in miles (10 statute miles or less) from nearby towns or landmarks. (e.g. 7 miles SSE of Tribune).

Col. (3 and 4): State local time when modification activity began and ended. Use 24-hour clock time (e.g., 0100 signifies 1:00 A.M. and 2300 signifies 11:00 P.M.). For intermittent operations, the start and end of the total sequence are acceptable.

Col. (5): Give duration of operation of each unit of weather modification apparatus, in hours and minutes. (Col. 5=Col. 4—Col. 3).

Col. (6): Describe seeding agent used, such as silver iodide pyrotechnic flares, silver iodide in acetone solution, sodium chloride, liquid urea, dry ice, etc.

Col. (7): Give rate of dispersal of seeding agent in gm./min., lbs./min, or other appropriate units.

Col. (8): Give total amount of seeding agent used.

Col. (9-12): Identify the predominant cloud or precipitation type being modified, such as snow or rain from stratiform clouds, rain or hail from cumuliform clouds, etc.

C. On the daily log sheet for the last day of each month, give monthly totals for Columns (2, 5, 8, and 9-12).

NORTH DAKOTA

NORTH DAKOTA WEATHER MODIFICATION BOARD

RULES AND REGULATIONS RELATING TO WEATHER MODIFICATION OPERATIONS AND RULES OF PRACTICE AND PROCEDURE PERTAINING TO HEARINGS BEFORE THE BOARD

(Adopted on July 1, 1976, North Dakota Century Code Chapter 2-07—Weather Modification)

STATE OF NORTH DAKOTA,
Bismarck, N. Dak., May 18, 1976.

Mr. MARTIN R. SHOCK,
Director, North Dakota Weather Modification Board, Bismarck, N.D.

DEAR MR. SHOCK: We have examined the proposed regulations titled "Rules and Regulations of the North Dakota Weather Modification Board" and "Rules of Practice and Procedure Before the North Dakota Weather Modification Board" which you submitted to this office by your letter of April 30, 1976. From our examination, it is our opinion that when they have been duly adopted by the Weather Modification Board, and filed in accordance with Chapter 28-32 of the North Dakota Century Code, they will be valid and binding regulations having the force and effect of law.

Sincerely,

ALLEN I. OLSON,
Attorney General.

RULES AND REGULATIONS OF THE NORTH DAKOTA WEATHER MODIFICATION BOARD

R2-07-01 GENERAL PROVISIONS

01.100 Scope: These regulations are promulgated pursuant to Chapter 2-07 of the North Dakota Century Code and shall apply to any weather modification operation conducted wholly or partially within the state of North Dakota. These regulations shall be applied in conjunction with Chapter 2-07.

01.200 Definitions: As used in these regulations, the following words shall have the meaning given to them below unless otherwise made inappropriate by use and context. Words not defined in this section shall have the meaning given to them in Chapter 2-07.

01.201 "Act" shall mean Chapter 2-07 of the North Dakota Century Code.

01.202 "Applicant" shall mean any person who applies for a professional weather modification license pursuant to the provisions of the Act and these regulations.

01.203 "Board" shall mean the North Dakota Weather Modification Board.

01.204 "Director" shall mean the Executive Director of the North Dakota Weather Modification Board.

01.205 "License" shall mean a weather modification license issued under these regulations and Section 2-07-03.3 of the Act.

01.206 "Licensee" shall mean a person to whom a license has been issued.

01.207 "Permit" shall mean a weather modification permit issued under these regulations and Section 2-07-04 of the Act.

01.208 "Permittee" shall mean a person to whom a permit has been issued.

01.209 "Operations area" shall mean an area in which weather modification operations are conducted.

01.210 "Target area" shall mean an area in which the effects of weather modification are desired.

01.211 "Weather modification apparatus" shall mean any device used to disperse any chemical material used to modify any weather condition.

01.300 Administration: Except as otherwise provided in Sections 05.204 and 10.203 of these regulations, the powers and duties of the Board shall be exercised by the Director and such other persons as he may direct.

R2-07-02 EXEMPT ACTIVITIES

02.100 Notice to Board: Any person intending to conduct any exempt activities under the provisions of Section 2-07-03.1 of the Act shall furnish notice of such intention to the Board at least thirty (30) days prior to the time such activities are to begin. Notice shall consist of the following information and such other information as the Board deems necessary.

02.101 Name and address of the person giving notice;

02.202 Name and address of the person who will conduct the activity;

02.203 A description of the procedures to be used in the operation or the research and development;

02.204 A description of the object of the activity;

02.205 The legal description of, and a map showing the area of, the operations area and target area, if any;

02.206 The date upon which the activity is to commence and its approximate duration; and

02.207 A description of the equipment to be used in conducting the activity.

02.208 Approval of Exempt Activities: No weather modification activity intended to be conducted pursuant to the provisions of Section 2-07-03.1 of the Act shall be commenced without prior approval of the Board if such activity is to be conducted in the out-of-doors with weather modification apparatus. The Board may approve only those activities which provide for the protection of the health, safety and welfare of those persons who may be affected by such activities, and which otherwise comply with the provisions of Section 2-07-03.1.

R2-07-03 ACQUISITION OF LICENSE

03.100 License Required: Every person intending to conduct operations in this state shall designate to the Board, on forms furnished by the Board, at least one natural person who shall at all times be physically present during all operations for which a permit is required and who will be in control of such operations.

03.200 Criteria for Issuance: The competence of any applicant to engage in weather modification operations shall be demonstrated to the Board pursuant to Section 2-07-03.3 of the Act upon the showing that the natural person designated by the applicant pursuant to Section 03.100 has:

03.201 A minimum of one year of field experience in the management and control of weather modification operations or research; and

03.202 One of the following requirements:

(1) Four additional years experience in weather modification operations or research; or

(2) A degree in mathematics, engineering, or the physical sciences, plus two years additional experience in weather modification operations or research; or

(3) A degree in meteorology; or a degree in engineering, mathematics, or the physical sciences which includes at least twenty-five semester hours of course work in meteorology.

In determining competency, the Board may also consider any other items to be set forth in a license application pursuant to Section 03.300.

03.300 Application Procedure: An applicant for a license shall apply to the Board on forms supplied by the Board. The forms may require relevant information about the knowledge and experience of the applicant and the natural person designated under Section 03.100, and shall include the following:

03.301 Educational background, at the college and graduate level of both the natural person designated by the applicant and the other employees of the applicant. This includes the dates of attendance and of graduation, the major and minor subjects (including the number of semester hours of meteorological course work), the degrees received, and the titles of any thesis and/or dissertation.

03.302 Experience in weather modification or related activities of both the natural person designated by the applicant and the other employees of the applicant. Attention should be given to experience with reference to meteorological conditions typical of North Dakota. The applicant should list the dates of each position held by the natural person designated pursuant to Section 03.100, the title of the position (indicate whether it was of subprofessional or professional level), the name and address of the employer, a description of the work done (indicate both the magnitude and complexity of the work and the duties and degree of responsibility for the work), and the name and address of the supervisor.

03.303 Scientific or engineering society affiliations of the natural person designated by the applicant and the grade of membership in and certification by each.

03.304 Publications, patents and reports of the natural person designated by the applicant.

03.305 Three references who will attest to such natural person's character, knowledge and experience.

03.306 A list of all jurisdictions in which the applicant has previously filed application for a professional weather modification license. The results of the applications should be indicated.

03.307 Indication whether a professional weather modification license issued to the applicant in any jurisdiction has ever been suspended or revoked or whether there has been refusal to renew such a license by any jurisdiction. If the answer is yes, the circumstances must be explained in detail.

03.400 Procedure for Issuance: The Board shall evaluate the applications, including responses from any references given by the applicant. On the basis of all such information the Board shall, within thirty days of receipt of an application, determine whether the natural person designated by the license applicant under Section 03.100 meets the education and experience criteria established by subsections 03.201 and 03.202 and whether such person and the applicant possess the knowledge and experience necessary to engage in weather modification operations and shall issue a license to the applicant who satisfies the requirements of these regulations and Section 2-07-03.3 of the Act. If an applicant for a license or the natural person designated by the applicant do not satisfy any of such requirements, the Board shall deny the license.

03.500 Renewal of License: Forty-five days before expiration of licenses, the Board shall mail license application forms to all licensees and request each licensee to complete the form and file the original with the Board. The Board shall evaluate the available data about the licensee and the natural person designated by the license applicant under Section 03.100 and shall issue a renewal license within thirty days of receipt of the application to each applicant who pays the license fee established by Section 2-07-03.3(1) of the Act and who has the qualifications necessary for issuance of an original license. The Board shall deny a renewal license within thirty days of receipt of the application of each applicant who does not pay the renewal fee or who does not possess the qualifications necessary for issuance of an original license or who does not designate a natural person, pursuant to Section 03.100, who satisfies the requirements of Section 03.200.

03.600 Responsibility of Controller: The natural person designated by the license applicant under Section 03.100 is deemed by the Board to be in control of and primarily responsible for operations conducted under the terms of any permit. However nothing in this section shall be construed to prevent appropriate enforcement of any regulation, limitation, permit condition, or order against either the permittee, or licensee, whether or not such licensee is a natural person.

R2-0704 LICENSES-SUSPENSION, REVOCATION AND RESTORATION

04.100 Suspension, Revocation, Refusal to Renew a License: The Board may suspend, revoke or refuse to renew a license for any one or any combination of the following reasons:

- 04.101 Incompetency;
- 04.102 Dishonest practice;
- 04.103 False or fraudulent representation in obtaining a license or permit under the Act or these Rules;
- 04.104 Failure to comply with any of the provisions of the Act or of these Rules; and
- 04.105 Violation of any permit or permit condition.

04.200 Restoration of License: At any time after the suspension or revocation of a license or after refusal to renew a license the Board may restore it to the licensee or renew it upon a finding that the requirements for issuance of an original license have been met by the licensee.

R2-07-05 PERMITS—APPLICATION, CRITERIA, ISSUANCE

05.100 Application for Permit: Application for a weather modification permit shall be made on forms furnished by the Board. A properly executed application shall be submitted to the Board by every applicant. The application may contain such information as the Board deems necessary, and shall include the following information:

- 05.101 Name and address of the applicant;
- 05.102 Whether a weather modification operational permit issued to the applicant in any jurisdiction has ever been suspended or revoked or whether there has been refusal to renew such a permit by any jurisdiction. If the answer is yes, the circumstances must be explained in detail;
- 05.103 If the applicant is a corporation, whether it is licensed to do business in North Dakota;
- 05.104 Whether a license has been issued under Section 2-07-03.3 of the Act, and if so, the names, addresses and professional license numbers of the controller(s);
- 05.105 Whether professional weather modification licenses issued to such licensee(s) in any jurisdiction have ever been suspended or revoked or whether there has been refusal to renew such license(s) by any jurisdiction. If the answer is yes, the circumstances must be explained in detail;
- 05.106 Whether proof of financial responsibility has been furnished in accordance with Section 2-07-04-3 of the Act and regulation R2-07-08;
- 05.107 If the operation will be conducted under a contract, the value of the contract;
- 05.108 If the operation will not be conducted under a contract, an estimate of the costs of the operation and information as to how the estimate was made;
- 05.109 Whether the applicant has paid the application fee;
- 05.110 Whether the applicant has North Dakota workmen's compensation coverage;
- 05.111 A copy of any promotional and advertising material used in connection with negotiations for the contract (if any);
- 05.112 Whether the applicant has furnished a performance bond, as required by subsection 10.204 of these rules;
- 05.113 Whether the applicant has furnished a bid bond, as required by Section 2-07-09.1 of the Act;
- 05.114 Whether the applicant has registered all pilots and aircraft to be used in the operation for which the permit is sought with the North Dakota Aeronautics Commission.
- 05.115 A complete and detailed operational plan for the operation which includes:
 - (1) The nature and object of the operation;
 - (2) The legal descriptions of, and a map showing the operations area, and the target area;

(3) The approximate starting date of the operation and its anticipated duration;

(4) The kind of seeding agent(s) intended for use and the anticipated rate of their use;

(5) A list of equipment which will be used and the method(s) of seeding for which they will be used;

(6) An emergency shutdown procedure which states conditions under which operations will be suspended because of possible danger to the public health, safety and welfare or to the environment;

(7) The means by which the operation plans will be implemented and carried out; such as the location of the main operational office and any other offices used in connection with the operation, the location of such ground equipment as seeding generators, radar and evaluation instrumentation, the number and kinds of aircraft which will be used and the extent to which weather data will be made available to the licensees and other personnel carrying out the project; and

(8) How conduct of the operation will interact with or affect other weather modification operations.

05.116 The application shall show an acceptable plan for evaluation of the operation by the use of surface data reasonably available to the applicant.

05.117 Such additional information as will assist the Board in deciding whether or not to issue the permit.

05.200 Procedure for issuance:

05.201 Notice: The Board shall give notice of its consideration of an application in accordance with Section 2-07-04.1 of the Act. Notice shall be given once a week for two consecutive weeks. The notice shall:

(1) Describe the primary target area.

(2) Describe the operations area.

(3) Specify the period of operation including starting and ending dates.

(4) Describe the general method of operation.

(5) Describe the intended effect of the operation.

(6) State the name of the proposed permittee.

05.202 Hearings: The Board shall allow twenty days for public comment, in accordance with Section 2-07-04.1 of the Act, from the date of the last publication of the notice. Any hearing held upon objection received by the Board or any hearing held upon the Board's own motion shall be held upon at least ten days notice in the county newspaper in which notice of consideration of the application was published. At any such hearing, the Board shall make a brief record of the testimony received, and shall consider all such testimony in its decision on the permit application.

05.203 Director's Recommendation: At the close of the public comment period provided for in Section 2-07-04.1 of the Act, the Director of Weather Modification Board shall review all applications for permits which have been received and shall recommend approval or disapproval of such applications and the reasons therefor.

05.204 Final Action by Board: The Board shall take final action on all applications for permits for which notice of consideration was published, pursuant to Section 2-07-04.1 of the Act within 45 days of the close of the public comment period. Approval of applications considered shall be by majority vote. In acting on any such applications, the Board shall consider any recommendations made by the Director of the Board and all testimony received at any hearing pursuant to Section 2-07-04.1 of the Act. The Board may issue a permit only if it determines that the requirements of Section 2-07-04(2) of the Act have been met.

R2-07-06 PERMITS—FORM, CONDITIONS, EXPIRATION

06.100 Permit form: Each permit shall set forth the permit number, effective period of the permit, name of the permittee, the name of the licensee and the license number, the location of the operation, and such other information, terms or conditions as the Board shall deem appropriate.

06.200 Permit conditions: The Board may attach to any permit such conditions as it may deem appropriate, including any conditions concerning method and time of operation, target and operation areas, safety precautions and record keeping. The Operations Manual for Hail Decrease and Precipitation increase is hereby made a condition of all permits issued and all permits shall be subject thereto. Violation of any permit or any permit condition may result in permit revocation or suspension or other appropriate enforcement action by the Board.

06.300 Permit expiration: All permits shall expire in accordance with Section 2-07-04 of the Act and shall not be renewable.

R2-07-07 PERMITS—SUSPENSION, REVOCATION, MODIFICATION AND RESTORATION

07.100 Suspension, Revocation, Modification: The Board may suspend, revoke, or modify any permit or any provision or condition of a permit if it appears to the Board that the permittee no longer has the qualifications necessary for the issuance of an original permit or has violated any provisions of the Act, the terms or conditions of any permit, or any of these regulations. Any provisions or conditions of a permit may be revised in accordance with the provisions of Section 2-07-04.2 of the Act.

07.200 Automatic Suspension of Permit: Any permit issued to any person under these regulations shall be suspended automatically if such person's weather modification license expires or is suspended, revoked or not renewed by the Board. Automatic suspension shall result in the case of a permit issued to a corporation, partnership, or other business association, if the natural person designated as being in control of the operation in such business association's application for a weather modification license becomes incapacitated, leaves his employment, or is in any way unable to continue in control of the operation. A permit of a business association suspended under such circumstances may be reinstated by the nomination of replacement personnel in accordance with Section 03.100 of these regulations.

07.300 Restoration of Permit: At any time after the suspension, revocation or modification of a permit the Board may restore it to the permittee, or delete any modification thereof, upon a finding that the requirements for issuance of an original permit have been met by the permittee, or that the conditions requiring modification no longer exist.

R2-07-08 PROOF OF FINANCIAL RESPONSIBILITY

Proof of financial responsibility is made by showing to the satisfaction of the Board that the permittee has the ability to respond in damages to liability which might reasonably result from the operation for which the permit is sought. Such proof of financial responsibility may be shown by:

08.100 Presentation to the Board of, or proof of purchase of, a prepaid non-cancellable insurance policy or a corporate surety bond issued by a company against whom service of legal process may be made in North Dakota against such liabilities in an amount five times the value of an operation conducted under contract or in an amount five times the estimated costs of an operation not conducted under contract; or

08.200 Depositing with the Board cash or negotiable securities in an amount five times the value of an operation conducted under contract or in an amount five times the estimated costs of an operation not conducted under contract.

08.300 Any other manner approved by the Board.

R2-07-09 RECORD KEEPING AND REPORTS

09.100 Records:

09.101 Daily Log: Each permittee shall fill in and retain a daily log of weather modification activities for each unit of weather modification apparatus used during an operation. Such log shall include a record of the following information for each day of weather modification operations.

(1) Date of the weather modification activity;

(2) Each aircraft flight track and location of each radar unit during each modification mission. Maps may be used;

(3) Local time when modification activity began and ended. For intermittent operations, the beginning and ending time of the total sequence are acceptable;

(4) Duration of operation of each unit of weather modification apparatus, in hours and minutes;

(5) Description of type of modification agent(s) used;

(6) Rate of dispersal of agent during the period of actual operation of weather modification apparatus, by hour or other appropriate time period;

(7) Total amount of modification agent used. If more than one agent was used, report total for each type separately;

(8) Local time when any radar monitoring operations were turned on and turned off;

(9) Type of clouds modified; that is, whether they were stratiform, isolated cumuliform, organized cumuliform or other types of clouds;

(10) Remarks indicating such operational problem as equipment failure, weather conditions not conducive to successful performance of the operation, personnel problems and the like.

09.102 Monthly Totals: Monthly Totals shall be kept on the basis of the daily logs, listing the total:

- (1) Days during month in which operation conducted;
- (2) Time of operation;
- (3) Amount of each kind of agent used;
- (4) Average rate of dispersal of each kind of agent used;
- (5) Days of each type of cloud treated; and
- (6) Duration of operation of each unit of weather modification apparatus, in hours and minutes.

09.103 Weather Records

Each permittee shall obtain and retain copies of all daily precipitation total records available from the National Weather Service stations for the target area.

09.104 Addresses of Participants

Each permittee must keep a roster of the names and North Dakota addresses of all employees participating in the state on an operation for which a permit has been issued.

09.105 Inspection

Duly authorized agents of the Board shall have the authority to enter and inspect any equipment and to inspect any records required by this regulation and to make copies thereof.

09.106 Exempted Weather Modification Activities

All persons conducting weather modification activities exempted by the Board under the provisions of Section 2-07-03.1 of the Act shall record and maintain all of the records required of any permittee by this regulation.

09.200 Reports:

09.201 Monthly: Within ten days after the conclusion of each calendar month, each permittee shall submit a written report to the Board which shall include:

- (1) A copy of the summary record prepared under 09.102;
- (2) A copy of the roster of the names and North Dakota addresses of all employees participating in state operations which were prepared under 09.104;
- (3) A copy of the federal interim activity report form filed for that month with the National Oceanic and Atmospheric Administration in accordance with the rules adopted under the authority of Public Law 92-205; and
- (4) A narrative account of the manner in which operations during the month did not conform to the operational plan filed in accordance with 05.101(15).

09.202 Final: Within thirty days after final completion of any operation, each permittee shall file with the Board a final report on the operation which shall include:

- (1) Copies of the logs prepared in accordance with 09.101, copies of the weather records obtained in accordance with 09.103 and, copies of the totals for the entire operational period from the monthly summary records prepared under 09.102;
- (2) A copy of the federal final activity report form filed with the National Oceanic and Atmospheric Administration in accordance with the rules adopted under the authority of Public Law 92-205; and
- (3) A narrative account of the manner in which the operation did not conform to the operational plan filed in accordance with 05.101(15).

09.203 Evaluation: Within sixty days after completion of any operation for which a permit was issued, each permittee shall file with the Board a narrative evaluation of the operation. The data for this report shall be assembled and evaluated in accordance with the evaluation plan prepared in compliance with 05.101(16).

09.204 Exempted Weather Modification Activities: The Board may, in its discretion, require persons operating weather modification activities exempted under R2-07-02 but who have been required to keep records pursuant to this regulation, to file all or any part of such records with the Board.

10.100 Bid Procedure :

10.101 Advertisement and Request for Bid: (1) In all cases where the Board shall undertake to contract for services, supplies, or materials, the estimated cost of which shall exceed \$10,000 for any one contract, the Board shall advertise for bids for such services, supplies, or materials. Such advertisement shall be placed for three consecutive weeks in the official newspaper of the county in which the Board's offices are located and in at least one official newspaper in general circulation in the state. In the case of contracts for weather modification operations, such advertisement shall also be placed in some trade publication of general circulation among those groups most likely to bid on the contract. The advertisement shall state :

(a) That any prospective bidders may secure such contract specifications and requirements as may be available by applying in writing to the offices of the Board.

(b) The place where and the day and hour when the bids will be opened ;

(c) That the right of the Board to reject any and all bids is reserved ;

(d) Each bid shall be accompanied by a bidder's bond in a sum equal to five percent of the full amount of the bid, executed by the bidder as principal and by a surety company authorized to do business within this state, conditioned that if the bid be accepted and the contract awarded to him, he, within ten days notice of award, will execute and effect a contract in accordance with the terms of his bid and a contractor's bond in the manner specified by subsection 10.204.

(e) No bid will be read or considered which does not fully comply with the above provisions concerning bonding and no contract will be awarded to any person who has not complied with any applicable licensing requirements of the Board.

(2) In the case of contracts for weather modification operations, the Board may, in addition to the requirements of subsection 10.101(1), prepare a request for bid in which it shall describe the minimum requirements for aircraft, radar, communications and other equipment, operational and such other requirements as it may deem necessary. Such request for bid shall include those items of information specified in subdivisions (b) through (e) of subsection 10.101(1). The request may be sent by the Board to those persons having a recognized interest in operations contracts.

10.102 Opening of Bids: At the time and place designated in the request for bids, the Board shall conduct a public hearing at which it shall open all bids received. After opening each bid, the Board shall determine whether such bid meets the minimum requirements set forth in the Act, these regulations, and the request for bid, and then read aloud each bid meeting such minimum requirements. Bids which do not meet such minimum requirements shall not be read or considered.

10.200 Award of contracts :

10.201 Deviation from technical requirements: Any or all bids may be rejected by the Board on the basis of technical inadequacy or other failure to comply with the specifications included in the request for bids. Bids which are technically adequate but which show price quotations beyond the budget restrictions may be negotiated with the Director for reduction in equipment and/or services either required by, or bid over and above the requirements of, the request for bid. All such negotiations shall be conducted at the discretion of the Board.

10.202 Point scoring system to be used: Bidders for weather modification operation contracts shall be evaluated on the basis of the amount of the bid submitted and a system of points allotted to each bidder for evaluation criteria established by the Board. Sole authority for establishment of point values and scoring shall rest with the Director. Point scores assigned shall be final and non-negotiable. Previous experience and performance shall be a criteria to be considered in scoring each bidder. The bidder scoring the lowest cost per point shall be awarded the contracts in accordance with subsection 10.203.

10.203 Low bid-preference for North Dakota bidders: In awarding any contract, the Board shall award it to the lowest and best bidder, and shall, if all other factors are equal, give that preference for North Dakota bidders established by Section 44-08-01 of the North Dakota Century Code.

10.204 Contractor's bond: Before the Board shall award any contract, it shall require the contractor to furnish a surety bond for the faithful performance of the

contract in the amount of twenty-five percent of the contract price, conditioned that the contractor and his agents will, in all respects, faithfully perform all weather modification contracts undertaken with the Board and will comply with all provisions of the Act, these regulations, and the contract entered into by the Board and the contractor.

RULES OF PRACTICE AND PROCEDURE BEFORE THE NORTH DAKOTA WEATHER MODIFICATION BOARD

228-32-01 GENERAL PROVISIONS

01.100 **Scope:** The provisions of these regulations shall apply to all hearings held by the Board for the purposes of adjudicating the rights of parties under Chapter 2-07 of the North Dakota Century Code. These regulations shall provide procedures in addition to or in explanation of those procedures provided by such chapter and Chapter 28-32.

01.200 **Liberal Construction:** These regulations shall be liberally construed in order to secure just, speedy, and inexpensive determination of the issues presented.

01.300 **Suspension of Rules:** The Board or any hearing officer shall have the right, upon either its own motion or the motion of any party, to suspend the operation and effect of these regulations or any portion thereof, whenever the public interest or the interests of any party to a proceeding shall not be substantially prejudiced by such suspension.

01.400 **Definitions:** As used in these regulations, the following words shall have the meaning given to them below, unless otherwise made inappropriate by context.

01.401 "Board" shall mean the North Dakota Weather Modification Board.

01.402 "Hearing Officer" or "Officer" shall mean the person appointed by the Board to call and conduct a hearing.

01.403 "License" means a professional weather modification license issued under the provisions of Chapter 2-07.

01.404 "Order" shall mean any written command or direction made by the Board as provided by law.

01.405 "Person" shall mean any real person, county, municipality or other political subdivision, department, agency or commission, any public or private corporation, any partnership, association or other organization, any receiver, trustee, assignee, or other legal entity, other than a court of law, or other legal representative of the foregoing but does not include the Board.

01.406 "Permit" means a weather modification permit issued under the provisions of Chapter 2-07.

01.500 **Case Numbers and Title:** Each matter coming formally before the Board for hearing will be known as a case and shall be given a docket number and title, descriptive of the subject matter. Such number and title shall be used on all papers in the case, and as far as possible, any communication to the Board in any particular case shall bear the number of said case.

01.600 **Personal Appearances:** Participants may appear in any proceeding in person or by an attorney or other representative qualified under Section 01.703. An individual may appear in his own behalf, a member of a partnership may represent the partnership, a bona fide officer or duly authorized employee of a corporation, association or group, and an officer or employee of a state agency, of a department or political subdivision of the state or other governmental authority, may represent the state agency or the department or the political subdivision of the state or other governmental authority in any proceeding.

01.700 **Practice Before the Board:**

01.701 **Person in own interest:** Any person may appear before the Board in his own right if he has a bona fide interest in the subject matter of the proceeding.

01.702 **Attorneys:** Attorneys at law who are admitted to practice before the courts of the state of North Dakota may represent any party to a proceeding. Any member of the bar of another state may be permitted by the Board to appear in and conduct a case or proceeding while retaining his residence in another state.

01.703 **Other Persons:** Any other person who shall file proof to the satisfaction of the Board that he is possessed of necessary legal or technical qualifications to enable him to render valuable service may be permitted to practice before the Board.

01.704 Rules of Conduct : All persons appearing before the Board must conform to the standards of ethical conduct required of practitioners before the courts of the state of North Dakota.

01.800 Parties :

01.801 Parties : Any person whose legal rights, duties, or privileges may be determined in the case for which the hearing may be held shall be a party. When a hearing is held pursuant to a request for a hearing, the person making the request shall be a party. The Board shall be a party in any action to enforce any regulation, statute, permit, condition, or order of the Board. Any person who has properly intervened in a case shall be a party.

01.802 Petitioner : Any person seeking reconsideration, as provided by law, of any administrative action taken pursuant to law and these regulations, shall be styled the petitioner.

01.803 Respondent : Any person against whom any complaint is filed or order issued under these regulations shall be styled the respondent.

01.804 Intervenor : Persons petitioning to intervene when admitted as a participant to a proceeding shall be styled intervenors. Admission as an intervenor shall not be construed as recognition by the Board that such intervenor might be aggrieved by any order of the Board in such proceeding.

01.805 Complainant : Persons who complain of any act or omission in violation of any statute, regulation or permit of the Board shall be styled complainants.

01.900 Investigation Upon the Board's Own Motion : The Board may at any time, upon its own motion, or upon the complaint of any person, institute investigations and order hearings in any thing done by any person which the Board may believe is in violation of the law or any order, regulation or permit of the Board. The Board may secure and present such evidence as it may consider necessary or desirable in any proceeding in addition to the evidence presented by any other party.

01.1000 Computation of Time :

01.1001 In determining the day upon which an answer must be served pursuant to Section 28-32-05, the day of the hearing and the last day upon which an answer may properly be received shall not be included in computing the required three-day time period. If the day upon which the answer is due falls on a Saturday, Sunday, or legal holiday, the answer shall be due on the preceding business day.

01.1002 In computing any period of time prescribed or allowed by these rules, other than that time period set out in subsection 01.1001, the day of the act, event, or default after which the designated period of time begins to run is not to be included. The last day of the period so computed is to be included, unless it is a Sunday or legal holiday, in which event the period runs until the end of the next day which is neither a Sunday nor a holiday. When the period of time prescribed or allowed is less than seven days, intermediate Sundays and holidays shall be excluded in the computation.

01.1100 Service : For the purposes of these Rules, service or filing shall be deemed to have occurred upon actual receipt of the document served or filed.

01.1200 Record : Unless any party demands otherwise at least ten days prior to the date of hearing, a written summary record or tape recording of the proceeding will be made and filed. If demanded, the Board shall cause a verbatim transcript to any proceedings to be made at the expense of the demanding parties. The time period required herein shall be computed, as nearly as practicable, by that method specified in Section 01.1001.

R28-32-02 PLEADINGS

02.100 Informal Complaint : Informal complaints may be made orally or in writing addressed to the Board. Letters of complaint to the Board will be considered as informal complaints. Matters thus presented will be handled by correspondence or by other informal communications, or by conference with the party or parties complained of, or by formal investigation instituted by the Board upon its own motion, or in such other manner as the Board shall deem to be appropriate and warranted by the facts and the nature of the complaint in an endeavor to bring about satisfaction of the complaint without formal hearing.

02.200 Formal Complaints :

02.201 Complaints shall be made by the Board on its own motion by complaint in writing, setting forth any act or thing done or omitted to be done in violation or claimed to be violation of any provision of law or of any order, rule, regulation, or permit of the Board.

02.202 Each formal complaint shall show the venue, "Before the North Dakota Board of Weather Modification" and shall contain a heading, "In the Matter of", showing the name and address of the respondent. The complaint shall be so drawn as to fully and completely advise the respondent or the Board of the facts constituting the ground of the complaint; the provisions of the statutes, regulations, orders, or permit relied upon; the injury complained of; and shall contain a clear, concise statement of the relief sought.

02.203 The Board shall serve a true copy of the complaint and notice for hearing upon the respondent personally, or by registered or certified mail, as the Board may direct, in such time as provided by law before the time specified for hearing thereof unless the service of such complaint or notice of hearing is waived, in writing, by the respondent, or unless the parties agree upon a definite time and place for hearing thereof with the consent of the Board; provided, however, that in case of an emergency, the Board shall notice a proceeding for hearing upon its merits as provided by law.

02.300 Order to Show Cause :

02.301 The Board may, by order, compel any person who it believes is violating any law, regulation, or order of the Board subject to enforcement by these regulations, or any person who has been granted a permit, to show cause why such law, regulation or order should not be enforced against such person or why such permit should not be suspended, revoked or modified, either in whole or in part.

02.302 An order to show cause shall specifically advise the respondent of the facts of the violation and law applicable thereto and of the time and place of the hearing to be conducted on the order.

02.303 If the Board finds that the respondent is committing or is about to commit an alleged violation, it may order the respondent to cease and desist from the acts constituting the violation. The Board may also, or in lieu thereof, enter any other just and reasonable order.

02.400 Petition for Hearing : Any petitioner requesting the Board to review by hearing, as provided by law, any Board action, rule, or regulation, shall file with the Board a petition, which may be in letter form, advising the Board of the facts constituting the grounds for the petition, the injury complained of and a clear and concise statement of the relief sought.

02.500 Answers :

02.501 Each answer filed with the Board shall be designated as an "answer" shall contain the correct title of the proceeding, and a specific denial of such material allegations of the complaint as are controverted by the respondent and also a statement of any new matter which may constitute a defense. If the answering party has no information or belief upon the subject sufficient to enable him to answer an allegation of the complaint, he may so state in his answer and place his denial upon that ground. The filing of an answer will not be deemed an admission of the sufficiency of the complaint.

02.502 An answer must be signed and verified by the respondent filing the same.

02.503 Two true and correct copies of the answer shall be served upon the Board personally or by registered mail, at least three days before the time specified in the complaint for hearing.

02.600 Response to Petition for Hearing :

02.601 Upon receiving a petition for hearing upon any matter, as provided by law, the Board shall, within thirty (30) days of such receipt, serve upon the petitioner, a response to the petition. Such response may be in letter form and shall state the decision of the Board whether or not to hold the requested hearing. If a hearing is granted, the response shall state the date upon which the petitioning party may appear to be heard, and such other conditions of the hearing as the Board may determine. If the requested hearing is denied, the reasons for such denial shall be clearly stated. This subsection shall not apply to hearings on emergency orders.

02.602 Upon receiving a petition for hearing pursuant to an emergency order, as provided by law, the Board shall set a date for hearing to be held within ten (10) days of receipt of such petition and shall notify the petitioner of such date and of such other conditions of the hearing as the Board shall determine.

02.700 Intervention : In any formal proceeding, any person having a substantial interest in the subject matter of such proceeding may petition for leave to intervene in such proceeding and may become a party thereto upon compliance with the provisions of this rule. In general, such petitions will not be granted unless it shall be found that such person has a statutory right to be made a party to such proceedings or that such person has a property, financial, or other legally-

recognizable interest which may not be adequately represented by existing parties, and such intervention would not unduly broaden the issues or delay the proceeding.

02.701 A petition for leave to intervene shall be in writing, unless made at the commencement of a hearing, and must set forth the grounds of the proposed intervention, the position and interest of the petitioner in the proceeding, and whether the petitioner's position is in support of or in opposition to the relief sought.

02.702 A written petition for leave to intervene in any proceeding may be filed prior to or at the commencement of the hearing, but not after commencement, except for good cause shown.

02.703. The petitioner shall furnish a copy of any written petition to each party to the proceeding, including the Board.

02.704 Admission as an intervenor shall not be construed as recognition by the Board that such intervenor might be aggrieved by any act of the Board in such proceeding.

02.800 Amendments: The Board, prior to any hearing, or the hearing officer during any hearing, may, after notice to the other parties to a proceeding, allow any pleading to be amended or corrected or any omission therein to be supplied, provided that if any such amendment, when allowed, so alters or broadens the issues that it appears proper, the Board may permit any party affected thereby a reasonable time to prepare to meet the changed issues.

02.900 Withdrawal of Pleading: A party desiring to withdraw a pleading filed with the Board may file a notice of withdrawal thereof with the Board. Such notice shall set forth the reason for the withdrawal. A copy of such withdrawal notice must be served upon all other parties to the proceeding and a certificate of service to that effect filed with the notice of withdrawal. Withdrawal of any pleading in any proceeding in which a hearing has been held or convened shall not be allowed without express permission of the Board.

02.1000 Motions: After a complaint or petition has been served, a request may be made by motion for any procedural or interlocutory ruling or relief proper and desired. All motions not made in the course of a hearing shall be in writing and shall be served on the other parties to the hearing by the moving party.

02.1001 The Board, prior or subsequent to any hearing, or the hearing officer during any hearing, may set any motion for oral argument.

02.1002 The hearing officer designated to preside at a hearing is authorized to rule upon any motion not formally acted upon by the Board prior to the commencement of the hearing, wherein the immediate ruling is essential in order to proceed with the hearing and upon any motion filed and made after the commencement thereof and prior to the decision in the proceedings; provided, however, that no motion made before or during a hearing, a ruling upon which would involve or constitute a final determination of the proceeding, shall be ruled upon by an examiner.

02.1003 Motions not ruled upon by the examiner shall be ruled upon by the Board.

02.1004 Appeals from rulings of the examiner on any motion may be taken as provided in 04.600.

R28-32-03 PRE-HEARING MATTERS

03.100 Informal Disposition: Informal disposition may be made of any case, or any issue therein, by stipulation, or consent order at any point therein, subject to the approval of such informal disposition, or any terms thereof, by the Board.

03.200 Prehearing Conference: A prehearing conference may be held at any time at the discretion of the Board or hearing officer prior to any hearing. The prehearing conference shall be an informal proceeding conducted fairly and expeditiously by the hearing officer, for purposes of identifying and simplifying the issues to be determined, identifying and limiting the number of witnesses, and reaching an agreement on any or all issues of law or fact without the necessity for further hearing thereon. In addition to any offer of settlement, the following are appropriate for consideration at a prehearing conference:

- (1) The simplification of issues;
- (2) The necessity or desirability of amendment to the pleadings;
- (3) The exchange and acceptance of service of exhibits proposed to be offered in evidence;
- (4) The obtaining of admission as to, or stipulations of, facts not remaining in dispute, or the authenticity of documents which may properly shorten the hearing;

(5) The limitation of the number of witnesses ; and

(6) Such other matters as may properly be dealt with to aid in expediting the orderly conduct of the proceeding.

03.300 Conference Results Stipulated: Upon conclusion of prehearing conference, the parties shall immediately reduce the results thereof to the form of a written stipulation which recites the matters agreed upon, which stipulation shall be filed with the Board. Any such stipulation may be received in evidence at a hearing and, when so received, shall be binding on the parties with respect to the matters therein stipulated.

03.400 Consolidation: The Board, upon its own motion, or upon motion by any party, may order two or more proceedings involving a similar question of law or facts to be consolidated for hearing where rights of the parties or the public interest will not be prejudiced by such procedure.

R28-32-04 HEARINGS

04.100 Hearing Officers:

04.101 Appointment: All hearing officers shall be appointed by the Board. The Board shall appoint a hearing officer within five (5) days of service of a complaint or petition. Notification of the appointment shall be made to all parties in such manner as the Board may determine.

04.102 Qualification:

(1) All appointments hereunder shall be consistent with the purpose of obtaining objectivity and impartiality in making decisions.

(2) The hearing officer may be an employee or a member of the Board. The Board may appoint as hearing officer a person who is not an employee or member of the Board. In such event, the hearing officer shall be an attorney at law licensed to practice in the State of North Dakota, unless some other person is agreed upon by all parties; provided that such hearing officer shall be considered an employee of the Board for the sole purpose of compensation, if any, and authorization to conduct the hearing and recommend findings of fact and a decision to the Board. In all other respects, he shall be independent of the Board.

(3) In all cases, the Board retains discretion to conduct the hearing itself, in which case an employee of the Board shall be the hearing officer.

04.103 Authority: The appointment of the hearing officer shall, to the extent permitted by law, authorize and direct the hearing officer to conduct the hearing and recommend a decision to the Board. When evidence is to be taken in a proceeding, one or more of examiners, when duly designated for that purpose, shall preside at the hearing. An officer duly designated by the Board to preside at a hearing shall have the authority to take any of the following actions in the name of the Board.

(1) To regulate the course of hearing;

(2) To administer oath;

(3) To issue subpoenas;

(4) To take depositions or cause same to be taken;

(5) To rule upon offers of proof and to receive evidence;

(6) To hold appropriate conferences before or during hearings;

(7) To dispose of procedural matters but not to dispose of motions made during hearings to dismiss proceedings or other motion which involves a final determination of proceedings;

(8) To exclude evidence which is cumulative or repetitious;

(9) To authorize any party to furnish and serve designated late-filed exhibits within a specified time after the close of the hearing;

(10) To order discovery;

(11) Within their discretion, or upon direction of the Board, to certify any question to the Board for its consideration and disposition; and

(12) To take any other action necessary or appropriate to discharge the duties vested in them, consistent with statutory or other authorities under which the Board functions and with the rules, regulations and policies of the Board.

04.104 Limitations: Hearing officers shall perform no duties inconsistent with their responsibilities as such. No officer shall in any proceeding for an adjudication required by statute to be determined on the record after opportunity for hearing, consult any person or party on any fact in issue unless upon notice and opportunity for all parties to participate.

04.105 Disqualification:

(1) Any party may file a petition with the Board to disqualify any hearing officer. The Board shall determine the petition in accordance with this subsection and enter its decision on the record.

(2) The Board may, for good cause, revoke the appointment of any hearing officer upon the filing of a petition of a party or upon the Board's own motion. Any such revocation shall be effective upon notice to the officer.

(3) A hearing officer shall withdraw from participation in a hearing at any time prior to the final determination if he deems himself disqualified for any reason.

(4) Whenever a hearing officer withdraws or is disqualified, the Board shall appoint another in his place, without the need for such newly appointed officer hearing evidence already presented in the case.

04.200 Discovery :

04.201 Agency Discovery

(1) Information

Upon request of the Board or the hearing officer, any party to the matter shall furnish to the Board or the hearing officer any information which the party may have which is relevant to the matter under consideration.

(2) Examination of Records

Upon request of the Board or the hearing officer, any party shall allow the Board or any member, employee, or agent of the Board, when authorized by it or the hearing officer, or the officer himself, to examine and copy any books, papers, records or memoranda pertaining to the matter under consideration.

(3) Inspection of Premises

Upon request of the Board or the hearing officer, any party shall allow the Board or any member, employee, or agent of the Board when authorized by it or the hearing officer, or the hearing officer himself, to enter upon any of the party's property for the purpose of obtaining information, examining any physical facility, or examining records or conducting surveys or investigations.

04.202 Discovery by Parties :

(1) Parties other than the Board may obtain discovery by examination of those public records which are in possession of the hearing officer or the Board. Any party to a case may request the Board or the hearing officer to exercise its powers in subsection 04.201(1) to obtain public information or to issue a subpoena as provided in 05.300. The Board or the hearing officer may grant or deny such requests. A party may request voluntary disclosure of information by any other party.

(2) The deposition of any witness or party required in any proceeding before the Board may be taken in the same manner and on the same notice as in an action pending in the district courts of this state. Any person whose deposition is taken shall receive the same fees and mileage as a witness in a civil case in the district courts and such costs shall be paid by the party at whose insistence the deposition is taken.

(3) Interrogatories may be issued, in any proceeding before the Board, in the same manner as in an action pending in the district courts of this state.

04.300 Appearance : Interested parties shall enter their appearances at the beginning of the hearing by giving their name and address and briefly stating whether they appear in support of the complaint or in opposition thereto, or otherwise. All such appearances shall be noted on the record with a notation in whose behalf each appearance is made. Included in such appearances shall be the names of the members of the Board's staff participating in the hearing of investigation and the names of any other persons appearing for the Board.

04.400 Continuance : Before or after any hearing, continuances may be granted by the Board for good and sufficient cause. A motion for such a continuance shall be made in writing, filed with the Board, and served on opposing counsel or parties. Such motions shall be presented as far in advance of date fixed for hearing as possible to insure favorable action. The Board may affect a continuance before or after any hearing upon its own motion. The hearing officer may grant oral or written requests for continuances during any hearing.

04.500 Order of Procedure : In hearings on formal complaints and petitions, the complainant or petitioner, as the case may be, shall open and close. In hearings on an order to show cause, the respondent shall open and close. When proceedings have been consolidated for hearing, the officer shall designate who shall open and close. Intervenor shall follow the parties in whose behalf the intervention is made ; where the intervention is not in support of an original party, the

presiding officer shall designate at which stage such intervenor shall be heard. In proceedings where the evidence is materially within the knowledge or control of another party or participant, the foregoing order or presentation may be varied by the officer.

04.600 Appeal to Board From Ruling of Hearing Officer—Offer of Proof: An appeal may be taken to the Board from a ruling officer during the course of a hearing only where extraordinary circumstances necessitate a prompt decision by the Board to prevent detriment to the public interest.

Any offer of proof made in connection with an objection taken to any ruling of the hearing officer rejecting or excluding proffered oral testimony shall consist of a statement of the substance of the evidence which counsel contends would be adduced by such testimony; and, if the excluded evidence in documentary or written form or reference to documents or records, a copy of such evidence shall be marked for identification and shall constitute the offer of proof.

04.700 Oral Argument:

04.701 Before Officer: When, in the opinion of the hearing officer, time permits and the nature of the proceedings, the complexity or the importance of the issues of fact or law involved, and the public interest warrant, such officer may, either on his own motion, or at the request of any party at or before the close of the taking of testimony, allow and fix a time for the presentation of oral argument imposing such limits of time on the argument as deemed appropriate. Such arguments shall be transcribed and bound with the transcript of testimony, if a transcript is prepared.

04.702 Before Board: Request for authority to present oral argument before the Board may be made at the time of any appeal taken during the hearing, at the conclusion of the taking of evidence, or on brief, at such time as the Board may allow. The Board will fix the time for oral argument, if allowed and notify the parties.

04.800 Briefs, Proposed Findings of Fact and Conclusions of Law:

04.801 Each party to any proceeding may file proposed findings of fact and conclusions of law, briefs, or memoranda of law; provided, however, that the Board or hearing officer may direct any party to file proposed findings of fact and conclusions of law, briefs, or memoranda of law.

04.802 The Board or hearing officer shall fix the time for the filing and service of proposed findings of fact and conclusions of law, briefs, or memoranda of law, giving due regard to the nature of the proceeding, the magnitude of the record, and the complexity or importance of the issues involved, and he shall fix the order in which such documents shall be filed.

04.803 Should a party find that it is unable to meet the date for filing and serving proposed findings of fact and conclusions of law, briefs, or memoranda of law, such party shall so notify the Board or hearing officer and the other parties in writing, therein setting forth the reasons for such inability together with a request for an extension of time to a date certain for filing and service.

04.804 When it is ordered that proposed findings of fact and conclusions of law, briefs, or memoranda of law be filed and served by the party initiating the proceeding, and where such party fails to file and serve by the date specified without complying with 04.803 above, the Board on its own motion or the motion of any party may, in its discretion, dismiss the proceeding. Such failure in the case of an intervenor, protestant, or respondent may be deemed a waiver of the right to participate further in the proceeding, and the Board on its own motion or the motion of any party may so order.

04.805 Exhibits should not be reproduced in a brief, but may, if desired, be reproduced in an appendix to the brief. Every brief of more than twenty pages shall contain a subject index, with page references, and the pages where the citations appear. All briefs shall be as concise as possible.

04.806 All briefs shall be accompanied by certificate showing service upon all parties or their attorneys who appeared at the hearing. One copy of each brief shall be furnished for the use of the Board unless otherwise directed by the Board or hearing officer.

04.900 Decisions of the Board: In all cases in which more than one member or employee of the Board shall act as hearing officer, only an odd number of members or employees shall so act. In all cases in which any matter shall be heard by more than one hearing officer, sitting jointly, and in all cases in which the Board shall rule on any issue, motion, or objection, the decision of the Board shall be determined by vote.

05.100 Rules: The admissibility of evidence shall be determined generally in accordance with the practice in the district courts of this state, except to the extent that these rules conflict therewith. However the Board or the hearing officer may waive the usual common law or statutory rules of evidence where such waiver is necessary to ascertain the substantial rights of the public and interested parties. When objection is made to the admissibility of evidence, the hearing officer shall receive such evidence subject to later ruling by the Board.

05.200 Witnesses: Witnesses will be orally examined under oath before the Board or hearing officer. Testimony may also be taken by deposition as provided in 04.202(2) hereof. Written testimony of any witness may be received when properly supported by the oral testimony of its author.

05.300 Subpena: Subpenas for the attendance of witnesses or for the production of documentary evidence, unless directed by the Board upon its own motion, will issue only upon application in writing to the Board, or to the hearing officer, except that during a hearing such application may be made orally on the record before the hearing officer who shall have the authority to determine the relevancy and the materiality of the evidence sought and to issue such subpoenas if warranted. Written application shall specify the general relevance and materiality of the testimony or documentary evidence sought, including, as to documentary evidence, specifications as nearly as may be of the documents desired and the facts to be proved by them. The cost of serving any subpoena shall be paid by the party requesting it. Any witness who is subpoenaed under the provisions of this rule and who appears at the hearing shall receive the same fees and mileage as witnesses in the district courts of this state, and such cost will be paid by the part at whose insistence the witness appears. No witness fees will be allowed except on a subpoena.

05.400 Stipulations: The parties to any proceeding or investigation before the Board may, by stipulation in writing, filed with the Board or orally entered in the record, agree upon the facts, or any portion thereof involved in the controversy, and any such stipulation may be received in evidence at a hearing and when so received, shall be binding upon the parties with respect to the matters stipulated therein.

05.500 Documentary Evidence:

05.501 Where relevant and material matter offered in evidence by any party is embraced in a book, paper, or a document containing other matter not material or relevant, the party must designate the matter so offered. If the other matter is in such volume as would unnecessarily encumber the record, such book, paper or document will not be received in evidence but may be marked for identification and, if properly authenticated, the relevant and material matter may be read into the record, or if the Board or hearing officer directs, a true copy of such matter in proper form shall be received as an exhibit and like copies delivered by the party offering the same to all parties or their attorneys appearing at the hearing who shall be afforded an opportunity to examine the entire book, paper, or document and to offer in evidence in like manner any portions thereof found to be material and relevant.

05.502 Any matter contained on a report or other official document on file with the Board may be offered in evidence by merely identifying the report, document, or other file containing the matter so offered.

05.600 Exhibits:

05.601 Exhibits must be on paper of good quality and so prepared as to be plainly legible and durable whether printed, typewritten, mimeographed, photographed or otherwise, and if possible should be folded to a size not to exceed 8½ by 14 inches. Whenever practicable, the sheets of each exhibit and line of each sheet should be numbered, and if the exhibit consists of five or more sheets, the first sheet or title page should contain a brief statement of what the exhibit purports to show with reference by sheet and line to illustrative or typical example contained in the exhibit. Whenever practicable, documents produced by a single witness shall be assembled and bound together suitably arranged and indexed so that they may be identified and offered as one exhibit. The source of all material contained in any exhibit should be definitely shown.

05.602 Two copies of each exhibit will be furnished for the use of the Board whenever it shall request; copies must also be available for all parties of record in a proceeding

05.700 Official Notice: The Board or the examiner may take notice of any fact or facts set forth in duly established regulations, annual reports, or any statisti-

cal data to which reference is made on the record at the hearing or any facts which are judicially noticed by the courts of this state, as set forth in Section 31-10-02.

R28-32-06 REOPENING, REHEARING, REVIEW

06.100 Petition to Reopen: At any time after the conclusion of a hearing, but before entry of the final order by the Board, any party to a proceeding may file with the Board a petition to reopen the proceeding for the purpose of taking additional evidence.

06.101 Such petition shall set forth clearly the facts claimed to constitute the grounds requiring reopening of the proceeding, including the material changes of fact or law alleged to have occurred since the conclusion of the hearing.

06.102 A copy of the petition to reopen shall be served by the petitioning party upon all parties to the proceedings or their attorneys of record, and a certificate to that effect will be attached to the petition when filed with the Board.

06.103 Within ten days following the service of any petition to reopen, any other party to the proceeding may file with the Board his answer thereto. Any party not filing such answer is in default thereof and shall be deemed to have waived any objection to the granting of such petition.

If, after the hearing in a proceeding, either before or after the issuance of its final order, or if no hearing has been held, only after the issuance of its final order, the Board shall have reason to believe the conditions of fact or law have so changed as to require, or that public interest requires, the reopening of such proceeding, the Board may issue an order for the reopening of the same.

The Board shall act on any petition to reopen within ten days of receipt thereof and may, in its discretion, hear oral argument on any such petition.

06.200 Petition for Rehearing:

06.201 A petition for rehearing of a proceeding must be filed within fifteen days after a copy of the final order has been sent to the petitioning party by the Board.

06.202 Such petition shall state concisely the alleged errors in the Board's decision or order and the specific grounds relied upon by the petitioner. If an order of the Board is sought to be vacated, reversed, or modified by reason of matters that have arisen since the hearing and decision or order, or by reason of a consequence that would result from the compliance therewith, the matters relied upon by the petitioner shall be set forth in the petition.

06.203 A petition for rehearing shall be served by the petitioner upon all parties to the proceeding or their attorneys of record.

06.204 Within ten days following the service of such petition, any party to the proceeding may file with the Board his answer thereto. Any party not filing such an answer is in default thereof and shall be deemed to have waived any objection to the granting of such petition.

06.205 The Board shall act on any petition for rehearing within ten days of receipt thereof and may, in its discretion, hear oral argument on such petition.

06.300 Appeal: Any party to a proceeding conducted pursuant to these rules or other provisions of Chapter 28-32 shall have the right of appeal, in the manner provided in Chapter 28-32, from any adverse ruling by the Board. Such appeal shall not be a trial de novo but shall be limited to the hearing record and to those issues specified in Section 28-32-19.

UTAH

STATE OF UTAH, DEPARTMENT OF NATURAL RESOURCES, DIVISION OF WATER
RESOURCES RULES, REGULATIONS, AND PROCEDURES

CLOUD SEEDING RESOLUTION

Whereas, the Utah Cloud Seeding Act of 1973, Laws of Utah, Chapter 193, authorizes the Utah Division of Water Resources to adopt such rules and regulations as are necessary in the performance of its powers and duties pursuant to the Cloud Seeding to Increase Precipitation Act and

Whereas, after careful deliberation and extensive study, the Utah Division of Water Resources has prepared such rules and regulations and has circulated same so far as practical to interested governmental bodies, groups, and individuals for their information and comments; and

Whereas, the Utah Division of Water Resources has considered and deliberated on the form and content of each proposed rule in the light of any and all suggestions from its staff, and other interested persons; and

Whereas, the Utah Board of Water Resources at its regular meeting on September 26, 1973, considered the proposed Rules and Regulations Relating to Cloud Seeding Activities; Now, therefore, be it

Resolved, That the Utah Division of Water Resources adopt the following Rules and Regulations relating to the Utah Cloud Seeding Act of 1973 on an interim basis, until such time as experience shows that the Rules should be modified.

I hereby certify that the above Resolution was adopted by the Utah Division of Water Resources on September 26, 1973.

DANIEL F. LAWRENCE,
Director, Utah Division of Water Resources.

DEFINITIONS

1. "Act" or "Cloud Seeding Act" means the 1973 Cloud Seeding To Increase Precipitation Act, Laws of Utah, Chapter 193.

2. "Cloud Seeding" or "Weather Modification" means all acts undertaken to artificially distribute or create nuclei in cloud masses for the purposes of altering precipitation, cloud forms, or other meteorological parameters.

3. "Cloud Seeding Project" means a planned project to evaluate meteorological conditions, perform cloud seeding, and evaluate results.

4. "Board" means the Utah Board of Water Resources, which is the policy making body of the Utah Division of Water Resources.

5. "Director" means the Director of the Utah Division of Water Resources.

6. "Utah Division of Water Resources" means the Director and staff of the Utah Division of Water Resources.

7. "License" means a certificate issued by the Utah Division of Water Resources certifying that the holder has met the minimum requirements in cloud seeding technology set forth by the State of Utah, and is qualified to apply for a permit for a cloud seeding project.

8. "Licensed Contractor" means a person or organization duly licensed for cloud seeding activities in the State of Utah.

9. "Permit" means a certification of project approval to conduct a specific cloud seeding project within the State under the conditions and within the limitations required and established under the provision of these Rules.

10. "Sponsor" means the responsible individual or organization that enters into an agreement with a licensed contractor to implement a cloud seeding project.

CHAPTER I

GENERAL PROVISIONS

1. Authority: The State of Utah through the Division of Water Resources shall be the only entity, private or public, that shall have authority to authorize, sponsor, and/or develop cloud seeding research, evaluation, or implementation projects to alter precipitation, cloud forms, or meteorological parameters within the State of Utah.

2. Ownership of Water: All water derived as a result of cloud seeding shall be considered as a part of Utah's basic water supply the same as all natural precipitation water supplies have been heretofore, and all statutory provisions that apply to water from natural precipitation shall also apply to water derived from cloud seeding.

3. Notice to State Engineer: The Director of the Utah Division of Water Resources shall, by written communication, notify the Director of the Utah Division of Water Rights of any applications for cloud seeding permits within ten (10) days of receiving such applications.

4. Consultation and Assistance: The Utah Division of Water Resources may contract with the Utah Water Research Laboratory, or any other individual or organization, for consultation and/or assistance in developing cloud seeding projects or in furthering necessary research of cloud seeding or other factors that may be affected by cloud seeding activities.

5. State and County Cooperation: The Utah Division of Water Resources shall encourage, cooperate, and work with individual counties, multi-county districts for planning and development, and groups of counties in the development of cloud seeding projects and issuance of permits.

6. **Statewide or Area-wide Cloud Seeding Project:** The State of Utah through the Division of Water Resources reserves the right to develop Statewide or area-wide cloud seeding programs where the Utah Division of Water Resources may contract directly with licensed contractors to increase precipitation. The Utah Division of Water Resources may also work with individual counties, multi-county districts for planning and development, organizations or groups of counties, or private organizations, to develop Statewide or area-wide cloud seeding projects.

7. **Liability:**

(a) *Trespass.*—The mere dissemination of materials and substances into the atmosphere or causing precipitation pursuant to an authorized cloud seeding project, shall not give rise to any presumption that such use of the atmosphere or lands constitutes trespass or involves an actionable or enjoicable public or private nuisance.

(b) *Immunity.*—Nothing in these Rules and Regulations shall be construed to impose or accept any liability or responsibility on the part of the State of Utah or any of its agencies, or any State officials or State employees or cloud seeding authorities, for any weather modification activities of any person or licensed contractor as defined in these Rules and Regulations as provided by Laws of Utah, Chapter 63.

8. **Rules:**

(a) *Purpose.*—The Rules contained herein are adopted for the purpose of ensuring both continued research and appropriate application of weather modification technology to the needs of Utah, and for minimizing the danger of weather modification activities to health and property, thus facilitating administration and enforcement of the State of Utah Cloud Seeding Act of 1973, Laws of Utah, Chapter 193.

(b) *Use and Limitation.*—These Rules are prescribed for the performance of the statutory powers and functions vested in the Utah Division of Water Resources. In no event shall any Rule, or Rules, be construed as a limitation or restriction upon the exercise of any statutory power of the Utah Division of Water Resources.

(c) *Suspension and Waiver of Rules.*—The Utah Division of Water Resources may suspend or waive a Rule, in whole or in part, upon a showing of good cause; or when, in the discretion of the Utah Division of Water Resources, the particular facts or circumstances render such suspension or waiver of the Rule appropriate.

(d) *Amending of Rules.*—These Rules may be amended from time to time and new Rules may be adopted by the Utah Division of Water Resources.

CHAPTER II

UTAH BOARD OF WATER RESOURCES

1. **Review of License and Permit:** The Board may review applications for Licenses and Permits and submit recommendations to the Director for his consideration for action on the applications.

2. **Policy Recommendations:** The Board may advise and make recommendations concerning legislation, policies, administration, research, and other matters related to cloud seeding and weather modification activities to the Director and technical staff of the Utah Division of Water Resources.

CHAPTER III

WEATHER MODIFICATION ADVISORY COMMITTEE

1. **Creation of Weather Modification Advisory Committee:** An advisory committee may be created by the Director of the Utah Division of Water Resources. Members of this committee shall be appointed by the Director, and serve for a period of time as determined by the Director.

2. **Duties of Weather Modification Advisory Committee:**

(a) Advise the Director and technical staff of the Utah Division of Water Resources on application for licenses and permits;

(b) Advise and make recommendations concerning legislation, policies, administration, research, and other matters related to cloud seeding and weather modification activities to the Director and technical staff of the Utah Division of Water Resources.

CHAPTER IV

LICENSE AND PERMIT REQUIRED

1. License and Permit Required: It is unlawful for any person or organization, not specifically exempted by law and these Rules, to act or perform services as a weather modifier, without obtaining a license and permit as provided for in the Cloud Seeding Act and these Rules.

2. To Whom License May Be Issued: Licenses to engage in activities for weather modification and control shall be issued to applicants who meet the requirements set out in the Act and Chapter V of these Rules. If the applicant is an organization, these requirements shall be met by the individual or individuals who are to be in control and in charge of the applicant's weather modification operations.

3. To Whom Permit May Be Issued: A permit may be issued to a licensed contractor as prescribed in Chapter VI of these Rules.

4. License and Permit Not Required: Individuals and organizations engaging in the following activities, and only the following activities, are exempt from the license and permit requirements of these Rules:

(a) Research performed wholly within laboratory facilities;

(b) Cloud Seeding activities for the suppression of fog;

(c) Fire fighting activities where water or chemical preparations are applied directly to fires, without intent to modify the weather;

(d) Frost and fog protective measures provided through the application of water and/or heat by orchard heaters or similar devices, or by mixing of the lower layers of the atmosphere by helicopters or other type of aircraft where no chemicals are dispensed into the atmosphere, other than normal combustion by-products and engine exhaust; and

(e) Inadvertent weather modification (such as emissions from industrial stacks.)

5. Effective Period of License: Each license shall be issued for a period of one (1) year. A licensee may renew an expired license in the manner prescribed by these rules.

6. Effective Period of Permit: Each permit shall be issued for a period as required by a proposed cloud seeding project, but not exceeding one (1) year.

CHAPTER V

PROCEDURES FOR ACQUISITION AND RENEWAL OF LICENSE

1. Application for License: In order to qualify for a cloud seeding license an applicant must:

(a) Submit a properly completed application to the Utah Division of Water Resources; and

(b) Submit to the Utah Division of Water Resources evidence of (1) the possession by the applicant of a baccalaureate or higher degree in meteorology or related physical science or engineering and at least five years' experience in the field of meteorology, or (2) such other training and experience as may be acceptable to the Utah Division of Water Resources as indicative of sufficient competence in the field of meteorology to engage in cloud seeding activities.

2. Renewal of License: A licensee may qualify for a renewal of a license by submitting an application for renewal. In the case of an organization, the application for renewal must state whether the personnel, on the basis of whose qualifications the original license was issued, continue to be in control and in charge of the organization's cloud seeding operations; or, if the organization has acquired replacement personnel, that there has been a change in personnel. If the organization has hired replacement personnel, the organization shall attach to its application for renewal a statement setting forth the names and qualifications of said personnel. Licensee should file an application for renewal thirty (30) days prior to the expiration date of his license.

CHAPTER VI

PROCEDURES FOR ACQUISITION OF PERMIT

1. Application for Permit: In order to qualify for receipt of a cloud seeding permit a licensee must:

(a) Submit a properly completed letter of application to the Utah Division of Water Resources, which shall include the name and qualifications of the person or persons who will be in control of, and in charge of the operations for the licensee. These qualifications shall comply with Chapter V Section B-1 of these Rules and Regulations;

(b) Demonstrate to the satisfaction of the Director his ability to respond in damages for liability which might reasonably arise as a result of the applicant's proposed cloud seeding activities;

(c) File a copy of the contract or proposed contract between the sponsor and licensed contractor relating to the project;

(d) Submit copies of all pamphlets and promotional material distributed in connection with the project;

(e) Submit the plan of operation for the project, including a map showing locations of all equipment to be used as well as equipment descriptions;

(f) Receive preliminary approval of the project from the Director before proceeding with notices of intent described in Chapter VI, Item 1, (g) and (h) of these Rules.

(g) File with the Utah Division of Water Resources and the Utah Division of Water Rights a notice of intention for publication which sets forth at least all of the following:

(1) the name and address of the applicant;

(2) the date he received a proper cloud seeding license, and all dates of renewal;

(3) the nature and the object of the intended operations, and the person or organization on whose behalf it is to be conducted;

(4) the specific area in which, and the approximate date and time during which, the operation will be conducted;

(5) the specific area which is intended to be affected by the operation;

(6) the materials and methods to be used in conducting the operation; and

(7) a statement that persons interested in such permit application should contact the Utah Division of Water Resources.

(h) File with the Utah Division of Water Resources, within fifteen (15) days from the last date of the publication of notice, proof that the applicant caused the notice of intention to be published at least once a week for three (3) consecutive weeks in a newspaper having a general circulation within each county in which the operation is to be conducted and in which the affected area is located. Publication of notice shall not commence until the applicant has received approval of the form and substance of the notice of intention from the Director.

2. Issuance of a Permit: A permit shall not be issued prior to the expiration of ten (10) days following the last date of publication of the notice of intent.

3. Description of Permit: A licensee shall comply with all the requirements set out in his permit. A permit shall include the following:

(a) The effective period of the permit, which shall not exceed one year;

(b) The location of the operation;

(c) The method(s) which may be employed; and

(d) Other necessary terms, requirements, and conditions.

4. Authority to Amend a Permit: The Utah Division of Water Resources may amend the terms of a permit after issuance thereof if the Utah Division of Water Resources determines that it is in the public interest.

CHAPTER VII

REVOCATION AND SUSPENSION OF LICENSES AND PERMITS

1. Automatic suspension of a Permit: Any cloud seeding permit issued under the terms of these Rules shall be suspended automatically if the licensee's cloud seeding license should expire, or in the case of an organization being the licensee, if the person listed on the application for the permit as being in control of, and in charge of, operations for the licensee should become incapacitated, leave the employment of the licensee, or for any other reason be unable to continue to be in control of, and in charge of, the operation in question; and a replacement, approved by the Director, has not been obtained.

2. Reinstatement of Permit: A permit which is suspended under Chapter VII, Item 1, may be, at the discretion of the Director, reinstated following renewal of

the expired license, or submission of an amended personnel statement nominating a person whose qualifications for controlling and being in charge of the operation are acceptable to the Director.

3. Director's Authority to Suspend or Revoke Licenses and Permits: The Director may suspend or revoke any existing license or permit for the following reasons:

- (a) If the licensee no longer possesses the qualifications necessary for the issuance of a license or permit;
- (b) If the licensee has violated any of the provisions of the Cloud Seeding Act;
- (c) If the licensee has violated any of the provisions of these Rules; or
- (d) If the licensee has violated any provisions of his license and/or permit.

CHAPTER VIII

RECORD KEEPING AND REPORTS

1. Information To Be Recorded: Any individual or organization conducting weather modification operations in Utah shall keep and maintain a record of each operation which he conducts. For the purposes of this Chapter, the daily log required by Title 15, Chapter IX, Sub-Chapter A, Part 908, Section 908.8 (a), Code of Federal Regulations, November 1, 1972, as amended, and the supplemental information required by Sections 908.8 (b), (c), and (d) will be considered adequate, provided that each applicant for a weather modification permit submit with his application a list containing the name and post office address of each individual who will participate or assist in the operation, and promptly report any changes or additions to this list to the Utah Division of Water Resources.

2. Reports:

(a) Each individual and organization conducting weather modification operations in Utah shall submit copies of the daily log and supplemental information described in Chapter VIII, Item 1, for each month, to the Utah Division of Water Resources by the last day of each succeeding month.

(b) Information copies of all other reports required by Title 15, Chapter IX, Sub-Chapter A, Part 908, Sections 908.5, 908.6, and 908.7, Code of Federal Regulations, shall be submitted to the Utah Division of Water Resources as soon as practicable, but in no case later than the deadlines set by the Federal Regulation.

(c) Copies of all reports, publications, pamphlets, and evaluations made by either the licensed contractor or sponsor regarding a cloud seeding project must be submitted to the Utah Division of Water Resources at the time these are made public.

(d) In relation to any evaluations made for cloud seeding effectiveness, both the method of evaluation and the data used shall be submitted to the Utah Division of Water Resources.

CHAPTER IX

SUSPENSION OF CLOUD SEEDING OPERATION

The policy in regard to suspension of seeding because of potential flood danger due to excessive snowpack shall be as follows:

1. All watersheds in a designated cloud seeding target area shall be monitored monthly by the Director of the Division of Water Resources.

2. When it is determined that any watershed in the designated cloud seeding target area has reached a critical maximum value, a thorough investigation of this watershed shall be conducted by the Division of Water Resources to determine if cloud seeding should be suspended.

WASHINGTON

FORM OF ORDER AND TRANSMITTAL BY AGENCY HAVING SINGLE HEAD

State of Washington

DEPARTMENT OF ECOLOGY

(agency name)

Administrative Order No. DE 77-29

1) I, Elmer C. Vogel, deputy director of
the Department of Ecology,
do promulgate and adopt at the Department of Ecology, Lacey, Washington,
(place)

the annexed rules relating to

repealing chapter 508-20 WAC (Weather Modification Rules) and adopting chapter 173-495 (Weather Modification). This action is taken since chapter 508-20 WAC is obsolete in form and content. The new chapter is restructured in currently approved format and contains definitive instructions implementing the intent of chapter 43.37 RCW--Weather Modification. Procedures for license and permit application are more clearly defined, exempt activities are brought into consonance with chapter 43.37 RCW, and Proof of Financial Responsibility is defined.

(2) ALTERNATIVE A. Use only for Adoption of Permanent Rules.

This action is taken pursuant to Notice No. 7826 filed with the code reviser on 10/27/77. Such rules shall take effect

pursuant to RCW 34.04 (MOR)

at a later date, such date being _____

(2) ALTERNATIVE B. Use only for Adoption of Emergency Rules.

I, _____, find that an emergency exists and that the foregoing order is necessary for the preservation of the public health, safety or general welfare and that observance of the requirements of notice and opportunity to present views on the proposed action would be contrary to public interest. A statement of the facts constituting such emergency is _____

Such rules are therefore adopted as emergency rules to take effect upon filing with the code reviser

(3) Pursuant to the requirements of RCW 34.04 ____ (1977 c 19 § 21) that "every agency shall incorporate the most specific, but in no case omit all, of the following language alternatives when adopting or amending rules" (fill in statement (a), (b), or (c) as appropriate)

(a) This rule is promulgated pursuant to RCW 43.37 and is intended to administratively implement that statute

(b) This rule is promulgated pursuant to RCW _____ which directs that the

_____ (agency)

has authority to implement the provisions of

_____ (name of act or RCW citation)

(c) This rule is promulgated under the general rule-making authority of the

_____ (agency)

as authorized in RCW _____

(4) The undersigned hereby declares that he has complied with the provisions of the Open Public Meetings Act (chapter 42.00 RCW), the Administrative Procedure Act (chapter 34.04 RCW) or the Higher Education Administrative Procedure Act (chapter 28B.19 RCW), as appropriate, and the State Register Act (chapter 34.08 RCW)

(5) This order after being first recorded in the order register of this agency is herewith transmitted to the Code Reviser for filing pursuant to chapter 34.04 RCW and chapter 1.12 WAC

CHAPTER 173-495 WAC

WEATHER MODIFICATION

WAC 173-495-010 Purpose.—The Department of Ecology, under the authority vested in it by Chapter 43.37 RCW, is charged with responsibilities for the supervision and control of all weather modification activities within the state, and representation by the state in all interstate contracts relating to weather modification and control. This regulation provides the basic framework for carrying out the state's responsibility for such a program through the establishment of license and permit requirements and procedures, report requirements, and fee requirements. The provisions of this chapter shall apply to all weather modification activities in all parts of the state except as specifically exempted in this chapter and or in chapter 43.37 RCW.

WAC 173-495-020 Definitions.—As used in these regulations unless the context requires otherwise:

(1) "Department" means the Department of Ecology.

(2) "Operation" means the performance of weather modification and control activities pursuant to a single contract entered into for the purpose of producing or attempting to produce a certain modifying effect within one geographical area over one continuing time interval not exceeding one (1) year; or in the case of the performance of weather modification and control activities, individually or jointly, by a person or persons to be benefited and not undertaken pursuant to a contract, operation means the performance of weather modification and control activities entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one geographical area and one continuing time interval not exceeding one (1) year.

(3) "Research and Development" means theoretical analysis, exploration and experimentation, and the extension of investigative findings of theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials, and processing.

(4) "Weather Modification and Control" means changing or controlling, or attempting to change or control by artificial methods the natural development of any or all atmospheric cloud forms or precipitation forms which occur in the troposphere.

WAC 173-495-030 Requirement for Licenses and Permits.—No person shall engage in weather modification activities except under and in accordance with a license and a permit issued by the department, unless specifically exempt from this requirement in WAC 173-495-050.

WAC 173-495-040 Exempt Activities—Requirements of Those Exempted.—The following weather modification and control activity shall be exempt from the license requirement of RCW 43.37.100, the permit requirements of RCW 43.37.100, and the liability requirements of RCW 43.37.190:

(1) All research and experiments related to weather modification control conducted within laboratories.

(2) Those weather modification operations designed to alleviate sudden, unexpected, hazardous conditions which require expeditious localized action for:

- (a) protection against fire
- (b) prevention of frost
- (c) dispersal of fog

(3) Field research and development by institutions of higher learning.

(4) Any person proposing to conduct weather modification and control activities as described in subsection (2) above shall make every reasonable effort prior thereto to notify the Department of Ecology, headquarters offices in Olympia, Washington, of the type of activity to be carried out, the person carrying out the activity and the materials and technique of application to be used.

(5) Any person proposing to conduct weather modification and control activities as described in subsection (3) above shall provide a written description of the proposed program, notice of actual operations ten (10) days prior to commencement, and quarterly reports of operations and status to the headquarters office Department of Ecology, Olympia, Washington.

WAC 173-495-045 Qualifications for License—Regular.—All applicants for a weather modification license shall be certified professional members of the American Meteorological Society or possess the academic achievements and professional experience necessary to receive such certification. In cases where the applicant is an organization, the individual or individuals who will be in control

and in charge of the weather modification and control activities shall be required to meet the above standard.

WAC 173-495-050 Qualifications for License—Restricted License.—(1) A restricted license may be issued to an applicant for such license when:

(a) the applicant's proposed weather modification activities are limited solely to those designed to disperse fog over airports; and

(b) the applicant will be fully advised of the pertinent weather information by the meteorologist on duty during the carrying out of the airport fog dispersal.

(2) Applicants for restricted licenses are not required to meet the qualifications otherwise imposed by WAC 173-495-040.

WAC 173-495-060 Procedures for Issuing License.—

(1) Any person or organization desiring to obtain a license or restricted license shall make an application to the Department of Ecology on the form prescribed, listing name, business address, etc.

(2) The department may require additional information of the applicant to determine competency in the field of meteorology. Such additional information shall be requested of the applicant by certified mail, and shall be submitted in writing.

(3) Prior to the issuance of any license, the applicant shall pay a fee of \$100 to the State of Washington.

(4) The application shall be deemed received by the Department of Ecology when received at the headquarters offices, Department of Ecology, Olympia, Washington 985504.

WAC 173-495-065 Period of License.—

(1) Licenses issued pursuant to chapter 43.37 RCW and these regulations shall be effective for a period of one (1) year, to terminate at the end of the calendar year of issuance.

(2) No later than thirty (30) days prior to the end of the calendar year, the licensee may request a renewal of the license. The department shall review said license upon the payment of a renewal fee of \$100 to the State of Washington.

(3) In the determination of whether or not to grant such renewal request, the department shall consider, and the applicant shall provide, information as to whether the facts and circumstances relied on in the issuance of the original permit have changed or altered. If the department determines that the licensee no longer meets the requirements of competency in the field of meteorology, the department may refuse to renew said license.

WAC 173-495-070 Permits Requirements.—

(1) Each weather modification operation not specifically exempted by statute or these regulations shall require a permit. A separate permit shall be issued for each operation.

(2) A license holder desiring to conduct a weather modification operation shall submit an application for a permit to the Department of Ecology.

(3) The permit applicant must hold a valid weather modification license from the State of Washington.

(4) The applicant shall publish notice of intention at least once a week for three (3) consecutive weeks in a legal newspaper having general circulation and published within any county in which the operation is to be conducted and in which the affected area is located, or, if the operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the operation is to be conducted, then in a legal newspaper having a general circulation and published within each of such counties. In case there is no legal newspaper published within the appropriate county, publication shall be made in a legal newspaper having a general circulation within the county.

(5) Proof of publication of the notice of intention, made in the manner provided herein, shall be filed by the licensee with the department within fifteen (15) days from the date of last publication of the notice.

(6) The notice of intention shall contain at least the following:

(a) the name and address of the licensee;

(b) the nature and object of the intended operation and the person or organization on whose behalf it is to be conducted;

(c) the area in which and the appropriate time during which the operation will be conducted;

(d) the area which is intended to be affected by the operation;

(e) the materials and methods to be used in conducting the operation.

(7) The applicant shall furnish proof of financial responsibility, as described in WAC 173-495-120 of this chapter.

(8) The applicant shall pay a permit fee of one and one-half percent (1½%) of the estimated cost of the operation. The estimated cost will be computed by the department from evidence available to it.

(9) Prior to issuance of a permit the department shall make a determination in writing that the weather modification and control activities proposed to be conducted under authority of the permit have been determined to be for the general welfare and public good.

(10) The department shall hold an open public hearing at its headquarters office in Olympia prior to any such permit issuance.

WAC 173-495-080 Permittee's Report of Operations—Requirement.—The permittee shall be required to maintain reports on all operations on a daily basis, and submit twice a month (1st day and 15th day) to the Department of Ecology. The semi-monthly reports shall include the following information:

(1) Number of days under contract.

(2) Number of days of operation and number of hours of each day, for all stations operated.

(3) The consumption rate and name of seeding agent used.

(4) A brief summary statement evaluating the past fifteen (15)-day period in regard to the seeding potential and experience.

(5) Location of operations.

(6) Name and mailing address of each individual, other than the licensee, participating or assisting in the operation.

(7) A brief statement of projected plans for the coming fifteen (15)-day period.

(8) In the event operations are unexpectedly terminated, a special report covering that fraction of the half-month period of operation is required. All reports must be post-marked not later than one (1) day after due date.

(9) All such records are public records which shall be open to public inspection.

WAC 173-495-100 Revocation, Suspension, Modification.—

(1) All permits authorized by RCW 43.37.110 shall contain the following provisions: "The department may, if it appears that continuing operation under this permit will cause immediate injury to persons or property, terminate or otherwise modify the terms of this permit in order to alleviate an emergency situation by giving notice to the permittee by telegram or other writing."

(2) All permits authorized by RCW 43.37.110 may be revoked, suspended, or modified when the department has reason to believe that good cause exists and that the revocation, suspension, or modification is required for the general welfare and public good. Any such revocation, suspension, or modification shall not be undertaken prior to written notice by certified mail to the permittee. Opportunity for comment by the permittee shall be allowed. Any final departmental decision shall be in writing.

(3) In the event the applicant desires to appeal any permit revocation, modification, or suspension action by the department such appeal must be filed with the Pollution Control Hearings Board in Olympia within thirty (30) days of the department's action. An appeal does not constitute a stay.

WAC 173-495-120 Proof of Financial Responsibility.—A permit applicant shall furnish proof of financial responsibility to the Department of Ecology by one of the following:

(1) Copy of insurance policy or binder for the operator.

(2) A current balance sheet showing sufficient assets to demonstrate financial responsibility.

(3) Bond for safe performance.

(4) Such other information as the applicant may provide the department, in writing, if one of the alternate methods (1)–(3), above, is not feasible or available, provided the applicant explains the infeasibility or unavailability.

The following sections of WAC 508-20 are repealed:

508-20-020 Board will notify Washington State University and the county agent when permit is issued.

508-20-030 Permittee's report of operations.

508-20-040 Board may modify or terminate permits.

508-20-050 Exempt activities.

508-20-060 Exempt activities—Olympic Mountains research project.

508-20-070 Qualifications of licensees—Restricted license, fog dispersal at airports.

508-20-080 Use of dry ice for fog dispersal over public airports.

APPENDIX N

DOCUMENTS OF THE WEATHER MODIFICATION ASSOCIATION

CONSTITUTION AND BY-LAWS OF THE WEATHER MODIFICATION ASSOCIATION¹

Article I. Name: The name of the organization shall be the Weather Modification Association.

Article II. Purpose: The Association shall function as a non-profit organization. Its intended purposes include, but are not necessarily limited to, the following:

(a) *Promotion*.—Promoting research, development, and understanding weather modification for beneficial uses.

(b) *Standards of Conduct*.—Encouraging and promoting the highest standards of conduct including certification of individual members qualified to execute field experiments or operations in weather modification.

(c) *Information Center*.—Serving as a clearinghouse and dissemination agent for weather modification oriented literature and information.

(d) *Policy Statements*.—Assuming an active role and maintaining a strong voice in the production and dissemination of policy statements concerning all aspects of weather modification practice.

Article III. Membership: There shall be four (4) classes of membership in the Association. Each class shall be afforded the privileges of membership as indicated.

(a) *Member*.—Any person who subscribes to the statement of purposes of the Association, upon payment of the prescribed annual dues (Ref Article IV), shall be afforded the privileges of membership. Members shall receive all publications of the Association, and shall have the right to vote in the business of the Association and to hold any office in the Association.

(b) *Student Member*.—Any person, engaged in a full-time program of study leading to a degree in the atmospheric sciences, engineering or other subjects related to the science of weather modification, and who subscribes to the statement of purpose of the Association, upon payment of the prescribed annual dues (Ref Article IV), shall be afforded the privileges of student membership. Student members shall receive all publications of the Association but may not vote in the business of, nor hold office in, the Association.

(c) *Corporation Member*.—Any organization with active programs in weather modification, or with interests directly related to weather modification activities, which subscribes to the statement of purposes of the association, upon payment of the prescribed annual dues (Ref Article IV), shall be afforded the privileges of corporate membership. Corporations members shall receive all publications of the Association and may designate one (1) individual to act for the corporation in the affairs of the Association. The designated individual shall have the same rights and privileges afforded members of the Association.

(d) *Honorary Member*.—Members, or former members, of the Association who have made outstanding contributions to any aspect of weather modification may, subject to the unanimous consent of the Executive Committee of the Association, be nominated in the Association. Election shall be by simple majority vote of the members present at any regular or special meeting. Honorary membership shall be non-expiring for the life of the member. Members so elected shall be excused from the payment of dues. They shall receive all publications of the Association and enjoy the same privileges as members of the Association.

Article IV. Dues: All dues for the Association shall be paid on a calendar year basis. Annual dues for the various categories of membership shall be set by vote of the members present at the annual meeting, on the recommendation of the Executive Committee (Ref Article VI).

¹ From the Journal of Weather Modification, v. 9, No. 1, April 1977, p. 198-201.

Article V. Certification of Members: Certification of individual members as being qualified to execute field experiments or operations in weather modification shall be based upon experience, knowledge, and character. Certification shall be granted by the unanimous vote of a Certification Board which shall be composed of three (3) Certified Members who shall be appointed by the President. The members of the Certification Board shall each serve three (3) years on staggered terms. Changes in procedure for certification of members shall be made only after an affirmative majority vote of the Certified Members present at any annual meeting.

Article VI. Administration: The administration of the Association shall be vested in an Executive Committee which shall include the elected officers and trustees of the Association as follows:

(a) *President*.—The President shall be responsible for the administration of the Association. He shall appoint such committees as he deems necessary for the successful accomplishment of the Association's aims. The President shall preside at all meetings and shall be a member ex-officio of all committees.

(b) *President-elect*.—The President-elect shall succeed the President in office. The President-elect shall preside over the administrative functions of the Association in the absence, or by direction, of the President.

(c) *Secretary*.—The Secretary shall be responsible for the minutes of each meeting and shall notify the membership of impending meetings (Ref Article VIII). In the absence of both the President and the President-elect, the Secretary shall preside over the administrative functions of the Association.

(d) *Treasurer*.—The Treasurer shall conduct the financial affairs of the Association and keep accurate records thereof. The functions of Secretary and Treasurer may be combined in one person at the pleasure of the Executive Committee.

(e) *Trustees*.—Three (3) Trustees, to serve staggered three-year terms shall be elected from members representing private groups, university groups, and government groups respectively. It shall be the duty of the Trustees to represent the interests of their respective groups as members of the Executive Committee and to assist the President and other elected officers, as may be required, in the administration of the Association.

The Executive Committee may employ such other persons as may be necessary for the conduct of Association business.

Article VII. Elections: Elections shall be held at the annual meeting (Ref Article VIII). Officers to be elected will include a President-elect, Secretary, Treasurer (Ref Article VI d), and one (1) Trustee.

Nominations for elective offices shall be made by a nominating committee appointed by the President. Nominations will also be accepted from the floor, as called for, prior to balloting.

New officers and trustees shall assume their duties at the conclusion of the annual meeting, and shall serve until their successors assume office.

Article VIII. Meetings: Meetings shall be held at least once a calendar year. The first meeting of each calendar year shall be the annual meeting unless otherwise designated by the Executive Committee. Advance notice of all meetings shall be mailed by the Secretary (Ref Article VI c) to all members at least thirty (30) days prior to the date of the meeting.

The presiding officer and ten (10) percent of the voting members shall constitute a quorum. The location and date of all meetings shall be determined by a majority vote of the Executive Committee.

Article IX. Amendments: This Constitution and By-laws may be amended at any meeting by a majority vote representing a combination of all members present plus any absentee ballots received up to the day of the balloting on the floor, providing that the total votes cast constitute a quorum as defined in Article VIII. All amendments must be submitted to the membership at least thirty (30) days prior to the meeting at which they are to be considered.

QUALIFICATIONS AND PROCEDURES FOR CERTIFICATION BY THE WEATHER MODIFICATION ASSOCIATION²

PURPOSE OF CERTIFICATION

One of the purposes of the Weather Modification Association is to certify individual members qualified to direct field experiments or operations in weather modification. This certification is considered desirable to accomplish other pur-

² From the "Journal of Weather Modification," v. 9, No. 1, April 1977, p. 202-204.

poses of the Association, namely, promoting research and engineering advancements, encouraging and promoting the highest standards for professional conduct, and assisting in arranging liability insurance upon application from members performing field operations or experiments.

This document gives the qualifications and procedures for such certification by the Weather Modification Association.

QUALIFICATION FOR CERTIFICATION

Certification of individuals to direct weather modification field experiments or operations shall be based on character, knowledge, and experience. Certification shall be made at the discretion of the Board, but the following shall be considered minimum requirements:

General: A minimum of two years' field experience at the professional level in directing weather modification operations or research shall be required of all applicants, in addition to the experience and educational requirements specified below:

Category A.—Eight (8) years' experience in weather modification field operations or research.

Category B.—A degree in engineering, mathematics, or the physical sciences plus two years' experience in weather modification field operations or research.

Category C.—A degree in meteorology, or a degree in engineering, mathematics, or the physical sciences which includes or is in addition to at least 25 semester hours of meteorological course work.

Weather modification field operations experience is defined to be that which is involved in the organization, development, and actual conduct of field projects designed to effect a change in the weather. Actual manipulation to produce a desired change is implied. In all cases, actual field experience is required to insure the qualifications of the person certified. Operations may be either commercial or research, but field operations of either type are required. "Professional level" indicates a level of responsibility for direct supervision and conduct of the field operations or substantial parts thereof.

COMPOSITION AND TERMS OF OFFICE OF CERTIFICATION BOARD

The initial Certification Board and the procedure by which the initial certification procedures are to be adopted are given in motions passed by the Weather Modification Association at their March 1967 meeting. The motions read as follows:

Motion No. 1.—That the initial certification committee as specified in Article V of the Constitution and Bylaws of the Weather Modification Association be composed of three (3) Executive Officers of the W.C.R.A.

Motion No. 2.—That the initial certification committee establish the qualifications and procedures to be followed for certification, and present same by mail for approval to all past officers of W.C.R.A. who are current members of the organization.

Affirmative majority vote by those replying from this group shall constitute approval of the procedures so specified. Subsequent changes in these procedures shall be made only after affirmative majority vote of the certified members present at any annual meeting.

The initial Certification Committee established by the March 1967 meeting of the WMA shall function for calendar year 1968. The length of terms of office of the initial certification board shall be determined by lot to be staggered to permit the appointment of one new member in each year beginning 1969. At the end of calendar year 1968, the President shall appoint one new member of the Certification Board. In subsequent years, a new member of the Certification Board shall be appointed by the President each year. As specified in Article V of the Constitution and Bylaws of the Weather Modification Association, members of the Certification Board shall each serve three years on staggered terms. The member of the Certification Board who has the longest tenure on the Board shall serve as chairman.

PROCEDURE AND FEES FOR CERTIFICATION

Persons desiring certification as individuals qualified for conducting field experiments or operations in weather modification shall write to the Secretary of the Weather Modification Association requesting an application form and in-

structions. The completed application form shall be returned to the Secretary and must be accompanied by a \$25 check made payable to the Weather Modification Association. This fee will be retained by the Weather Modification Association whether the application is accepted or denied.

The Certification Board shall review the application form and from the information contained therein and any other information it obtains, will determine whether the applicant has satisfied the requirements for qualification for certification. The Certification Board may request additional information from the applicant prior to making a final decision as to whether or not the applicant meets the criteria for certification.

After review of the application, the Chairman of the Certification Board shall notify the applicant of the decision of the Board. If the application is approved, the Chairman of the Certification Board shall give the applicant a certificate to verify that the individual has met the qualification for certification.

Unsuccessful applicants may reapply for certification not earlier than one calendar year after notification of disapproval. Each subsequent application for certification shall be accompanied by a payment of the \$25 fee.

PERIOD OF CERTIFICATION AND RENEWAL

Certification of a member shall be effective for a period of three years from the date of issuance. Application for renewal of certification shall be submitted prior to expiration date in writing and accompanied by a fee of \$5. Issuance of a renewal of certification shall be automatic upon certification by the Board that no notification of violation of the conditions of the original certification has been received. In the event such notice has been received, renewal will be granted if recommended by the Board. If the Board does not recommend renewal, the case will be presented for the consideration of the certified members at two consecutive meetings. Renewal shall be denied only if two-thirds of the certified members in attendance at the second meeting indicate by secret written ballot that renewal shall be denied. The \$5 fee will be retained whether renewal is granted or not.

WEATHER MODIFICATION ASSOCIATION

Proposed Draft Statement on Standards and Ethics for Weather Modification Operators³ Prepared by Committee on Standards and Ethics, September 1977

PURPOSE

The Weather Modification Association (WMA) has adopted this statement on ethics and standards in order to further the Association's purposes, which include but are not limited to:

1. Promoting research, development and understanding of weather modification for beneficial uses.
2. Encouraging and promoting the highest standards of conduct.

CODE OF ETHICS

WMA members are expected to comply with the following code of ethics which cover their relationships with the general public, their clients, and the meteorological profession.

Relationships with general public

1. The member will comply with all laws and regulations of the federal, state, and local governmental units, particularly those laws and regulations covering weather modification activities.

2. The member will not participate in activities detrimental to the general public interest or which inflict undue hardship upon individuals in proposed operational areas.

³ Distributed to members of the Weather Modification Association at the 1977 fall meeting, October 10, 1977, Champaign, Illinois, for review and comment.

Relationships with clients

3. The member will not exaggerate his (her) capabilities, nor guarantee results in terms of future weather conditions. Statements regarding the probable effects of weather modification projects should be compatible with the current "Statement of Capabilities" set forth by the WMA, unless they can be justified on the basis of documented results.

4. Contracts where a bonus is paid for "production" of rainfall over and above some arbitrary amount, such as a monthly normal, are detrimental to the development of a sound technology, and are to be discouraged.

5. The member will divulge fully to clients and potential clients all chemicals and methods used. Proprietary rights to newly developed materials or techniques for cloud seeding may be established through the obtaining of patents.

Relationships with meteorological profession

6. The member will conduct himself (herself) in a manner to reflect dignity and honor on the profession.

7. The member will keep abreast of scientific and technical developments in the field of weather modification and will seek to incorporate improvements into his (her) operational and research programs.

8. The member will endeavor to contribute new knowledge to the profession by making known significant results from operational and research programs.

9. The member will not knowingly take credit for work done by others, but will attempt to give credit where due.

10. The member will not unjustly criticize fellow workers in his (her) profession, but will refer to the Association information on apparent unethical practices on the part of other operators.

STANDARDS FOR CONDUCT OF INDIVIDUAL PROJECTS

The following standards shall apply to the conduct of both operational and research projects:

1. Each project should have a set of clearly defined objectives. The operator should provide as precise a statement as possible of how the objectives are to be reached.

2. The operator will not undertake work in an area where serious conflicts might arise from weather modification activities, without taking steps to identify and correct such situations in advance.

3. The operator will conduct each project in such a way as to minimize danger to the public and to the environment from the use of seeding devices, seeding agents, and other appurtenances of his (her) trade.

4. Each project should be under the personal direction of a meteorologist with special training or experience in weather modification field projects.

5. The project meteorologist should have access to up-to-date weather data including, as a minimum, the weather data available through circuits of the National Weather Service. Local atmospheric soundings, wind observations, radar data, and telemetered precipitation data from remote sites are highly desirable supplements.

6. Each project should have established criteria and procedures for shutting down operations in the face of impending severe weather to avoid contributing to, or appearing to contribute to, damaging weather situations. The shutdown criteria and procedures should be specified in advance in writing, and should take into account existing water management practices and flood control facilities.

7. A calibration curve showing ice nuclei output should be available for each type of cloud seeding generator used on a project.

8. Evaluations of projects are strongly encouraged, but limitations imposed by project duration, inadequacy of observations, and so on, should be pointed out.

policy statement of the American Meteorological Society on purposeful and inadvertent modification of weather and climate

As adopted by the Council on January 28, 1973 ^{1/}

Introduction

Man's ability to alter certain local weather conditions, either purposefully or inadvertently, in some areas is clearly established. However, most atmospheric scientists agree that man's ability to significantly alter the atmospheric environment in a purposeful manner is still in the early stages of development. Adequate research and operational support in the 1970s should permit major advances in developing weather modification techniques in the next decade.

A new statement by the American Meteorological Society (AMS) to inform the public and to answer scientific questions about weather and climate modification is therefore timely, and also useful in setting national scientific priorities. Specifically, four conditions have been significantly altered since the last AMS statement, issued in 1967, and the changes which have dictated this new statement include: 1) advances in knowledge and techniques of planned weather modification, 2) new evidence of urban-related inadvertent weather or climate modification, 3) a growing need to assess the partially developed and rapidly evolving weather modification technology in light of public interest and concerns, and 4) a need to issue recommendations regarding essential future weather modification efforts.

Status of planned weather modification

As we move into the 1970s there is mounting scientific evidence that cloud seeding using ice nuclei can produce substantial, albeit local, changes in clouds and storm systems. Definitive success in dispersing fog and in increasing rainfall and snowfall has been achieved in the United States and elsewhere in the 1960s.

Fog. Dissipation of cold (supercooled) fogs and low stratus is established as an operational application with clear economic benefits. Warm fog dissipation can generally be accomplished by expensive techniques, but a reliable and economically acceptable technique for dissipating warm fogs on a local scale is not established.

Precipitation. Precipitation amounts from certain cold orographic clouds in winter can apparently be substantially increased or decreased on a predictable basis, and thus seeding of these types of clouds for economic benefit appears to be justified. Seeding of cold orographic clouds sometimes increases, sometimes decreases, and sometimes has no effect on precipitation depending on the mete-

orological conditions. Overall increases from 5 to probably 30%, depending on location, seem reasonable with existing technology for certain mountainous areas of the western United States. Attempts to increase precipitation from convective clouds have provided local increases under certain circumstances, and under other circumstances local decreases. Too little is known about the physical, chemical, and dynamical processes of convective precipitation to make the outcome predictable in most areas. Precipitation increases from non-orographic and non-convective cloud systems, such as the shallow stratiform winter storms of the central United States, have not been demonstrated; but in theory, at least, it is possible to increase or relocate precipitation from such systems. There is also some evidence that precipitation alterations may occur 100 kilometers or more beyond the primary seeded areas, but much more proof and a better understanding of these "downwind effects" are needed.

Severe Storms. Results from efforts to mitigate the destruction of severe storms can be classed as encouraging but still indeterminate. Positive but unsubstantiated claims and growing optimism best describe results from lightning suppression efforts in the United States, recent hail suppression programs in the United States and abroad, and hurricane modification efforts in the Atlantic. Less optimism surrounds the possibilities of inhibiting tornadoes and severe local rainstorms. Too little controlled experimentation concerning modification of severe storms has been conducted to provide sufficient credible evidence of success. Recent evidence, particularly that from the Soviet Union and Europe, of hail suppression appears to make it more credible than the evidence for the control of other forms of severe storms.

Inadvertent weather modification

There is growing worldwide concern over man's inadvertent modification of weather and climate. Urban-industrial pollutants (thermal, gaseous, and particulate emissions) have been shown to alter urban weather and climate, and new evidence establishes that alterations occur in clouds and precipitation from 8 to 80 kilometers downwind of urban-industrial sources. Recent investigations of major shifts in land use practices, such as irrigation and different cropping, have pointed to possible alterations in weather and climate over substantial regions.

¹ Reprinted from the Bulletin of the American Meteorological Society, v. 54, No. 7, July 1973, pp. 694-695.

Man's effect on global climate is suspected, since his activities have resulted in regional changes in the cloud cover and surface albedo, and widespread increases in CO₂ concentration and particulate concentration. However, there is no clear evidence yet that these changes have accounted for any substantial part of the climatic fluctuations of the past century.

Public issues

Recent advances towards achieving planned "weather management," and an awareness of the reality of inadvertent weather modification, make it imperative that a great deal more be understood about their social, ecological, and legal implications. Limited economic and ecological studies of the potential effects of planned weather modification have produced conflicting results that point to the need for comprehensive socioeconomic studies. Before planned weather modification becomes a widely applied technology, comprehensive analyses of the overall public interests on a local, regional, national, and international scale must be made in order to achieve rational judgments and decisions concerning the wise use of weather modification.

Recommendations

Significant progress in weather modification has occurred in recent years. It has been demonstrated that man can and does modify the weather. However, we still have much to learn about the following subjects: 1) the exact atmospheric conditions in which it is possible to increase, decrease or relocate precipitation; 2) those techniques that might reduce the damage caused by severe storms; or 3) the extent of climatic change being produced inadvertently by man. These three items should be included among the major goals of our national program in weather modification, and more unified and stronger federal programs must be developed to meet the demands created by a society which is increasing in size and complexity.

Some specific recommendations regarding weather modification activities in the 1970s include:

- 1) development of improved numerical models of convective clouds and storm systems relevant to weather modification efforts;
- 2) performance of comprehensive, randomized experiments involving precipitation enhancement and redistribution in each of the major climatic zones of the United States in each season and for each of the principal forms of precipitation, with provisions for evaluations of downwind effects;
- 3) pursuance of fundamental research and field experiments to ascertain means of mitigating severe storms (thunderstorms, hail, hurricanes, and tornadoes);
- 4) extended research on operational warm fog dispersion;
- 5) creation and expansion of facilities and expertise devoted to this subject, including application of current

satellite programs, cloud physics research laboratories, laboratories for developing seeding devices and seeding agents, instrumented vehicles for penetrating severe storms, and statistical research groups; and

6) encouragement of programs to study inadvertent weather modification (a) by monitoring conditions critical to the global climate and man's well-being, including pollutants, water vapor, cloud cover, surface albedo, and heat balance, and (b) by measuring and defining the influences of urban development and land-use change on weather and climate.

For additional information

A few of many possible references were selected for this list describing the progress in all phases of weather and climate modification in recent years. Inclusion of a reference does not necessarily imply our sanction of the views or findings, but indicates it is a source of additional information for the interested reader.

American Meteorological Society, 45 Beacon Street, Boston, Massachusetts 02108, 1971: *Proceedings of International Conference on Weather Modification*. Canberra, Australia, 372 pp.

American Meteorological Society, 45 Beacon Street, Boston, Massachusetts 02108, 1972: *Preprints of Third Conference on Weather Modification*. Rapid City, S. Dak, 336 pp.

National Academy of Sciences, Printing and Publishing Office, 2101 Constitution Avenue, Washington, D.C. 20418, 1971: *The Atmospheric Sciences and Man's Needs: Priorities for Future*. Washington, D.C., 88 pp.

National Academy of Sciences, Printing and Publishing Office, 2101 Constitution Avenue, Washington, D.C. 20418 (to be published): *Weather and Climate Modification, National Policies and Programs*. Washington, D.C., 417 pp.

Colorado Associated University Press, University of Colorado, 1424 15th Street, Boulder, Colorado 80302, 1967: *Man and the Quality of his Environment*: Western Resources Conference, edited by J. E. Flack and M. C. Shipley. Boulder, Colo., 251 pp.

Lambricht, W. H.: Government and technological innovation: Weather modification as a case in point. *Public Administration Review*, 1, 1-10. 1972: American Society for Public Administration, 1225 Connecticut Avenue, NW, Washington, D.C. 20036.

Lackner, J. D.: *Precipitation Modification*. National Water Commission Report NWC-EES-71-005. 1971: National Water Commission, Room 405, 800 North Quincy, Arlington, Virginia 22203, 170 pp.

M.I.T. Press, 28 Carleton Street, Cambridge, Mass. 02142, 1971: *Study of Man's Impact on the Climate (SMIC Report)*, 302 pp.

World Meteorological Organization, Case Postale No. 1, CH-1211 Geneva 20, Switzerland, 1971: Present state of knowledge and possible practical benefits in some fields of weather modification. *General Summary of EC-XXII*, Document 38, 3 pp.

APPENDIX P

REPORTING AGENCIES OF MEMBER COUNTRIES AND QUESTIONNAIRE CIRCULATED TO RECEIVE WEATHER MODIFICATION INFORMATION FROM MEMBERS OF THE WORLD METEOROLOGICAL ORGANIZATION

REPORTING AGENCIES

ARGENTINA	Comisión Nacional de Investigaciones Espaciales Fuerza Aerea Argentina 1104 - Comodoro Pedro Zanni 250 Buenos Aires
BRAZIL	Instituto de Atividades Espaciais Divisão de Ciências Atmosféricas CTA/IAE 12000 - Sao José dos Campos, SP
BULGARIA	Hydrometeorological Service Boulevard Lenin 66 Sofia
CANADA	Cloud Physics Research Division Atmospheric Environment Service 4905 Dufferin Street Downsview, Ontario M3H 5T4
CUBA	Comité de Programe Lluvia Provocada Academia de Ciencias de Cuba ININTEP, Calle O No. 8 Havana 4
CZECHOSLOVAKIA	Hydrometeorological Institute Jesniova 17 885 32-Koliba
FED. REP. OF GERMANY	Der Landrat des Landkreises Rosenheim Landratsamt 82 Rosenheim/Obb.
HUNGARY	Meteorological Service of the Hungarian People's Republic Post Office Box 38 H-1525 Budapest
ISRAEL	EMS subd y "Mekorot" "Mekorot" Water Co. Post Office Box 308 Hulon
ITALY	Società Ricerche Esperienze Meteorologiche Via Pasubio 11 Rome
MALAYSIA	Malaysian Meteorological Service Jalan Sultan Petaling Jaya Selangor

- MEXICO Departamento de Hidrometeorología y Predicción
Dirección de Hidrología
Versalles 19, 4^o piso
México C D.F.
- NICARAGUA Comisión Nacional del Algodón
Sección de Investigaciones Climatológicas
Apartado Postal No. 2655
Managua
- NIGER Direction de la Météorologie Nationale
Boite Postale No. 210
Niamey
- NORWAY Directorate of Civil Aviation
Storgt. 10b Dep
Oslo 1
- PHILIPPINES Philippine Atmospheric, Geophysical and
Astronomical Services Administration (PAGASA)
Typhoon Moderation Research and Development Office
1424 Quezon Avenue
Quezon City
- ROMANIA Institut de météorologie et d'hydrologie
Sos. Bucuresti-Ploiesti No. 97
Sector 1
Bucarest 18
- SPAIN Servicio Meteorológico Nacional
Ciudad Universitaria
Apartado 285
Madrid
- SWITZERLAND Laboratory for Atmospheric Physics
Federal Institute of Technology
H.P.P. Hänggerberg
8095 Zurich
- THAILAND The Royal Rain Making Research and Development
Institute
(no address given)
- TURKEY Turkish State Meteorological Service
Post Office Box No. 401
Ankara
- U.S.A. Environmental Modification Office (EMS)
National Oceanic and Atmospheric Administration
6010 Executive Boulevard
Rockville, Maryland 20852
- UPPER VOLTA Direction de la Météorologie Nationale
Boite Postale No. 576
Ouagadougou
- YUGOSLAVIA Federal Hydrometeorological Institute
Birčaninova 6
Post Office Box 604
11000 Belgrade

COPY OF QUESTIONNAIRE CIRCULATED TO RECEIVE INFORMATION FROM MEMBERS

Member of WMO :-----

Reporting of activities in the year 19__

1. Type (purpose) of weather modification activity or project :
2. Approximate size of the project area overall :----- km².
and of the target area :----- km².
3. Name and/or reference of project :
4. Location of area in which project is carried out :
5. Year project commenced : 19__
6. Is it expected to continue during the coming year?
Yes ---- No ---- Not known ----
7. Nature of national organization sponsoring project :
Please place X.

	<i>Governmental</i>	<i>Private</i>
Agriculture -----	----	----
Energy -----	----	----
Forestry -----	----	----
Hydrology -----	----	----
Transportation -----	----	----
Other (please specify) -----	----	----

8. Description of weather modification apparatus, modification agents and their dispersal rates, the techniques employed, etc. (see instructions).

9. Months of current reporting year during which seeding or other weather modification activity took place :

10. Number of days during the year on which seeding (or other weather modification activity) took place :

11. Was a document prepared on the possible effects on the environment of the weather modification project?

Yes ----
No ----

12. Optional remarks :

13. Reporting agency :

- (a) Name of reporting agency :
- (b) Official title of responsible office :
- (c) Postal address :

Signed :

Date :

Please complete and return this questionnaire as soon as possible, and in any case not later than 15 March 1977, to :

The Secretary-General
World Meteorological Organization
Case Postale No. 5
CH-1211 GENEVA 20

NOTES FOR COMPLETING REPORT ON WEATHER MODIFICATION ACTIVITIES

WEATHER MODIFICATION ACTIVITIES WHICH SHOULD BE INCLUDED IN THE REGISTER

(1) The seeding or dispersing into clouds or fog of any substance with the object of altering drop-size distribution, producing ice crystals or the coagulation of droplets, altering the development of hail or lightning, or influencing in any way the natural development cycle of clouds or their environment ;

(2) The use of fires or heat sources to influence convective circulation or to evaporate fog ;

(3) The modification of the solar radiation exchange of the earth or clouds, through the release of gases, dusts, liquids or aerosols into the atmosphere ;

(4) The modification of the characteristics of land or water surfaces by dusting or treating with powders, liquid sprays, dyes, or other materials ;

(5) The releasing of electrically charged or radioactive particles, or ions, into the atmosphere ;

(6) The application of shock waves, sonic energy sources, or other explosive or acoustic sources to the atmosphere ;

- (7) The use of aircraft and helicopters to produce downwash for fog dispersal as well as the use of jet engines and other sources of artificial wind generation;
- (8) The use of lasers or other sources of electromagnetic radiation;
- (9) Any other similar activities falling within the definition of weather modification.

WEATHER MODIFICATION ACTIVITIES WHICH NEED NOT BE INCLUDED IN THE REGISTER

Activities of a purely local nature, such as the use of lightning deflection or static discharge devices in aircraft, boats, or buildings, or the use of small heat sources, fans, fogging devices, aircraft downwash, or sprays to prevent the occurrence of frost in tracts or fields planted with crops susceptible to frost or freeze damage.

Completing the form

One completed copy of this form is requested for each weather modification activity (hereafter referred to as the project) once per year.

Item 1—Enter the purpose of the project or activity: e.g. rainfall increase, hail suppression, cold fog dispersal, etc.

Item 2—Enter the size (in km²) of the area designated for the project, and the size of the target area if different (see "Definition", item 4).

Item 3—Enter the name and/or reference of project used by the operator. If the project was reported in the previous Register, please quote the WMO Register Number which appears in column 1.

Item 4—Indicate the location of the weather modification project by geographical co-ordinates and name of the region.

Item 5—Enter the year in which the first activities under the present project took place.

Item 6—Indicate whether the project is expected to continue in the future.

Item 7—Indicate the nature of the organization sponsoring the project and whether it is governmental (including local governments) or private.

Item 8—Describe the weather modification apparatus, modification agents and the techniques used. This might include type of ground or airborne apparatus used, type of modification material dispersed, rate of dispersal in grams per hour or other appropriate descriptions, and other information such as type of radars, type of aircraft used, techniques employed (e.g. cloud base seeding at 3,000 m msl), etc.

Item 9—Enter the months of the year to which the report applies during which seeding, etc., was carried out.

Item 12—This item is to permit the reporting person to include any information not covered by item 1 through 11 but which he feels is significant or of interest such as references to published reports describing results of the weather modification operation or experiment. Any definite plans for a new project during the coming year may be outlined under item 12.

Item 13—Please supply the name and address of agency to which any request for further information should be directed.

Use a separate sheet of paper if more space is needed.

Definitions

As used in the WMO Register, terms have the following meaning:

Item 1—Type (purpose) of weather modification activity or project: By project is meant a related series of weather modification activities having a common objective. Will be included any activity performed with the intention of producing artificial changes in the composition, behaviour or dynamics of the atmosphere.

Item 4—Location of area in which project is carried out: The area referred to includes both the target area and control area. By target area is meant the ground area within which the effects of the weather modification activity are expected to be found, and by control area is meant a preselected, untreated ground area used for comparison with the target area.

Item 8—Description of weather modification apparatus, etc.: By weather modification apparatus is meant any apparatus used with the intention of producing artificial changes in the composition, behaviour, or dynamics of the atmosphere. For example: seeding generators, propane devices, flares, rockets, artillery projectiles, jet engines, etc.

APPENDIX Q

REPORT OF THE WORLD METEOROLOGICAL ORGANIZATION/UNITED NATIONS ENVIRONMENT PROGRAM INFORMAL MEETING ON LEGAL ASPECTS OF WEATHER MODIFICATION

WORLD METEOROLOGICAL ORGANIZATION AND UNITED NATIONS ENVIRONMENT PROGRAM, GENEVA, NOVEMBER 17 TO 21, 1975

1. ORGANIZATION OF THE MEETING

1.1 *Opening of the meeting*

1.1.1 The Chairman, Professor R. List, declared the meeting open at 10:00 a.m. on Monday 17 November 1975. The list of participants is reproduced in Appendix A.

1.1.2 Mr. O. M. Ashford, Director of Program Planning and UN Affairs of the WMO Secretariat, welcomed the participants to the Headquarters of WMO on behalf of the Secretary-General, expressing appreciation to UNEP for having taken the initiative in arranging the meeting and for providing support to the participants. He observed that when the Seventh World Meteorological Congress in April 1975 decided to launch the Weather Modification Program, this marked a considerable change in the position of the Organization in this respect which was in line with the trend to give greater attention to the broad socio-economic responsibilities of WMO as a specialized agency of the United Nations. WMO already collaborated with UNEP in some ten different projects, and the present meeting where persons from different disciplines could discuss together topics of common interest was a good example of such collaboration. In conclusion Mr. Ashford gave a special word of thanks to the six experts nominated by WMO who had agreed to come to present on behalf of the Organization the current scientific situation in weather modification.

1.1.3 Mr. R. S. Mikhail, Deputy Director of the Division of Geophysics, Global Pollution and Health of the UNEP Secretariat conveyed the greetings of the Executive Director of UNEP and expressed appreciation to WMO for having organized the meeting in Geneva and thanked the co-chairman and participants for having come. He informed the meeting that the Governing Council of UNEP in March 1975 had agreed that the dialogue between WMO and UNEP on legal aspects of Weather Modification should continue since it was essential that international legal principles and guidelines should be considered hand in hand with the scientific advancement of the subject. Mr. Mikhail expressed the opinion that if the present state of scientific knowledge in the area of weather modification was not yet adequate to permit the development of formal legal instruments for the regulation of activities in this area, it was nevertheless feasible to develop general principles and operating guidelines as a first step in that direction.

1.2 *Adoption of the agenda*

1.2.1 The agenda as adopted as reproduced in Appendix B. List of supporting papers available at the time of the meeting is reproduced in Appendix C.

2. REVIEW OF DEVELOPMENTS SINCE THE THIRD SESSION OF THE WMO EXECUTIVE COMMITTEE PANEL ON WEATHER MODIFICATION IN NOVEMBER 1974

2.1 *Relevant decisions of the third session of the Governing Council of UNEP*

2.1.1 The meeting was informed that according to the decisions of the Governing Council, the strategy of UNEP in respect of the legal aspects of weather modification is as follows:

- (a) Consultations will be continued towards development of legal provisions which would define the responsibility of States to ensure that weather modification experiments and operations within their jurisdiction or control

do not cause damage to the environment of other States or to areas beyond the limits of national jurisdiction;

(b) The Executive Director will continue to consult with WMO and other scientific and legal experts as necessary on the desirability of developing general principles and operating guidelines on weather modification experiments and operations. He proposes a meeting between scientists and legal experts to develop such principles and guidelines. The question of calling an intergovernmental meeting to approve such principles and guidelines would be considered at a later stage, after consensus is reached between scientists and legal advisers.

2.2 *Relevant decisions of the seventh session of Congress and of the twenty-seventh session of the Executive Committee of WMO*

2.2.1 The Weather Modification Program of WMO incorporates as its most important component a Precipitation Enhancement Project (PEP) which will be an internationally planned, executed and evaluated experiment in artificial precipitation stimulation. The meeting was informed that in Resolution 12 (Cg-VII) Congress had specifically asked the Executive Committee in developing the plans for PEP to give particular consideration to minimizing any legal liability of WMO.

2.2.2 The position of the WMO Congress was in accord with that of the UNEP Governing Council in that international legal principles and guidelines should be developed hand in hand with the scientific progress in the field of weather modification. Congress was of the opinion that a better understanding of the physical basis of weather modification was needed before WMO would be able to provide definitive advice to Members on this aspect of weather modification experiments or operations.

2.2.3 The meeting agreed that scientific advancement in general did not progress smoothly, but was somewhat erratic and even subject to reverses on occasions. It was suggested that over a relatively short time scale the keyword should perhaps be "in phase" rather than "hand in hand".

2.3 *Relevant decisions of the Conference of the Committee on Disarmament (CCD) of the United Nations*

2.3.1 The meeting noted with interest that at the request of the Conference of the Committee on Disarmament, some experts had attended an informal meeting in Geneva in order to provide the Committee with scientific and technical background information concerning weather modification. Following this scientific briefing, the representatives of the U.S.A. and the U.S.S.R. had submitted independently an identical draft text for a convention on the prohibition of military or any other hostile use of environmental modification techniques. The General Assembly of the United Nations was currently discussing the report of the CCD and would indicate the future action to be taken on this draft.

2.3.2 The meeting was also informed that it was proposed to include a limitation on the use of environmental warfare in the protocols to the Geneva Conventions of 1949 now under discussion in a Diplomatic Conference on Humanitarian Law (Geneva).

3. REVIEW OF THE STATE OF THE ART AND POSSIBLE DEVELOPMENTS

3.1 *National laws related to weather modification*

3.1.1 Professor Samuels introduced this item and drew attention to some of the difficulties encountered in obtaining accurate up-to-date information, and in comparing different legal systems. After summarizing the principal control techniques and substantive rules as found mainly in the special laws of Australia, Canada, South Africa, and the United States, he recommended in particular the establishment of an international register of relevant national legislation and the development of a model national law comprising certain essentials such as registration and data reporting for all weather and climate modification activities.

3.1.2 In the ensuing discussion, reference was made to additional sources of national law, including the applicable rules contained in water legislation (e.g., Peru 1969), in natural resources legislation (e.g. Colombia 1974), and in the general body of environmental, administrative and civil law (e.g., in the U.S.S.R.). It was pointed out that even in those countries where special legislation had been enacted, a single statutory text normally could not cover all relevant aspects of weather modification.

3.1.3 There was general agreement on the desirability of an improved collection and mutual exchange of legislative information, also from an educational point of view. It was noted with satisfaction that WMO was initiating a register of weather modification activities and that the questionnaire circulated to Members to obtain information for inclusion in the register inquired as to the existence of laws relating to weather modification activities in the country concerned. The meeting suggested that WMO Members should be invited to supply full details of such laws so as to facilitate a complete compilation of national laws. However, the meeting agreed that indiscriminate transfer of laws from one country to another was not practicable, but that laws needed to be adapted to specific requirements of different legal and social systems.

3.1.4 In this connexion, reservations were expressed as to the feasibility of technical assistance and expert advice by WMO/UNEP to individual states on legal aspects of weather modification at the present stage of scientific knowledge. In particular, while legal rules on registration and data reporting were generally considered as beneficial, premature rules on liability for damage were viewed as potentially counter-productive.

3.2 *The science of weather modification*

3.2.1 The meeting agreed that the discussion would be concerned solely with intentional weather modification.

3.2.2 The meeting had the opportunity to examine the official WMO statement released in 1974 entitled "Present state of knowledge and possible practical benefits in some fields of weather modification" (see Appendix D) and also the amplification of this statement which had been prepared for use by the Secretary-General of WMO.

3.2.3 It was agreed that the statement and its amplification represented the current state of knowledge in the field of weather modification; the meeting noted that the International Commission on Cloud Physics of the International Association of Meteorology and Atmospheric Physics (IAMP) and indicated satisfaction at the statement and at Weather Modification Programs of WMO. It was recalled that the Precipitation Enhancement Project of WMO was designed to obtain further scientifically acceptable information concerning the feasibility of artificial stimulation of precipitation.

3.2.4 The meeting was informed that the role of WMO at the present time in helping developing countries was to give advice, on request, concerning proposed weather modification projects and occasionally to provide experts under the UNDP to visit countries in order to assess the possibilities of artificial precipitation augmentation. It was hoped to arrange courses in weather modification and to offer fellowships in these courses to a certain number of scientists from developing countries.

3.2.5 Seventh Congress strongly urged that when a Member country or a group of Members wished to conduct their own weather modification with the advice of WMO, a special WMO group of experts be set up to advise on the planning, implementation and evaluation of the project. The high scientific stature and independence of such a group would permit it to guide the project along sound scientific lines and thereby assume the greatest chance of success and ultimate acceptance of the results by the scientific community. The cost involved in providing for a WMO group for a special project of this kind would be borne by the Member or Members concerned.

3.2.6 There was a considerable discussion on the distinction for legal purposes between a weather modification experiment and an operation. It was generally agreed that in an experiment the major objective was using scientifically acceptable methods to obtain information, whereas in an operation the objective was to influence the atmospheric processes so as to produce a desired effect, e.g. additional rainfall. In the latter case, a scientific evaluation of the intervention was frequently not made. It was pointed out however that for the purpose of determination of legal liability the distinction was irrelevant.

3.3 *Legal problems facing public and private operators*

3.3.1 Professor Samuels introduced this agenda item. He suggested that the key problem facing operators is the legal responsibility they may bear for damage caused by their activities. He pointed out the difference between legal systems as regards the type of damage for which compensation may be received, the bases of liability and the kind of proof required. He also drew attention to possible links between an operator's liability and a State's international responsibility in the event of alleged extended area effects.

3.3.2 After a general discussion on the state of international environmental law and on the recourse available in situations involving alleged trans-frontier damage, the meeting briefly reviewed past experience with court litigation regarding injunctions and liability for damage. Weather modification activities, no adverse effects of which have been proved on the basis of the present state of scientific knowledge, were distinguished from other activities involving pollution and other harmful effects; the view was expressed that the development of new beneficial technology should not be constrained unduly by "Punitive" legal sanctions. Instead, the preventive function of administrative law was emphasized, especially in the field of licensing procedures and mandatory environmental impact assessment.

3.3.3 There followed a discussion on the practices of, and available controls over, private operators engaged in weather modification abroad, especially in developing countries. The meeting was informed of the 1973 recommendations of the WMO Commission for Atmospheric Sciences, which advised governments to seek advice from WMO on this subject and of the consequent decision of the WMO Seventh Congress authorizing the Secretary-General to establish on request a special WMO group of experts to advise on the planning, implementation and evaluation of projects where the costs involved will be borne by the Member(s) concerned. (See paragraph 3.2.5 above.)

4. DISCUSSION OF THE DEVELOPMENT OF GENERAL PRINCIPLES AND OPERATING GUIDELINES FOR WEATHER MODIFICATION

4.1 The meeting discussed in general terms the scientific, economic, ecological, sociological and political considerations which need to be taken into account in the development of general legal principles and operating guidelines for weather modification activities. It then turned to a discussion of the background paper on legal principles prepared by Professors E. B. Weiss and J. W. Samuels, UNEP legal experts. It was made clear that the discussion was not aimed at developing binding legal rules but rather at developing proposals for general principles to be considered in the formulation of a future legal regime. The legal experts expressed their desire for the advice of the scientists in the elaboration of general legal principles and operating guidelines. The WMO experts noted that they did not feel qualified to engage in detailed discussion of principles which were essentially political in spirit.

4.2 The first proposed principle which recognized the interest of all mankind in the weather was introduced. It was explained that this legal concept was employed in other common resource areas, such as the deep sea-bed beyond the limits of national jurisdiction. The meeting considered that a proper formulation of this principle, in this context, would be: "The earth's atmosphere is a part of the common heritage of mankind".

It was suggested that ultimately any statement of principles should be preceded by a Preamble in which reference is made to the WMO Statement on Weather Modification and the uncertainty of the state of the art. Furthermore, it was suggested that any commentary on this principle should make reference to the inextricable links between the atmosphere and other environmental spaces, e.g. the world's oceans, which are also part of the common heritage of mankind.

4.3 Concerning the second proposed principle which called for the limitation of the use of weather modification techniques to peaceful purposes, the meeting was of the opinion that the inclusion of the following provision in the general principles would be useful: "Any techniques developed to modify weather shall be dedicated exclusively to peaceful purposes."

Whereas the original proposals concerned weather and climate modification, on the advice of WMO experts reference is made only to weather modification.

4.4 The third proposed principle, which concerned the gathering and exchange of meteorological information was introduced. It was made clear that the WMO Convention already calls for such an exchange. Bearing this in mind, the meeting was of the opinion that a useful formulation would be: "Further to the continued exchange of meteorological and related information in accordance with the WMO Convention, States shall facilitate the gathering and exchange of information on weather modification activities and shall ensure that such information is made available to WMO and to interested States."

It was noted that WMO already receives reports from States on weather modification activities.

4.5 The fourth proposed principle concerned the giving of prior notification of prospective weather modification activities to interested States. It was explained that "adequate" and "timely" notification would help to defuse international tension arising from misinformation and speculation concerning a neighbour's activities. "Adequate" imports that the information provided shows clearly what will be done. "Timely" means that the notified State is given the time to analyze the information and consult with the acting State before the activity is conducted. In discussion, reference was made to UN General Assembly resolutions 3129 (XXVIII) and 2995 (XXVII) in which the Assembly expressed its consideration that the development and management by States of shared natural resources should be based on a system of information and prior consultation, in the spirit of co-operation and good neighbourliness. It was pointed out that the UNEP Governing Council was of the opinion that weather modification activities were related to the area of shared natural resources but that a separate development of legal principles for weather modification is of value.

4.6 The meeting discussed in considerable detail the problems inherent in the formulation of a principle concerning notification. In particular, the meeting explored the questions of how the decision is made on whom to notify, and what would be the mechanics of this notification. The WMO experts emphasized the limitations of the state of the art and the problems this posed in suggesting that neighbouring States might be affected by the weather modification activities. The meeting considered that a useful wording of a principle on notification would be: "States shall in good faith give adequate and timely notification of prospective major weather modification activities, within their jurisdiction or control, to WMO which should transmit such notification to all interested States."

This formulation involves the concept of "major" activities. It is only for activities of this significance that notification is necessary. Because there is judgment involved in what is "adequate", "timely" and "major", the notion of "good faith" was included to provide some legal standard for the judgment.

4.7 The meeting turned to a consideration of the possibility of requiring States to undertake an assessment of the environmental impact of an activity before it is conducted. The feasibility of such an assessment was questioned. The possibility of incorporating the concept in the aforementioned fourth principle was discussed and it was pointed out that the history of the development of national environmental legislation in several States indicated that notification and impact assessment were two separate requirements, to be dealt with as distinct obligations.

4.8 Whilst the meeting was unable to concur in recommending a principle concerned with the assessment, of the potential immediate and long-term environmental effects of weather modification activities, the following formulation was considered as being useful for further thought: "States shall ensure that a careful assessment is made of the environmental impact of prospective major weather modification activities within their jurisdiction or control, and shall make such assessments available to WMO and all interested States".

4.9 Discussion then turned to the possibility of prohibiting certain weather modification activities which offered the risk of significant harm, unless the consent of all interested States is obtained. It was pointed out that analogous limitation could be inferred from Recommendation 70 of the Stockholm Declaration and from UN General Assembly Resolution 2995 (XXVII). Concern was expressed that such a legal principle was unnecessary given the state of the art today and that express application of the general limitations found in the Stockholm Declaration, etc., to the field of weather modification was unwarranted. The meeting decided that such a principle should be deferred for further consideration.

4.10 The meeting then moved to consideration of the possibility of requiring States to monitor weather modification activities under their jurisdiction and control and to make such information available to interested States and the WMO. It was pointed out that in several States there was already legislation providing for the obligation to monitor. The meaning of the word "monitor" was discussed and it was suggested that it imports the observance of and recording of information concerning the conduct and effects of the activity during and after its undertaking.

4.11 Although no agreement was reached concerning the degree of monitoring, the meeting was of the opinion that the following formulation was valuable for further consideration: "States shall make every effort to ensure that weather modification activities within their jurisdiction or control are monitored, and

shall make such information available to WMO and interested States in accordance with Principle Three".

4.12 The possibility was considered of a formulation which would apply Principle 21 of the Stockholm Declaration to the field of weather modification, namely that States should ensure that weather modification activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction. The WMO experts considered that it was premature to recommend such a principle in view of the present limited state of scientific knowledge.

4.13 The meeting then moved to a discussion of the possibility of a principle calling for consultation between the acting State and other interested States in order to alleviate points of difference between the parties concerning proposed weather modification activities. The legal experts of UNEP pointed out that such consultation can be a useful means of maintaining friendly relations among States. Mention was made of the agreement between Canada and the United States which calls for such consultation in certain circumstances.

4.14 The meeting was of the opinion that a principle imposing a duty on States to consult would not be desirable, but that the following draft text would be preferable: "It is desirable that a State, in whose territory major weather modification activities are to be undertaken, should engage in meaningful and timely consultation with interested states at their request, with a view to working out mutually acceptable arrangements regarding the conduct of those activities".

The meeting made note of the following points in this formulation. Firstly, it concerns only "major" activities. Secondly "interested" States would involve the notion of legitimate concern. Thirdly, the consultation would be at the request of the interested States.

4.15 The meeting turned to the discussion of a possible principle recognizing the obligation of States to compensate persons beyond their national frontiers for significant damage caused by weather modification activities within their jurisdiction. It was noted that the state of the art today precluded any assessment of damage and the WMO experts express the opinion that the recommendation of any such principle was premature.

4.16 The legal experts of UNEP were of the opinion that it would be useful to include the principle that States shall co-operate in the development of a legal regime for the international regulation of weather modification activities.

4.17 In conclusion, reference was made to the future possibility of national legislation to implement any international legal principles and operating guidelines. The view was expressed that it might be useful to include in the general principles a provision that would call on States to adopt legislation to regulate weather modification activities at the national level.

5. LEGAL ASPECTS OF THE WMO PRECIPITATION ENHANCEMENT PROJECT

5.1 In Resolution 12 (Cg-VII) the WMO Congress, in approving the Precipitation Enhancement Project (PEP) as part of the Weather Modification Programme of WMO requested the Executive Committee to give particular consideration to minimizing and legal liability of WMO.

5.2 The meeting was informed that preliminary preparations for PEP were already under way but that the experiment itself would not start for at least two years and would be of several years' duration.

5.3 It was agreed that in the implementation of PEP careful attention would need to be given to the various legal aspects involved in any agreement between WMO and the state in which PEP will be conducted (for example immunity and liability in the case of gross negligence), and it was suggested that advice from legal experts be sought by WMO in this respect. The meeting observed that considerable legal experience had been acquired by organizations in the UN system in conducting projects in many different States, and that experience had shown that the time required to draw up such an agreement might amount to as much as a year.

6. ADOPTION OF THE FINAL REPORT

The meeting was able to approve the text of the report of items 1 to 4 during the session and it was agreed that the chairman and co-chairman should be authorized to approve the remainder of the report on behalf of the meeting.

7. CLOSING OF THE MEETING

The chairman and co-chairman each thanked the participants for their valuable contributions, and especially for the great lengths to which the legal and scientific experts had gone in endeavouring to understand each other's point of view. Appreciation was expressed to the authors of the documents for the session and for the support given by the WMO Secretariat. The representatives of UNEP and WMO also associated themselves with these remarks. The meeting was declared closed at 5:30 p.m. on Thursday 20 November 1975.

WMO/UNEP INFORMAL MEETING ON LEGAL ASPECTS OF WEATHER
MODIFICATION, GENEVA, NOVEMBER 17 TO 21, 1975

LIST OF PARTICIPANTS

Experts nominated by UNEP

J. W. Samuels (Co-Chairman), A. C. Kiss, M. Piskotin, P. H. Sand, and E. Brown Weiss.

Representatives of UNEP

R. S. Mikhail, H. Ahmed, and P. A. Bliss.

Experts nominated by WMO

R. List (Chairman), A. L. Alusa, A. Gagin, P. Goldsmith, R. Lavoie, and Y. Sedunov.

Representatives of WMO

O. M. Ashford, and N. K. Kljukin.

WMO Secretariat

R. D. Bojkov, E. Bollay, and R. M. Perry.

AGENDA

1. Organization of the meeting:
 - 1.1 Opening of the session.
 - 1.2 Adoption of the agenda.
2. Review of developments since the third session of the WMO Executive Committee Panel on Weather Modification in November 1974:
 - 2.1 Relevant decisions of the third session of the Governing Council of UNEP.
 - 2.2 Relevant decisions of the seventh session of Congress and of the twenty-seventh session of the Executive Committee of WMO.
 - 2.3 Relevant decisions of the Conference of the Committee on Disarmament (CCD) of the United Nations.
3. Review of the State of the Art and possible developments:
 - 3.1 National laws related to weather modification.
 - 3.2 The science of weather modification.
 - 3.3 Legal problems facing public and private operators.
4. Discussion of the development of general principles and operating guidelines for weather modification experiments and operations.
5. Legal aspects of the WMO precipitation enhancement project.
6. Adoption of the final report.
7. Closing of the meeting.

LIST OF SUPPORTING PAPERS AVAILABLE AT THE TIME OF THE MEETING

- 2.1: The decisions of UNEP Governing Council.
- 2.2: The decisions of Seventh WMO Congress and twenty-seventh WMO Executive Committee.
- 2.3: The draft-convention proposed to CCD by U.S.A. and U.S.S.R. on 21 August 1975.
 - 3.1: Review paper prepared by UNEP consultant Professor Samuels.
 - 3.2: Official WMO Statement on the present state of knowledge.
 - 3.3: Review paper prepared by UNEP consultant Professor Samuels.
- 4: Review paper prepared by UNEP consultants Professor Samuels and E. Brown Weiss.
- 5: WMO decisions on Weather Modification Programme and Precipitation Enhancement Project.

APPENDIX R

TEXT OF SENATE RESOLUTION 71, CONSIDERED, AMENDED, AND AGREED
TO JULY 11, 1973

93^d CONGRESS
1st SESSION

S. RES. 71

[Report No. 93-270]

IN THE SENATE OF THE UNITED STATES

FEBRUARY 22, 1973

Mr. PELL (for himself, Mr. BAYH, Mr. CASE, Mr. CHURCH, Mr. CRANSTON, Mr. GRAVEL, Mr. HART, Mr. HOLLINGS, Mr. HUGHES, Mr. HUMPHREY, Mr. JAVITS, Mr. KENNEDY, Mr. MCGOVERN, Mr. MONDALE, Mr. MURKIE, Mr. NELSON, Mr. STEVENSON, Mr. TUNNEY, and Mr. WILLIAMS) submitted the following resolution; which was referred to the Committee on Foreign Relations

JUNE 27 (legislative day, JUNE 25), 1973

Reported by Mr. PELL, with amendments

JULY 11, 1973

Considered, amended, and agreed to

RESOLUTION

Expressing the sense of the Senate that the United States Government should seek the agreement of other governments to a proposed treaty prohibiting the use of any environmental or geophysical modification activity as a weapon of war, or the carrying out of any research or experimentation directed thereto.

Whereas there is vast scientific potential for human betterment through environmental and geophysical controls; and

Whereas there is great danger to the world ecological system if environmental and geophysical modification activities are not controlled or if used indiscriminately; and

Whereas the development of weapons-oriented environmental and geophysical modification activities will create a threat to peace and world order; and

V

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Whereas the United States Government should seek agreement with other governments on the complete cessation of any research, experimentation, or use of any such activity as a weapon of war: Now, therefore, be it

1 *Resolved*, That it is the sense of the Senate that the
2 United States Government should seek the agreement of
3 other governments, including all Permanent Members of the
4 Security Council of the United Nations, to a treaty along the
5 following general lines which will provide for the complete
6 cessation of any research, experimentation, and use of any
7 environmental or geophysical modification activity as a
8 weapon of war:

9 “The Parties to this Treaty,

10 “Recognizing the vast scientific potential for human
11 betterment through environmental and geophysical
12 controls,

13 “Aware of the great danger to the world ecological
14 system of uncontrolled and indiscriminate use of environ-
15 mental and geophysical modification activities,

16 “Recognizing that the development of weapons-
17 oriented environmental and geophysical modification
18 techniques will create a threat to peace and world order,

19 “Proclaiming as their principal aim the achievement
20 of an agreement on the complete cessation of research,

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1 experimentation, and use of environmental and geo-
2 physical modification activities as weapons of war,

3 "Have agreed as follows:

4 "ARTICLE I

5 "(1) The States Parties to this Treaty undertake to
6 prohibit and prevent, at any place, any environmental or
7 geophysical modification activity as a weapon of war;

8 "(2) The prohibition in paragraph 1 of this article shall
9 also apply to any research or experimentation directed to
10 the development of any such activity as a weapon of war,
11 but shall not apply to any research, experimentation, or use
12 for peaceful purposes;

13 "(3) The States Parties to this Treaty undertake not to
14 assist, encourage or induce any State to carry out activities
15 referred to in paragraph 1 of this article and not to partici-
16 pate in any other way in such actions.

17 "ARTICLE II

18 "In this Treaty, the term 'environmental or geophysical
19 modification activity' includes any of the following activities:

20 "(1) any weather modification activity which has
21 as a purpose, or has as one of its principal effects, a
22 change in the atmospheric conditions over any part of
23 the earth's surface, including, but not limited to, any
24 activity designed to increase or decrease precipitation,

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1 increase or suppress hail, lightning, or fog, and direct
2 or divert storm systems;

3 “(2) any climate modification activity which has
4 as a purpose, or has as one of its principal effects, a
5 change in the long-term atmospheric conditions over
6 any part of the earth’s surface;

7 “(3) any earthquake modification activity which
8 has as a purpose, or has as one of its principal effects,
9 the release of the strain energy instability within the
10 solid rock layers beneath the earth’s crust;

11 “(4) any ocean modification activity which has as
12 a purpose, or has as one of its principal effects, a change
13 in the ocean currents or the creation of a seismic dis-
14 turbance of the ocean (tidal wave).

15 “ARTICLE III

16 “Five years after the entry into force of this Treaty, a
17 conference of Parties shall be held at Geneva, Switzerland,
18 in order to review the operation of this Treaty with a view
19 to assuring that the purposes of the preamble and the pro-
20 visions of the Treaty are being realized. Such review shall
21 take into account any relevant technological developments
22 in order to determine whether the definition in Article II
23 should be amended.

24 “ARTICLE IV

25 “1. Any Party may propose an amendment to this
26 Treaty. The text of any proposed amendment shall be sub-

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1 mitted to the Depository Governments which shall circulate
2 it to all parties to this Treaty. Thereafter, if requested to do
3 so by one-third or more of the Parties, the Depository Gov-
4 ernments shall convene a conference, to which they shall
5 invite all the Parties, to consider such an amendment.

6 "2. Any amendment to this Treaty shall be approved
7 by a majority of the votes of all the Parties to this Treaty.
8 The amendment shall enter into force for all Parties upon the
9 deposit of instruments of ratification by a majority of all
10 the Parties.

11 "ARTICLE V

12 "1. This Treaty shall be of unlimited duration.

13 "2. Each Party shall, in exercising its national sov-
14 ereignty, have the right to withdraw from the Treaty if it
15 decides that extraordinary events, related to the subject
16 matter of this Treaty, have jeopardized the supreme interests
17 of its country. It shall give notice of such withdrawal to all
18 other Parties to the Treaty three months in advance.

19 ARTICLE VI

20 "1. This Treaty shall be open to all States for signature.
21 Any State which does not sign this Treaty before its entry
22 into force in accordance with paragraph 3 of this Article
23 may accede to it at any time.

24 "2. This Treaty shall be subject to ratification by sig-
25 natory States. Instruments of ratification and instruments of

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1 accession shall be deposited with the Governments of the
2 United States of America, _____, and

3 which are hereby designated the Depositary Governments.

4 "3. This Treaty shall enter into force after its ratifica-
5 tion by the States, the Governments of which are designated
6 Depositaries of the Treaty.

7 "4. For States whose instruments of ratification or ac-
8 cession are deposited subsequent to the entry into force of
9 this Treaty, it shall enter into force on the date of the de-
10 posit of their instruments of ratification or accession.

11 "5. The Depositary Governments shall promptly inform
12 all signatory and acceding States of the date of each signa-
13 ture, the date of deposit of each instrument of ratification of
14 and accession to this Treaty, the date of its entry into force,
15 and the date of receipt of any requests for conferences or
16 other notices.

17 "6. This Treaty shall be registered by the Depositary
18 Governments pursuant to Article 102 of the Charter of the
19 United Nations."

APPENDIX S

REPORTED CASES ON WEATHER MODIFICATION

Slutsky v. City of New York, 197 Misc. 730, 97 N.Y.S. 2d 238 (Sup. Ct., 1950).
Southwest Weather Research, Inc. v. Rounsaville, 320 S.W. 2d 211 (Tex. Civ. App., 1958), and *Southwest Weather Research, Inc. v. Duncan*, 319 S.W. 2d 940 (Tex. Civ. App. 1958), both affd. sub nom. *Southwest Weather Research, Inc. v. Jones*, 160 Tex. 104, 327 S.W. 2d 417 (1959).

Summerville v. North Platte Valley Weather Control Dist., 170 Neb. 46, 101 N.W. 2d 748 (1960).

Pennsylvania Natural Weather Assn. v. Blue Ridge Weather Modification Assn., 44 Pa. D. & C. 2d 749 (1968).

APPENDIX T

GLOSSARY OF SELECTED TERMS IN WEATHER MODIFICATION¹

GLOSSARY 1/

ACRE-FOOT—The volume of water required to cover one acre to a depth of one foot: 43,560 cubic feet, 325,852 gallons.

AEROSOL—A colloidal system in which the dispersed phase is composed of either solid or liquid particles, and in which the dispersion medium is some gas, usually air.

There is no clear-cut upper limit to the size of particles comprising the dispersed phase in an aerosol, but as in all other colloidal systems, it is rather commonly set at 1 micron. Haze, most smokes, and some fogs and clouds may thus be regarded as aerosols.

AIRCRAFT SEEDING—The use of aircraft to disperse cloud seeding agents.

ALTOCUMULUS—A principal type of cloud, 8,000 to 20,000 feet, consisting of a layer where the denser parts have modified cumuliform characteristics of roundness and sharpness of outline.

ALTOSTRATUS—A principal type of "middle" cloud (altitude approx. 8,000 to 20,000 feet), appearing as a fairly uniform grey layer that often covers the entire sky.

ANVIL CLOUD—Popular name given to a cumulonimbus cloud whose upper, ice-crystal portion is spread out horizontally to give the appearance of an anvil. In the International Cloud Classification, this is a "cumulonimbus capillatus" cloud with the supplementary feature "incus."

ARTIFICIAL NUCLEATION—Any process whereby the nucleation of cloud particles is initiated or accelerated by human intervention.

CAP CLOUD—An approximately stationary cloud, on or hovering above an isolated mountain peak. It is formed by the cooling and condensation of humid air forced up over the peak.

CELLULAR CONVECTION—An organized, convective, fluid motion characterized by the presence of distinct convection cells or convective units, usually with upward motion (away from the heat source) in the central portions of the cell, and sinking or downward flow in the cell's outer regions.

CHAFF—Metallic, electrical dipoles, several centimeters long, commonly made of fine wire.

The original use of chaff, dropping large quantities of it from aircraft in WWII, was to jam enemy radars. It is now used experimentally to alter the electrical properties of thunderstorms.

CHAFF SEEDING—The dispensing of chaff into a cumulonimbus cloud for the experimental purpose of altering the cloud's electrical structure and hence affecting the occurrence and character of lightning.

It is hypothesized that the chaff is the medium for leakage currents (through corona point discharges) which forestall the development of the charge centers necessary for lightning formation.

CIRRUS—A principal cirriform cloud type, composed of ice crystals aggregated into delicate wisps or patches at high altitudes.

The term "cirrus" is often used as a generic term for all cirriform clouds.

CLOUD—A visible aggregate of minute water and/or ice particles in the atmosphere above the earth's surface. Cloud differs from fog only in that the latter is, by definition, in contact with the earth's surface.

Clouds form in the free atmosphere as a result of condensation of water vapor in rising currents of air, or by the evaporation of the lowest stratum of fog. For condensation to occur at the point of saturation or a low degree of supersaturation, there must be an abundance of condensation nuclei for water clouds, or ice nuclei for ice-crystal clouds. The size of cloud drops varies from one cloud type to another, and within any given cloud there always exists a finite range of sizes. Generally speaking, cloud drops range between one and one hundred microns in diameter, and hence are very much smaller than rain drops.

CLOUD MICROPHYSICS—A specialized field within cloud physics dealing with extremely small-scale phenomena, particularly the molecular-scale processes of evaporation, condensation, and freezing of cloud particles, and the complex interactions, including electrical effects, among cloud particles.

CLOUD MODEL—In general, any idealized representation of a cloud or cloud processes. Increasingly, this term is used for mathematical representations of cloud processes, particularly those formulated for numerical solution on electronic computers.

CLOUD MODIFICATION—Any process by which the natural course of development of a cloud is altered by artificial means.

CLOUD PHYSICS—The body of knowledge concerned with physical properties of clouds in the atmosphere and the processes occurring therein.

CLOUD SEEDING—Any process of injecting a substance into a cloud for the purpose of influencing the

¹ From Project Skywater; 1973-74 Biennial Report. U.S. Department of the Interior, Bureau of Reclamation, Division of Atmospheric Water Resources Management. REC-ERC-76-21. Denver, December 1976. pp. A-21 to A-25.

cloud's subsequent development. Ordinarily, this refers to the injection of a nucleating agent, but sometimes alludes to substances which do not directly affect nucleation (such as carbon black).

CLOUD SEEDING AGENT—Any variety of substances dispensed for the purposes of cloud seeding. In addition to the commonly used silver iodide and dry ice, a number of other materials have been experimented with for various purposes, for example: calcium chloride, urea, metaldehyde, chlorosulfonic acid, carbon black, common salt, and water spray.

COALESCENCE—In cloud physics, the merging of two water drops into a single larger drop.

COALESCENCE EFFICIENCY—The fraction of all collisions between water drops of a specified size which result in actual merging of the two drops into a single larger drop.

CONDENSATION—The physical process by which a vapor becomes a liquid or solid; the opposite of evaporation. In meteorological usage, this term is applied only to the transformation from vapor to liquid; any process in which a solid forms directly from its vapor is termed sublimation, as is the reverse process.

CONDENSATION LEVEL—That level in the atmosphere at which saturation and hence condensation, will occur in a column of rising air. This occurs by virtue of the adiabatic cooling of the air as it rises.

CONDENSATION NUCLEUS—A particle, either liquid or solid, upon which condensation of water vapor begins in the atmosphere. See nucleation.

CONTROL CLOUD—In cloud seeding experiments on individual clouds, a cloud chosen to remain unseeded, but is otherwise monitored as if it had been, in order to provide data for comparison with seeded clouds.

CONVECTION—1. In general, mass motions within a fluid resulting in transport and mixing of the properties of that fluid.

2. As specialized in meteorology, atmospheric motions that are predominantly vertical, resulting in vertical transport and mixing of atmospheric properties.

CONVECTION CURRENT—(or convective current) Any current of air involved in convection. In meteorology, this is usually applied to the upward moving portion of a convection circulation, such as a thermal or the updraft in cumulus clouds.

CUMULIFORM—Like cumulus; generally descriptive of all clouds, the principal characteristic of which is vertical development in the form of rising mounds, domes, or towers.

CUMULONIMBUS—(Commonly called thundercloud, thunderhead, thunderstorm.) A principal cloud type, the ultimate stage of development of cumulus or convective clouds. They are very dense and very tall, commonly 5 to 10 miles in diameter and sometimes reaching a height of 12 miles or more. The upper portion is at least partly composed of ice crystals, and often takes the form of an anvil ("incus") or vast plume. The base of the cloud is invariably dark and often accompanied by low, ragged clouds.

CUMULUS—A principal cloud type, actually a cloud "family" all of which are characterized by vertical development; a convective cloud.

DIFFUSION—In meteorology, the exchange of fluid parcels (and hence the transport of conservative properties between regions in space, in the apparently random motions of a scale too small to be treated by the equations of motion.

In meteorology, the diffusion of momentum (viscosity), vorticity, water vapor, heat (conduction), particulate matter, and gaseous components of the atmospheric mixture, have been studied extensively. The atmospheric motions diffusing these properties may in many cases be of much larger scale than the molecular, the exchanging parcels being called eddies, and the diffusion equation extended by analogy to turbulent diffusion.

DOPPLER EFFECT—(Also called Doppler shift.) The change in frequency with which energy reaches a receiver when the receiver and the energy source are in motion relative to each other.

DOPPLER RADAR—A radar which detects and interprets the Doppler effect in terms of the radial velocity of a target. The signal received by a radar from a moving target differs slightly in frequency from the transmitted wave.

Doppler radar is widely used in cloud studies because it enables the deduction of the motions of cloud and precipitation particles.

DRY-ICE—Solid carbon dioxide (CO_2). It evaporates directly from solid to gas at a temperature of -78.5°C .

DRY-ICE SEEDING—The dispensing of dry-ice pellets into supercooled clouds for the purpose of transforming the supercooled droplets into ice crystals, which then grow and fall out. Dry ice creates a sufficiently cold environment around the droplets for them to undergo spontaneous nucleation.

ECHO—In radar, a general term for the appearance, on a radar indicator, of the radio energy returned from a target. More explicitly, it refers to the energy reflected or scattered back from a target.

FREEZING NUCLEUS—Any particle which, when present within a mass of supercooled water, will initiate growth of an ice crystal about itself (see nucleation).

GLACIATION—In cloud physics, the transformation of cloud particles from water drops to ice crystals.

GROUND GENERATOR—In weather modification, almost invariably referring to silver-iodide smoke generators that are operated on the ground (as opposed to airborne equipment).

HAIL SUPPRESSION—Any method of reducing the damaging effects of hailstorms by operating on the hail-producing cloud.

The currently prevailing hypothesis is that silver-iodide seeding provides more hailstone nuclei (and, at the same time, reduces the amount of supercooled water available to build up large hailstones) with the net effect that the hail that reaches the ground is smaller and less damaging, and also has a higher probability of melting before reaching the ground.

HYGROSCOPIC NUCLEI—Condensation nuclei composed of salts which yield aqueous solution, of a very low equilibrium vapor pressure compared with that of pure water at the same temperature. Condensation of hygroscopic nuclei may begin at a relative humidity much lower than 100 percent (about 75 percent for sodium chloride); while on so-called non-hygroscopic nuclei, which merely furnish sufficiently large (by molecular standards) wettable surfaces, relative humidities of nearly 100 percent are required. "Damp haze" is formed of hygroscopic particles in the process of slow growth in relatively dry air.

HYGROSCOPIC SEEDING—Cloud seeding with hygroscopic material which encourages condensation and collects water vapor.

ICE CRYSTAL—Any one of a number of macroscopic crystalline forms in which ice appears, including hexagonal columns, hexagonal platelets, dendritic crystals, ice needles, and combinations of these forms.

ICE-CRYSTAL CLOUD—A cloud consisting entirely of ice crystals (such as cirrus); to be distinguished in this sense from water clouds and mixed clouds.

ICE NUCLEUS—Any particle which serves as a nucleus in the formation of ice crystals in the atmosphere, used without regard to the particular physical process involved in the nucleation.

Due to an apparent scarcity of natural ice nuclei (or, at least, freezing nuclei) in the atmosphere, cloud seeding with ice-nucleating agents becomes a practical endeavor. Both silver iodide and dry ice perform the function of nucleating ice in an aggregate of supercooled water droplets.

ICE-PHASE SEEDING—Cloud seeding with an agent which serves as an artificial ice nucleus.

ISOHYET—A line drawn on a map connecting geographical points having equal amounts of precipitation during a given time period, or for a particular storm.

LIQUID WATER CONTENT—(Abbreviated LWC.) The amount of liquid water (that is, not counting water vapor) in a cloud, usually expressed as grams of water per cubic meter of cloud volume.

MESO-SCALE—In meteorology: having characteristic spatial dimensions somewhere between 1 and 100 miles, usually implying between 5 and 50 miles.

NUCLEATING AGENT—(or nucleant) In cloud physics, any substance that serves to accelerate the nucleation of cloud particles. Nucleating agents may themselves be nuclei (silver iodide, salt, sulfur dioxide, dust) or they may enhance the nucleation environment (dry ice, propane spray).

NUCLEATION—Any process by which the phase change of a substance to a more condensed state (condensation, sublimation, freezing) is initiated at certain loci (see nucleus) within the less condensed state.

A number of types of nucleation are of interest. The process by which condensation nuclei initiate the phase change from vapor to liquid is of decisive importance in analyses of all cloud formation problems. The physical nature of freezing nuclei which may be responsible for the conversion of drops of supercooled water into ice crystals is critically important in precipitation theory, as is also the clarification of the role of spontaneous nucleation near -40°C . The importance of sublimation nuclei in promoting the growth of ice crystals directly from the vapor phase is doubtful.

NUCLEUS—In physical meteorology, a particle of any nature upon which, or the locus at which, molecules of water or ice accumulate as a result of a phase change to a more condensed state; an agent of nucleation.

NUCLEUS COUNTER—Any of several devices for determining the number of condensation nuclei or ice nuclei in a sample of air.

NUMERICAL MODEL—In meteorology, a mathematical formulation of atmospheric processes constructed so that the dynamical and thermodynamical equations of atmospheric motion can be solved by numerical methods on electronic computers.

OROGRAPHIC CLOUD—A cloud whose form and extent is determined by the disturbing effects of orography, mountains, upon the passing flow of air. Be-

cause these clouds are linked with the form of the terrestrial relief, they generally move very slowly, if at all, although the winds at the same level may be very strong.

OROGRAPHIC LIFTING—The lifting of an air current caused by its passage up and over mountains.

OVERSEEDING—Cloud seeding in which an excess of nucleating material is released. As the term is normally used, the excess is relative to that amount of nucleating material which would, theoretically, maximize the precipitation received at the ground. In seeding a supercooled cloud with dry ice or silver iodide, addition of too much seeding material may create so many ice crystals that none can grow to a size large enough to fall out of the updraft sustaining the cloud.

PLUME—The volume of air space containing any of the substance emitted from a point source.

PRECIPITATION—Any or all of the forms of water particles, whether liquid or solid, that fall from the atmosphere and reach the ground.

PRECIPITATION ECHO—A Type of radar echo returned by precipitation.

PRECIPITATION EFFICIENCY—For a given cloud or storm system, the ratio of the amount of precipitation actually produced to the maximum amount theoretically possible by that system.

PRECIPITATION GAGE—General term for any device that measures the amount of precipitation; principally, a rain gage or snow gage.

PYROTECHNIC GENERATOR—A type of silver iodide smoke generator in which the silver iodide forms as a part of the pyrotechnic fuel mixture. A great flexibility of design is possible with these generators, and they are capable of an extremely high output of silver-iodide nuclei.

RADIOSONDE—A balloon-borne instrument for the simultaneous measurement and transmission of meteorological data.

RAIN MAKING—Popular and general term for all weather modification effort aimed at increasing precipitation.

RANDOM—Eluding precise prediction, completely irregular. In connection with probability and statistics, the term random implies collective or long-run regularity; thus a long record of the behavior of a random phenomenon presumably gives a fair indication of its general behavior in another long record, although the individual observations have no discernible system of progression.

RANDOMIZE—To make random. Specifically, in weather modification contexts, it refers to the design of experiments and projects in such a way as to minimize the sources of bias in the evaluation of results by dictating that "seed" or "don't seed" decisions (for example) be made on a purely random basis. If the total number of such decisions is sufficiently large, this procedure ensures that a comparison of "seed" versus "don't seed" results contains minimal bias.

REAL-TIME—Nearly instantaneous.

SALT NUCLEUS—A minute salt particle serving as a condensation nucleus.

SALT SEEDING—Cloud seeding with salt particles, a technique that has been applied to warm (non-supercooled) clouds and fog on the principle that the hygroscopic droplets of salt solution will grow at the expense of other particles.

SEEDING RATE—The quantity of seeding agent (in grams or kilograms) released either per unit of time (if applied to ground-based generators) or per unit of distance (traveled by an aircraft) used in cloud seeding.

SILVER IODIDE—(Chemical formula: AgI.) The compound of silver and iodine whose crystalline structure very closely approximates that of ice-crystals.

SILVER-IODIDE GENERATOR—Any of several devices used to generate a smoke of silver-iodide crystals. Most burn an acetone solution of silver iodide; the other important (and newer) category is that of pyrotechnic generators.

SILVER-IODIDE SEEDING—The world-wide "work-horse" method of cloud seeding, where, by any of several techniques, silver-iodide crystals are introduced into the supercooled portions of clouds to induce the nucleation of ice crystals.

SNOW COURSE—An established line, usually from several hundred feet to as much as a mile long, traversing representative terrain in a mountainous region of appreciable snow accumulation. Along this course instruments (such as snow stakes, radioactive snow gages) are installed, and/or core samples of the snow cover are periodically taken and averaged to obtain a measure of its water equivalent.

STRATOCUMULUS—A principal, low-altitude, cloud type, consisting of a layer of rounded or roll-shaped elements which may or may not be merged and which usually are arranged in orderly files or a wave pattern.

SUBLIMATION—The transition of a substance from the solid phase directly to the vapor phase, or vice

versa, without passing through an intermediate liquid phase.

SUPERCOOLING—The reduction of temperature of any liquid below the melting point of that substance's solid phase; that is, cooling beyond its nominal freezing point. A liquid may be supercooled to varying degrees, depending upon the relative lack of freezing nuclei or solid boundary irregularities within its environment, and freedom from agitation.

SYNOPTIC—In general, pertaining to or affording an overall view.

In meteorology, this term has become somewhat specialized in referring to the use of meteorological data obtained simultaneously over a wide area for the purpose of presenting a comprehensive and nearly instantaneous picture of the state of the atmosphere. Thus, to a meteorologist, "synoptic," takes on the additional connotation of simultaneity.

TARGET AREA—In a weather modification project, the area within which the effects of the weather modification effort are expected to be found.

TRACER—An easily detectable substance injected into the atmosphere for the purpose of subsequent measurement and reconstruction of its history (trajectory, diffusion, etc.)

TRAJECTORY—(Or path.) A curve in space tracing the points successively occupied by a particle in motion. At any given instant the velocity vector of the particle is tangent to the trajectory.

WARM CLOUD—In weather modification terminology, a water cloud that is not a supercooled cloud, i.e., that exists entirely at temperatures above 0°C.

WATER EQUIVALENT—The depth of water that would result from the melting of the snowpack or of a snow sample.

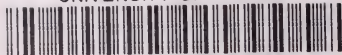
WATER VAPOR—(Also called aqueous vapor, moisture.) Water substance in vapor form; one of the most important of all constituents of the atmosphere.

WEATHER MODIFICATION—The intentional or inadvertent alteration of weather by human agency.

WEATHER RADAR—Generally, any radar which is suitable or can be used for the detection of precipitation or clouds.



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