

SOUTH TEXAS WEATHER MODIFICATION ASSOCIATION

EDWARDS AQUIFER AUTHORITY TARGET AREA



Cloud in Medina County on May 29, 2009. Photo taken from plane by Ed Walker.

2009 REPORT

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THE YEAR IN REVIEW

The 2009 season marked year number eight for cloud seeding operations for the STWMA in the EAA's tri-county area of Bandera, Bexar and Medina. The drought that began in late 2007 and extended through 2008 continued for much of 2009 before a major pattern change in September finally brought the welcome rains so desperately needed to south Texas. The heat was also a big story, with many locations experiencing their hottest June to August periods since record keeping began along with an unprecedented number of days where highs reached or exceeded 100°F.

May was dry for most areas in south Texas, although southern Medina, extreme eastern Bandera and southeastern Bexar counties saw above normal rainfall where pockets of 4+ inches of rain fell. A bout of 100°F days during the first part of the month would be a harbinger of things to come later in the summer. The latter half of May saw several disturbances affecting the area, bringing a number of seeding opportunities to the target area including one randomized seeding case.

The start of June continued to see active weather, but was quickly shut down as a strong ridge of high pressure parked itself over the area bringing more 100°F+ highs and little rain. Most areas saw less than 25% of the normal monthly rainfall or less than half an inch, with pockets of 2+ inches in Bandera and eastern Medina counties. Toward the end of the month a couple more days of favorable weather allowed for seeding operations.

The strong subtropical high returned in July and stayed put for much of the month, although occasional disturbances were able to penetrate through and bring scattered convection to the area. Normally by this time of year the majority of convective cells will move inland from the Gulf and head northwest across the area, but in July 2009 a majority of events moved from north to south across the area. Rainfall was varied, with much of Bexar County seeing 50% or less of the average monthly rainfall, while parts of Medina County saw upwards of 150% of their normal July rainfall, or about 2-3 inches. The intense heat continued, with many more days of highs at or above 100°F.

August saw the hot and dry weather continue, with most locations receiving less than 25% of their normal monthly rainfall, most of which fell during the latter half of the month. Southern and western Bexar County and southern Medina County fared slightly better, with 1.5-2 inches of rainfall recorded in these locations. By the end of the month, San Antonio had recorded its warmest June to August period since record keeping began. This also translated into an incredible number of 100°F days, with San Antonio recording 59 days where highs reached or exceeded the century mark, while Hondo recorded 68 days, and Stinson Field 70 days!

September brought a welcome change to the weather pattern as the strong high that had plagued the area for much of the summer finally broke down and moved away from southern Texas. Tropical moisture, which had been largely absent for much of the summer, also began to affect the area with showers and thunderstorms dropping heavier amounts of rain than had been seen all summer. While this was certainly good news for the area, in terms of cloud seedability the highly tropical airmass produced many unfavorable clouds for treatment. The month ended with most locations seeing above normal rainfall; in fact, southeastern Medina County recorded

8-12 inches of rain, which is 300-400% of the normal monthly rainfall. There was one more randomized case on the 1st.

With the conclusion of the season, radar data from the TITAN machine were sent to Archie Ruiz, who works for Active Influence performing radar evaluations for the Texas weather modification projects. Despite the dry weather experienced much of the season, the analysis does indicate increases in rainfall from the clouds that were able to be seeded.

The STWMA continued with an experiment within the EAA target area where randomized seeding would take place. With a bit of guidance from the National Center for Atmospheric Research (NCAR), a randomization protocol was developed that would guide both the pilot and the meteorologist in conducting a randomized seeding experiment. The flight to the area of developing convection would take place and the pilot would determine if the activity was seedable based on cloud appearance, inflow strength and location. In the case of the last criterion -- location, if other clouds of similar size and structure were present within 25km, the cloud could not be considered a candidate. Once a seedable candidate was found, the randomized decision procedure would take place. This involves both the meteorologist and pilot opening an envelope, inside of which would be a card with either "SEED" or "NO SEED" written on it. The meteorologist would convey his envelope content to the pilot, but the pilot would not tell the meteorologist what was in his envelope. If both envelopes matched, the pilot would seed the cloud. He would continue the mission as usual, burning flares as long as conditions warranted. If the envelopes did not match, the pilot would continue to fly in the favorable location, but only "pretending" to burn flares as long as conditions warranted. By doing the randomization in this manner, only the pilot truly knows if the cloud or clouds were seeded. The cards and notes for each day were to be placed into separate manila envelopes for future analysis, the purveyor of which has yet to be determined. Radar data from each day was also to be saved, again for future analysis.

2009 saw only two randomized seeding cases coming to fruition. The continuing problem of clouds developing in clusters as opposed to being isolated resulted in many "no-case" days.

2009 FLIGHT LOG

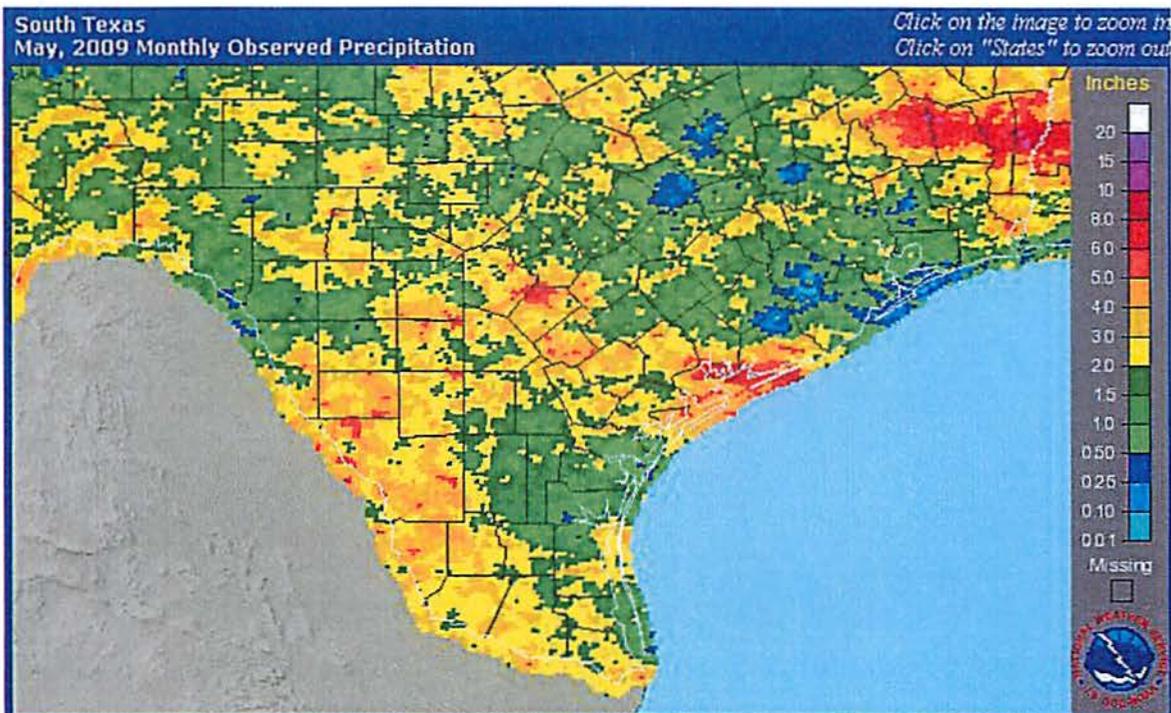
Date	Plane	Flight No.	Take Off Time	Landing Time	Total Time	No. Flares Used	Amount of Agl (g)	Flare Locations
16-May	78M	1	16:00	17:20	1.3	8	320	Medina - 8
22-May	78M	2	18:25	19:25	1	8 ¹³	320	Medina - 8
22-May	7AA	3	23:10	0:45	1.6	2 ¹⁸	80	Medina - 2
23-May	7AA	4	16:35	20:05	3.5	25 ⁴³	1000	Medina - 21; Uvalde - 4
24-May	7AA	5	18:10	21:45	3.6	10 ⁵³	400	Bexar - 4; Medina - 6
27-May	7AA	6	20:20	22:55	2.6	12 ⁶⁵	480	Bandera - 2; Medina - 10
28-May	47P	7	0:10	1:55	1.8	12 ⁷⁷	480	Bandera - 12
29-May	47P	8	18:35	19:45	1.2			Recon to Bandera
29-May	78M	9	21:05	22:45	1.7	2 ⁷⁹	80	Medina - 2
29-May	47P	10	22:15	23:15	1	10 ⁸⁹	400	Frio - 10** (random case for Medina Co. cell)
30-May	47P	11	22:00	1:20	3.3	14 ¹⁰³	560	Medina - 14
30-May	7AA	12	22:05	0:55	2.8	12 ¹¹⁵	480	Bandera - 6; Medina - 6
2-Jun	78M	13	3:25	4:55	1.5	26 ¹⁰¹	1040	Bandera - 12; Medina - 14
3-Jun	70P	14	19:10	0:05	4.9	8 ¹⁴⁹	320	Bexar - 8
25-Jun	78M	15	20:25	22:30	2.1	9 ¹⁵⁸	360	Medina - 9
30-Jun	47P	16	18:35	21:50	3.3	10 ¹⁶⁸	400	Bandera - 6; Medina - 4
1-Jul	60P	17	22:05	0:35	2.5	3 ¹⁷¹	120	Bandera - 2; Uvalde - 1
2-Jul	47P	18	22:20	23:55	1.4	10 ¹⁸¹	400	Bandera - 10
6-Jul	47P	19	20:20	0:00	3.6	26 ²⁰⁷	1040	Medina - 22; Uvalde - 4
7-Jul	60P	20	21:20	23:10	1.8	12 ²¹⁹	480	Medina - 8; Uvalde - 4
7-Jul	47P	21	0:00	0:35	0.6	6 ²²⁵	240	Medina - 6
17-Jul	47P	22	20:00	23:00	3	35 ²⁶⁰	1400	Bandera - 10; Bexar - 6; Medina - 19
18-Jul	60P	23	19:55	21:25	1.5	4 ²⁶⁴	160	Medina - 4; Medina - 1 hygro
20-Jul	78M	24	21:30	0:45	3.3	18 ²⁸²	720	Medina - 16; Uvalde - 2; Medina - 1 hygro
22-Jul	47P	25	22:05	23:30	1.4	3 ²⁹⁵	120	Bandera - 2; Kerr - 1
30-Jul	47P	26	18:05	21:20	1.3	23 ³⁰⁸	920	Medina - 23
12-Aug	47P	27	21:05	23:45	2.7	21 ³²⁹	840	Bexar - 10; Medina - 11
26-Aug	47P	28	22:20	23:55	1.6	6 ³³⁵	240	Bandera - 6
27-Aug	78M	29	2:05	3:50	1.8	6 ³⁴⁹	240	Bexar - 6
28-Aug	7AA	30	18:45	21:30	2.8	13 ³⁵⁴	520	Bandera - 4; Medina - 9
1-Sep	47P	31	21:35	23:00	1.4	4 ³⁵⁸	160	Medina - 4**
4-Sep	47P	32	22:25	0:10	1.6	19 ³⁷⁷	760	Medina - 19
		32 flights			69.5	377	15080	Bandera - 72; Bexar - 34; Medina - 245+2 hygro

Take off and Landing times are given in UTC. Local time is UTC-5 hours.
 In "Flare Locations", the numbers with ** indicate "potential flares" associated with the randomized seeding cases; these may or may not have been burned.

MAY

May turned out to be a very busy month as far as cloud seeding operations go, with several days during the latter half of the month seeing scattered convection. For the most part, operational seeding was conducted as convective initiation seemed to occur in clusters. There was one randomized case on the 29th when a single storm developed in southern Medina County, fitting the protocol. Although there were several days of seeding, rainfall amounts were quite varied, as one would expect with convection. Above normal rainfall occurred over southern Medina County and southeastern Bexar County, with the remainder of the tri-county area experiencing below normal rainfall for May.

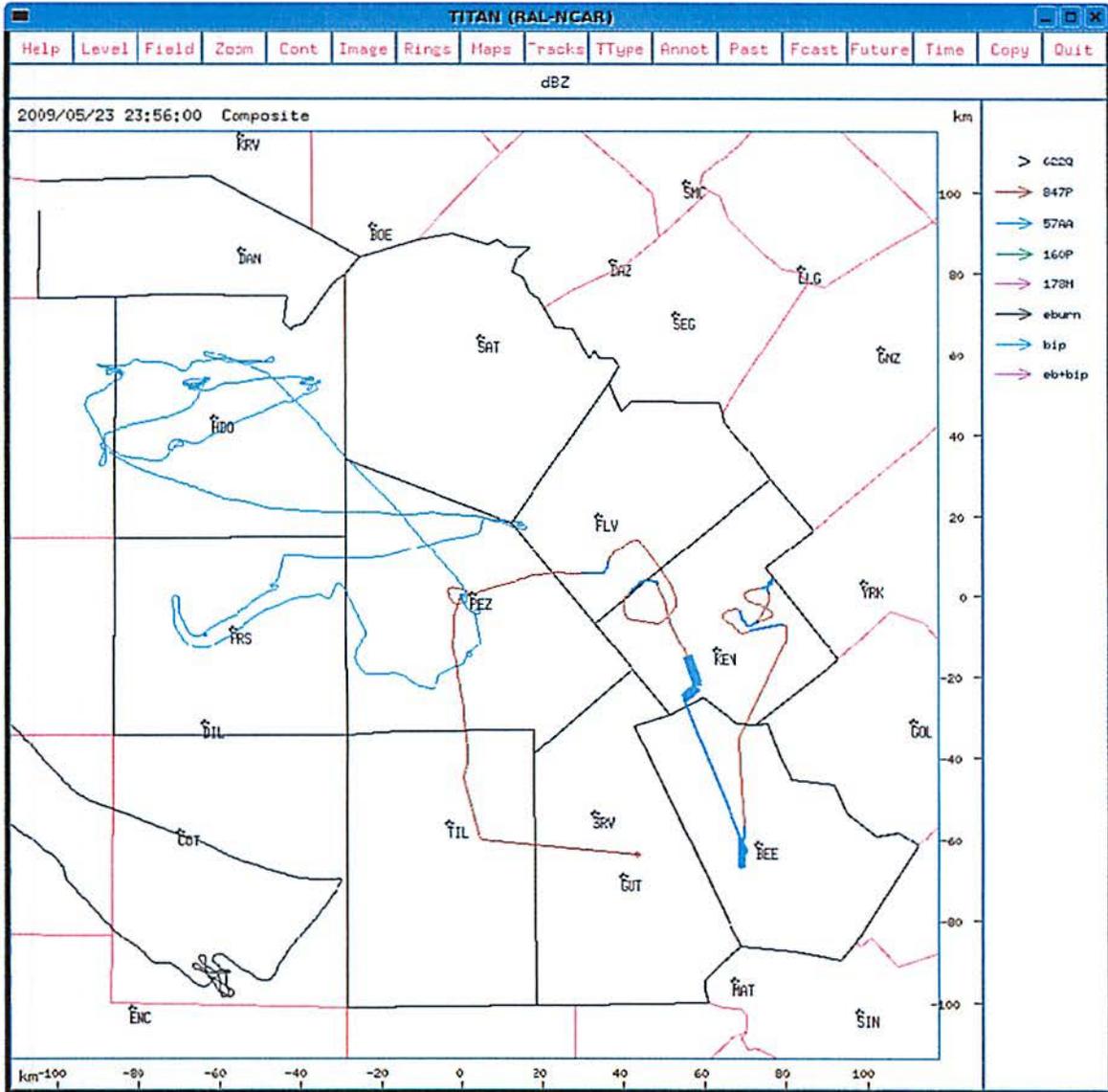
For the month, eight days of seeding occurred between the 16th and 30th. A total of 101 flares were used for seeding in Bandera (20) Bexar (4) and Medina (77) counties, totaling 4040g of AgI. Additionally, 4 flares were used for seeding in Uvalde County, which amounts to 160g of AgI and the randomization case on the 29th resulted in 10 "potential" flares being used for seeding, which is another 400g of AgI.



MAY 23

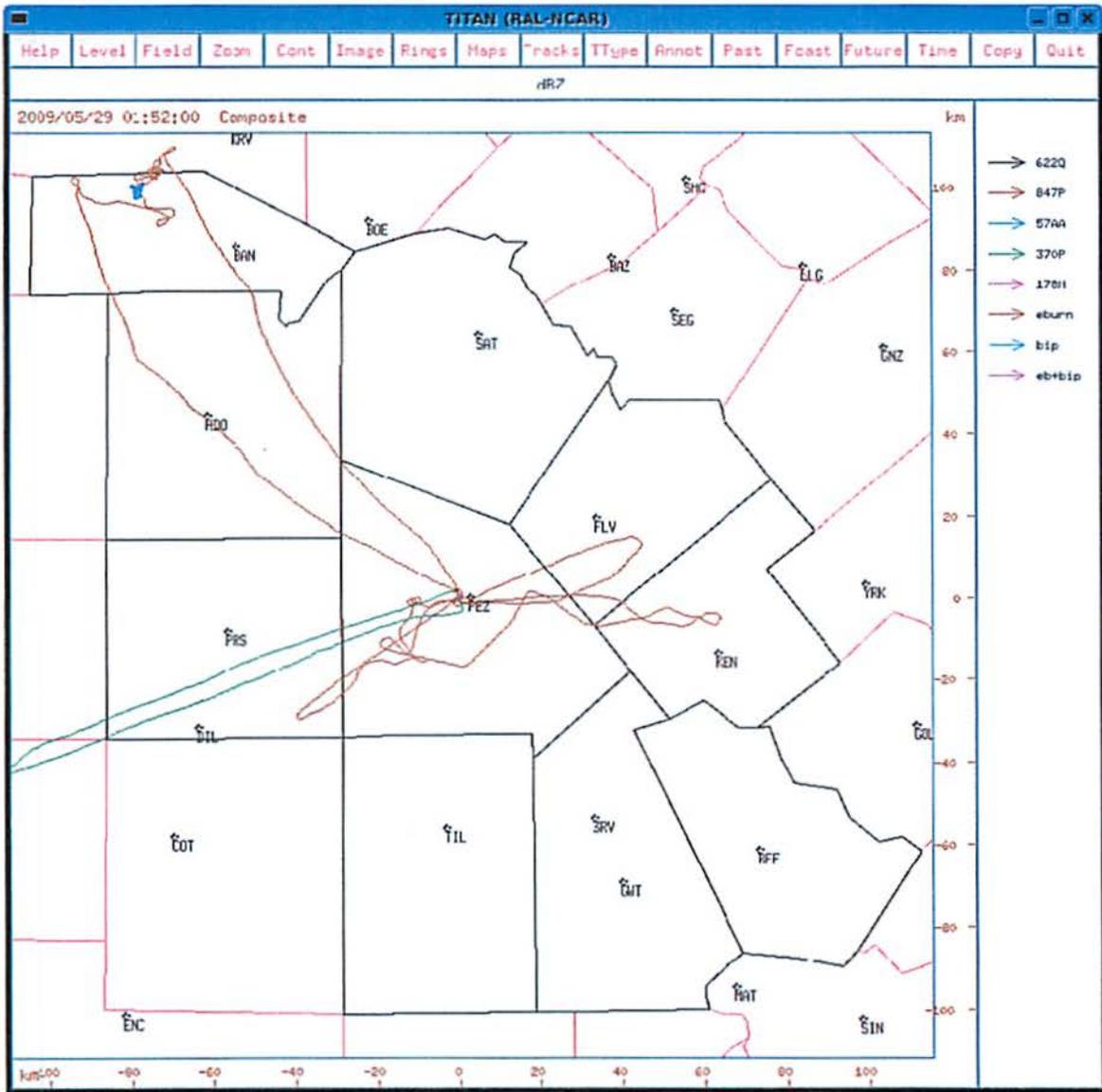
Convection once again initiated over the southern Hill Country/Balcones Escarpment during the late morning hours as strong heating allowed the low convective temperatures to be realized early. A flight was dispatched to Medina and Uvalde counties where seeding took place; no randomization was done due to close proximity of cells.

A total of 25 flares were used for seeding in Medina (21) and Uvalde (4) counties, which amounts to 1000g of AgI.



MAY 28

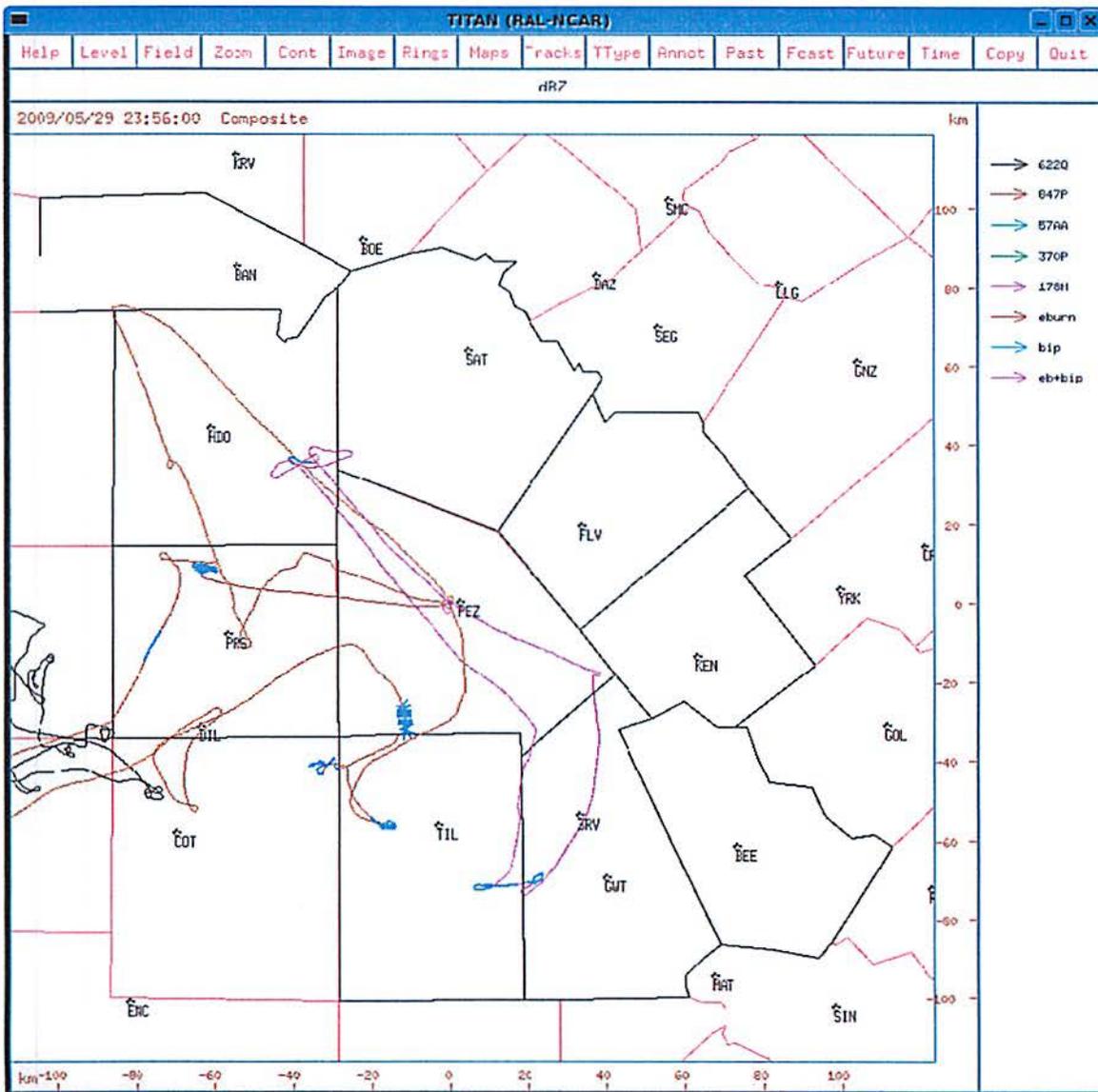
Early in the evening, a large storm which appeared to be propagating along the axis of greatest instability approached Bandera County and a flight was dispatched to investigate, with seeding taking place in Bandera County. No randomization. A total of 12 flares were used for seeding in Bandera County, which amounts to 480g of AgI.



MAY 29

Early in the afternoon convection began to form along the Balcones Escarpment, with clouds building in Bandera and northern Bexar counties. A flight was dispatched to the area but the clouds were fuzzy with not much definition and no inflow. Plane RTB. A second flight was dispatched as convection in western Bexar County had finally exited the San Antonio International Airport's approach airspace, heading S. Randomization was not done as several large clouds were close together. Late in the afternoon a cell began to develop rapidly in southern Medina County between Hondo and Pearsall. This cloud fit the randomization protocol and it was enacted, with "potential" seeding taking place in extreme northern Frio County while the cloud itself was in southern Medina County.

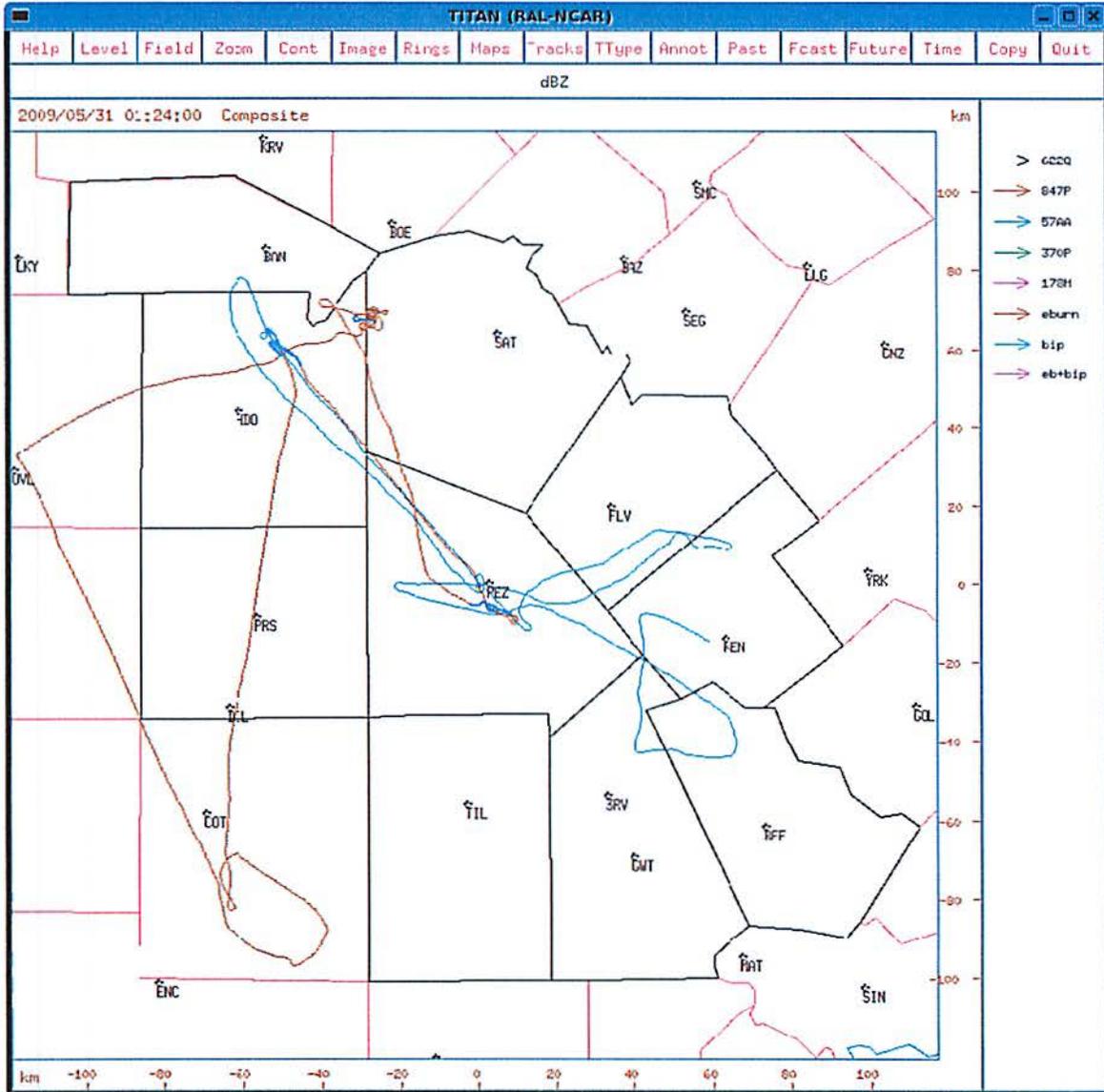
A total of 2 flares were used for seeding in Medina County, which amounts to 80g of AgI. Also, 10 "potential" flares were used for seeding during the randomization case on the cell in southern Medina County (potential flares actually fired just across the county line in Frio County), which amounts to 400g of AgI.



MAY 30

Convection formed near Medina Lake with one of the planes investigating this, but it was located within San Antonio approach airspace, so seeding was not done initially. In the early evening, convection was becoming concentrated in the Medina Lake area (eastern Bandera/northeastern Medina) and this was seeded operationally as the cluster did not fit the randomization protocol.

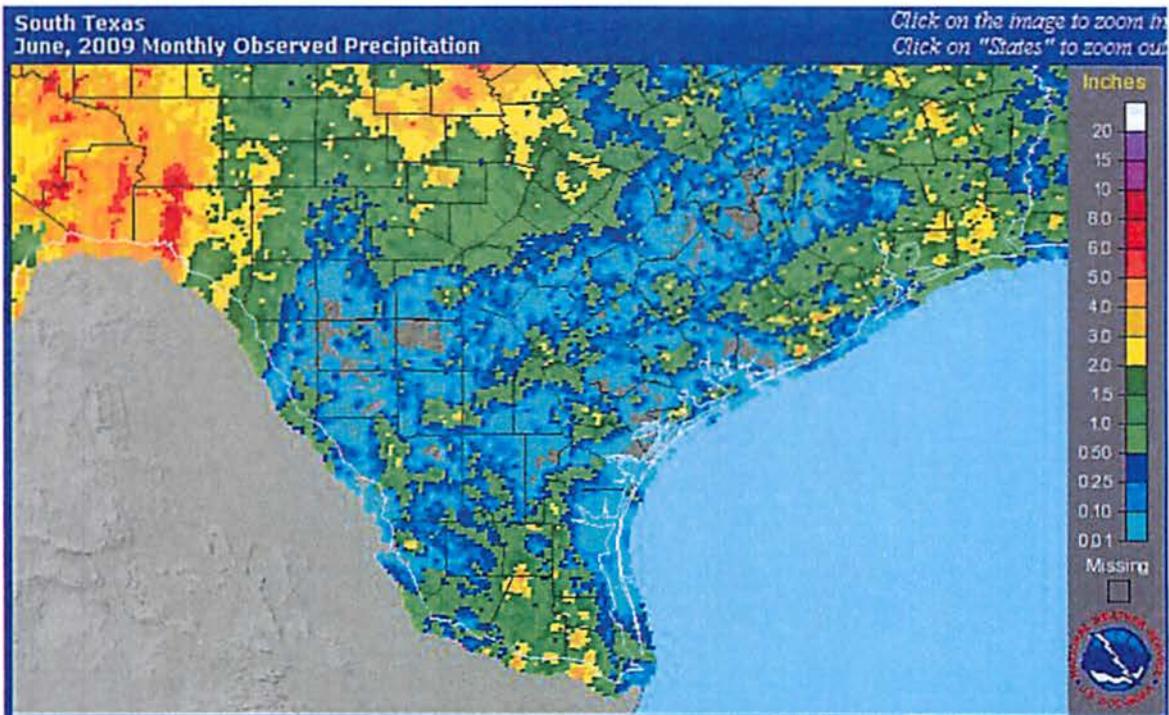
A total of 26 flares were used for seeding in Bandera (6) and Medina (20) counties, totaling 1040g of AgI.



JUNE

June was a very dry month for most areas of south Texas, including the EAA target area. The busy weather pattern of late May continued into early June. An MCS affected the area on the night of the 2nd, with the first night mission taking place and the leading edge of convection being seeded. More activity developed on the 3rd which was also seeded. The pattern then became very quiet as a large and strong ridge of high pressure developed and parked itself over the area. This promoted dry and hot weather, with several days of 100°F+ temperatures. Late in the month the high weakened, allowing for isolated to scattered convection to develop. Two more days of seeding activity took place. No randomized seeding cases were found as convection tended to develop in clusters as opposed to single, isolated clouds which are required.

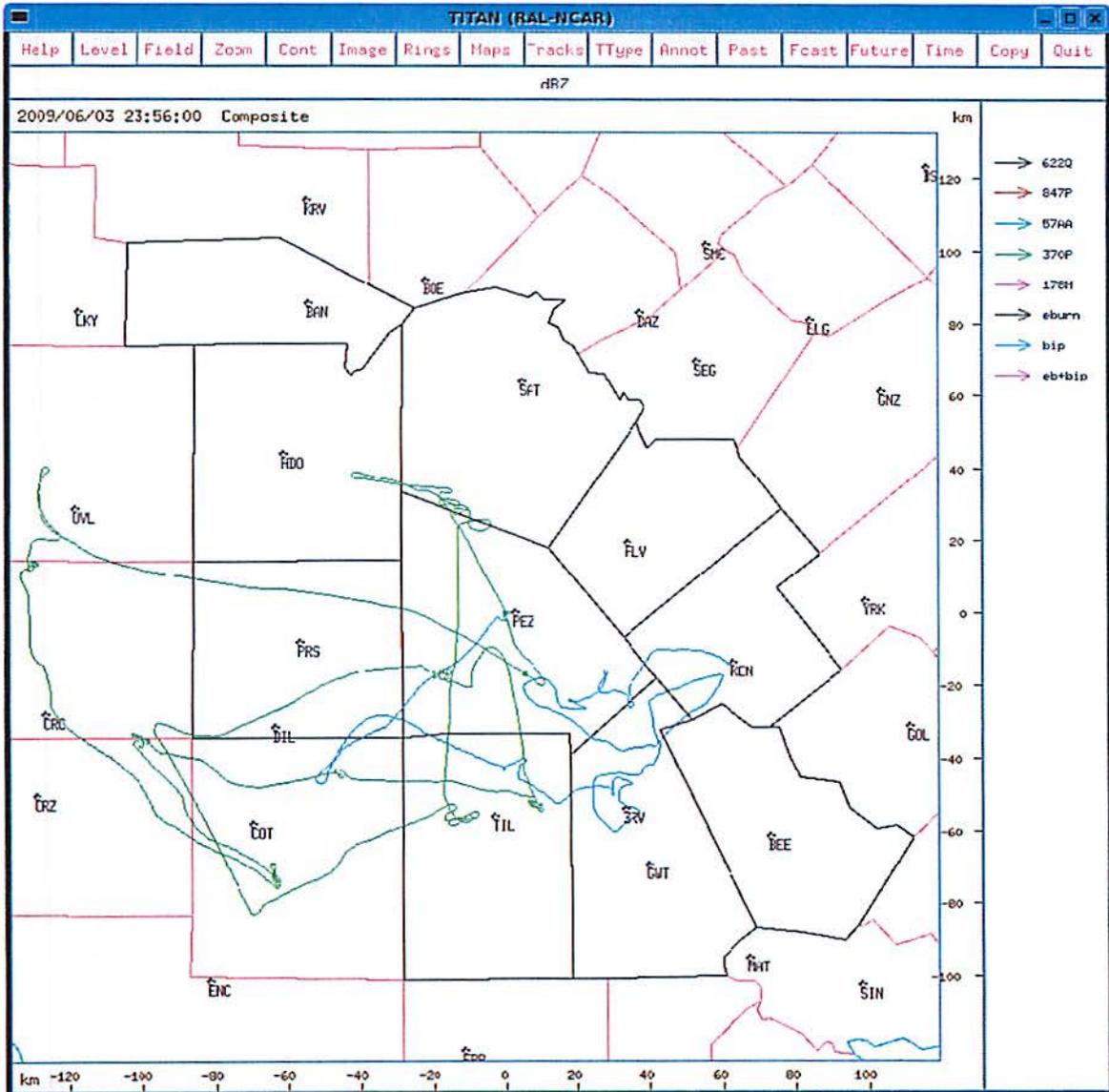
For the month, there were four days on which seeding took place. Four flights were launched into the tri-county area. A total of 53 flares (Bandera – 18; Bexar – 8; Medina – 27) were used for seeding, totaling 2120g of AgI.



JUNE 3

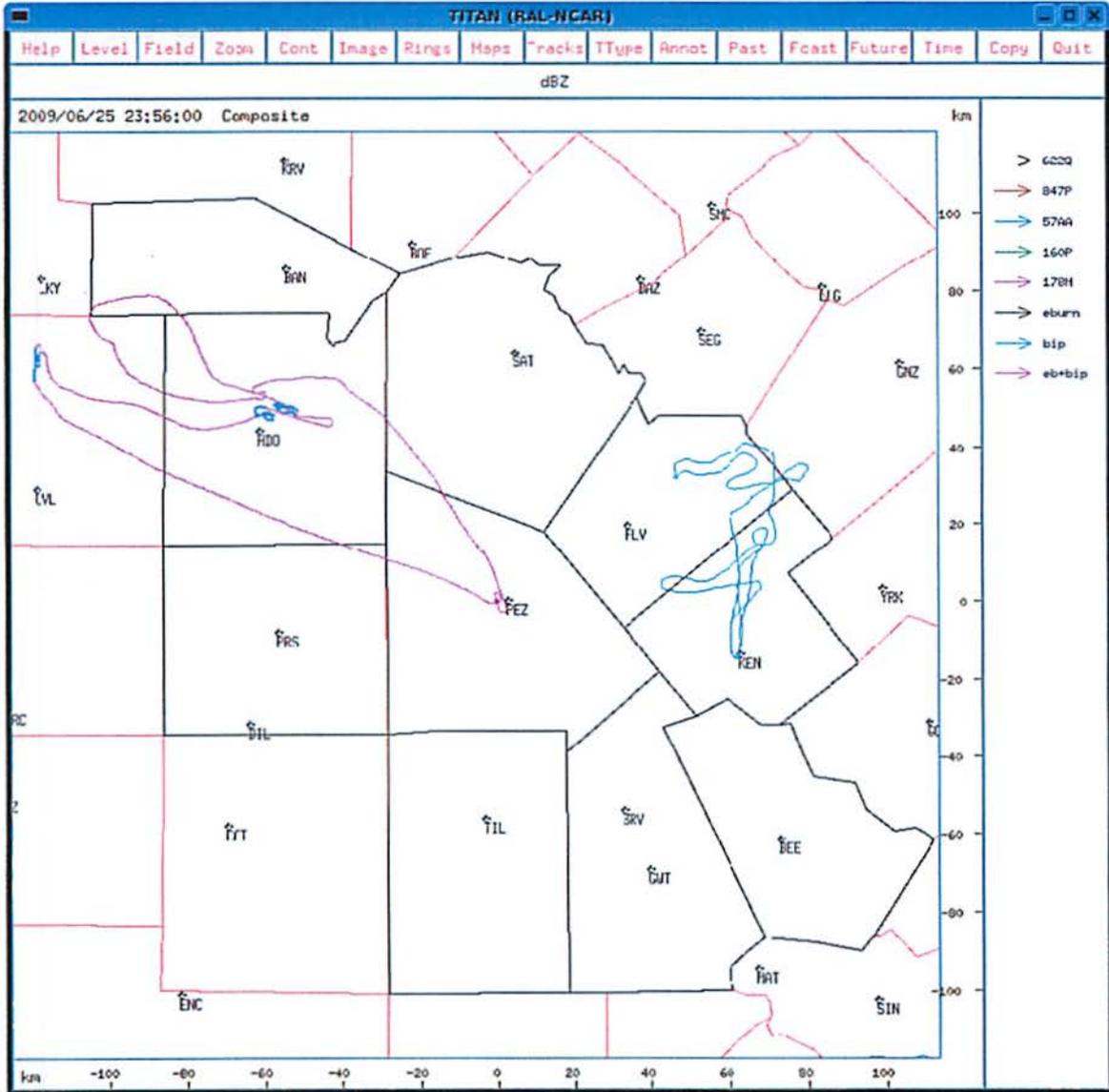
The combination of good moisture availability, a passing shortwave, approaching cold front and strong heating led to the development of scattered convection during the afternoon hours. Convection initiated in Bexar County early in the afternoon and a flight was launched to investigate. The randomization protocol could not be enacted, and operational seeding of this activity commenced. While most activity in south-central Texas was moving south and southeast, the Bexar County storm moved against the mean flow, heading west along US 90.

8 flares were used for seeding in Bexar County, totaling 320g of AgI.



JUNE 25

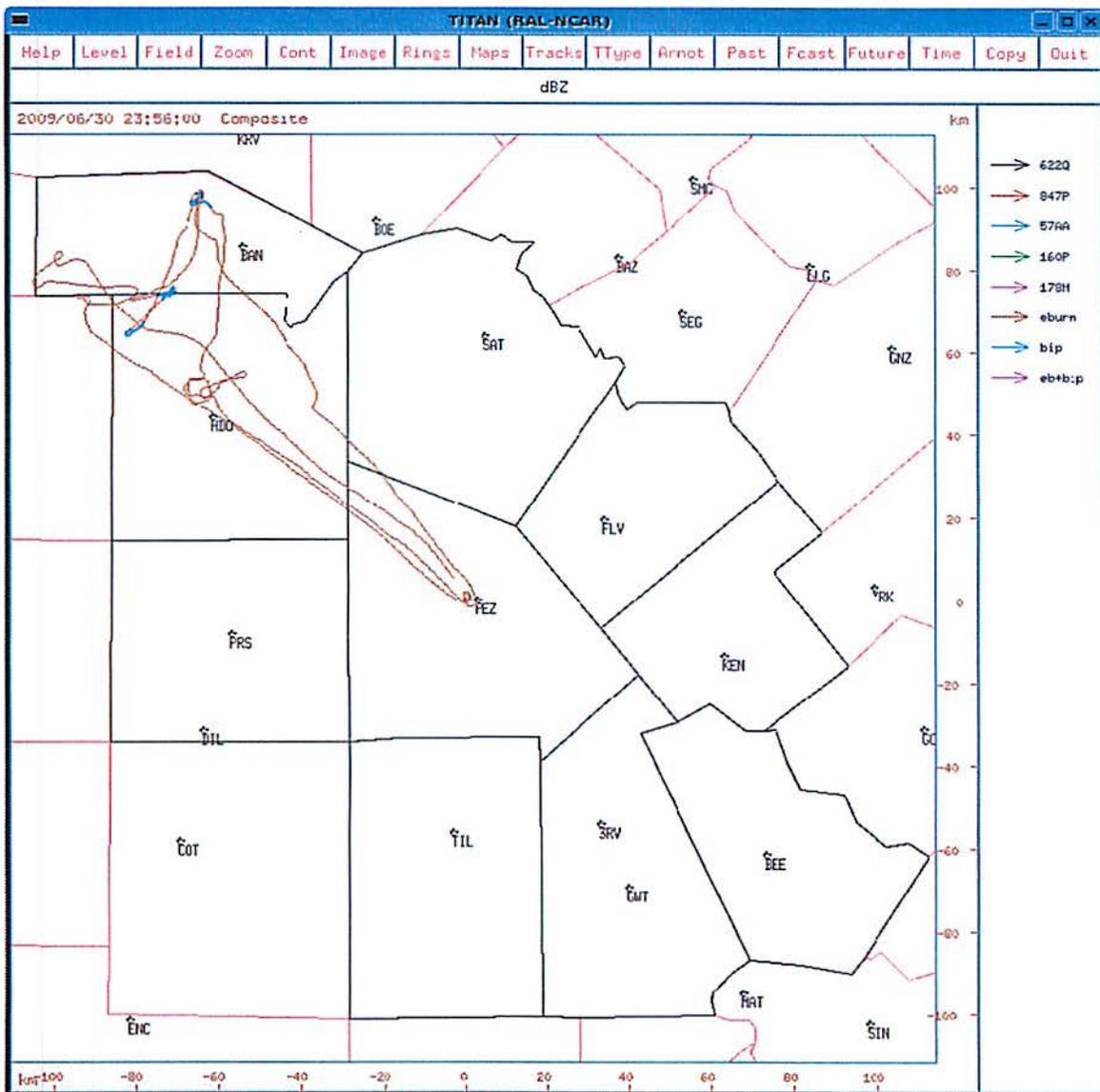
Convection developed along the Balcones Escarpment in Medina and Bexar counties towards the middle part of the afternoon, and a flight was sent to the area to investigate, with one large cloud being seeded in Medina County. 9 flares were used for seeding in Medina County, totaling 360g of AgI.



JUNE 30

Scattered showers and thunderstorms developed over the southern Hill Country and Edwards Plateau during the early afternoon hours, affecting Bandera County. A flight was dispatched to investigate, with one cloud receiving AgI treatment. The pilot reported that thunderstorms west and northwest of the target area were blocking out the sun across the western half of Bandera County, which was limiting surface heating and therefore limiting instability. Just outside this "shadow area", a second cloud began to develop in north-central Bandera County and this was treated with silver iodide as well. This cloud continued to grow in size and intensity as it moved north into central Kerr County, where eventually a flood advisory was issued due to heavy rain from the slow moving storm.

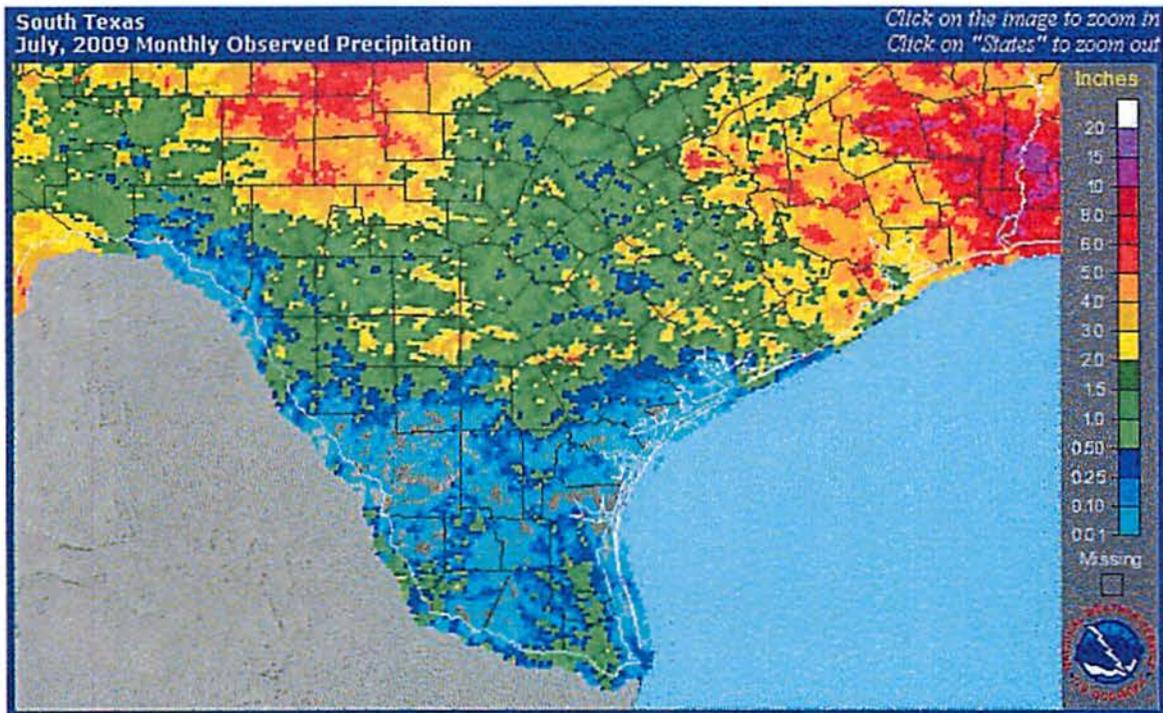
10 flares were used for seeding in Bandera (6) and Medina (4) counties, totaling 400g of AgI.



JULY

The big story weatherwise in July was the continuation of the drought, but also the intense heat. Many areas in south Texas baked under the strong July sun as a strong subtropical high dominated the weather for much of the month. Records were broken as far as high temperatures and the number of 100°F days, making the summer of 2009 on track to becoming the hottest summer in south-central Texas since weather records began. Even with the strong high in place, occasional disturbances were able to affect the area on several days during the month. The vast majority of activity moved from north to south, which is atypical for this time of year, when flow off the Gulf is normally more dominant.

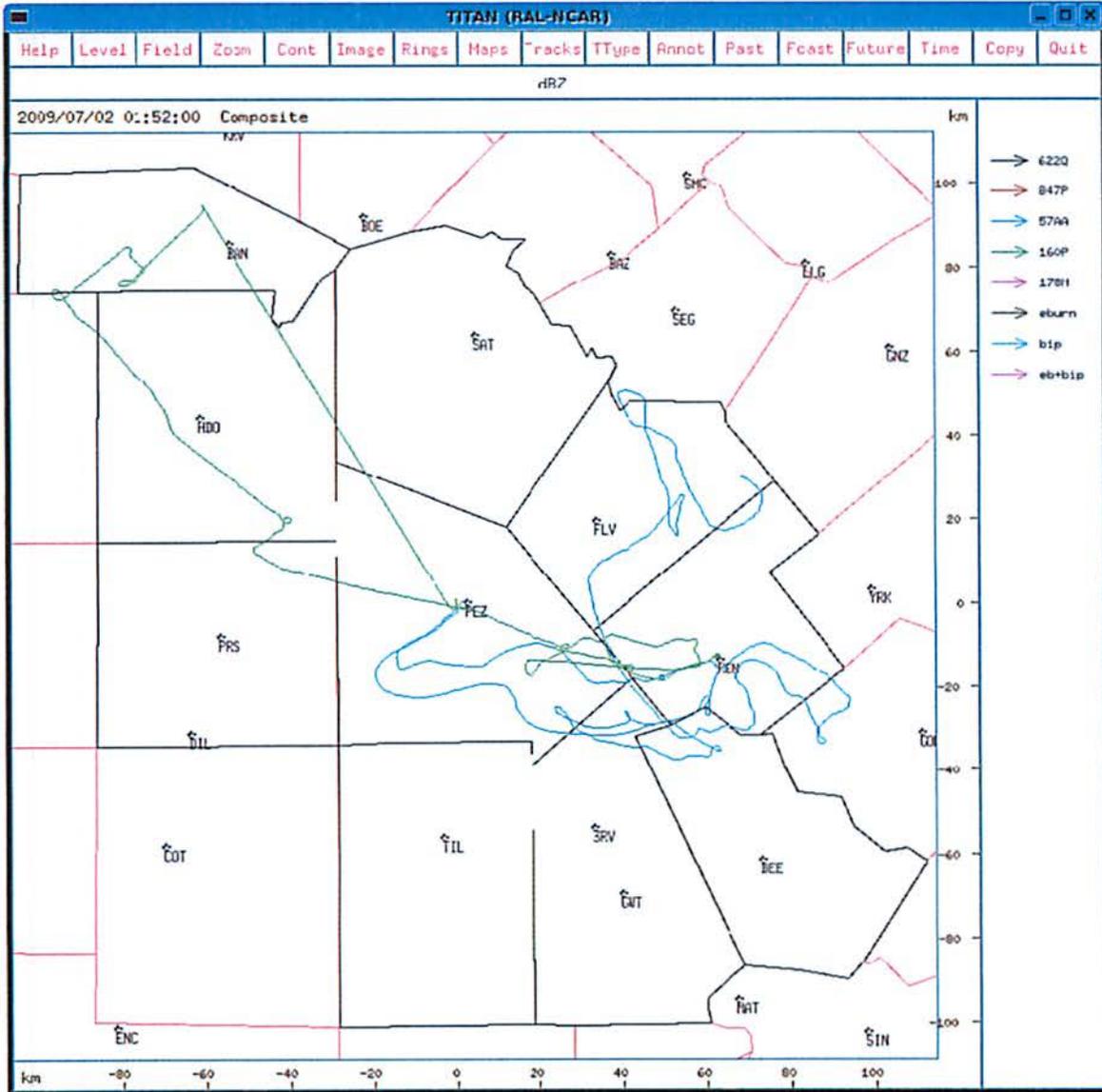
For the month, there were eight days on which seeding took place within the EAA target area. 10 flights were logged for the month. A total of 139 AgI flares were used for seeding in Bandera (24), Medina (98), Bexar (6) and Uvalde (11) counties, totaling 5560g of AgI. In addition, two hygroscopic flares were used for seeding in Medina County, totaling 2000g of CaCl.



JULY 1

A few showers developed along the Balcones Escarpment during the latter part of the afternoon and a flight was dispatched to this area, with two clouds receiving AgI treatment.

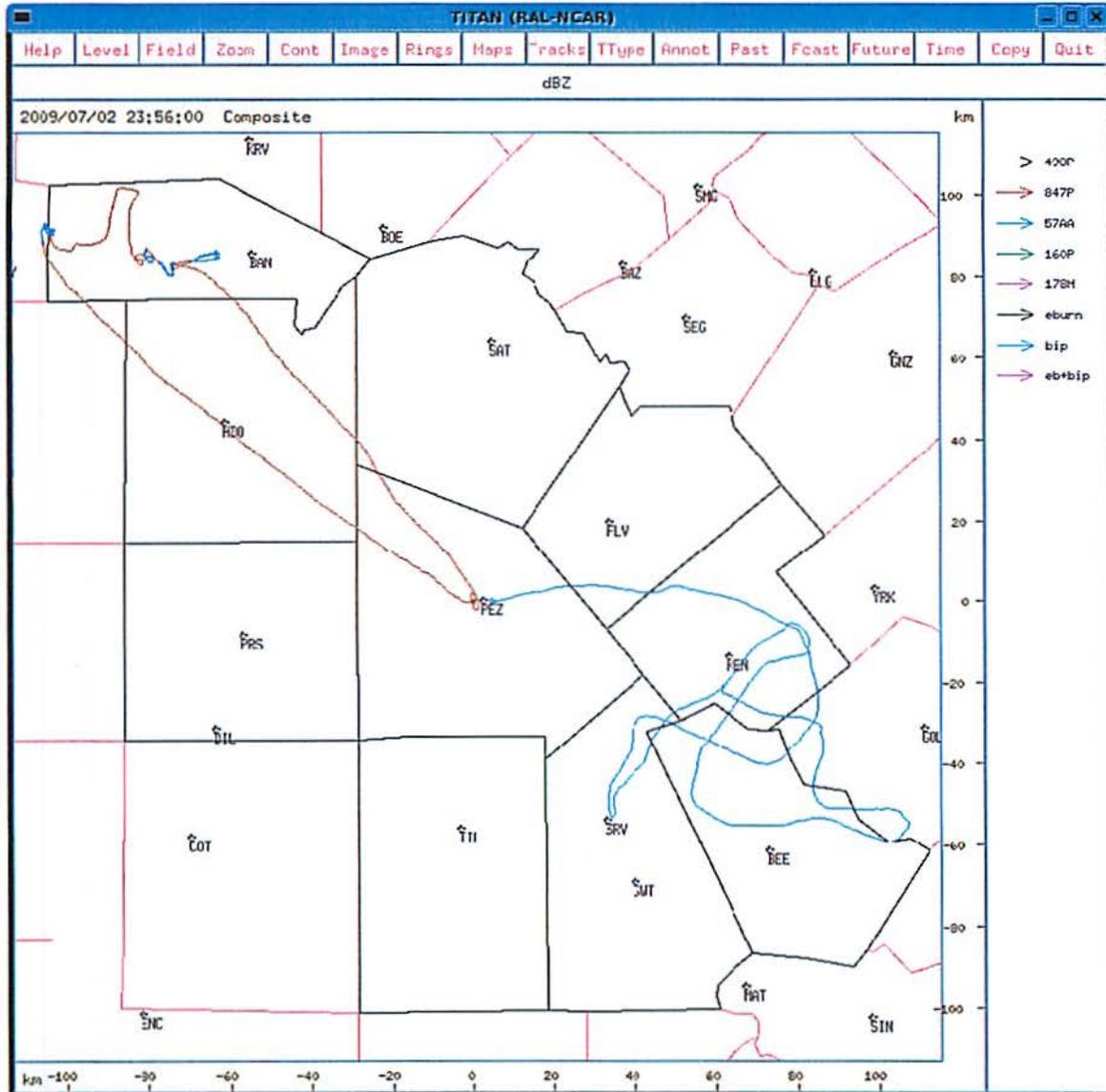
Two flares were used for seeding in Bandera County, totaling 80g of AgI. In addition, one flare was used for seeding in Uvalde County, totaling 40g of AgI.



JULY 2

A weak boundary was draped over the Hill Country and convection began to develop there. A seeding flight was launched to Bandera County where decent convection was occurring.

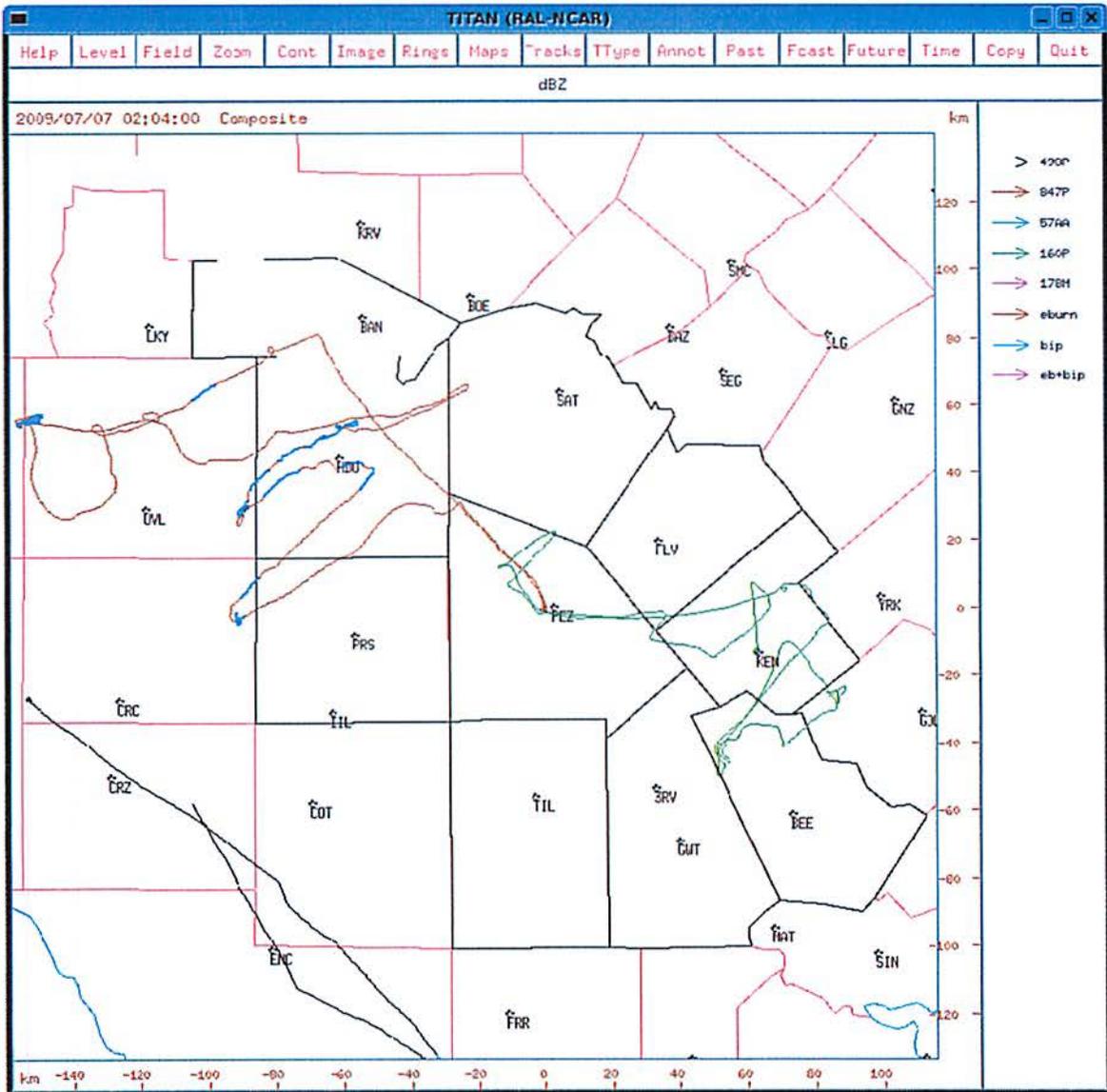
10 flares were used for seeding in Bandera County, totaling 400g of AgI.



JULY 6

An MCS moved across west-central Texas early in the day, leaving behind an outflow boundary that continued to move southeast toward the northern target area. Once convective temperatures were reached at mid-afternoon, scattered showers and thunderstorms developed along the boundary and began to enter the northwestern target area. A flight was sent to Bandera County but initially convection looked poor, so the plane headed to Uvalde County where better clouds were located, and seeding began there. The plane returned to the STWMA target area and continued to seed clouds along the boundary as it moved toward the I-35 corridor.

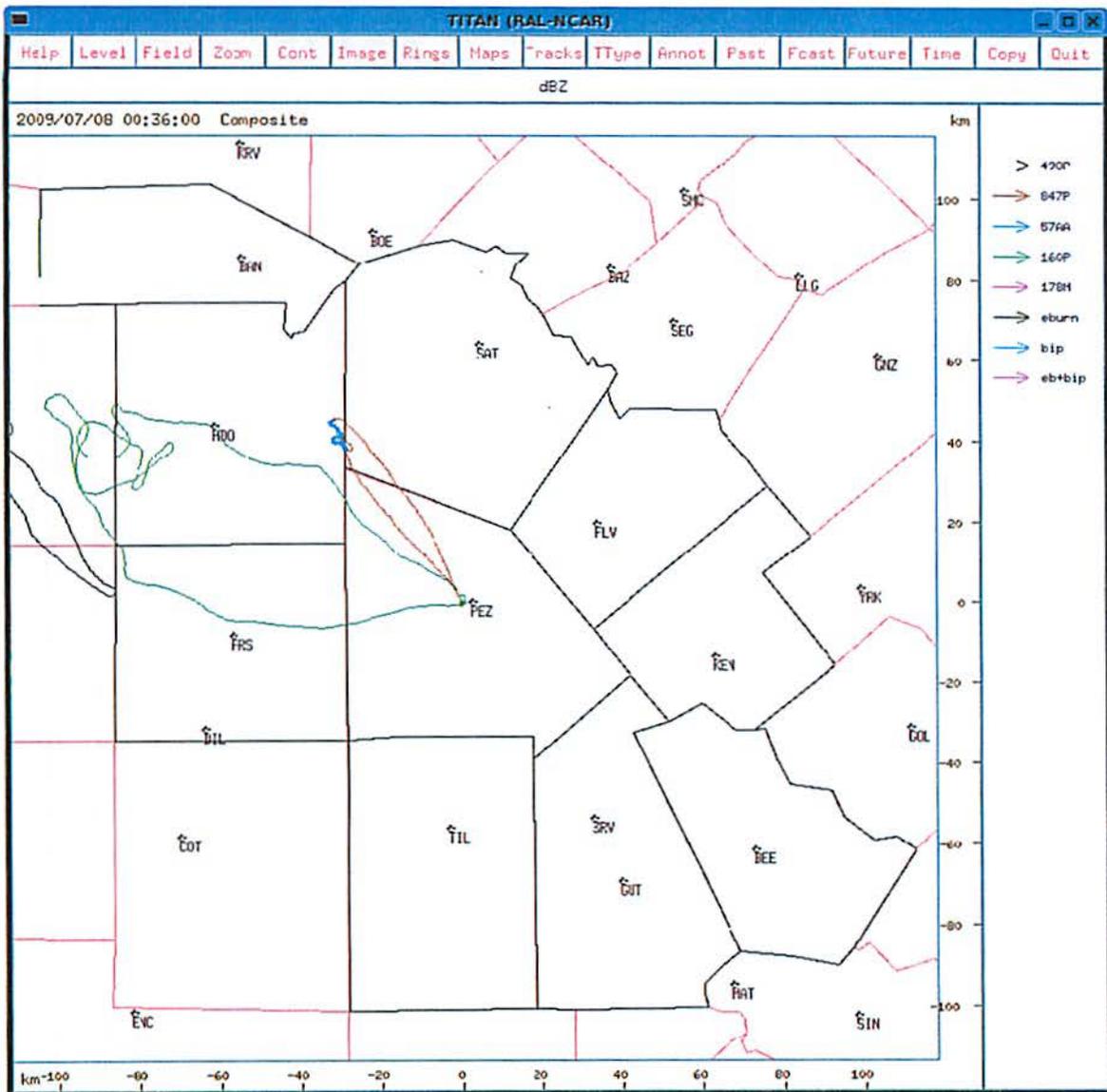
26 flares were used for seeding in Medina (22) and Uvalde (4), totaling 1040g of AgI.



JULY 7

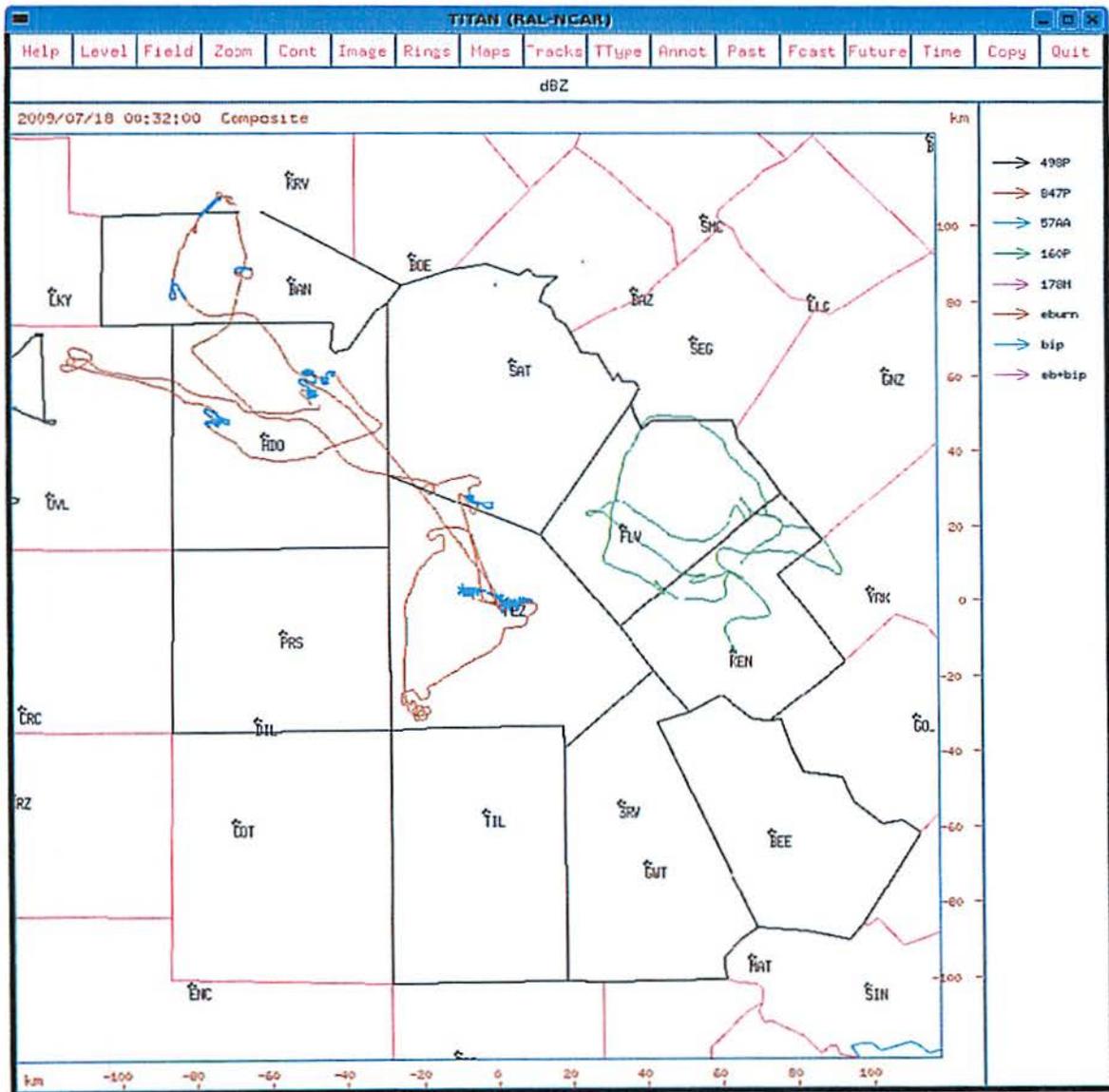
A weak disturbance riding south around the eastern side of the large subtropical high helped induce lift which worked with intense daytime heating and sufficient moisture to produce a few showers and thunderstorms across the northern target area. A flight was sent around mid-afternoon to investigate, with seeding of a few clouds along the Medina/Uvalde county line. These merged into one larger system and continued to move south. Early in the evening, a large cell moved south across the west side of San Antonio near the Medina County line. A second flight was launched to investigate, with seeding of this cell taking place.

18 flares were used for seeding in Medina (14) and Uvalde (4) counties, totaling 720g of AgI.



JULY 17

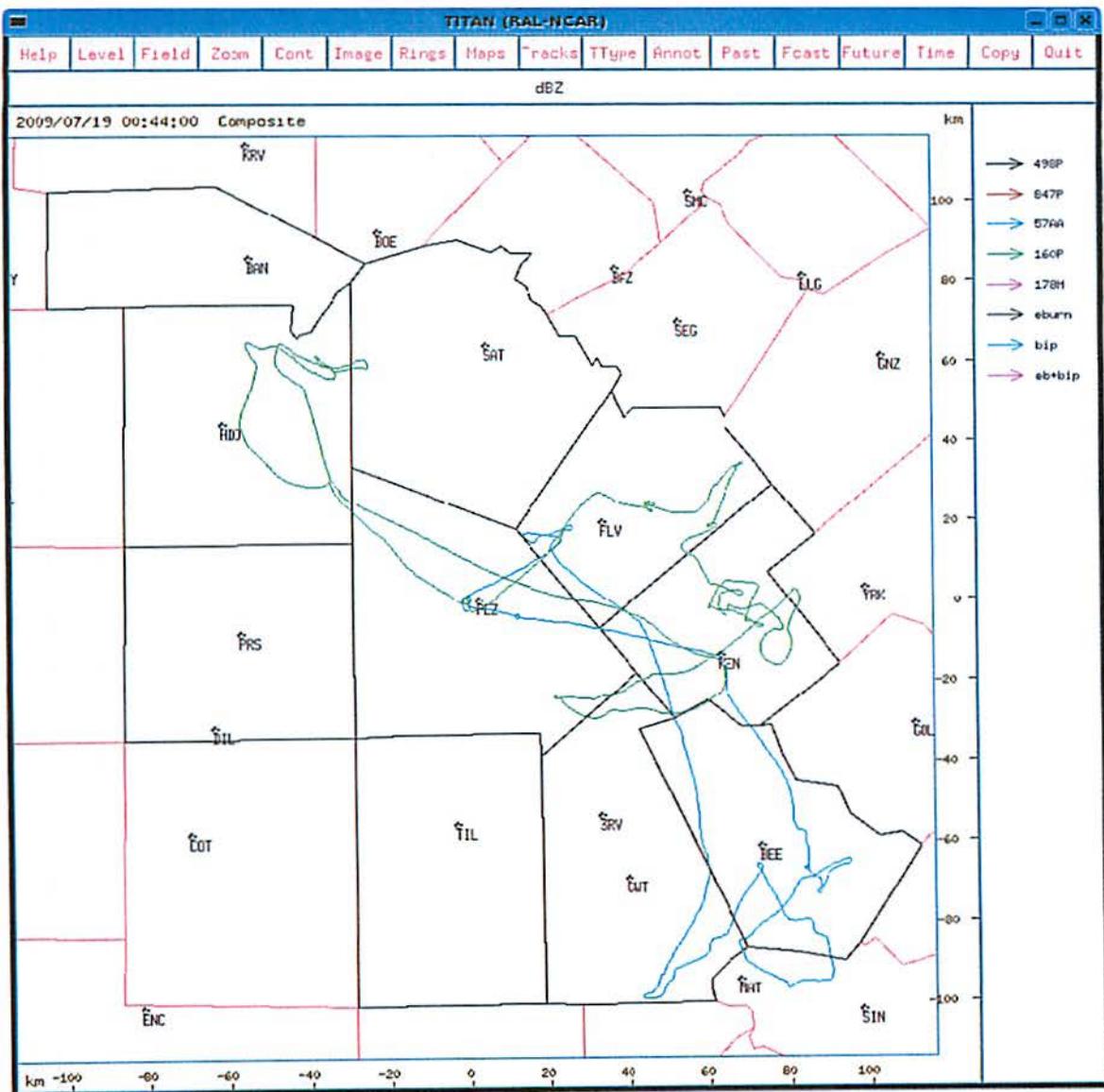
Intense heating, an approaching shortwave from the northwest, residual outflow boundaries and sufficient moisture worked in concert to initiate convection over the Hill Country and adjacent areas around 1900 UTC. As this activity developed/moved toward the northern target area, a flight was dispatched to intercept and investigate the convection. Several clouds were seeded in Medina and Bandera counties. Additional convection formed in Bexar County and points east, with a southward movement noted. The plane headed to southern Bexar County. 35 flares were used for seeding in Medina (19), Bandera (10) and Bexar (6) counties, totaling 1400g of AgI.



JULY 18

A shortwave riding southeast between the ridge to the west and the trough to the east was generating convection north of the area, focused along a stationary front. This activity waned during the late morning hours but early in the afternoon new convection began to form along this feature and move southeast into the northern target area. A plane was sent to the area to investigate, with seeding of a small cluster of clouds taking place near Medina Lake.

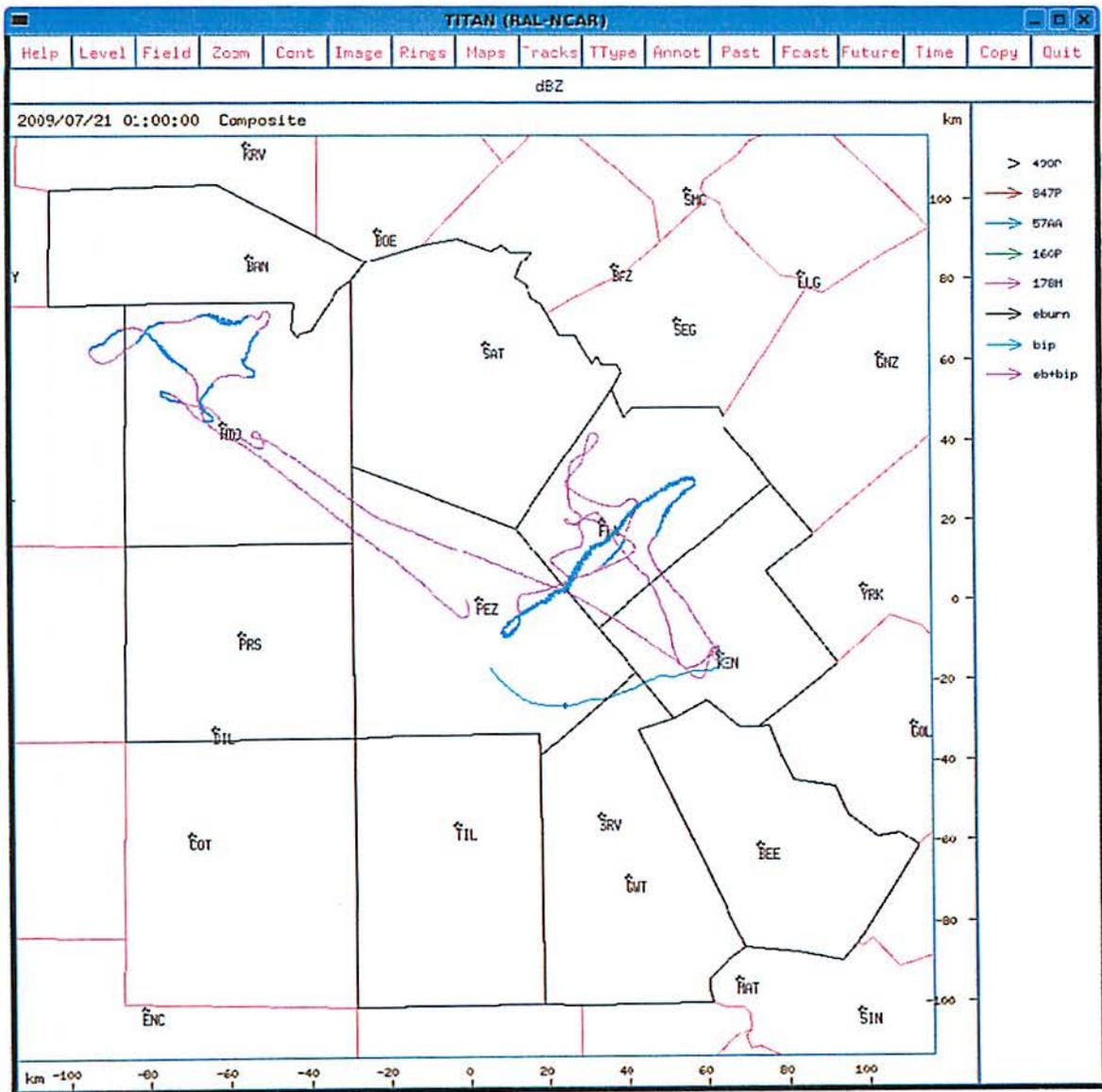
Four AgI flares were used for seeding in Medina County, totaling 160g of AgI. Also, one hygroscopic flare (CaCl) was used for seeding in Medina County, totaling 1000g of CaCl.



JULY 20

As was the case a couple days ago, a shortwave was riding southeast between the ridge to the west and the trough to the east. Associated with this shortwave was a small MCS that was moving slowly into the northwestern target area. A plane was sent up to intercept the incoming MCS with some seeding taking place along the leading edge. Plentiful cirrus blowoff from the MCS spread over much of the target area, limiting heating. An outflow boundary began to race out ahead of the MCS, which cut off inflow to the complex and it began to weaken.

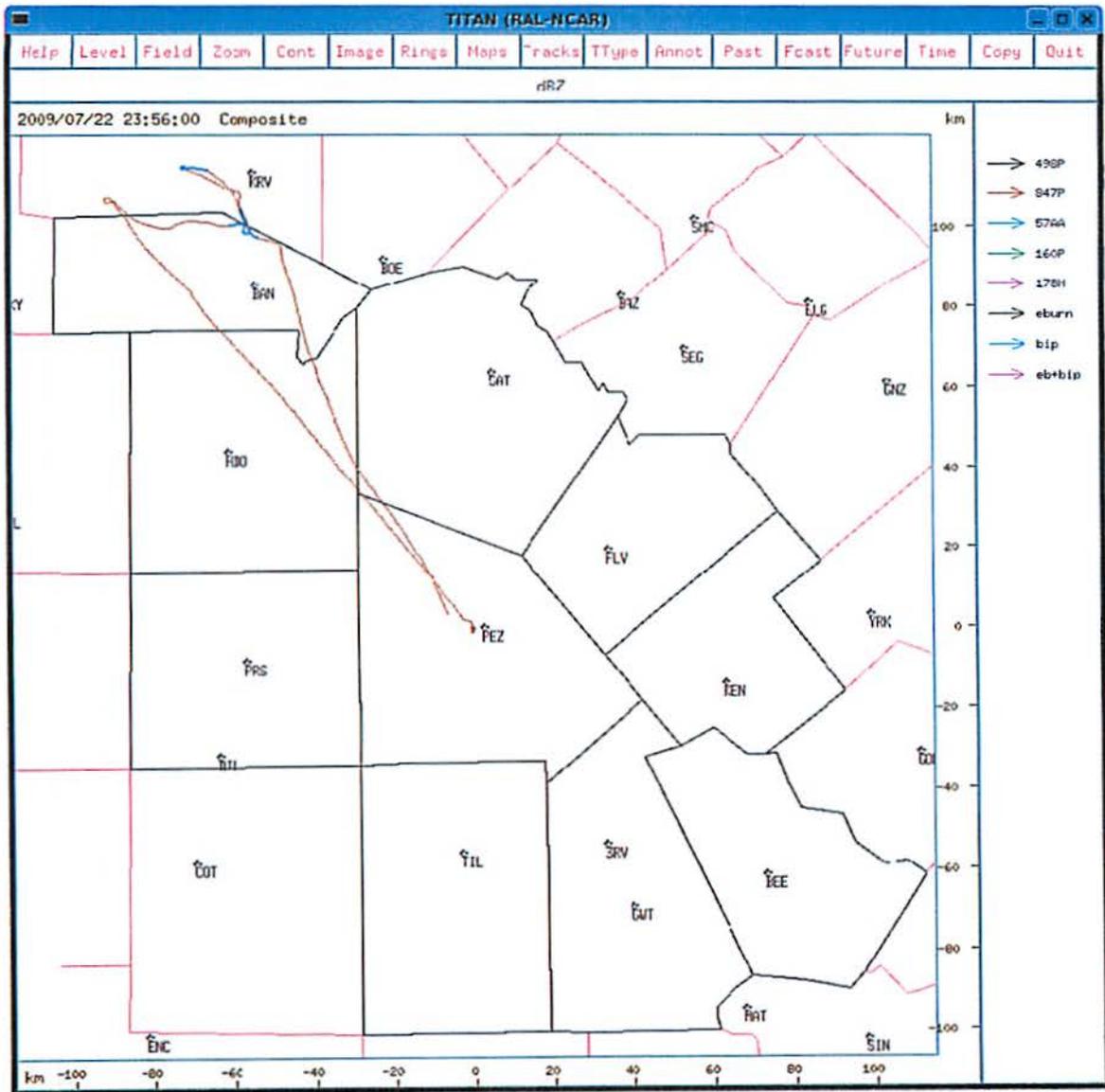
18 AgI flares were used for seeding in Medina (16) and Uvalde (2) counties, totaling 720g of AgI. In addition, one hygroscopic flare (CaCl) was used for seeding in Medina County, totaling 1000g of CaCl.



JULY 22

Overnight and early morning MCS activity once again was spreading a large shield of cirrus clouds southward into the northern target area. A stationary boundary was lying in a west to east fashion just north of the target area, and with some heating beneath the cirrus shield, scattered convection began to develop, with erratic movement noted. Some of this activity appeared to be heading for the far northern target area, and a plane was launched during the latter part of the afternoon to investigate, with seeding taking place along the Bandera/Kerr County line. The activity remained near Kerrville with a small part of the cloud moving briefly into northern Bandera County.

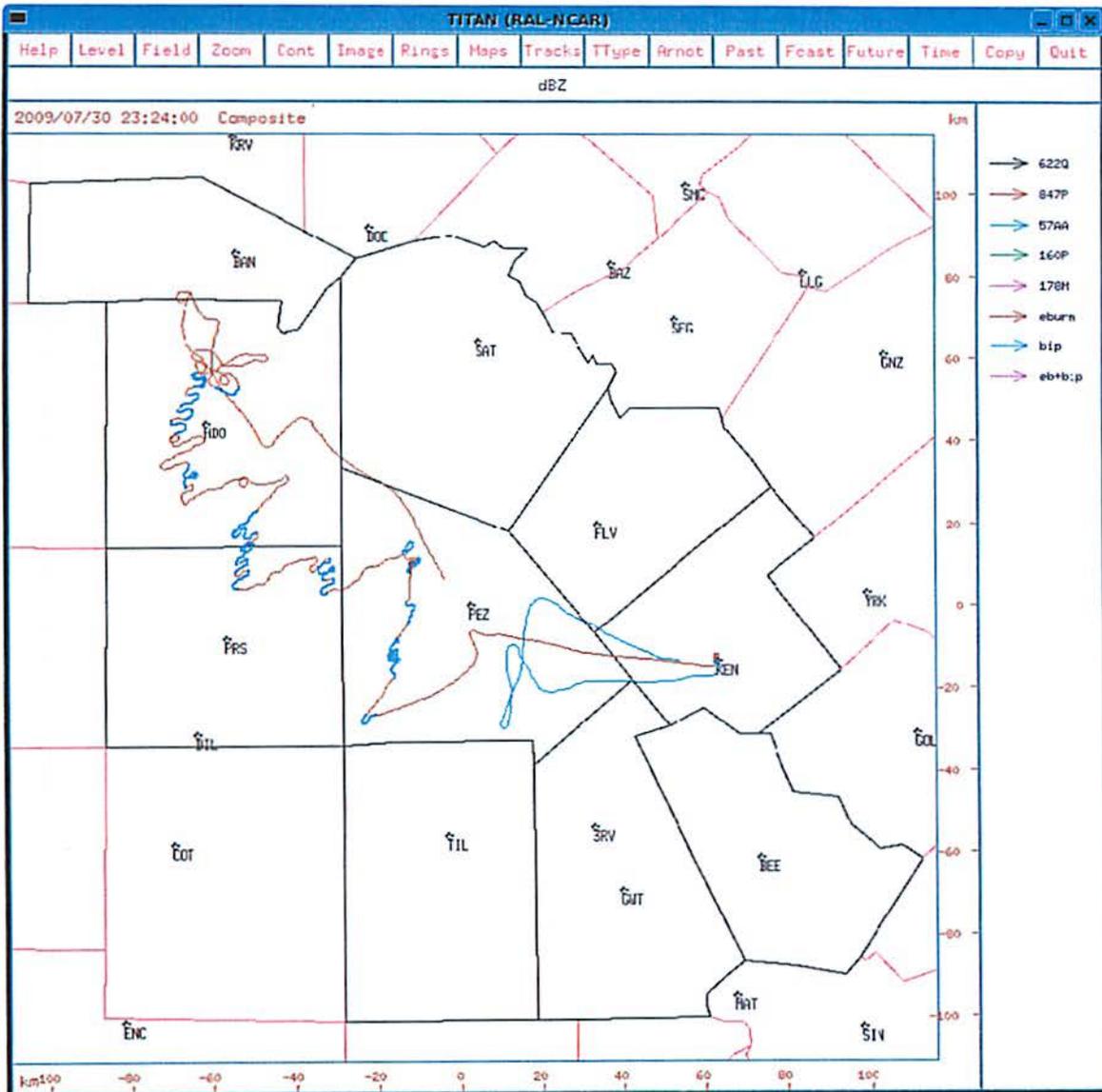
Three flares were used for seeding in Bandera (2) and Kerr (1) counties, totaling 120g of AgI.



JULY 30

During the morning hours an MCS was moving southeast through west-central Texas, helped along by a mid-level shortwave moving across the state. By early afternoon the edge of the MCS entered the northwestern target area and a flight was launched to investigate the activity. Seeding of the leading edge and along the outflow boundary commenced and continued for nearly two hours as it trekked southeast across the target area. The outflow boundary outran convection over the north/northeastern target area and subsequently choked the inflow region, resulting in the demise of convection over eastern Bexar/Wilson counties.

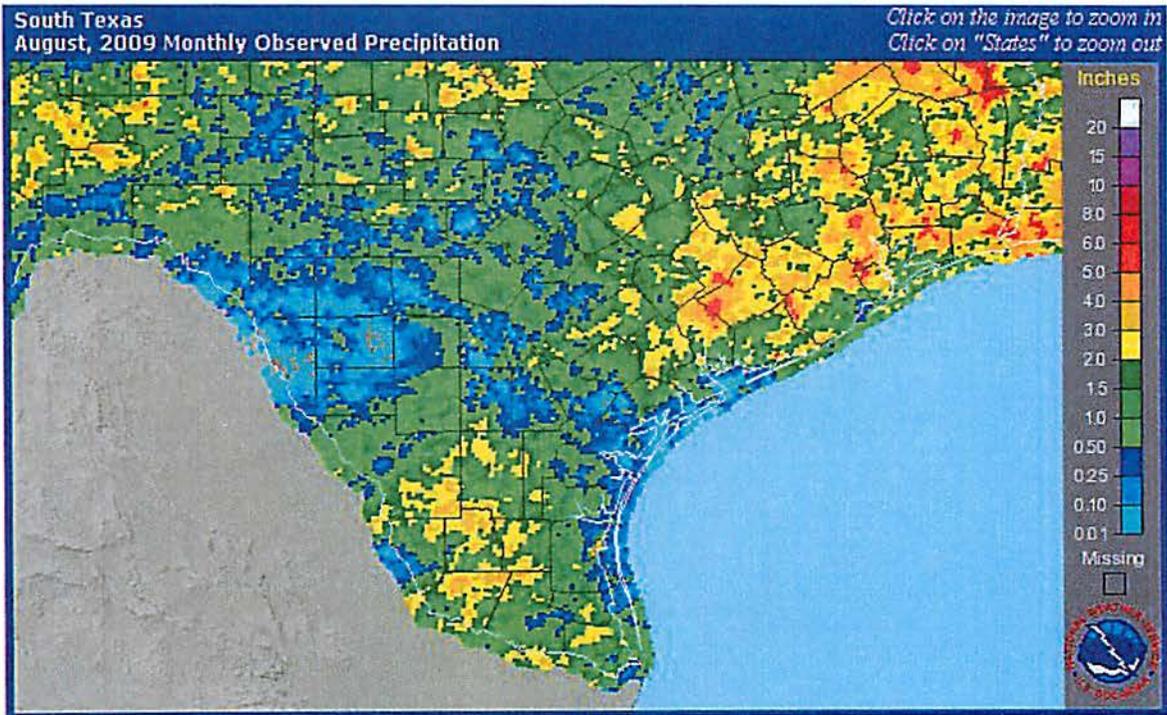
23 flares were used for seeding in Medina County, totaling 920g of AgI.



AUGUST

The severe to exceptional drought continued through August with the tri-county area of Bandera/Bexar/Medina receiving below normal rainfall amounts for the month. Rainfall was characterized by isolated to scattered showers and thunderstorms occurring throughout the month, with the best concentration of activity during the last week of August. The intense heat continued, with San Antonio obliterating their record of number of 100°F days recorded in a summer period. The absence of tropical moisture, which usually presents itself during August, only highlighted the rainfall deficit experienced across much of south Texas. No randomized missions took place. One nighttime mission took place on the 27th.

For the month, there were four days on which cloud seeding took place within the EAA target area. Four flights were logged. A total of 46 flares were used in Bandera (10), Bexar (16) and Medina (20) counties, totaling 1840g of AgI.



AUGUST 12

An axis of convergence and enhanced moisture was positioned in a northwest to southeast fashion from west-central Texas to the upper Texas coast. A shortwave was moving south across the state and helped increase lift in addition to intense heating and frontal convergence north of the target area. Scattered showers and thunderstorms developed over the Hill Country early in the afternoon, increasing in size and number as it moved southeast into the northern target area. A flight was dispatched to the northern target area where initial investigation showed "mushy-looking clouds". Further south, near Medina Lake, the developing clouds looked better and seeding commenced. The plane continued to seed convection in eastern Medina and southwestern Bexar counties as the activity developed/moved south and southeast.

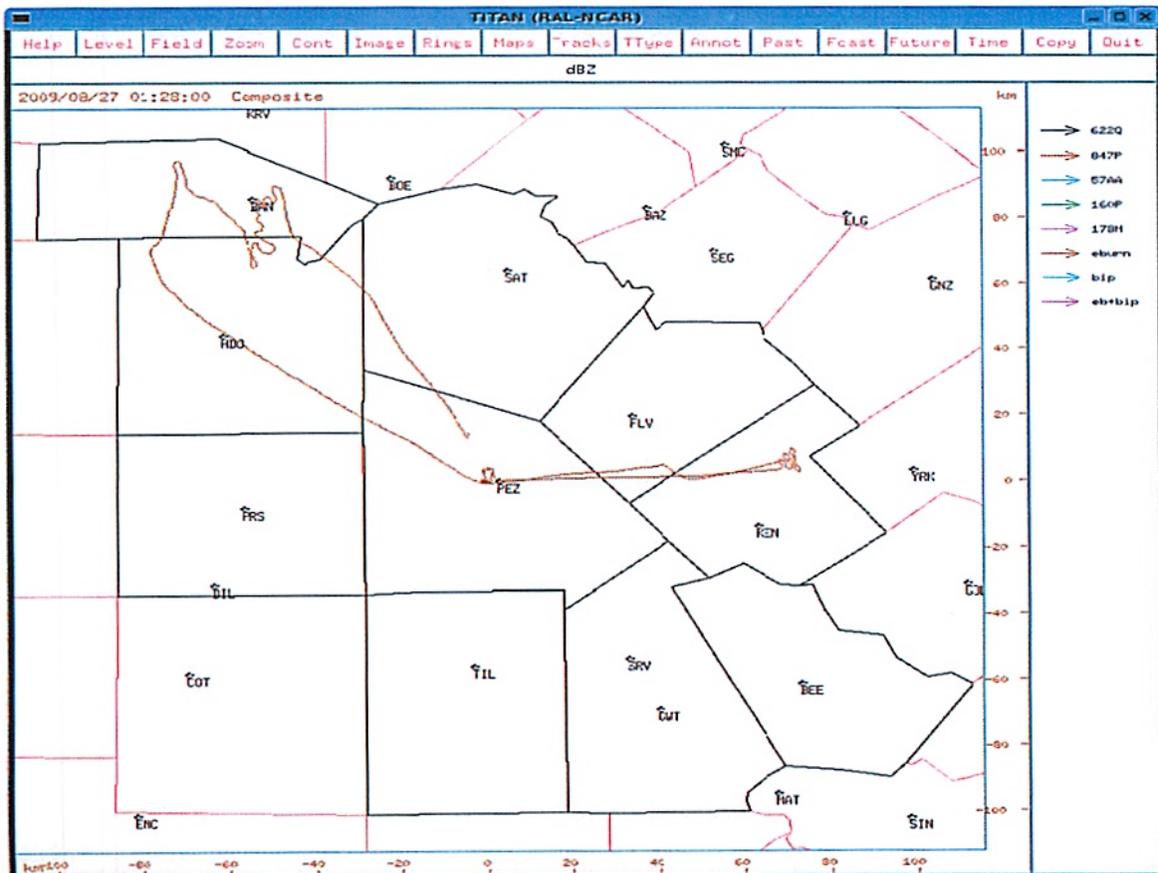
21 flares were used for seeding in Bexar (10) and Medina (11) counties, totaling 840g of AgI.

Flight track for this day is not available.

AUGUST 26

Scattered airmass convection developed north of the target area and moved south-southwest toward Bandera and Bexar counties. A plane was dispatched to the area to investigate, with a couple of marginal clouds seeded in Bandera County. These produced areas of light rain across the eastern half of Bandera County and northern Medina County.

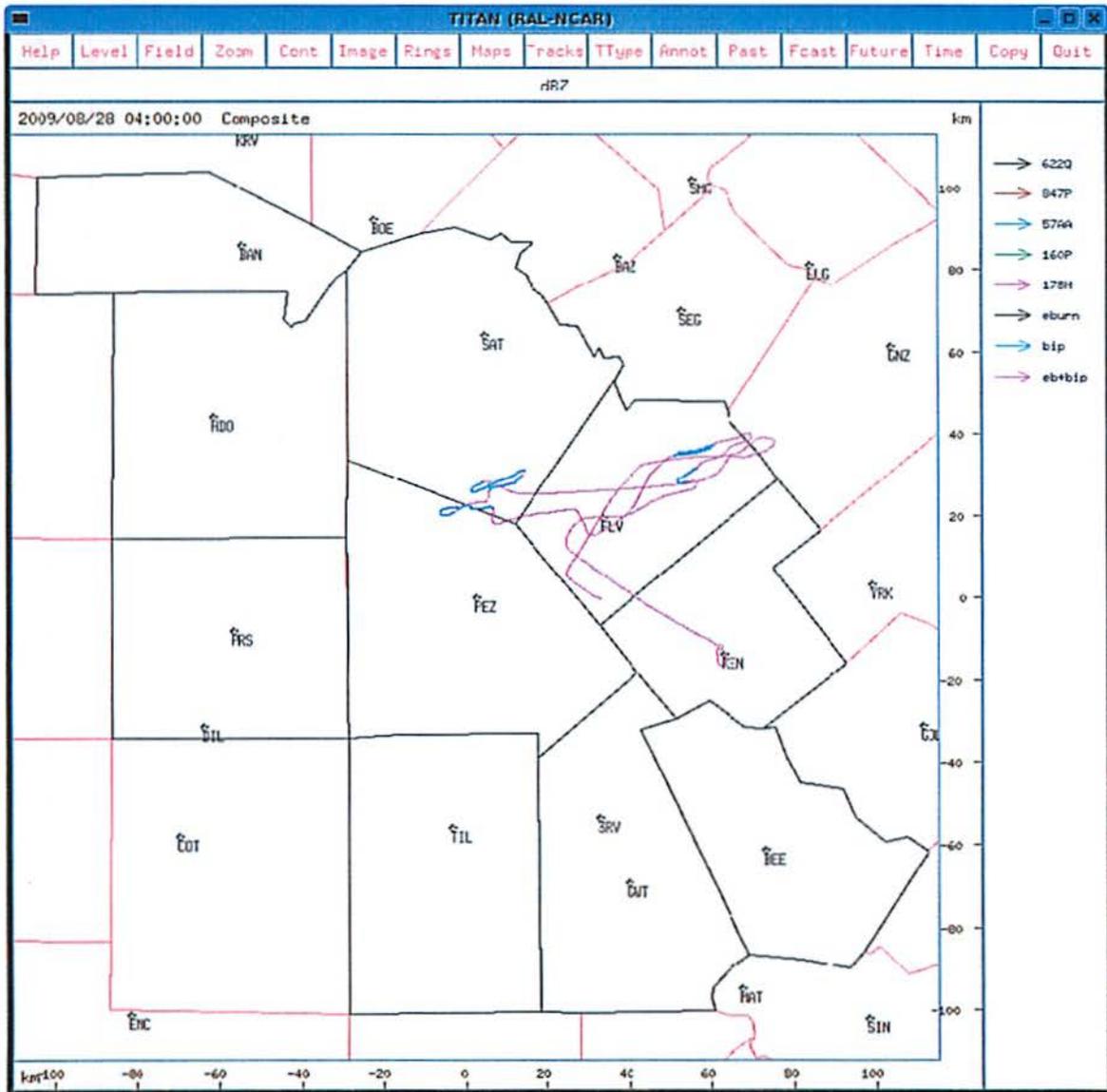
Six flares were used for seeding in Bandera County, totaling 240g of AgI.



AUGUST 27

Scattered convection developed over central Texas during the afternoon hours with some organization noted. An outflow boundary emanating from this activity pushed south toward the northern target area during the evening hours with additional convection developing along it. This activity pushed into the northern tier of counties between 01-02 UTC (8-9pm CDT). A flight was launched to investigate the approaching convection. Radar indicated unfavorable convection over Medina County, with more suitable clouds across central and southern Bexar County, where seeding took place. The mission was terminated when the plane could no longer reach the leading convective activity due to clouds along/above the outflow boundary.

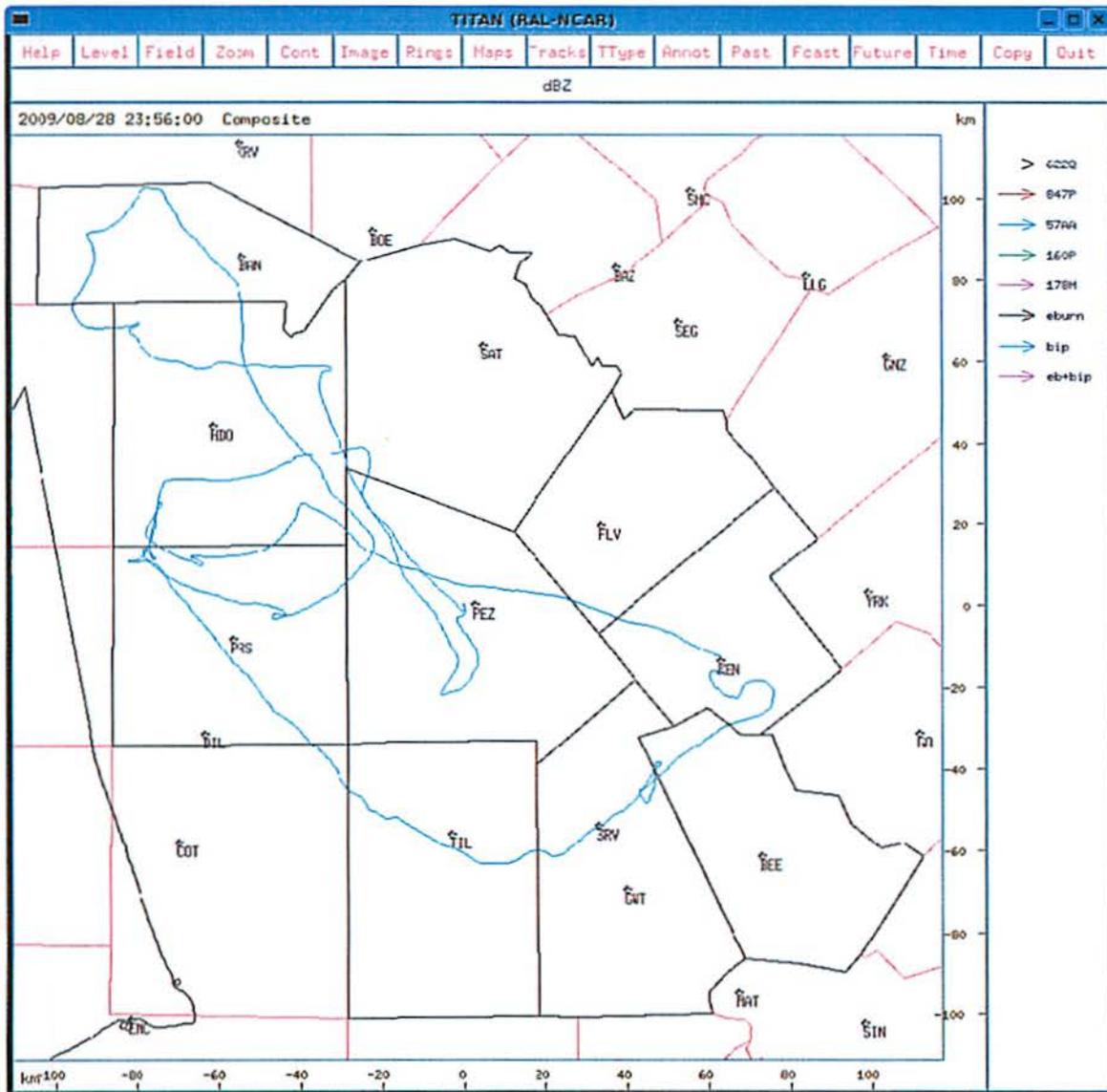
Six flares were used for seeding in Bexar County, totaling 240g of AgI.



AUGUST 28

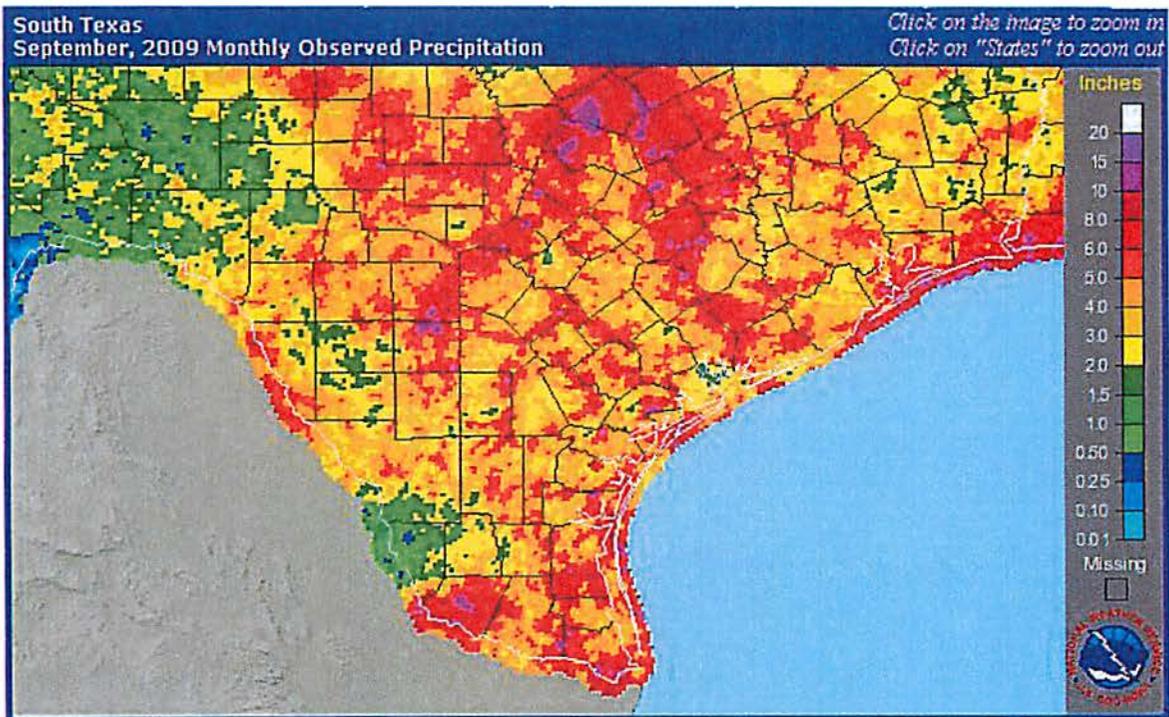
Strong heating, a stationary boundary in the vicinity, sufficient moisture and an approaching upper level trough all combined to produce a favorable environment for convection. Initiation took place just after 1800 UTC over the northern target area. A flight was dispatched to investigate activity approaching Bandera County, but before the plane reached the area, additional convection began forming in southern Medina County in the vicinity of the stationary boundary. Inspection by the pilot revealed decent inflow and a good cloud structure, with crisp edges, a flat rain-free base and sufficient height. Seeding of this cloud took place before the pilot moved on to other activity developing/moving into Bandera County, where more seeding took place. The plane headed south into northern Medina County with more clouds receiving treatment.

13 flares were used for seeding in Bandera (4) and Medina (9) counties, totaling 520g of AgI.



SEPTEMBER

It seems as if the start of the new month also signaled a change in the weather pattern, as September ended up being wetter than normal for a good chunk of south Texas. Rainfall events occurred during the first 10 days of the month and also near the end. Many of these events had clouds and flying conditions that were unfavorable for seeding despite being efficient rain producers. Of all the days, there were two days where flights were conducted within the tri-county area. A randomization case took place on the 1st of the month as an isolated shower developed near Hondo. Another flight on the 4th investigated clouds in Medina County, with seeding taking place as the randomization protocol was not satisfied. For the month, there were two days on which cloud seeding took place within the EAA target area. Two flights were logged. A total of 19 flares were used in Medina County, totaling 760g of AgI. In addition, 4 "potential" flares were used for the randomization case in Medina County, totaling 160g of "potential" AgI.



SEPTEMBER 4

During the afternoon hours a shortwave moved into the area from northern Mexico along the base of an upper level trough. This trough and associated shortwave combined with ample moisture and daytime heating to produce scattered convection across south Texas. Convection began developing in the tri-county area during the latter portion of the afternoon. A flight was dispatched to the area to investigate the developing clouds. Well-defined bases and sufficient inflow values were reported with these clouds, with seeding taking place in Medina County.

19 flares were used for seeding in Medina County, totaling 760g of AgI.
Flight track for this day is not available.

2009 RADAR ANALYSIS FOR THE EAA

The following is taken from the 2009 radar analysis report for the EAA target area conducted by Archie Ruiz-Columbié of Active Influence and Scientific Management.

A total of **57 clouds** were seeded and identified by TITAN in **26 operational days**.

Number of operational days: 26

(one in March, six in May, four in June, nine in July, four in August, and two in September)

Number of seeded clouds: 57

(21 small seeded clouds, 18 large seeded clouds, 17 type B seeded clouds, 1 npf)

Missed Opportunities: one (~ 2%) (with lifetime longer than 45 minutes)

September 9th: # 3012 on SWTREA TITAN screen at 23:00 over Medina County

Small Clouds

Table 2: Seeded Sample versus Control Sample (21 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	55 min	45 min	1.22	22 (10)
Area	79.1 km ²	48.3 km ²	1.64	64 (11)
Volume	248.3 km ³	126.5 km ³	1.96	96 (13)
Top Height	7.9 km	6.8 km	1.16	16 (4)
Max dBz	51.8	48.6	1.07	7 (3)
Top Height of max dBz	3.6 km	3.4 km	1.06	6 (1)
Volume Above 6 km	46.3 km ³	13.7 km ³	3.37	237 (39)
Prec.Flux	634.5 m ³ /s	292.1 m ³ /s	2.17	117 (19)
Prec.Mass	2385.2 kton	1066.8 kton	2.24	124 (93)
CloudMass	210.9 kton	96.6 kton	2.18	118 (13)
η	11.3	11.0	1.03	3 (57)

Bold values in parentheses are modeled values, whereas **η** is defined as the quotient of Precipitation Mass divided by Cloud Mass, and is interpreted as efficiency. A total

of 92 flares were used in this sub-sample with an excellent timing (**78%**) for an effective dose about **40 ice-nuclei per liter**. The seeding operations lasted on average about 9 minutes. An excellent increase of **93%** in precipitation mass together with an increase of 13% in cloud mass illustrates that the seeded clouds grew at expenses of the environmental moisture (they are open systems) and used only a fraction of this moisture for their own maintenance. The increases in lifetime (10%), area (11%), volume (13%), volume above 6 km (39%), and precipitation flux (19%) are noticeable although affected by the small size of the sample, which implies a great variability. There were slight increases in maximum reflectivity (3%) and in top height (4%). The seeded sub-sample seemed 57% more efficient than the control sub-sample. Results are evaluated as **excellent**.

An increase of **93%** in precipitation mass for a control value of 1066.8 kton in 21 cases means:

$$\Delta_1 = 21 \times 0.93 \times 1066.8 \text{ kton} = 20,835 \text{ kton} = 16,897 \text{ ac-f}$$

Large Clouds

The sub-sample of 18 large seeded clouds received a synergetic analysis. On average, the seeding operations on these large clouds affected 59 % of their whole volume; with a perfect timing (100% of the material went to the clouds in their first half-lifetime). A total of 268 flares were used in this sub-sample for an effective dose about **75 ice-nuclei per liter**.

Also on average, large clouds were 45 minutes old when the operations took place; the operation lasted about 63 minutes, and the large seeded clouds lived 180 minutes.

Table 3 shows the corresponding results:

Table 3: Large Seeded Sample versus Virtual Control Sample (18 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	180 min	160 min	1.13	13
Area	662 km ²	613 km ²	1.08	8
Prec.Mass	25,962 kton	18,190 kton	1.43	43

An increase of 43% in precipitation mass for a control value of 18,190 kton in 18 cases may mean:

$$\Delta_2 = 18 \times 0.43 \times 18,190 \text{ kton} = 140,791 \text{ kton} = 114,181 \text{ ac-f}$$

Type B Clouds

Seventeen type B clouds over EAA target area were seeded during the season. On average, the seeding operations on these type B clouds affected 18% of their whole volume; with a very good timing (73% of the material went to the clouds in their first half-lifetime). A total of 334 flares were used in this sub-sample for an effective dose about **100 ice-nuclei per liter**.

Also on average, type B clouds were 120 minutes old when the operations took place; the operation lasted about 35 minutes, and the large seeded clouds lived 265 minutes.

Table 4: Large Seeded Sample versus Virtual Control Sample (17 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	265 min	260 min	1.02	2
Area	2756 km ²	2707 km ²	1.02	2
Prec.Mass	157 088 kton	144 117 kton	1.09	9

$$\Delta_3 = 17 \times 0.09 \times 144,117 \text{ kton} = 220,499 \text{ kton} = 178,825 \text{ ac-f}$$

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3 = 309,903 \text{ ac-f}$

Micro-regionalization

Increases in precipitation mass were analyzed county by county in an attempt to better describe the performance and corresponding results. **Table 5** below offers the details:

County Seeding	Initial Seeding	Extended (increase)	Acre-feet (increase)	Inches (increase)	Rain gauge (season value)	% (increase)
Uvalde	23	31	107,300	1.29	9.94 in	13.0
Bandera	11	16	40,700	1.01	10.40 in	9.7
Medina	21	29	79,300	1.09	9.59 in	11.4
Bexar	2	10	51,000	0.77	9.02 in	8.5
Total	57	86	278,300			
Average				1.04 in	9.74 in	10.7

(**Initial seeding** means the number of clouds seeded when the operations began; whereas **extended seeding** means the counties favored by seeding after the initial operations took place.

Final Comments

- 1) Results are evaluated as **excellent**; no data corresponding to operations were lost;
- 2) The micro-regionalization analysis showed increases per county; different zones received downwind benefits; the average increase in precipitation, referred to rain gage seasonal value, is **10.7%**;
- 3) Radar estimations of precipitation should be considered as measurements of trend. Nevertheless, seeding operations appeared to improve the dynamics of seeded clouds.

APPENDIX

Mesoscale Convective System (MCS) is a large complex of showers and thunderstorms at least 100 km (~60 miles) across, and may be as large as 500 km (~310 miles) across.

Shortwave, or shortwave trough, refers to a small-scale area of lower pressure and associated lift on its forward side, sometimes accompanied by showers and thunderstorms.

Cell refers to an updraft-downdraft couplet in a cloud. Clouds with several updraft-downdraft couplets are called **multicell** clouds. A storm with a single updraft-downdraft couplet (often rotating) that lasts for several hours is called a **supercell**.

Pre-frontal trough refers to an elongated area of low pressure found ahead of an advancing cold front. In south Texas, the passage of a pre-frontal trough usually signals the end of precipitation, as winds tend to turn more to the west or northwest, cutting off moisture supply.

Precipitable Water or PW is the total amount of water vapor in a column of air above a given location. This value is expressed in inches. High precipitable water values (>1.5 inches) are indicative of the potential for heavy rain. Tropical airmasses usually have a precipitable water value in excess of two inches.

Convective temperature is the temperature required at or near the ground in order for convection (surface-based) to occur.

TUTT, or Tropical Upper Tropospheric Trough, refers to a upper level cold core area of low pressure found in the tropical and sub-tropical regions of the Earth. These disturbances are sometimes associated with shower and thunderstorm activity, and are associated with tropical waves.

Theta-e, or equivalent potential temperature, is the temperature a parcel or bubble of air would reach if it was lifted until all of the moisture condensed out, then brought back down to 1000 mb (at/near surface). A forecaster looks at theta-e to see how moisture is distributed over a region. High theta-e values are associated with moist airmasses, which storms may develop in and feed on.

Jet streak refers to the maximum wind speed within a river of faster-moving air (jet stream). Forecasters may look for jet streak locations at 850mb, 700mb, 500mb, and 250 mb in order to assess the possibility of strong/severe thunderstorms.

Cap refers to a warm layer of air aloft which acts as a lid, suppressing convection. The strength of the cap varies with time and location.

Convective Inhibition is the amount of energy required to overcome the cap, or the amount of energy required by a parcel of air to initiate deep convection (i.e., thunderstorms).

Lifetime refers to the length of time a cloud was detected on radar, with a reflectivity maximum of at least 32 dBZ.

Area refers to the two-dimensional space (length x width) covered by a cloud.

Precip Flux refers to the radar-derived volume of water falling through the bottom of the cloud per second.

Precip Mass refers to the total mass of water and ice for all droplets/crystals larger than $100\ \mu\text{m}$ ($10^{-4}\ \text{m}$) in a cloud.

Small seeded clouds are those clouds with a radar-derived Precip Mass less than 10,000 kilotons.

Large seeded clouds are those clouds with a radar-derived Precip Mass greater than 10,000 kilotons.

Type B clouds are those clouds, small or large, that were not seeded until they were at least one hour old, as determined by their presence on radar.

Control clouds are those clouds within 100 km of the radar that were NOT seeded. Control clouds are used to determine the effectiveness of seeding, as it represents "what would have happened" if seeding had not taken place.

Effective dosage refers to the amount of seeding material that was placed in the cloud. It is expressed as a concentration of ice nuclei per liter of air.

ACKNOWLEDGEMENTS

Seeding operations were carried out in the EAA target area on 26 days, with 32 flights launched. Radar analysis showed that seeding effects this year were positive once again. The success of the project comes about through the hard work of many people, and it is here where gratitude must be expressed.

Tommy Shearrer and Mike Mahoney continue to do many hours of work to ensure that the project gets past any red tape and runs as smoothly and efficiently as possible. Many thanks go their way, as the project would likely be lost without them. Thanks also go to the board members of both the STWMA and Evergreen Underground Water District, who meet to discuss purchases, improvements, seeding methods, and any other factors that affect the way the program is run. Their input in the past has helped run a successful program, and we hope they will continue their good work. We couldn't have the great planes and the successful flights without the hard work of the pilots: Craig Funke in particular, who flew many missions while also wearing the hat of STWMA mechanic, keeping our planes in good shape; Larry Dement and Robert "Butch" Card, the Kenedy pilots who continue to provide excellent piloting and seeding skills; Matt Pope, our newest pilot who trained with the others, eventually going solo and doing a great job -- they deserve many thanks. A note of gratitude must be given to Stephanie Beall, Ed Walker and the Southwest Texas Rain Enhancement Association who continue to work together with our project and have provided invaluable assistance. Thanks must also go to the Evergreen staff: Candi Gonzales, who handles the bookkeeping and much of the laborious paperwork for the project, and Larry Akers, who keeps our radar in tip-top shape. An expression of gratitude is extended to Archie Ruiz, who performs the ever-challenging radar analysis. With his work, we may yet find a way to quantify once and for all the true success of cloud seeding. The state projects may not be here had it not been for George Bomar, who works with the projects and the Department of Licensing and Regulations - thank you. Thanks also to Rick Illgner and the EAA for working with us this year and in the years to come. A big thanks to the crew at WDT, Inc., who have provided us with our NWS radar feed along with plenty of help when things weren't working so well. Finally, thanks go out to the public, most of who continue to believe in our project and our mission. Without your approval, our project would cease to exist. Thank you all!

Rainfall maps for 2009 came from the following website:
http://www.srh.noaa.gov/rfcshare/precip_analysis_new.php

Radar analysis numbers came from Archie Ruiz's final report of the 2009 season for the EAA (5 pp.)