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The Texas Weather Modification COURIER

Sunset Storm North of San Angelo. May 6, 2007. *Photo taken by Robert Rhodes.*

Recent Legislation on Weather Modification

By George Bomar
State Meteorologist, TDLR

Lawmakers at both State and Federal levels recently considered new legislation that would have profound impacts on the way weather modification is done in Texas. Creation of a weather modification research program by State Legislation barely missed becoming law, while a Federal bill was re-introduced to establish a comprehensive national program in

Legislation Continues on Page 13

Inside this issue:

The Grass is Greener Across Much of Texas

By Robert Rhodes

The grass is green, the weeds are overgrown and the lawn mowers are working overtime this season. Generous amounts of rain have fallen over Texas and the cloud seeders have only had a small percentage of influence. Many records or top ten records for daily and monthly rainfalls have occurred since January of this year. What has been going on?

The Sub-Tropical Jet (STJ) has been significantly further south through early June of this year. The general position was from northern Baja, through central Texas, and the central Gulf of Mexico. The STJ rose into its more typical position during the middle of June to northern California and the central Plains, and then combined with the Polar Jet or faded away. In addition, the low level-jet, in combination with saturated soils over south and west Texas has promoted many mornings with a thick stratus layer reducing surface heating until early or late afternoon.

The southerly position of the STJ is beneficial for Texas because it provides a direct route for Pacific moisture to stream

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Texas Project Updates
A Review of 2007 Through July

West Texas Weather Modification

By Robert Rhodes

As of July 31, West Texas has flown 123 hours over 31 days this season. It had been quite slow through June, but activity picked up in July. Most seeding events through early June were large clouds and required heavy doses of seeding agent to produce results. July clouds became more scattered and on many occasions were very tropical producing very little or no inflow. Nevertheless, given the wet season we have had thus far, seedable clouds have consumed 982 flares. The significant number of very large clouds covering the target area with convective leading edges, and the increase of small clouds in July supports the total.

As July clouds became more scattered, the rain totals did as well. Some of the rain gauges around the target area for July were above normal again, but the widely scattered nature of showers and storms during the month may allow for some areas being drier than others.

Table 1

Town	Total (Inches)
Grape Creek	16.85
Eldorado	15.25
McCamey	11.79
Barnhart	16.3
San Angelo	21.05
Sonora	4.98*
Abilene	24.65
Midland	15.38
Big Springs	11.32
Junction	23.19

Table 1: As of July 31, 2007, rainfall totals for rain gauges in and around the WTWMA Target Area.

Southwest Texas Rain

By Stephanie Beall

Mission and seeding day totals are below normal this year; which can be attributed to a more stagnate weather pattern across most of the southern parts of Texas. The Southwest Texas project, as of July 31, 2007, has flown a total of ten days with 12 seeding flights and four reconnaissance missions. Out of the 12 seeding flights four were hail suppression and eight were rain enhancement. The last flight in July took place on the 16th.

The project has been in suspension mode for portions of June and July due to an abundance of rainfall in the target area. Suspension during mid June and July 4th weekend was due to flash and river flooding mostly confined to the Northern portions of the Target Area. The tropical nature of the airmass has also contributed to less seeding opportunities. A portion of the cloud needs to be below freezing for glaciogenic seeding material to work. Large parts of the clouds were above freezing in a lot of the convection encountered during the past couple of months; therefore, glaciogenic seeding would be ineffective. Sometimes convection was present; however, seeding operations did not commence due to the tropical nature of the clouds.

Annual precipitation is above normal within the Target Area for this time of year. Some locations have already received their annual rainfall such as eastern LaSalle and Northern Uvalde counties. Rainfall totals in these counties are currently 25 to 35 inches, where annual normal totals are 25 to 30 inches. Most locations throughout the Target Area are 2 to 2.5 inches above normal for the year.

Below are some climatological facts from the National Weather Service:

Del Rio, TX
- The fourth wettest January to May period was recorded
- The wettest May ever was recorded
- The wettest January to June during the 1906-2007 period

San Antonio, TX
- The ninth wettest January to May period was recorded
- The wettest January to June during the 1871-2007 period

Table 2

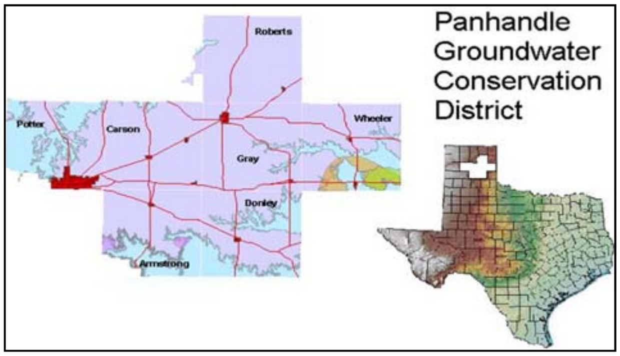
Town	County	May 2007 (in inches)	June 2007 (in inches)
Carrizo Springs	Dimmit	8.36	4
Crystal City	Zavala	6.36	5.3
Cotulla	LaSalle	9.84	6.03
Laredo	Webb	7.31	3.31
Uvalde	Uvalde	2.67	2.7

Table 2: Above are rainfall totals for a city within the counties in the Southwest Texas Target Area for May and June of 2007.

July was on track to be another wet month as a steady progression of upper level lows and a tropical atmosphere affected the target area. The upper level lows, which are uncommon for this time of year, were being driven by two areas of high pressure over the Western and Southeastern U.S. Normally during the summer high pressure is only centered over the Central U.S.

Panhandle Groundwater Conservation District Precipitation

By Jennifer Wright



This diagram shows where the district is located within Texas. The district includes Potter, Armstrong, Carson, Gray, Donley, Wheeler and Roberts counties.

The Panhandle Groundwater Conservation District Precipitation Enhancement Program has conducted seeding on 30 days as of July 31, 2007. The number of seeding days is comparable to 2006 at 31 days through July; however, the seeding events occurred at different times within the season. In 2006 all of the seeding days occurred from May to July, where as in 2007 seeding days were spread from March through July with May and July having the most at eight events.

Total amount of flares used for the season thus far is however, less than 2006. In 2006 222 40g burn-in-place (BIP), 149 80g BIP, and 397 20g ejectable flares had been dispensed which amounts to 28,760g of Silver Iodide (AIg). In 2007 285 40g BIP, 138 75g BIP, and 204 20g ejectable have been used which amounts to 25,920g of AIg. The decrease in the amount of flares could be attributed to smaller clouds rather than larger storm systems.

Several of the earlier events in March through May were caused by a dry line moving through the Target Area. On March 28, April 21 and 23, and May 21 and 23 operations were ended early due to severe thunderstorms warning issued by the National Weather Service. Later events from June through July have been characterized by smaller clouds with little to no inflow; however, in most cases seeding helped to develop the clouds further and conclude with large amounts of rainfall.

Table 3

	March	April	May	June	Totals
Armstrong	5.45	1.59	5.82	2.71	15.57
Cason	4.76	1.79	3.67	1.95	12.17
Donley	7.68	2.21	6.75	4.27	20.91
Gray	6.65	1.98	3.98	2.03	14.64
Potter	4.5	1.6	2.88	3.04	12.02
Roberts	4.5	3.3	4.06	3.5	15.36
Wheeler	5.89	2.2	4.95	2.98	16.02

Table 3: Above are rainfall totals for counties in the PGCD Target Area for March through June in inches.

South Texas Weather Modification Association

By Todd Flanagan

In 2006 the South Texas Weather Modification Association target area was much drier than normal with only 30 to 60% of the average annual rainfall measured. Ironically, this was also the year with the most days of seeding since the inception of the program. This was due to the increased number of isolated events that were flown on. This year we are seeing a mirror image: south Texas is currently running between 150 to 300% of their average annual rainfall yet so far we have only seven days on which seeding has occurred. The lack of seeding missions is attributed to both unfavorable cloud profiles and periodic flooding that has occurred since June. July has been particularly wet with many locations reporting in excess of 10 inches of rain, where the normal rainfall is between one and three inches. Following is a brief summary of operations between April and July.

April turned out to be a near normal month in terms of precipitation. While parts of Atascosa, Frio and Live Oak counties saw slightly below normal rainfall, parts of Karnes, Wilson and Gonzales counties saw above normal rainfall. There were several severe weather episodes during the month, notably on the 13th, 24th, and 30th. Severe weather warnings were also issued on the 28th, the only day in April where seeding took place. The other days severe weather warnings either canceled any chance of seeding or they occurred at night. April's temperatures were some of the coolest in history.

The one day seeding took place two flights were launched. One was a reconnaissance only since low clouds hampered the plane from reaching the convection. A total of seven flares were burned totaling 280g of Silver Iodide (AgI).

STWMA Continues on Page 4

STWMA Continued from Page 3

May saw a variety of rainfall totals with near normal amounts in the Eastern Target Area, and well above normal rainfall over the Central and Western Target Area. Some locations received in excess of 10 inches of rain. Several severe weather episodes occurred during the first half of the month. Despite the increased rainfall seeding missions were only conducted on three days during the month. The best mission was on May 10, where early seeding of developing convection in Medina County resulted in very good to excellent responses when looking at radar trends. One area of convection seeded near Hondo tracked southeast across the entire Target Area dissipating only after it reached just north of Corpus Christi. Seeding on May 21 of a few weak showers did not appear to have much of an effect. On May 24, a few cells were treated in the Northwestern Target Area with good responses noted, particularly in areal expansion. Overall for May, five flights were launched over four days. One flight was reconnaissance only. A total of 79 flares were used for seeding which amounts to 3160g of AgI.

The rainfall pattern in June was similar to that of May. Eastern areas saw near to slightly above average rainfall while central and western areas saw well above normal rainfall. Once again a few locations reported in excess of 10 inches of rain. Flooding began to pose a problem towards the end of the month as a tropical air mass moved into the area and worked in concert with an upper low to produce rounds of heavy rainfall. The number of days on which seeding operations were able to take place was limited due to excessive rains and the tropical nature of the convection. June 16 appeared to be the best day for the month, as a weak boundary was located in the Central Target Area and convection developed along this feature. Seeding of this activity appeared to produce favorable results with several of the cells merging into one cluster. This continued to grow and expand into a mesoscale convective system that pushed slowly south across the Southern Target Area. Flood warnings and severe thunderstorm warnings promptly ended the mission. On June 21, convection developed in a tropical air mass over the central and eastern target area. Several clouds were treated, although radar trends did not suggest much response. The last day of seeding was on the 27th, when late day convection developed over the Eastern Target Area. A weak to moderate response was noted in the radar trends. A total of three seeding days took place during the month. Seven flights were launched; however, four were reconnaissance only. A total of 74 flares were used for seeding totaling 2960g of AgI.

July was excessively wet over south Texas. Rains fell on a near-daily basis. As a result, soils became nearly saturated with flash and river flooding a persistent problem. Much of the target area received in excess of 10 inches with a couple of spots in Frio and Medina counties recording over 20 inches of rain. This is more rainfall than the area received in all of 2006. Due to the excessively wet weather and flooding problems no seeding took place during the month; however, one reconnaissance flight occurred on the 14th.

The outlook for the next three months shows a better than 33% chance of warmer than normal temperatures and, for the Southeastern half of the Target Area a better than 33% chance of above normal precipitation.

2007 Midseason Cloud Seeding Briefing

By Archie Ruiz Columbié

During the first months of the 2007 Cloud Seeding Campaign, the weather has been generous in precipitation for South and West Texas, although stingy in seedable conditions. For instance, San Angelo received 19.21 inches from January to June which represents 188 % of the precipitation normal for the period (10.2 inches), but only 32 clouds were seeded without missed opportunities. This generosity in precipitation was due to synoptic scale conditions that included a very anomalous location of the sub-tropical jet which promoted in turn a very strong pineapple connection in March, April and May when the sea surface temperatures (SST's) were still above normal in certain regions of the Equatorial Pacific Ocean, and later the long presence of an Upper Level Low over North Texas in June. These synoptic conditions brought to Texas mostly embedded convective clouds that very often were trailing stratiform ones.

Table 1 shows some details about the cloud seeding operations for four of the current projects in contrast with the corresponding information from previous years (S is for small clouds, L for large clouds, TB for Type B clouds).

The table indicates that there are some similarities between 2005 and 2007, especially in the amount of small seeded clouds per projects. These were years with anomalous locations of the sub-tropical jet stream during the spring, when South and West Texas were on the north side of the jet (its cyclonic side), and this feature was in resonance with weather patterns in transition from El Niño conditions to Neutral ENSO conditions. The strong pineapple connection with the Equatorial Pacific Ocean weather seems to promote the formation of migrant and large storms over Texas that inhibits the formation of local small seedable clouds. On the other hand, 2004 and 2006 did not offer those patterns and more small seedable condi-

Table 1

	Year (Midseason)	Seeded Clouds	Operational Days
Panhandle Program (White Deer)	2007	**29** (11 S, 10 L, 8 TB)	16
	2006	34 (13 S, 7 L, 14 TB)	18
	2005	5 (0 S, 5 L, 0 TB)	3
	2004	27 (14 S, 10 L, 3 TB)	10
WTWMA Program (San Angelo)	2007	**32** (7 S, 5 L, 20 TB)	18
	2006	63 (27 S, 19 L, 7 TB)	27
	2005	18 (3 S, 8 L, 7 TB)	11
	2004	38 (15 S, 11 L, 12 TB)	19
STWMA Program (Pleasanton)	2007	**16** (8 S, 8 L, 0 TB)	6
	2006	32 (21 S, 6 L, 5 TB)	8
	2005	12 (5 S, 4 L, 3 TB)	7
	2004	45 (25 S, 10 L, 10 TB)	13
SWTREA Program (Carrizo Springs)	2007	**5** (1 S, 3 L, 1 TB)	4
	2006	22 (15 S, 7 L, 0 TB)	11
	2005	7 (0 S, 7 L, 0 TB)	4
	2004	22 (6 S, 6 L, 10 TB)	13

Table 1: Shows some details about the cloud seeding operations for four of the current projects in contrast with the corresponding information from previous years (S is for small clouds, L for large clouds, TB for Type B clouds).

tions occurred. In fact, 2004 and 2006 were years of stable neutral ENSO conditions without any transition. More studies should be done in this direction to clarify the important role those aforementioned weather patterns have on the occurrence of seedable conditions in Texas.

The Ins and Outs of Hail Suppression

By Stephanie Beall

The Southwest Texas Rain Enhancement Association is the only project conducting hail suppression missions within Texas. The following is a brief review of what hail suppression is, its history and its future in the Southwest Texas landscape.

First and foremost, what is hail suppression? The theory of beneficial competition, from Krauss and Santos, 1999, is stated as follows, "Beneficial competition assumes a deficiently of natural ice nuclei in the environment and that the injection of silver iodide (AgI) will result in the production of a significant number of "artificial" ice nuclei. The natural and artificial ice crystals compete for the available supercooled liquid water within the storm. Hence, the hailstones may be small enough to melt completely before reaching the ground." In theory bombarding the cloud or storm with a large amount of nuclei will rob the storms' ability to produce large hail that would otherwise reach the ground without the effects of hail suppression. Figure 1 shows a typical storm containing hail and how hail suppression works. There are five basic conceptual models behind hail suppression which include beneficial competition (which was highlighted above and is the most widely accepted concept), early rain out, trajectory lowering, promotion of coalescence, and dynamics effects (ASCE Standard for Hail Suppression Projects, 2003).

Hail suppression has a long history dating back to the Middle Ages. The earliest records of hail suppression started with the ringing of church bells when large storms would affect areas in Europe. Also, gun powder was used in many European countries near the Alps Mountain ranges during WWI in the form of large explosions which were believed to inhibit the formation of hail. This was the earliest evidence of hail cannons. The shock waves from the explosions were thought to affect hail formation by disrupting the main updraft of a thunderstorm. The modern age of hail suppression research was conducted at the General Electic lab during the 1940s (Schaefer 1946, Vonnegut 1947). Through the 1950s and 1960s, many counties experimented with rockets and explosive devices to stop hail from causing damage to crops over parts of

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Hail Suppression Continued from Page 5

Europe. Commercial hail suppression operations involving Silver Iodide (AgI) from both ground based generators and aircraft became commonly used in the 1950s in the U.S. The U.S.S.R also operated extensive projects in the 1960s (Atlas, 1965). During the 1970s, operational and research projects were in place all over the world. One project of interest would be the Alberta hail suppression research project that lasted for over 30 years with 14 years of seeding but unfortunately did not yield any conclusive results. Other research projects such as Hailswath in 1966 and The National Hail Research experiment (NHRE) in the U.S. included randomized operations during the 1970s, but were also unable to reach any type of conclusive results.

There are three basic types of delivery for AgI to a hail storm. The three include airborne application via pyrotechnics or generators, ground based ice nucleus generator networks, and rockets, artillery, and hail cannons.

The Southwest Texas project uses burn-in-place flares delivered by aircraft at cloud base. Generators have been used in the past but were deemed ineffective. The typical hail suppression mission starts with the pilot being launched after the project meteorologist determines that conditions are right for seeding. Hail suppression commences with the issuing of a severe thunderstorm warning for a specific county or storm. This warning issued by the National Weather Service indicates the presence of hail. Intense reflectivities which are elevated in the main updraft of the storm, where large areas of supercooled water are located, is usually a good indication of the presence of hail. Once operations are started the usual dosage is about three to four times what a normal rain enhancement mission would be, in order to meet the conditions of the beneficial competition theory. Hail suppression ends when the meteorologist determines that either enough material has been put into the cloud or the severe thunderstorm warning is allowed to expire and the threat of hail no longer exists.

The Southwest Texas project has been conducting hail suppression activities since 2000, and has continued participating for a number of reasons. Severe thunderstorms are a common threat in the spring and fall months across the Target Area, due to the Target Area's location east of the Sierra Madre Mountains in Mexico and its constant supply of moisture from the Gulf of Mexico.

This leads to a steady progression of sometimes very damaging hail across the area. Another reason is the economical aspects of the region. Many farmers in this area of Texas grow crops that are very susceptible to large hail storms. Crops such as watermelon, cantaloupe, and spinach could be completely lost due to one major hail storm across a ranch. With a continued effort of hail suppression in this Texas project, new insights and new knowledge will be obtained in the field of weather modification.

References:

American Society of Civil Engineers. Standard Practice for the Design and Operation of Hail Suppression Projects, 2003. p1-10.

Krauss, T., Santos, J.R., 1999. Exploratory analysis of the effect of hail suppression operations on precipitation in Alberta. *Atmospheric Research*, v. 71, iss. 1-2, p. 35-50.

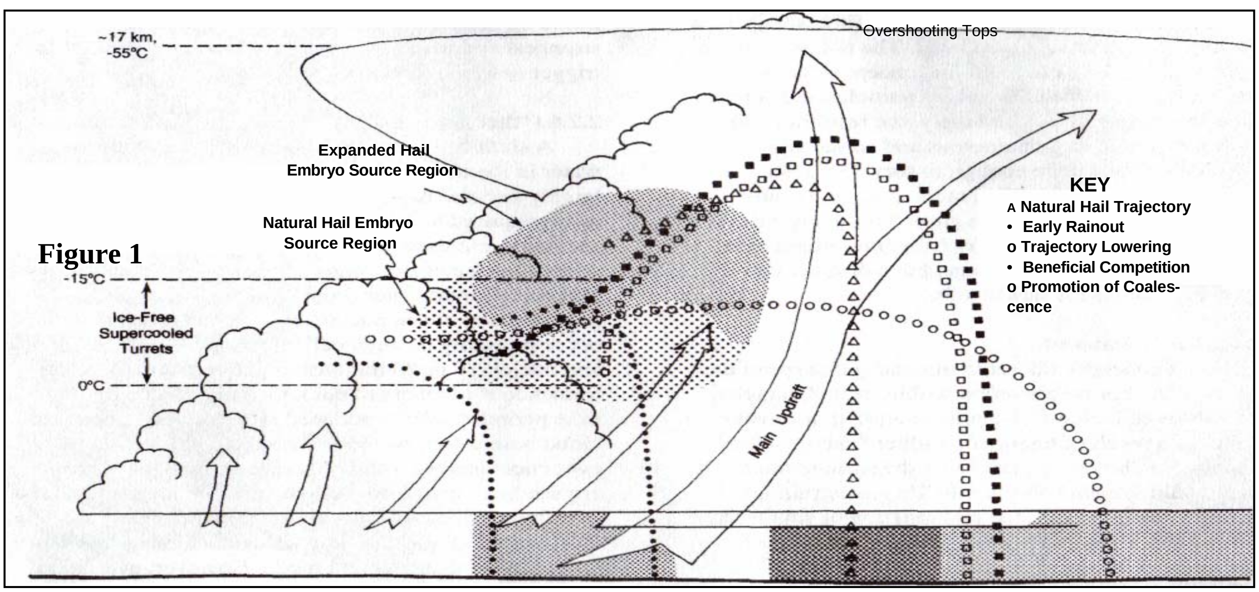

Figure 1: Hail suppression concepts, largely microphysical effects (WMO 1996).

Cloud Seeding: A Pilot's Perspective

By Jamie Linderman

To be quite honest when I was hired for this job I was worried. I was not concerned about being sucked up into a thunderstorm, flying an airplane through hail, or having an engine failure. Instead, I was afraid that we would have a drought or another problem and we would not have much rainfall; then people would be angry with us for not making it rain. Fortunately, this season has been the opposite of my concerns.

When I tell people what I do for a living there are mixed reactions. The majority of people say, “Isn’t that dangerous?” Just like anything else there is a chance of danger; however, I feel that I was well trained. I am pleased that if the situation is too dangerous I have absolutely no pressure from the meteorologist.

I also receive many questions such as, “Does that work?” or “Do they still do that?” During the first two months I worked for the West Texas Weather Modification Association (WTWMA) the meteorologists answered many similar questions of mine. I appreciate the patience they had with me because now I can answer the many questions I receive.

The first question on whether or not it works is my favorite one. I get to answer yes. After that most people ask how the process works. Learning first hand and seeing the clouds up-close I do believe it works. I have seen the proof in the radar animations after returning from a mission. When I tell people this they are usually shocked. What really throws them for a loop is when I tell them about the hail suppression aspect of it. We had a storm not too long ago that had a big reflectivity return which indicated hail. We put quite a few flares into it and one could see from the animation that just before it got to San Angelo, the hail returns diminished! Usually after I tell people that they thank me.

The second question, “Do they still do that?” is an intriguing one to me, and is probably the most disappointing one. This is also the question that I am asked the most. Unfortunately, I have not been in the weather modification business long enough to know why this is the case; however, I have been here long enough to know how to begin fixing this dilemma. We need to inform the public that we still act on their behalf to increase water storage on the ground. Coincidentally, one of the biggest steps that we could have taken has been done. The Discovery channel filmed a show that aired on August 5, 2007. I am willing to bet that most people in our industry tuned in.

This article is about my perspective on cloud seeding. My opinion is one that we should work to enrich other people’s perspective about cloud seeding. As far as I can tell we are on the right track.

This picture taken in the West Texas Target Area shows cloud inflow that is often times visible to pilots. *Photo taken by Robert Rhodes.*

Rosenfeld/Woodley Method Summary of Evaluation of Texas Projects 2002-2006

By Todd Flanagan

Weather modification operations have been in place in Texas on and off since the late 1800's. More recently several weather modification programs were formed in the mid and late 1990's and continue to currently run. Evaluations of these programs to determine their efficacy did not take place until 2000, when a TITAN-based analysis method was developed by Arquimedes Ruiz-Colombie of Active Influence.

Within the past year a desire to have a second independent entity conduct an analysis of the state's weather modification programs led to a contract between Woodley Weather Consultants (WWC), the Texas Weather Modification Association (TWMA) and the Sandyland Underground Water Conservation District. Dr. William L. Woodley, president of WWC, along with Dr. Daniel Rosenfeld received all available flight and radar data from all existing programs between 2002 and 2006. These five years of data were analyzed using a method developed by Rosenfeld and Woodley and a final report was produced in June 2007. Herein we will summarize the results of the analysis.

Briefly, the method in which the data were analyzed involved defining a floating target analysis unit with radius of $25km^2$ in which a cloud or several clouds were seeded. Similar floating target analysis units were identified that served as control or unseeded units. The rain volume rates of these units were looked at to determine the effects of seeding. Various parameters were used to partition the results and assess seeding efficacy. In reality the description here barely scratches the surface; the analysis itself is far more complex. A more in depth report of the data analysis can be found in "The Development and Testing of a New Method to Evaluate the Operational Cloud Seeding Programs in Texas'" in the *Journal of Applied Meteorology*, Vol. 43, Issue 2, February 2004, pgs 249-263.

During the analysis period, 3834 seed units were identified and tracked and their control matches were made. A quarter of these were from the West Texas Weather Modification Association's target area alone. The analysis was broken up into different catego-

Figure 1

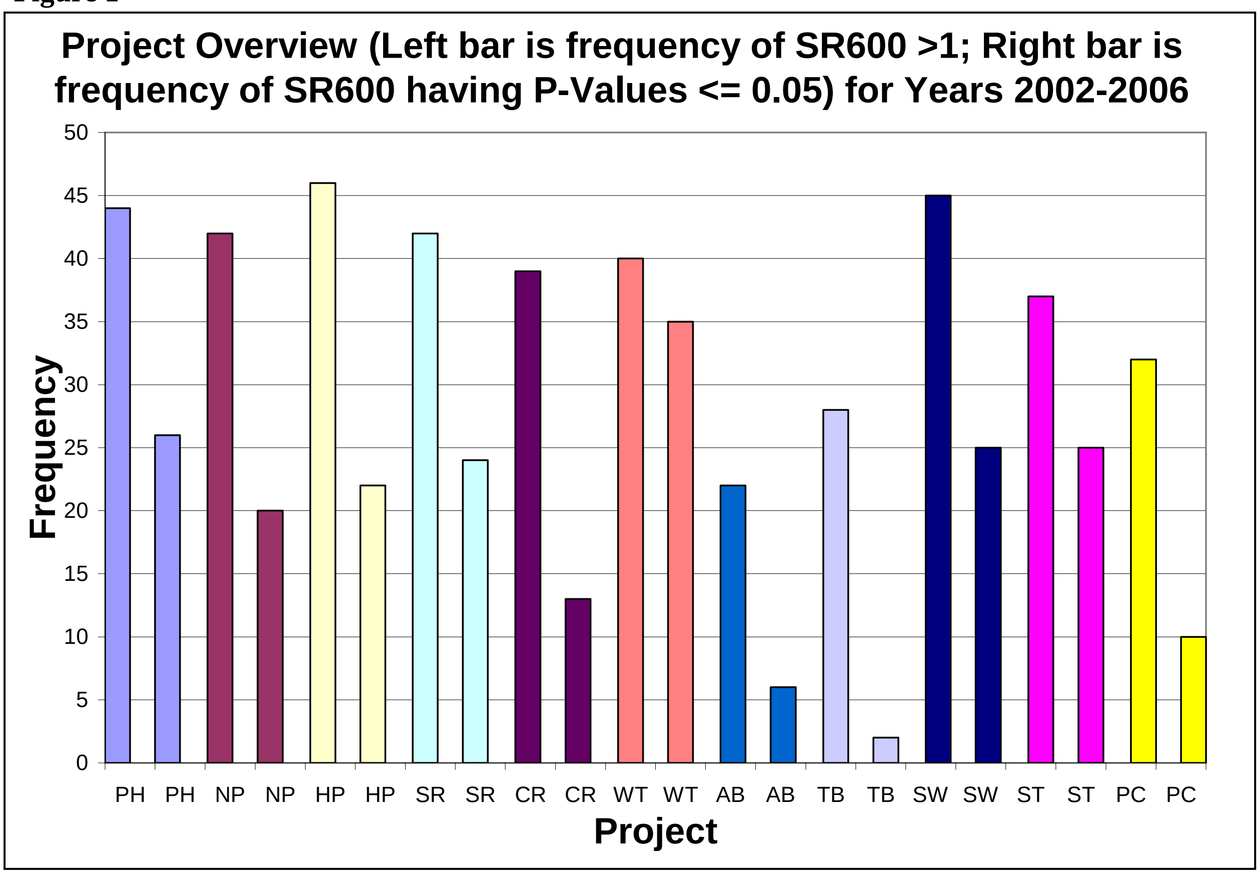

Figure 1. Results overview by project, where the left bar for each project is the frequency of SR600 (seed/control ratio at 600 min) > 1 and the right bar is the frequency of SR600 values that have P-values $\leq$ 0.05.

ries relating the difference in rain volume rate between seeded and unseeded units as a function of cloud age at seeding, ICA values on the day of seeding, and the rainfall intensity at the moment of seeding. Results indicate that the strongest performing projects were the Panhandle, SOAR, CRMWD, West Texas and South Texas projects. Figure 1 shows the overall results for all the projects studied. These projects had the most statistically significant results. Positive results were also found for the High Plains and Southwest Texas projects. The Abilene and Pecos projects showed a negative response, but datasets for these projects were seriously lacking and the results only had weak statistical support.

Reference

Woodley, W.L. and D. Rosenfeld, 2007: Evaluation of the Texas seeding programs for seeding effects (2002-2006). 143 pp

Table 2

Estimated Additional Seeded Rainfall By Project				
Project	Avg. Rain Inc./unit (kilotons)	# Seed Units 2002-2006	Total Rain Volume (kilotons)	Total Rain Volume (acre-feet)
NP	2,699	278	750,322	610,018
PH	3,583	652	2,336,116	1,899,281
HP	8,257	136	1,122,952	912,969
SR	2,056	328	674,368	548,267
CR	5,297	104	550,888	447,876
PC	-374	157	-58,718	-47,738
WT	1,990	1,040	2,069,600	1,682,602
AB	-4,034	94	-379,196	-308,289
SW	1,970	487	959,390	779,992
ST	2,370	424	1,004,880	816,976

Table 2: Estimated additional seeded rainfall by project in kilotons and acre-feet.

Table 1

Summary of Project Results Based on RVR199 3H and 6H Inout Matches

Projects With Strongest Evidence for Seeding Induced Rain Increases

Project	% Change	AVG. Rain Increment Kilotons	P-Value Support	6RVR113 Results
PH	23 To 27	3,583	Very Strong	Positive
SR	12 To 17	2,056	Very Strong	Positive
CR	47 To 61	5,297	Very Strong	Negative
WT	23 To 26	1,990	Very Strong	Positive
ST	26 To 32	2,370	Very Strong	Positive
Projects With Weaker Evidence for Seeding Induced Rain Increases				
NP	22 To 23	2,699	Weak	Positive
HP	49 To 61	8,257	Strong	Positive
SW	17 To 32	1,970	Strong	Positive
Projects With No Evidence for Seeding Induced Rain Increases				
PC	-18 To 0	-874	Weak	Positive
AB	-35 To -24	-4,034	Weak	Negative

Table 1: Summary of project results based on RVR199 3 hour and 6 hour inout matches. The table is divided into projects with strong evidence, weaker evidence and no evidence.

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Summary Continued from Page 7

Figure 2

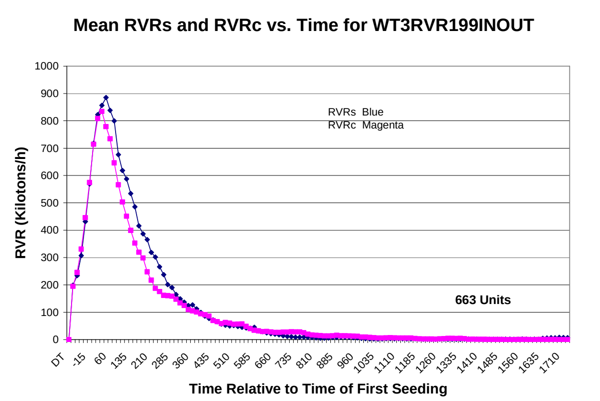

Figure 2: Plot (366 units) of mean S and C RVR obtained from the original method (i.e., RVR199) for 3 h matches selected from within and outside the seeding target for the West Texas project.

Figure 3

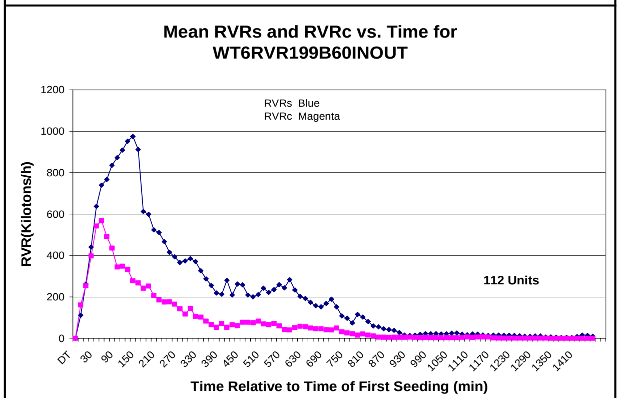

Figure 3: Plot (93 cases) of mean S and C RVR obtained for young units from the original method (i.e., RVR199) for 6 h matches selected from within and outside the seeding target for the West Texas project.

Grass Continued from Page 1

into the state. 2007 has seen a combination of Pacific and Gulf moisture due to multiple upper-level lows and accompanying surface lows moving either slowly across the southern Plains or being cut-off over the state. When lows become cut-off from the driving winds long periods of heavy rain can be expected. June provided an unusual type of cut-off low.

This unusual type of cut-off low developed from the spin of two ridges: One over the Desert Southwest and one over the Southeast. Northerly flow from the western ridge over west Texas, and southerly flow from the eastern ridge over east Texas caused a counter-clockwise circulation over central Texas. Ridges are generally more persistent than low pressure systems or troughs. However, the two persistent ridges over both coasts promoted the sustained development of a low/trough over the state of Texas. Given the enhanced soil moisture, Pacific moisture, and Gulf moisture combining over Texas with a persistent low the state saw very significant rain and flooding over much of the eastern half.

Soil moisture has increased or remained much above a typical value since rain has continued to fall. This leads to a sustained source for moisture over the region and with minimal surface heating a slight forcing mechanism can produce the next high precipitation thunderstorm. Many precipitation events such as those created by weak forcing mechanisms are not seedable because they have very low tops or low ceilings. Low topped thunderstorms often produce inadequate supercooled water and insufficient inflow for seeding. Thick, low-level stratus clouds often have ceilings that are ill-defined and make flying an aircraft dangerous. However, seeing as the atmosphere is very humid from the surface moisture copious amounts of water can be squeezed out of the atmosphere.

West Texas has been less favorable for the significant precipitation which was seen in east Texas but the majority of the target area has received close to or above the annual precipitation average. Typically, when west Texas receives a northerly flow on the downwind side of a ridge subsidence dominates and clear skies prevail. Numerous short-wave troughs running around the edge of the ridge improved chances for precipitation over west and central Texas. The more typical, northerly flow aloft pattern became more pronounced the second week of July permitting at least a vision of summer. However, as the ridge became more pronounced over the northern Plains through late July; a combination of both the western and eastern ridge shifting westward, an upper low developed over south-central Texas. This low brought several days of scattered tropical rain showers and thunderstorms across the region which pushed rainfall totals above the monthly normal for precipitation.

Anomalous Propagation and Its Increasing Affects on Radar

By Nick Jones

Anomalous propagation (AP) in general has become an increasing problem in Western Texas because of wind farms and the affect they have on radar accuracy and its use as a weather tool. A brief description will be given here, but National Weather Service (NWS) has determined that this is an important consideration and has further and more technical information at the web site: http://www.roc.noaa.gov/windfarm/

Figure 1

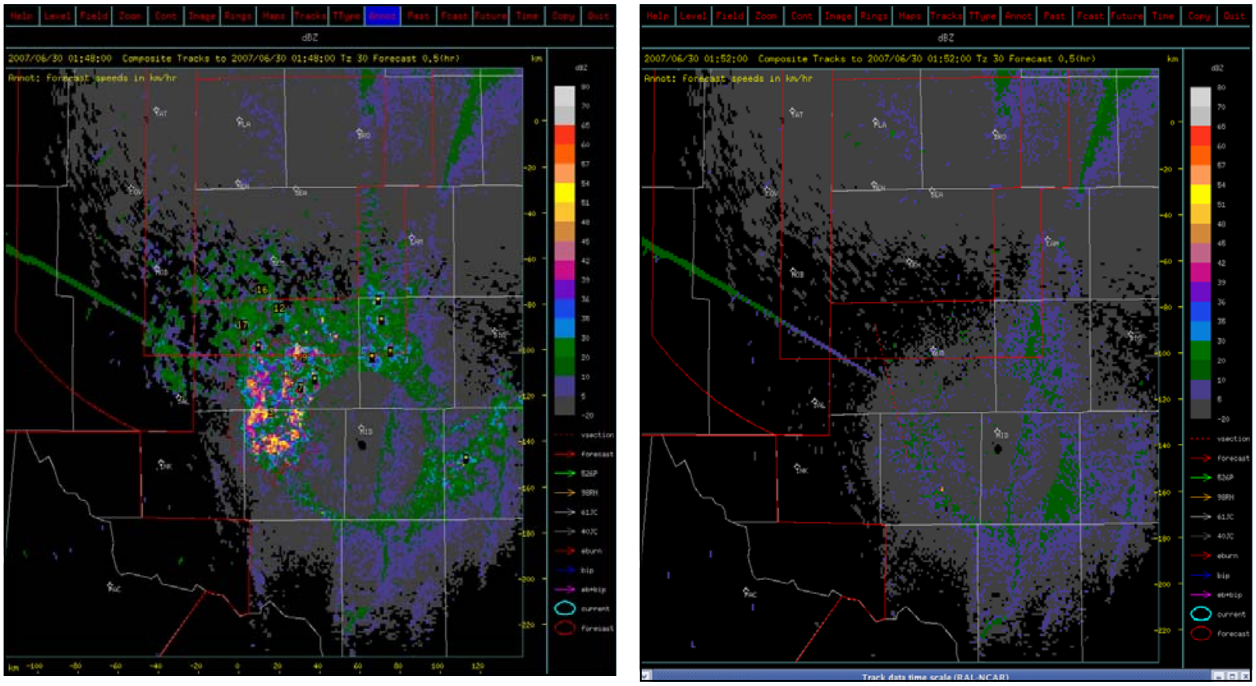

Figure 1: The first Titan image from the SOAR program shows the wind farms on the radar as storms. The second Titan image shows a clear picture after the radar has been adjusted.

windfarm_index.asp. The wet conditions during the month of June have enhanced the problem that the wind farms generate. Moreover, NWS expects the problem to get much worse with even bigger wind farms planned for West Texas.

AP is bending of the radar beam down to hit the ground. It is an issue that develops more as the radar antenna is turned down a 0.5 degree increment for warning purposes and to allow the NWS to use the full 230-mile radius of the radar. NWS insists on placing their radar hardware almost exclusively on a tower 63 feet off the ground. This 0.5 degree drop allows good coverage of meteorological data at great distance. It also enhances AP. The radar beam bends, hits the ground and is reflected to the receiving antenna and may be reported as a weather echo. This effect is removed mathematically by the modern radar system; however, the wind farms have affected this math and made it far less accurate.

In the June 13, 2007, Mission Report Forecaster Ray Fagan stated, “The problem with anomalous propagation is an increasing one. The National Weather Service has a tool “Spectrum Width” filter that is supposed to remove AP echoes from the Radar Display. Substantially, in some cases and on average *through out* the spectrum of the tool’s use.”

The increasing number of wind farms in the Midland area has required the tool to be modified. This modification has reduced the ability to correctly eliminate AP. In addition to seeing the actual wind farms on the radar the use of the operational tool can cause dramatic changes in the ground return picture we see on Titan. These changes are made on a number of mornings, and the return may even look like a full thunderstorm or cluster. Then the cluster disappears when Midland adjusts with their tool. Here are two attached samples. Others may be converted to an animated presentation and be submitted to those publications, agencies, or entities where they impact operations. One of those might include Unisys Corporation as they have on many cool mornings reported on their home page AP as actual rainfall.

A great part of the identification problem is solved as far as it impacts SOAR operations. We have developed procedures to use the Titan “vertical section” to virtually eliminate confusion over the radar display here at the Plains operations area. It can, at times, still be difficult when real convection develops in the ground clutter—and with the wet year this has been more common.

For economic impact and saving, further study is ongoing and this environmental impact might suggest a small but important customer base in the Electric Generation industry, particularly for our research aircraft.

Cloud Seeding With Silver Iodide as a Glaciogenic Agent

By Archie Ruiz Columbié

Cloud Seeding Activities for precipitation enhancement purposes are intended to assist Nature in the formation of precipitation. In general, there are two types of cloud seeding activities: **glaciogenic seeding** and **hygroscopic seeding**. The former uses ice-forming chemicals which when activated can transform supercooled water particles in ice particles, whereas the later uses hydrophilic chemicals that can coagulate water vapor in droplets with desired sizes. As a general rule, ice-forming particles are hydrophobic.

Silver Iodide (AgI) is used as an ice-forming agent (a glaciogenic one) because it fulfills some of the requirements needed:

Crystallographic requirement: ice nucleation over a foreign surface occurs as an oriented overgrowth that is facilitated by a geometric arrangement which is as close as possible to the ice crystal geometry. Silver iodide crystals are very similar to ice crystals.

Insolubility requirement: ice-forming chemicals are highly hydrophobic. The presence of soluble ions would diminish the freezing point of water which in turn would be an undesired effect. Silver iodide is highly insoluble.

Active-Site requirement: ice formation is preceded by the adsorption of water at distinct active points on the surface of the foreign particle. Impurities on the surface can help water to overcome the natural hydrophobic barrier with preferential adsorption on these sites. For silver iodide particles the presence of both ions (positive silver ion and negative iodide ion) in one site can favor the formation of ice at such site. Positive potassium ion and negative nitrate ion impurities can also favor the formation of ice.

Size requirement: ice-forming particles should have sizes which promote the formation of ice particles capable to overcome critical values. Field observations indicate that the central particles in snow crystals usually have radii between 0.25 and 2.5 µm (microns). Snow crystals with smaller central particles seem not to survive as precipitation particles. This requirement is very important in the evaluation of flares. The next paragraphs are dedicated to explain it in detail.

The two most important features to take into the account when one is using flares are:

1. Flare's Activity (number of nuclei produced per unit mass)
2. Flare's Rate of Nucleation (time needed to produce a determined amount of nuclei)

These two characteristics depend upon temperature and moisture, variables that are under control when the flares are tested in cloud chambers. For instance, as a general rule, the cooler the chamber (the environment) the higher the amount of produced nuclei (higher activity) and the shorter the time needed to produce the nuclei (faster rate). Additionally, the activity is directly related to the particle sizes, since the higher the production of particles from a unit mass, the smaller the particles. Excessive activity can produce undesired effects because particles that are too small tend to produce too small ice-embryos which never grow to overcome the critical radius, whereas many of them will be dissolved losing their nucleating quality. Small ice-particles tend to go to the anvils. At least for rain-enhancement purposes this is undesired, although for hail suppression it might imply temporarily relief. However, blown-cloud tops can also bring down severity through high-speed winds from above; another undesired issue.

Here are the data corresponding to the RS-3 flares at interesting temperatures:

T(°C)	LWC (gm^{-3})	Activity (g^{-1})	Rate 63% (min)	Rate 90% (min)
-6	1.5	1.7×10^{11}	0.96	7.61
-8	1.5	1.6×10^{12}	0.74	1.71

For instance, to obtain an idea about the average particle size produced by RS-3 flares at – 6 °C one needs to calculate the average mass of the particle, in this case the inverse of the activity:

$$m = 1 / (1.7 \times 10^{11}\ g^{-1}) = 5.8824 \times 10^{-12}\ g$$

Knowing now that the silver iodide density is 5675 kg m^{-3}, one can calculate the average radius of the particle since

$$m = \text{density} \times \left(\frac{4\pi}{3}\right) r^3$$

$$\text{Therefore, } r = \left[\left(\frac{3}{4\pi}\right)\frac{m}{density}\right]^{\frac{1}{3}}$$

The corresponding value of average r is ≈ 0.63 microns.

Nature usually uses ice-nuclei as highly water-insoluble particles with radii between 0.25 and 2.5 microns (see Pruppacher and Klett, **Microphysics of Clouds and Precipitation**, Kluwer Academic Publishers, 2003, page 327, for details). As the reader can see, the calculated average radius of 0.63 microns falls in the aforementioned interval.

Samplings of RS-3 smokes have indicated that about 70 % of the particles have radii above 0.27 microns. The distribution of sizes follows very well a log-normal distribution, and particles in the ~ 30 % below 0.27 microns could grow by clogging improving even more the smoke for nucleation purposes. Of course some of these particles are going to be diluted since silver iodide is highly water-insoluble but not perfectly insoluble. The problem is very complicated but the calculation of the average radius is a great clue to approximately understand the quality of a flare. For example, following the same steps for a flare with activity one order of magnitude higher ($6.49 \times 10^{12}\ g^{-1}$ at T = - 6 °C) than the RS-3 would give us an average radius of about 0.19 microns, which is too small (outside the Nature preferred interval). The smart user will never release a flare with too high activity because too much silver iodide would be lost in solution.

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cloud-seeding research activities.

At the State Level

A bill that would have established a weather modification research program in Texas narrowly missed adoption by the 80th Texas Legislation, which concluded business on Memorial Day, May 28, 2007. The bill (S. 822), sponsored by Senator Jeff Wentworth of San Antonio, would have created a "competitive research grant program" for faculty researchers at Texas public and private colleges and universities having expertise in weather modification. The program would have been administered by the Texas Department of Agriculture in Austin, with an "atmospheric modification research center" based at Texas Tech University to conduct "basic and applied research designed to increase understanding of precipitation and the ability to control precipitation to decrease the damaging effects of drought, hail, and flooding on the environment and man-made structures."

The legislation, introduced in the Texas Senate on February 22, 2007, eventually passed the Senate on May 8 by a near-unanimous vote. The bill, then sponsored in the Texas House by Rep. Tracy King of Uvalde, was voted out of committee a week later and sent to the full House for a vote. However, the bill could not be scheduled for a vote on the House floor before the last day, May 22, legislation originated by the Senate could be considered by the full House. As a result, the bill died just one short step from enactment.

Moreover, S.822 would have transferred the licensing and permitting of weather modification activities to the Texas Department of Agriculture from the Texas Department of Licensing & Regulation (TDLR).

A second piece of legislation (H.R. 2027), introduced by Rep. Pete Gallego of Alpine, would have required applicants for permits to use anti-hail devices (so called "hail cannons") for the suppression of hail to have obtained endorsements from county commissions. That bill was heard in the Agriculture & Livestock Committee of the House of Representatives on April 10. The bill was never voted out of committee.

Federal Legislation

Senator Kay Bailey Hutchison of Texas introduced a bill in the U.S. Congress on July 18, to develop and implement a comprehensive and coordinated national weather modification research effort. The bill, known as the "Weather Mitigation Research and Development Policy Authorization Act of 2007," is a variation of legislation she introduced in a prior Congressional session. If enacted, S. 1807 would create a Weather Mitigation Advisory and Research Board to help formulate and implement a national weather mitigation policy. The Board would review and fund proposals for research in the area of weather damage mitigation, such as drought alleviation and hail suppression.

This new legislation is a response to a 2003 report by the National Research Council that recommended a federal research program in weather modification technologies. If enacted, Sen. Hutchison's bill would make available 5 million per year for ten years to states working on developing and improving cloud seeding technologies.

Nearly all of the cloud seeding research done in Texas over the past 33 years has stemmed from Federal funds channeled to Texas agencies through the U. S. Bureau of Reclamation and the National Oceanic & Atmospheric Administration (NOAA). Senate bill 1807 would re-open the funding pipeline to enable Texas to complete cloud seeding research work begun in 2004, as well as to investigate several new approaches to more effective rain-enhancement technologies.

"We see potential for research in this area, and the bill I've filed would direct the development of a comprehensive and coordinated national research effort through federal and state programs," said Senator Hutchison. "Specifically, the legislation will bring agencies, departments, experts, and scientists together to foster collaboration on research in an area about which we know little. This could have great potential for Texas and for the nation."

Look for the U.S. Senate to hold hearings on this proposed legislation in the months ahead.

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The sun sets over the West Texas Target Area to end another day.
Photo taken by Robert Rhodes.

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