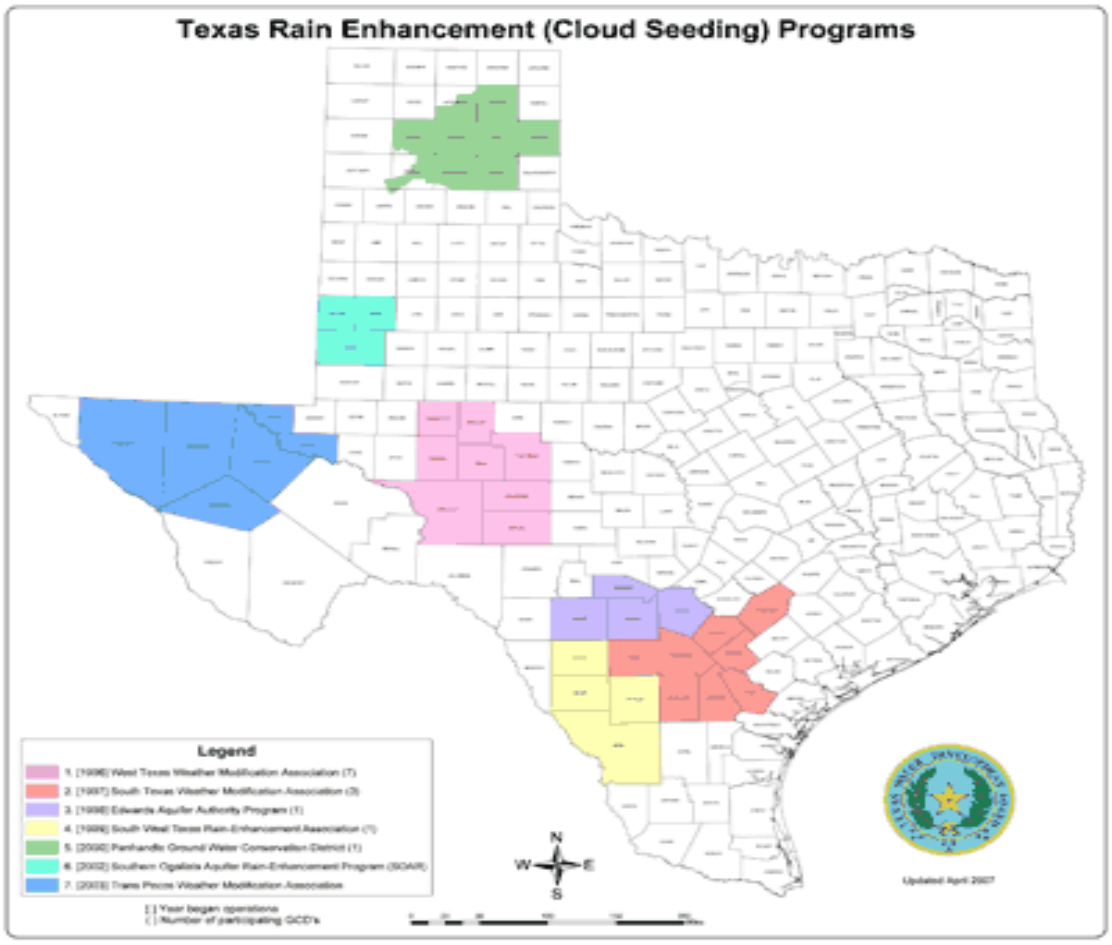
Southwest Texas Rain Enhancement Association

2009 Final Report



Authored by: Project Meteorologist, Stephanie Beall

In this edition of the Southwest Texas Rain Enhancement Association Annual Report, we want to memorialize our board member, Lewis E. Bracy, Jr. Mr. Bracy was a charter member of the SWTREA and served on the Board from the time of its inception. He passed away on June 17, 2009, at the age of 85.

At the time of his death, Mr. Bracy had just completed his 39th year as Chairman and CEO of First State Bank of Uvalde. He was the fifth chairman of the bank in its 102 year history. Previous chairmen were: Tom McNelly, John Nance Garner, J.H. Ashby and Dolph Briscoe, Jr.

We appreciate his years of dedicated service to the SWTREA and he will be greatly missed.

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Introduction

The report presented here is an operational summary of the 2009 seeding season of the Southwest Texas Rain Enhancement Association. This report will include a month-by-month look at seeding operations for the project. Each month will include a worded summary of seeding operations, the weather that occurred that day, and any other points of interest. At the end of each worded summary a radar estimated precipitation map for the month will be provided. A separate disc will be included with the report that shows the flight tracks from days when seeding operations took place.

The Year in Review

2009 marked another season in the books for the Southwest Texas Rain Enhancement Association. 2009 was the eleventh year of operations and the ninth full year of 24-hour 7-day per week cloud seeding and hail suppression. 2009 was typically classified as another drought year for the area, a drought that began in late 2008. Most locations in the target area only received 25-50% of its normal precipitation through December of 2009. Drought conditions could have been much worse if not for the emergence of El Nino during the fall months, leading to a wetter pattern over the target area and most of south Texas. The eastern and northern portions of the target area faired the best while locations in the western part of the target area saw little relief, even with the onset of El Nino.

March, April, and May were pretty normal for most of the area flight activity wise, with a very active severe weather season in May, spawning a number of hail suppression missions. Near the end of May, a progressive spring weather pattern transitioned to a more stagnant one, with high pressure building into south Texas. Drought conditions were only worsened by above normal temperatures for most of May, June, and July. Hot and dry conditions prevailed through the core summer months, as a persistent ridge of high pressure settled over south Texas. However, relief finally came to south Texas as El Nino conditions continued to persist in the eastern Pacific. This pattern, which typically signals a wetter winter for south Texas, allowed for much cooler temperatures and much needed rainfall to fall starting in late August into September, October, and November. Even with a very persistent drought in place over the area, flight activity was not hampered by this weather pattern. The project staff was more aggressive than usual in order to help mitigate drought. The staff took every opportunity to increase rainfall over the 2009 seeding season. Even with the drought in place, many seeding flights took place over the area. As well, a historic number of reconnaissance missions took place in the target area, showing that even clouds that may not have the greatest potential for seeding were flown on, in hopes of creating some type of increase. May and August were the busiest months for the project, with June and July being the slowest. For the first time in five years, no seeding took place in October due to unfavorable operating conditions for seeding at base. This included low

ceilings and thunderstorms embedded in light rain, which makes inflow almost impossible to find. Additionally, as has occurred the past several years of the project, no flights occurred during November.

One notable change from the last season to this one was almost a total absence of tropical waves and disturbances that moved into Texas from the Gulf of Mexico. As well, no tropical cyclones impacted the area due to a moderate El Nino evolving in the Pacific over the summer. Interestingly enough, El Nino actually helped contribute to drought over the summer, as it typically decreases tropical wave and tropical cyclone activity in the Atlantic and Gulf of Mexico. Typically during the summer months, large complexes of convection develop along tropical waves and disturbances that move inland from the Gulf. This helps to give the target area, especially the southern portions, its annual rainfall. This was not the case this year, as high pressure settled in over south Texas, allowing rainfall to occur further to the south, into Mexico and further north, into west and central Texas.

Below is a table for one town in each of the five counties in the SWTREA target area. The table contains precipitation totals for 2008 and 2009, and the climate normal.

Dimmit County
Carrizo Springs (2008): 11.36 inches
Carrizo Springs (2009): 14.56 inches
Carrizo Springs (normal): 21 inches

LaSalle County
Cotulla (2008): 13.34 inches
Cotulla (2009): 19.74 inches
Cotulla (normal): 21 inches

Uvalde County
Uvalde (2008): 9.26 inches
Uvalde (2009): 13.84 inches
Uvalde (normal): 23 inches

Webb County
Laredo (2008) 22.78 inches
Laredo(2009): 12.58 inches
Laredo(normal): 19 inches

Zavala County
Crystal City (2008) 9.79 inches
Crystal City (2009): 14.82 inches
Crystal City (normal): 19 inches

When comparing the two years with the data above, one can see that the drought in 2008 seemed to be much worse than this year, with the exception of Webb County. Even though in

most locations rainfall totals were better than last year, every location was below normal. LaSalle County seemed to fair the best, as it was on the eastern side of the target area which seemed more favorable for precipitation this year. The basic trend from this data shows that the further west you go, the worse the drought was. Keep in mind, most of this precipitation came early in the spring and fall. This kept the middle part of the year very dry as high pressure seemed to linger over the area for weeks at a time. Laredo, in western Webb County, seemed to fair the worst as seen in the rainfall totals above. As well, due to substantially decreased tropical activity and seabreeze activity, Webb County remained dry.

The following paragraphs contain a month-by-month review of weather modification activities for the Southwest Texas Rain Enhancement Association.

The project year started as it usually does in March. Only a few missions took place as is normal for early in the season. A total of two seeding flights took place on two seeding days. Of the two seeding flights, one was classified as hail suppression. As well one reconnaissance flight took place near the end of the month.

April was a little less active than it usually is due to a dry pattern that evolved over the area for a majority of the month. Only one seeding flight on one seeding day took place this year and it was classified as hail suppression. As well, one reconnaissance mission took place during the month of April.

May was much busier than the previous two months of the operational season with all of these flights confined to the latter part of the month. The first two weeks of the month was characterized by hot and dry conditions over most of the target area and most of south Texas. However, a progressive pattern during the last two weeks of the month brought a total of eleven seeding flights on seven seeding days. Of the eleven flights, four were classified as hail suppression. A total of four reconnaissance flights took place during the month.

June brought a renewed hot and dry pattern to the area. Temperatures were well above normal, with a number of days at or above 100 degrees. This impacted seeding efforts with seeding taking place mostly on small clouds. But even with only small clouds to work with, a total of seven seeding flights on five seeding days took place. As well, two reconnaissance flights took place during June.

July was slightly busier than June. Thunderstorms did occur but the majority of them were classified as small cloud systems and were not the best candidates for seeding. Even with this being the case, seeding operations were very aggressive over the target area due to continuing drought. A total of eleven seeding flights took place on seven seeding days. Additionally, four reconnaissance flights took place, further showing the poor quality of seeding candidates available during the month.

August continued to be an active month weather modification wise, but was below average rainfall wise. Seeding operations, similar to May, did not occur until the midpoint of the month. A total of nine seeding flights on six seeding days took place during the month of August. Of the

nine seeding days, one was classified as hail suppression. It is very unusual to have a hail suppression mission in August, whereas hail suppression operations are usually confined to the spring months. In addition, one reconnaissance flight took place on the last day of the month.

September offered a number of seeding flights for the project with a total of ten seeding flights on eight seeding days. As well, September finally brought a pattern change to the area with most locations seeing high rainfall amounts. The central and southern portions of the target area saw the greatest rainfall totals while the central parts of the target area were drier. In addition to the ten seeding flights, three reconnaissance flights took place during the month.

October which usually offers up a few seeding flights did not offer any this year due to unfavorable seeding conditions. There were no seeding flights during the month of November either.

For the 2009 seeding season, there were a total of sixty-seven flights. Of those sixty-seven flights, fifty-one were seeding flights and sixteen were reconnaissance flights. Of the fifty-one seeding flights, seven were classified as hail suppression. A total of 113 flight hours were flown with 1,083 flares and 43,280g of AgI (Silver Iodide) burned.

During the second half of the 2009 season, a new type of seeding material was being used on an exploratory basis. The use of hygroscopic flares was used in conjunction with glaciogenic flares on four separate cloud systems during the summer months. This was not just being done in the Southwest Texas project, but also in the South Texas project to the east and in the West Texas project to the northwest. This new type of seeding was analyzed and showed very promising results. This information can be found in the analysis section of this report.

In addition to normal weather modification activities in the Edwards Aquifer Authority (EAA) target area, which is just to the north of the SWTREA target area, 2009 continued another year of a randomized seeding experiment. The randomized seeding experiment was also being conducted by the EAA's other weather modification contractor, the South Texas Weather Modification Association (SWTMA). The objective of randomized seeding operations for the Edwards Aquifer Authority is to select clouds that meet the criteria for suitable seeding candidates. This is seeding at random and from that point measurements and observations are being taken to determine if seeding has had an effect on the cloud. The experiment is double blind so that ground operations staff does not know which clouds are seeded and which are not seeded due to bias that may occur. In other words they are unaware of the seeding decision.

Since 2009 was another dry year in the northern portions of the target area, mainly Uvalde County, no randomized flights took place during the 2009 seeding season, which ran for Uvalde County from May to September.

Randomized procedures involve a black box that inside contain envelopes that contain a card. The card is denoted "SEED" or "NO SEED". A box is placed in the office for both projects, STWMA and SWTREA. Each of the aircraft that is participating in the experiment has a box.

Once the pilot has declared a "case" based on the criteria listed above, both the meteorologist and the pilot open then first envelope in the box. The meteorologist tells the pilot the word on the card, who determines whether to seed or not to seed based on the table below:

Radar	Aircraft	Action
Seed	No Seed	No Seed
Seed	Seed	Seed
No seed	Seed	No Seed
No seed	No Seed	Seed

The pilot, under any circumstances, does not tell the meteorologist whether the decision is to seed or not seed, and the pilot and meteorologist do not communicate on issues related to the apparent effect of seeding or no noticeable effect. Any other normal conversation regarding safety of the pilot, aircraft, or any type of air traffic communication can be talked about as normal.

Operational Summary

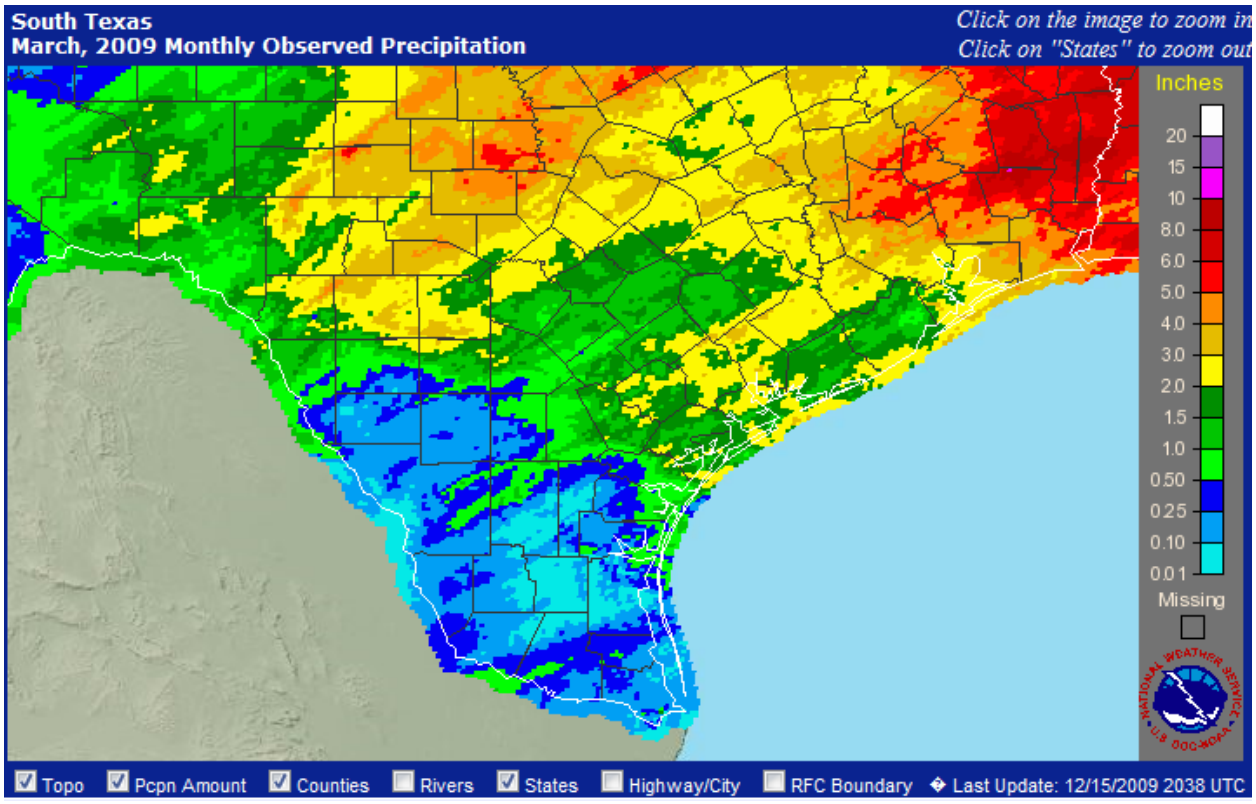
March 2009

Albeit a slow start to the season, March offered two seeding flights on two seeding days. Of these two missions, one was classified as hail suppression and one was classified as rain enhancement. Additionally, one reconnaissance flight took place during the month.

On the 11th, convection started during the early morning hours but ceilings were below 2000 feet and cells were embedded in light rain. Convection continued later into the daytime hours but ceilings did start to lift. Convection was occurring in Uvalde and Zavala counties and this is what was launched upon. Light rain was occurring during the flight but flares were fired during the small time frames when rain was not occurring. Rain continued to get heavier and cloud ceilings were lowering once again, so the mission was concluded due to these reasons.

Destabilization of the atmosphere occurred quickly on the morning of the 26th ahead of an upper level jetstreak and a mid level vorticity maxima. This increasing instability lead to cells initiating in Uvalde County where the nose of the high instability existed. Once again, ceilings were an issue early on, but gradually a flight was able to be launched on convection in Uvalde and Zavala counties. Convection was elevated and the pilot was required to attain a high altitude in order to find inflow. More flares would have been fired but ceilings dropped during the last part of the flight and the pilot was forced to terminate flight.

A total of 31(40g) flares and 1,240g of AgI was used during the month of March. The next graphic ~~below~~ shows heavier precipitation for the northern portions of the target area while only very meager amounts occurred over the southern parts of the target area, especially along the Rio Grande River in western Webb County.

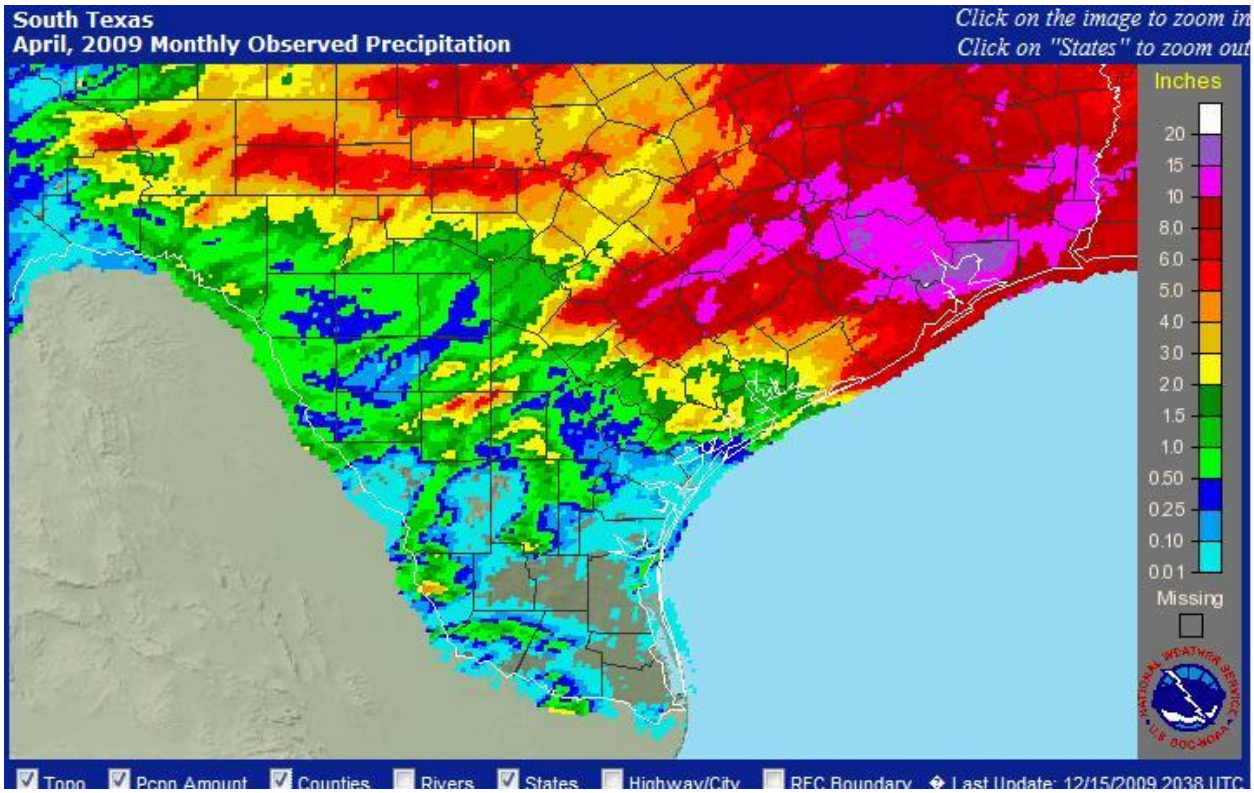


April 2009

April offered very few flights in a month that is usually very active. The month only offered one seeding flight on one seeding day and it was classified as hail suppression. As well, one reconnaissance flight took place near the end of the month.

A shortwave/jetstreak was moving across the area on the 17th when convection started across the target area. These two dynamics combined with good moisture convergence and high cape values initiated convection. Convection that had been south of Webb County in Zapata County has finally started to move into the southern part of Webb County during the evening hours. Ceilings were originally thought to be a problem but upon watching surface observations, ceilings finally allowed for a seeding flight. Inflow throughout the mission was not as intense as one would expect with a storm of this intensity. Hail suppression was conducted for the possible presence of hail with the storm and the issuing of a severe thunderstorm warning by the National Weather Service. Seeding was eventually concluded as enough material had been put into the storm and ceilings were becoming an issue.

For the month of April, as stated above, a total of one mission on one seeding day took place. A total of 53(40g) BIP flares were used with a total of 2,120g of AgI burned. The graphic below shows another month of rather meager precipitation across most of south Texas. Some locations saw amounts as high as 2 inches, which is about 2 to 3 inches below normal. Webb County seemed to be the driest with less than 1/10 of an inch of rainfall falling across most locations there for the entire month.



May 2009

With the start of spring came the increasing chance of severe weather across south Texas. This May was no exception as weather modification activities were on the increase. However, this only occurred during the last two weeks of the month, as high pressure caused for very dry and hot conditions for the target area for the first two weeks.

Convection rapidly exploded across the entire target area during the early afternoon hours on the 15th across the target area as a shortwave was lifting out of Mexico into a moist and unstable air mass. Cells became quickly mature in a matter of 10 minutes. A pilot was called and a seeding mission was launched on convection. However, the first pilot could not find any inflow with strong cells over Uvalde, Dimmit, and Zavala counties. Another pilot was launched and proceeded to nearest convection in southwestern Dimmit County. The second pilot found inflow with convection in southwestern Dimmit County. Severe weather statements were issues by the NWS but no severe thunderstorm warnings occurred. Flood advisories were issues for the Dimmit and Zavala counties around 0245Z.

Convection started to occur early in the morning on the 16th over LaSalle and Webb. A pilot was launched on this convection. This was the first convection that fired during the day and as the day went on, convection began to occur in locations further to the north. An outflow boundary/cold front was located over the Hill County and convection began to form ahead of and along this boundary. Convection was seeded in LaSalle and Webb counties first then in Frio

County for STWMA as convection began to form everywhere. Cells in Zavala County were then seeded. The pilot tired to find inflow with storms in Uvalde County as well but visibility became a problem near the end and bases were almost to the ground. This ended seeding over the area even though convection was still ongoing. Overall, inflow was good during the duration of the flight and almost all convection was seeded or looked at.

On the 22nd, a reconnaissance flight was launched on convection that was moving in the northwestern corner of Uvalde County. When convection was encountered, the flares on the aircraft would not fire. Additionally the convection seemed to be showing an overall weakening trend.

During the latter half of the afternoon on the 23rd, convection began to develop and move into both the northern and southern sections of the target area. A flight was launched initially to investigate clouds in Uvalde County, but the plane was redirected to LaSalle County as the activity in Uvalde County was marginal at best and convection near Encinal appeared to be faring better on radar before seeding. This activity was seeded, after which the plane returned to base. Additional convection developed in Webb County after 8pm and another flight was launched to investigate and eventually seed this activity. An MCS approached the Rio Grande and western sections of the target area after 10pm but much of this activity was embedded in a larger shield of light rain and was not seeded. A total of three flights were conducted today due to the persistent and the widespread nature of convection.

Convection developed over the northern target area during the mid afternoon hours on the 24th and gradually moved southward. A flight was dispatched shortly after 3pm to investigate clouds over the EAA portion of the target area where the convection was concentrated. Because there were several clouds close to each other, the randomization protocol could not be enacted and operational seeding commenced. The plane also assisted with seeding in STWMA's target area in Bandera and Medina counties.

A quasi-stationary boundary existed across the Hill County on the 27th. As well, an outflow boundary was across the coastal bend and made its way westward throughout the afternoon. A very unstable airmass was in place with high dewpoint values and good daytime heating occurring in the late afternoon hours. A weak upper level jetstreak moving out of Mexico also helped to fuel convection into the evening hours. Convection first started to form to the east but as the afternoon went out, showers and thunderstorms started to build into the target area. A pilot was launched on convection that was located in Edwards County near Rocksprings. A very strong thunderstorm quickly became severe and was moving southeast into the target area. Rain enhancement was preformed first and after a warning was issued, hail suppression was conducted Pilot reported good lightning and strong inflow with the storm initially. As the cell moved into the target area, more convection was forming along outflow boundaries from convection east of Uvalde County. Another flight was launched soon after the first one and once again hail suppression was conducted as the storm quickly became severe. Seeding ended with this cell as a Flash Flood Warning was issued. However, strong to severe convection was seeded for hail suppression purposes in Zavala County. Seeding ended due to a Flash Flood warning and later a tornado warning being issued. The pilot was not able to see the cell sufficiently before the warning was issued. More convection was being monitored across the Rio Grande but

low level steering did not allow these to enter the target area. A total of two flights took place today in the target area.

The first seeding flight of May 29th was launched on an MCS that started to approach the northern/northwestern edge of the target area shortly after midnight. This MCS had been showing signs of weakening as it approached the target area but radar was still showing strong convection. Seeding was done in northern Uvalde County and the pilot reported good inflow and frequent lightning. However, after some length of time, the pilot was having trouble finding inflow and as well radar showed weaker intensities occurring as the MCS continued to move to the east/southeast.

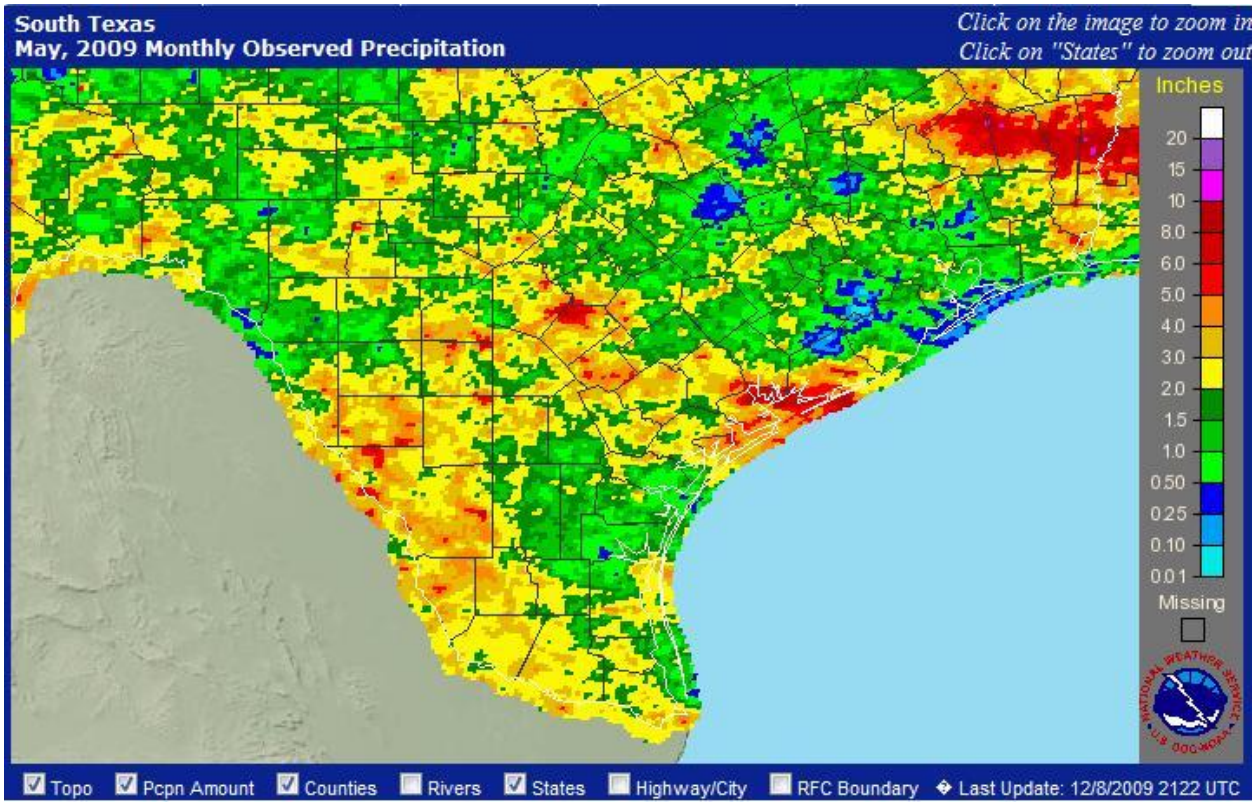
Very weak showers and thunderstorms started off the day but as the day went on, explosive development of thunderstorms occurred as a shortwave moved across the area from Mexico. This shortwave was well timed with the peak of daytime heating and an unstable profile existed over the area. A pilot was launched on weak convection forming in southeastern Zavala County. Echoes were slow to show up but pilot reports of tall Cumulus clouds and satellite imagery showing the same thing allowed seeding to take place. Most of the seeding early on was conducted on clouds that were not producing any type of radar return. However, as seeding continued, radar returns were showing up in these areas. Seeding with the first flight was done mostly in Zavala County where the best cumulus field existed. However, storms begin to fire after this mission concluded in Uvalde County. Another flight was launched on convection that began to fire in Uvalde County. The convection in Uvalde was small in coverage but very intense. This was seeded successfully. Additionally, convection that has been moving east into Texas across the river finally started to work into western Webb County. The pilot flew down to these storms as they entered the target area and was able to fire a couple of flares, but light rain was reported with the inflow and seeding was then terminated.

Weak convection was developing in Uvalde County during the early evening hours of the 30th. A flight was launched into the northern county to see if convection was seedable. The pilot reported that clouds were not developing vertically as they should be. Convection continued there but the pilot was unable to find inflow with the weak convection.

Convection was moving into the target area from the east out of Mexico on the 31st. As this convection moved closer to the border, small cells began to form in front of it. As these cells entered the target area, where strong instability had existed all day, a rapid intensification occurred. In addition, a strong shortwave was moving out of Mexico into the Rio Grande Plains which helped to further help convection across the border and help with intensification. A pilot was already in route when this began to occur in western Dimmit and Zavala counties. Due to the severity of the storms, hail suppression operations were conducted. These storms rapidly become severe as they worked their way across the western side of the target area. Gradually, the individual cells merged and formed a line of convection that extended from La Pryor south to northern Webb County. Seeding was conducted along the western side of the line, from Crystal City to about Carrizo Springs. However, when the pilot tried to move further south of Carrizo Springs, light rain was occurring ahead of the main line of convection. Many attempts were made to seed the convection, but the lack of inflow and an abundance of rain out ahead of this line of convection inhibited further seeding to take place. As well, seeding could not continue

further to the east or south due to a flash flood warning that had been issued for LaSalle and Webb counties.

For the month of May, as stated above, a total of eleven missions too place on five seeding days. Of the eleven days, four were classified as hail suppression and seven as rain enhancement. Additionally, four reconnaissance missions took place this month. A total of 364(40g) BIP flares were used with a total of 14,560g of AgI burned. As seen in the graphic below, most of the target area saw somewhat good rainfall during the month. Lower rainfall amounts were seen in northern Zavala County and most of Uvalde County.



June 2009

June was a somewhat busy month weather modification wise, even though exceptional drought conditions continued to develop across portions of the target area. Even with little to work with, the month was still busy flight wise. For most of the month, the target area remained under high pressure yielding mostly hot and dry conditions. Flight activity occurred during the first and last of the month.

Weak thunderstorms started to occur during the late afternoon hours across eastern Webb County on the 1st. These showers were due to the seabreeze boundary making its way into Webb County. These showers were very isolated in nature, but one of the cells became very potent as a

pilot was launched to it. The pilot reported a very good shelf with this cloud and new growth on the northwestern side. The pilot did most of the seeding here. However, the cell quickly began to dissipate and the pilot was unable to find anymore inflow. A reconnaissance flight was launched on a cell that formed in northeastern Dimmit/northwestern LaSalle County right before sunset. This cell formed as the seabreeze boundary moved inland and became very potent for 2-3 scans. A pilot was launched on this cell but did not last long and upon encounter of it, the pilot was unable to find any inflow associated with the cell. As well, the pilot reported that the tops on the northwest side were becoming less defined and was only able to find smooth air associated with this cell. During the progression of the evening, the seabreeze could be seen on radar as far north as Uvalde and Kinney counties.

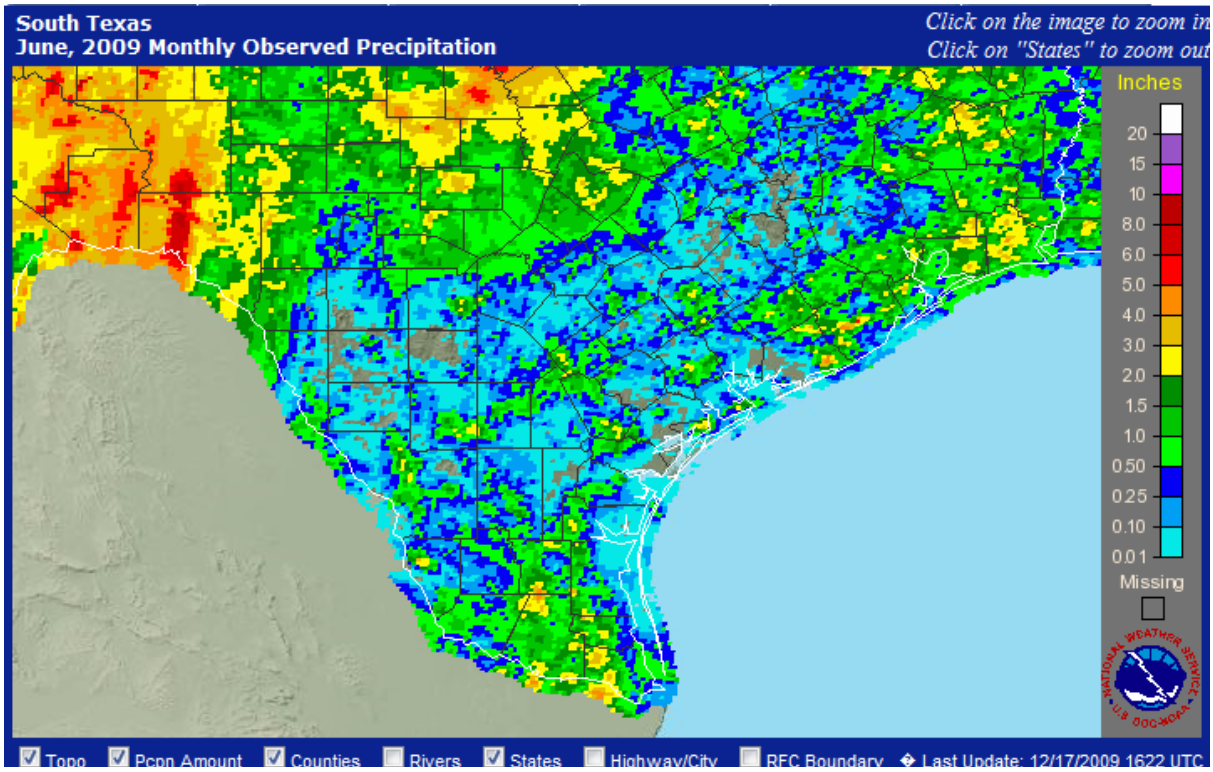
On the 2nd, convection in Val Verde County that occurred earlier in the day produced an outflow boundary that started to move into the northwestern target area around 930pm. As this outflow boundary moved into western Uvalde County, convection started to occur along it. As well, an MCS was moving into the Hill County from west Texas. Showers and thunderstorms formed along the western edge of the target area in Zavala and Uvalde County. Convection further south of the main outflow boundary in Uvalde County did not fair very well, but the main line of convection in Uvalde County faired very well. This is where the majority of the seeding took place and seeding was concluded as this line of convection moved out of the target area. Throughout the mission, the pilot stated that the convection had excellent lightning associated with it and a large, pronounced shelf was present. The MCS that was moving into south Texas ended sliding to the east/southeast and did not impact the target area.

The MCS from the overnight hours left an outflow boundary located across the SWTREA target area on the 3rd. During the afternoon hours, weak showers began to form in LaSalle and Zavala counties. A flight investigated these showers, but they were not mature enough to conduct seeding on. The pilot then flew back into the STWMA target area. After a short amount of time, showers and thunderstorms began to increase in coverage and intensity in LaSalle and Dimmit counties. Seeding was conducted here and a short while later, seeding was also conducted in Zavala County. Inflow was somewhat hard to find today, probably most likely due to slow storm motions. However, when it was found, inflow values were rather high especially with convection that formed near the tail end of the flight. Eventually, convection merged together over the target area and extended from an Uvalde County to LaSalle County line as it moved to the south/southeast.

A Cumulus field developed early over the western Hill County on then 25th. The bulk of the convection today developed in Bandera and Medina counties. Convection moved from northeast to southwest and around 5pm, moved into Uvalde County. A seeding flight was already taking place in the STWMA target area, so the plane came into Uvalde County to investigate convection there. The first round of convection that moved into the northeastern corner of Uvalde County was investigated but no inflow was found with it. Another round of convection developed over northern Uvalde County and the aircraft flew back to take a look at it. This convection was weak and the pilot reported marginal bases and low cloud tops. As well, when seeding was conducted, only weak inflows were reported.

Convection was forming along a boundary just to the north of the area during the early afternoon hours on the 30th. Convection started to move closer to the northern boundary of Uvalde County so a flight was launched. Convection during this flight only moved into the extreme northern fringes of Uvalde County and was marginal. A short while later, convection started to develop across the border from Webb County in Mexico. As well, the outflow boundary that was north of the area earlier this afternoon finally started to make its way south into the target area. This allowed an explosion of convection across northern Webb, southern Maverick and Dimmit counties. Seeding was conducted on this convection and the pilot reported frequent lightning, good inflow, and very good bases. After the complex of storms had received a proper dosage, the flight was terminated. An hour after the second flight was concluded, convection began to re-fire over central Webb County due to lower CIN values and convergence occurring there. Another flight was launched in response of this. Inflow was somewhat difficult to find and when inflow was found it was weak and associated with light rain. However, some seeding did occur. The flight was concluded when a flash flood warning was issued for the convection being seeded. A total of three flights were flown today in the target area.

For the month of June, a total of seven seeding flights took place on five seeding days. As well two reconnaissance flights were flown during the month. A total of 155(40g) BIP flares were used with a total of 6,200g of AgI burned. The precipitation graphic below shows a very dry month for almost the entire target area. Locations in southeastern LaSalle County and central Webb County were the wet spots for the month, but still were very much below normal for this time of year.



July 2009

July continued to be a busy flight activity month for the target area, while the drought of 2009 continued to allow very little rainfall to fall over the target area.

On the 2nd, an upper level high was located over west Texas/northern Mexico with an upper level ridge across most of the central and western parts of the U.S. A mid level high was a bit further to the east than its upper level counterpart. In the lower levels, high moisture values existed mostly along coastal areas and further into the lower Rio Grande Plains due to a weak tropical wave coming ashore near Brownsville. Conditions were favorable today for the seabreeze boundary to move into the target area. A large complex of showers and thunderstorms associated with a weak tropical wave only helped to enhance the seabreeze boundary today. A pilot was launched on convection that was moving in from the Coastal Plains. However, as this convection moved into Webb County, it started to weaken considerably. As well, the SWTREA meteorologist was working for the STWMA meteorologist, so after seeding was done in the SWTREA target area, the pilot moved over to the STWMA target area to help out. Seeding was done in the STWMA target area in Live Oak, McMullen, Frio, and Atascosa counties. In the SWTREA target area, seeding was conducted in LaSalle and Webb counties. Convection that was seeded in LaSalle and Webb counties was not as good as convection that was closer to the coast.

On the 6th, weak showers and thunderstorms began to form to the north and northwest of the target area during the late afternoon hours. As time progressed, convection began to move into target area and new cells were forming. A seeding flight took place in Uvalde County but the pilot was unable to find inflow with most of the cells early on. The only cell that was seeded that had workable bases was in northwestern Uvalde County. As time went on, a line of thunderstorms formed from about the town of Uvalde to Hondo and further to the northeast. Convection was seeded and was located across southeastern Uvalde County and northeastern Zavala County. The information for this flight can be found on the STWMA report as they did the seeding at this point. As the convection continued to the south/southeast, it did start to fall apart. Meanwhile, further to the southeast, the seabreeze boundary has moved into eastern LaSalle and Webb counties. Another seeding flight was launched. The pilot did have a little luck with this convection but weak inflow values plagued most of the flight. Even more convection continued in Dimmit and Maverick counties but upon encounter, the storms were decreasing in intensity. Seeding operations concluded when there were not any other cells around to seed.

During the 7th, some weak convection developed earlier in the day in southeastern Webb County ahead of the seabreeze boundary but upon encounter, the pilot reported that air was very dirty. Upon encounter of convection, cells were very short-lived, no bases, and had very little vertical depth. A bit later in the day and further to the northwest in the central target area, convection began to occur in Uvalde and Zavala counties. As well, convection was occurring in northeastern Maverick County and was moving into northwestern Zavala County. The pilot initially had problems finding inflow with the convection in Uvalde County, so the pilot continued into Zavala County where inflow was found with the convection there. Seeding continued until the pilot ran out of flares. Another plane was going to launch but was unable to do so due to mechanical problems. However, over time, it seemed that most of the convection in the target area was seeded.

Convection began to form in the Hill County during the afternoon hours of the 17th. This convection slowly moved to the south/southwest and entered the target area along the northern edge. A pilot launched on this convection and was seeded until the pilot ran out of flares. Meanwhile, another pilot was being readied to launch on the convection as it continued from Uvalde County in Zavala County. The convection remained rather strong, so a second flight was launched on the convection to be seeded again. The pilot on the second flight had trouble finding inflow and as the flight progressed, the convection began to weaken considerably. The pilot was no longer able to find inflow and seeding concluded.

A mid level to upper level trough was located over the area which gave rise to the showers and thunderstorms over the northern portions of the target area on the 18th. However, the seedable convection today was due to an enhanced seabreeze boundary moving into the southeastern target area. Convection once again began to form along the northern end of the target area. However, as the convection moved to the south, it dissipated rather quickly. This occurred just as the convection was entering northern Uvalde County. The convection was short lived due to an ample cirrus shield that was located over the northern parts of the target area from a dying MCS that moved close to the area earlier in the day. However, the southern target area remained immune from this shield seeing that it was too far to the north and by the late afternoon to early evening hours, convection began to occur in southeastern Webb County along the seabreeze boundary. Convection along the seabreeze boundary was seeded and the pilot reported that inflow was adequate for seeding and bases were good. The pilot did report that cloud depth was not as good as it usually was, as these cells really did not get that tall.

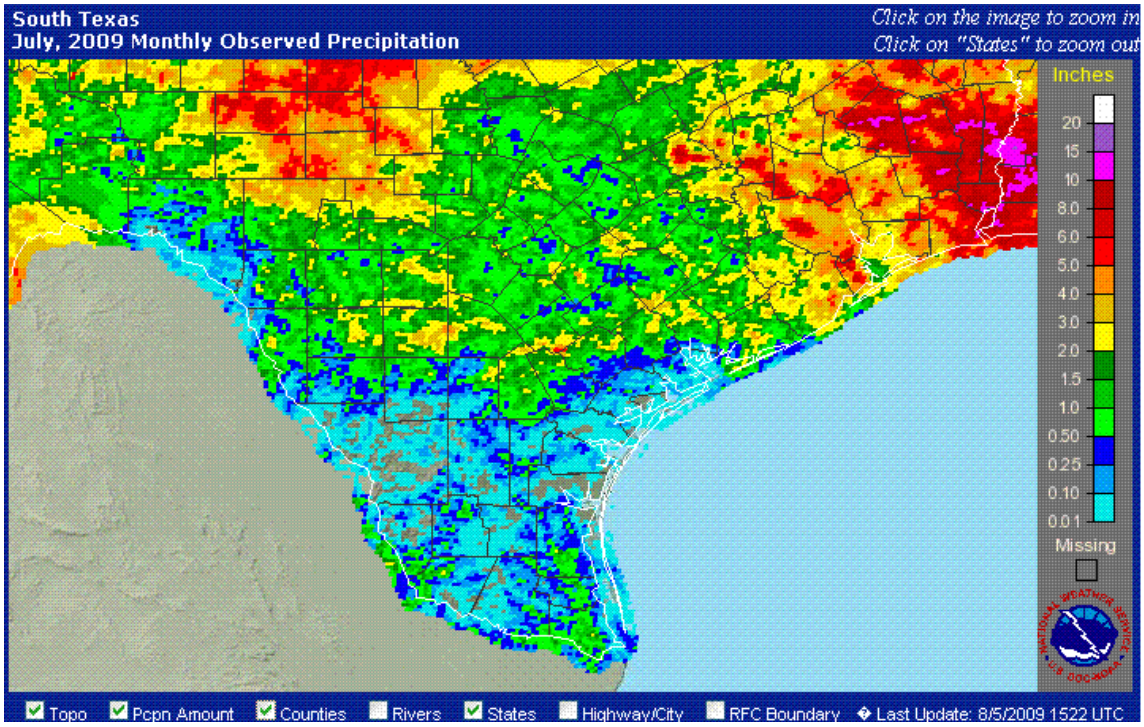
A mid to upper level high moved even further to the west of the area over the past couple of days. This allowed a mid level trough to meander across Texas into the lower Mississippi River Valley. This trough allowed a weak stationary boundary to move back and forth across central Texas the past couple of days. This boundary combined with daytime heating and a good moisture profile over the area and allowed for convection to occur on the 20th. Convection once again formed along a stationary boundary located across the Hill County. By the afternoon hours, this convection began to move to the south/southeast into the target area. A pilot was launched on the convection as it moved into Uvalde County. Near the beginning part of the mission, the pilot was having trouble finding inflow with the initial convection. The pilot flew along the front of the leading edge of the convection and was not able to find inflow. The pilot was instructed to return to base. However, before he landed, another cell formed in southern Uvalde County that was further south of the initial convection. The pilot proceeded to the new cell and was able to find inflow with this cell and the subsequent cells that formed in northeastern Zavala County. After these cells were seeded, not much else in the way of convection was in the target area, so the pilot returned to base.

An MCS moved just to the north of the area early in the morning on the 30th. The convection associated with this MCS was expected to dissipate as the previous days' MCS's had. But as the MCS continued to move to the south/southeast, it began to regenerate just to the north and northwest of the target area. The leading edge of the MCS was seeded in northern Uvalde County. The pilot continually reported good bases, good inflow, and frequent lighting throughout the mission. As this convection moved south, an outflow boundary was produced and the convection "jumped" in front of the old leading edge, leaving the pilot behind the

outflow boundary. During the mission, this convection produced a very strong gust front and the pilot reported a large amount of dust being ingested by the convection. Even with this, the convection continued to move to the south/southeast. The pilot finally ended up moving through the gust front and working along the leading edge again. The pilot initially was able to find distinct areas of inflow associated with each particular cell. However, when he was on in front of this gust front, he found inflow all along it, even when he was not near the cell. The majority of the seeding took place behind the gust front but the last four flares were fired when the pilot was located on the southern side of the gust front.

A vorticity maxima was located across the Rio Grande on the 31st. This vorticity maxima combined with daytime heating and excellent moisture gave rise to convection today. During the early afternoon hours, convection began to form near the river and into northwestern Webb County. A few weak cells developed in southern Maverick and southwestern Dimmit counties. A seeding flight was launched on these cells and after a short while, an explosive development of showers and thunderstorms occurred in northern Webb County and western Dimmit County. Seeding was done on these cells and along a line that stretched from northern Webb County into southern Uvalde County. The pilot reported frequent lightning throughout the flight and very good inflow. The line continued to move to the east/northeast and seeding operations were concluded when enough material had been put into the convection.

For the month of July, eleven missions took place on seven seeding days. A total of 231(40g) BIP flares were used with a total of 9,240g of AgI burned. Below is the monthly precipitation map. It shows that dry conditions existed across most of south Texas for the month. Locations in the northern target area were the wet spots for the month, even though precipitation amounts there were only about two inches. Further south in the target area, some locations did not see any measurable rainfall for the month, this is especially true in portions of Webb County.



August 2009

August-continued to offer a steady stream of flight opportunities but not as many as in the past couple of months. Similar to May, most of the flight activity for the month took place in the last couple of weeks of the month. Another note of interest is that a hail suppression mission occurred on the last day of the month. Hail suppression activities are usually confined to the spring months, but this year was an exception.

A shortwave moving across central Texas gave rise to convection during the afternoon hours of the 12th. This convection produced a well organized outflow boundary that spawned new showers and thunderstorms in the Hill County and further south into the target area. As convection began to move into the northern target, a seeding flight was launched on it. The convection initially had good reflectivity values and good cloud tops. As the convection moved into the target area, it seemed to go downhill in a hurry. By the time the pilot actually reached the convection, undefined bases, weak convection and minimal inflow was present. Meanwhile, it put out an outflow boundary that moved through the target area. This helped to make way for convection as it reached the central parts of the target area where peak heating was occurring. Another seeding flight was launched on a cell in southeastern Dimmit County.

On the 13th, high pressure over west Texas shifted a bit further to the east than the day before. This allowed more moisture to work into the eastern/southeastern parts of the target area. As well, another outflow boundary moved in from the north into southwest Texas. The seabreeze boundary was able to move further than it usually does into the southern parts of the target area during the afternoon. Convection was located at both extremes of the target area. In the northern target area, convection was initiating along a southward propagating outflow boundary. In the southern target area, the seabreeze boundary was causing convection in Webb and LaSalle counties. Convection to the north was marginal at best and the pilot worked hard to find inflow. Only two flares were fired during this mission as the flare racks failed to allow flares to be fired when inflow was actually found. Convection was best in the southern target area today and a plane was launched to investigate it. Convection was robust and provided good inflow. Convection began to work into the target area from Duval and the STWMA target area during the latter half of the mission. Convection was seeded for a second time in eastern LaSalle after it had been seeded by the STWMA in McMullen County. This convection continued its movement to the west and the seeding flight was terminated due to all the convection in the target area being seeded.

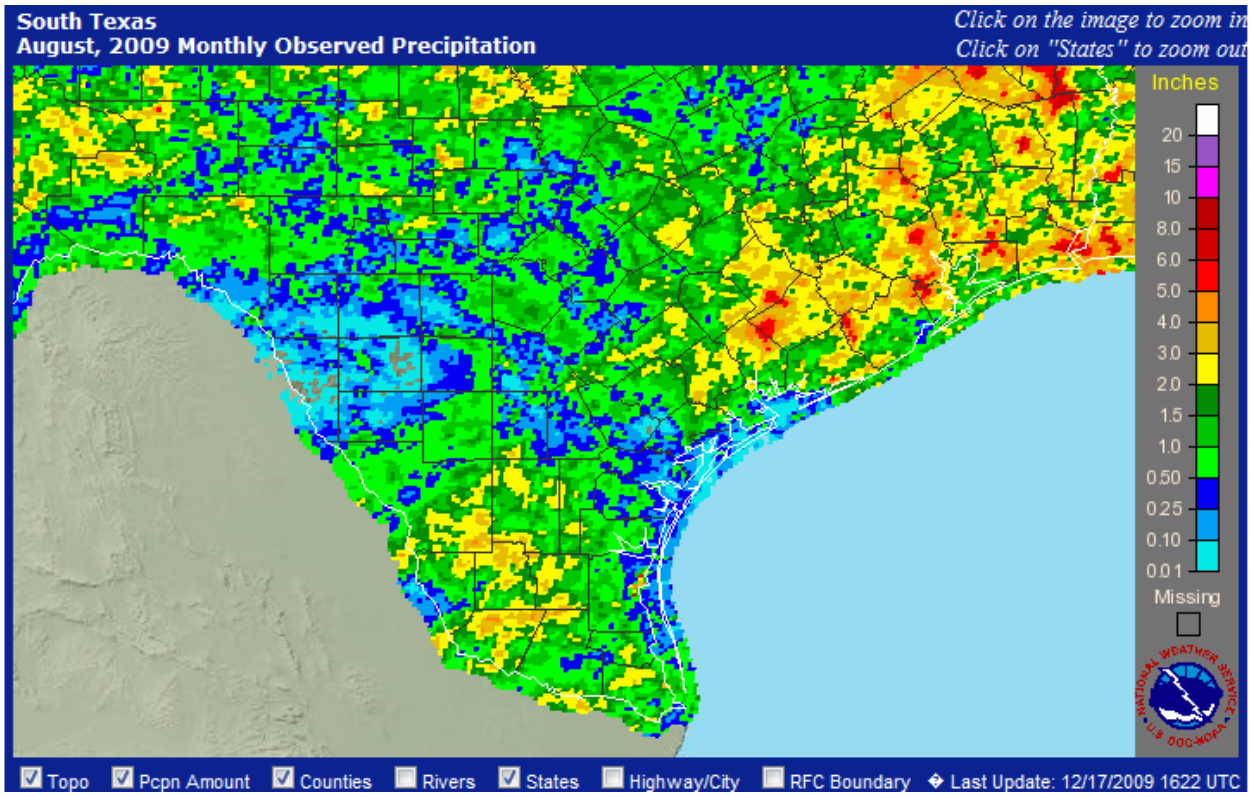
On the 18th, an upper level high was located over the western Gulf of Mexico and an upper level trough was across the Southwestern U.S into the northern Plains. Convection initiated along the seabreeze boundary today and eventually worked its way into Webb County. Convection seemed pretty marginal through most of the afternoon but intensified a bit when it entered the target area. A pilot was launched on this convection but was short-lived while being investigated and seeded. The pilot returned to base but did find a developing cumulus cloud that was producing some weak reflectivity on TITAN. This cloud was seeded then the pilot returned to base.

On the 27th, a weak trough axis existed to the east of the area. As a result, disturbances moved down from north Texas into west Texas. These disturbances were putting out outflow boundaries that propagated into the western Hill County during the afternoon hours giving rise to convection. Convection was moving into the target area from the north and northwest during the afternoon hours. KDFX was not operational for the entire mission but by using surrounding radars, allowed the flight to continue. During the mission, the pilot only reported a small number of clouds the contained workable bases and inflow was only confined to a small area. Convection was seeded in northern Uvalde County on this flight.

A weak trough axis existed to the east of the area on the 28th, but was further west than the day before. As well at the surface, a weak frontal boundary was located just north of the area. Moisture combined with daytime heating and the weak boundary, leading to convection. Convection began to first form in the northern parts of Uvalde County. As the afternoon went on, convection began to form in the southern parts of the target area as well. However the best convection, in terms of inflow and bases, was located in Uvalde and Zavala counties. A pilot was launched on convection in northern Uvalde County and eventually flew down to Webb County where additional convection was occurring. Convection in Uvalde County only produced weak inflow and was hard to find. The convection in Webb and LaSalle counties was better but it was still somewhat difficult to find inflow. Convection began to form along an outflow boundary in Zavala County, therefore another flight was launched. Convection seeded in Zavala County was by far the best in regards to inflow and bases. Into the evening hours, convection exploded across the southern target area and eventually formed into an MCS that covered most of Dimmit, LaSalle, and Webb counties. The second flight landed due to being almost out of fuel and out of flares. As well, radar showed it increasingly hard to find inflow and bases without rain due to the formation of the MCS.

At the surface, a weak frontal boundary was located over the southern target area, mainly over Webb County on the 30th. This boundary separated very moist air from much drier air to the north. Most of Webb County resided on the south side of this boundary and thus very moist air was in place. As daytime heating got going, convection started to form in an east/west oriented line across the county. Convection started off weak early in the afternoon in Webb County but quickly became stronger. A pilot was launched on this convection and upon encounter, found very good inflow and good bases. Shortly after seeding began, convection became severe and hail suppression was conducted in Webb County. Throughout the flight, the pilot reported good rain shafts and plentiful inflow. Seeding was finished when enough material had been put into the cloud.

For the month of August, a total of 130(40g) BIP Flares and 5,000g of AgI were used. A total of nine seeding flights took place on six operational days. As well, one reconnaissance flight took place. The precipitation map below shows that precipitation amounts were once again meager this month. This month for the target area, the precipitation amounts were flip-flopped from last month, with the northern and central parts of the target area being very, very dry and the southern target area being the wetter. In eastern Zavala County, there were locations that did not see any measurable precipitation for the month. Southeastern Webb County was the wettest, as a few tropical waves that developed in the Gulf moved inland.



September 2009

September continued to bring more rain chances to the target area and more opportunities in regards to seeding flights. Most locations in the target area finally started to get some much needed rainfall as the first cold fronts of the season moved into the area. Additionally, a very tropical like atmosphere moved into the area during the first half of the month, allowing for very good setup for much needed heavy rainfall.

On the 1st, an upper level trough was located just to the east and a strong jetstreak moving across the area during the afternoon hours. This combined with peak heating and good moisture gave way to convection during the afternoon hours. Convection began to occur over LaSalle and Dimmit counties during the early afternoon hours. Convection got off to a slow start in this area and never really blossomed into anything more than a few cells. Meanwhile, to the south of Webb County convection was slowly moving in. The first flight occurred in LaSalle and Dimmit counties and the second flight was launched on convection in Webb County, but better convection popped up as soon as the pilot was launched in LaSalle County. The convection south of Webb County started to dissipate as soon as it got close to the target area border. Convection was seeded in LaSalle County and another small cluster of cells popped up in Uvalde County. Initially the convection was not very strong and lacked bases, but upon further investigation, the pilot was able to seed these cells.

A trough of low pressure was located over New Mexico into west Texas on the 4th. A shortwave moved through during the evening hours making the flow a bit more diffluent over the area. This combined with residual boundaries from convection yesterday and a very buoyant atmosphere gave rise to convection during early evening hours. A thick shield of cirrus was noted throughout most of the day which delayed the onset of convection. However, when a shortwave moved in south Texas from Mexico, convection began to form in LaSalle, Dimmit, and Webb counties. A flight was launched on this convection and the pilot was able to find good inflow with most of the convection forming in the target area. Most all of the convection was seeded but the pilot finally needed to land as ceilings were becoming an issue near the end of the mission.

A weak low was located to the northwest of the area on the 5th. As well, moisture was being brought in from the Pacific at the mid and upper levels from the remnants of a tropical storm with low level southeasterly flow coming from the Gulf of Mexico. Lift from the low and daytime heating gave rise to very tropical like convection today. Showers and thunderstorms began to form during the afternoon hours as daytime heating got going. The convection started in LaSalle and Webb counties and a seeding flight occurred. During the flight, the pilot found good inflow and a very prominent shelf along the convection. As he went further to the west/southwest, bases were increasingly hard to find and was unable to see the southwestern part of the line of convection. Convection occurred in other parts of the target are today, but with the majority of the mass of the cloud below 4 km, which was below the freezing level, seeding was not conducted due to the ineffective nature of glaciogenic seeding on this warm convection.

Very weak showers started to occur in Uvalde County during the early afternoon hours of the 6th. A flight was launched on this activity but knowing that the atmosphere was very tropical in nature, no seeding was done in Uvalde County. This tropical atmosphere was characterized by very warm convection with low cloud tops. Convection became unorganized and soon after launching, there was no storm structure present which was reported by the pilot.

A mid to upper level trough was located across the southern Plains and Texas on the 7th. As well, during the afternoon hours a shortwave moved into the area from northern Mexico along the base of the trough. This trough and the associated shortwave combined with ample moisture and daytime heating-led to convection today. Another day of very high precipitable water values yielded very weak convection starting during the afternoon hours. By the mid afternoon hours, convection became a little bit more intense and taller clouds developed in Zavala and Frio counties. It pilot took awhile to find inflow and when it was found, it was weak and only in small area. Additionally, the pilot reported unorganized and broken bases with the developing thunderstorms. The pilot continued to investigate this area, but was having no luck finding inflow with the storms around the central target area.

A mid to upper level trough was located across the southern Plains and Texas on the 9th. As well, during the afternoon hours a shortwave moved into the area from northern Mexico along the base of the trough. This trough and associated shortwave combined with ample moisture and daytime heating led to convection today. As well during the evening hours, convection moved in from west Texas. Weak convection started to form in Uvalde County during the early afternoon hours. Most of the cloud mass was generally below 4 km but this eventually changed

with convection in Uvalde County and a pilot was launched. Upon encounter, the pilot reported some good bases but the ones that were found were unorganized and inflow was hard to find. On the eastern side of the thunderstorm is where the majority of the inflow was found as the west yielded mostly rain and no bases. This was sufficiently seeded and the pilot returned to base. As well, weak convection was starting to work into the area from Mexico in Webb County and this was monitored for the possibility of another flight. The convection in Uvalde County continued to propagate into Zavala County and seemed to be aided by an outflow boundary located there. Another flight was launched to seed this area of convection a second time. The pilot was able to do some seeding but there was a downtrend in reflectivity and bases. Additionally convection occurred during the afternoon hours in the target area but most of it was warm cloud rain processes and no lightning was being reported with it. One last flight occurred as convection moved into the western side of the target area from west Texas. Convection first entered northwestern Uvalde County, but a flash flood warning was issued for this section of the line of convection. Convection soon moved into western Zavala and Dimmit counties which were not warned on. This convection seemed to have more depth than most of the convection seeded earlier in the day and lightning was frequent with this convection. The last flight was concluded early to deteriorating visibility.

Convection quickly fired on the southwestern border of Webb County as a weak shortwave moved into Texas from northern Mexico on the 19th. Most convection remained in Mexico for some time but when it crossed the border it was located over Laredo and could not be flown on. As the convection continued to move to the east, it became embedded in light rain. A pilot was launched on this convection but upon encounter, was unable to get to stronger cells due to the embedded nature of the convection.

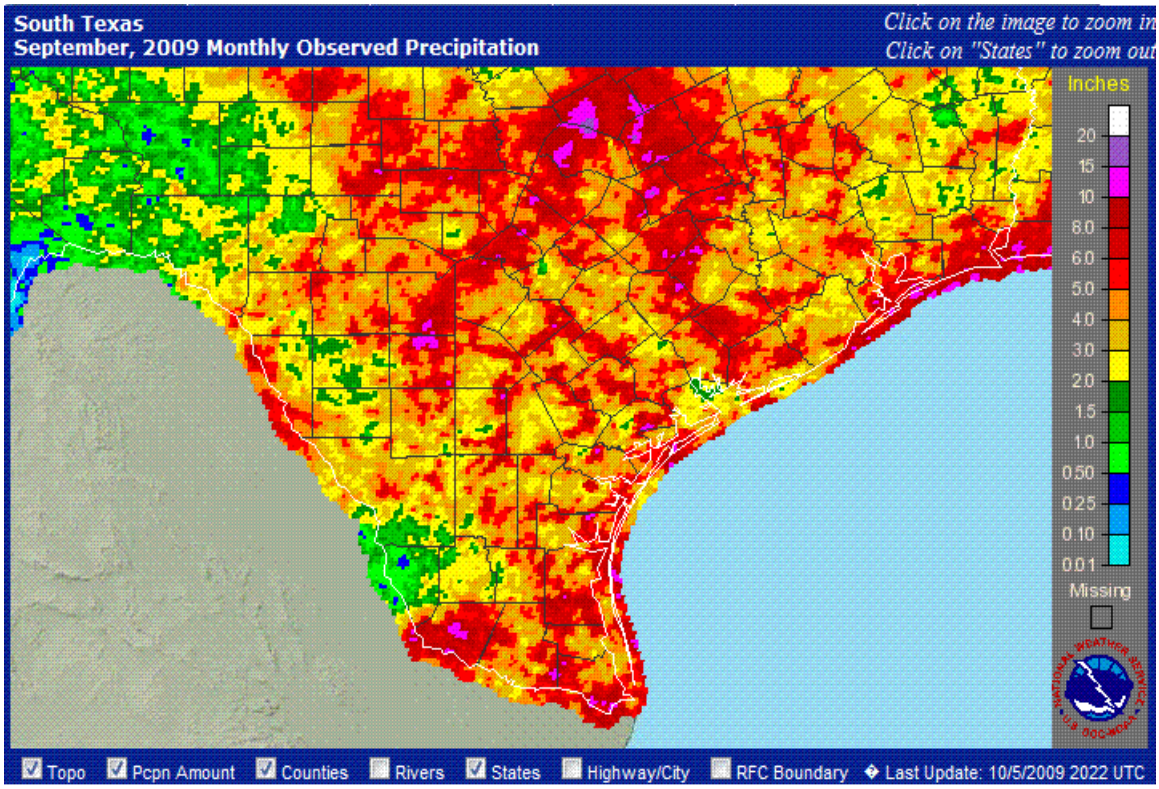
A very potent vertically stacked low was located over the central Plains on the 22nd. This put Texas on the southeastern side of the low and as disturbances moved along the base of the low, this triggered convection over the area. Convection had added help as a cold front was moving into south Texas. The front combined with a very good mid level flow from the Pacific and good low level flow off the Gulf led to a line of convection during the early morning hours. A broken line of convection was located just north of the target area around 7am. Convection did not look that promising before it entered the target area but as it moved into Uvalde County, it was of suitable strength and cloud depth. A pilot was launched on this due to the fact that clear sky conditions were available during takeoff. As the pilot reached the convection, ceilings lowered substantially and he was unable to get to the main area of convection located in northeastern Uvalde County. However, the pilot found a row of new development, probably along the outflow boundary, in Uvalde and Medina counties. The STWMA pilots were unable to take off due to low ceilings, so seeding was done for them during this mission. The pilot found a line of good inflow along these developing turrets and seeding operations were conducted. After most of the new development was investigated, the pilot returned to base as ceilings were becoming an issue.

A late night mission occurred over Uvalde County as a weak cold front was moving through the target area on the 28th. This combined with a weak shortwave allowed for convection to develope over Uvalde County. A seeding flight was conducted on this convection and the pilot

reported frequent lightning with the convection that was seeded. Seeding operations were concluded as all of the convection in the target area ~~has~~ had been sufficiently seeded.

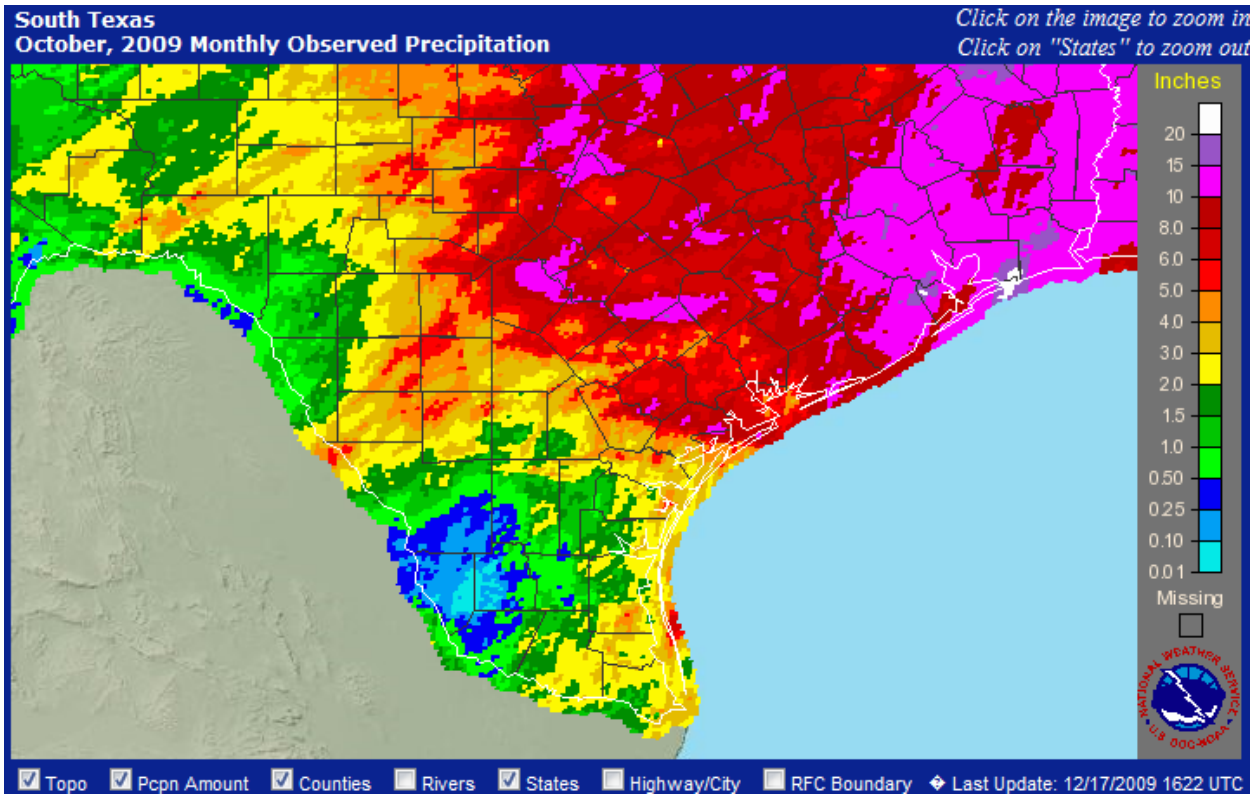
Convection started to develop in Webb and LaSalle counties during the early morning hours on the 29th as a cold front that caused convection late last night, continued its movement to the south. This weak boundary encountered very moist and unstable air as it moved into the southern target area. A flight was launched on this convection but upon encounter, the pilot was unable to see it due to the total lack of bases associated with the convection and no inflow. Soon after the flight concluded, flash flood warnings were issued for Webb County, thus ending any hope for another flight with that area of convection. Later into the afternoon, more convection fired in LaSalle and Dimmit counties. This convection was much better organized with good bases and inflow. Seeding was concluded as this convection had been given the proper dose due to its size.

September was very active this year, with a total of 119(40g) BIP Flares and 4,720g of AgI burned. A total of ten seeding flights took place on eight operational days. As well, three reconnaissance flights took place. The precipitation graphic below shows that September was probably the wettest month of the operational season. Almost all locations in the target area saw greater than 2 inches of rain during the month, with the exception of extreme southern Webb County and portions of Dimmit and Zavala counties. The wet spots were northeastern LaSalle County, northern Uvalde County, and central Webb County.



October 2009

As stated before, no operational seeding flights took place during the month of October. The graphic below can tell a lot about what type of precipitation fell during the month. Usually, when convection is present, rainfall totals have a much larger gradient within a small distance. When precipitation is more stratiform in nature, precipitation totals are more uniform. The graphic below shows much more uniform precipitation distributions over the target area. This explains why no cloud seeding missions were conducted in October, since operations usually only take place with convective type clouds. Locations in the central and eastern portions of the target area were the wettest while locations in southern Webb County seemed to be the driest.

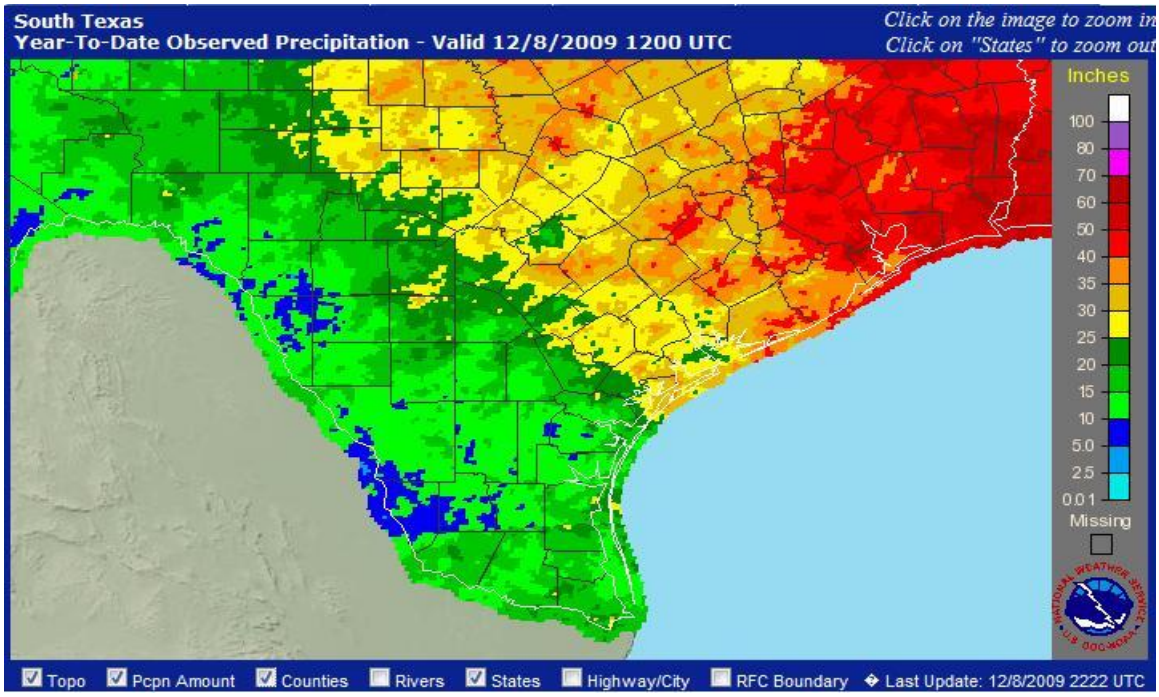


November 2009

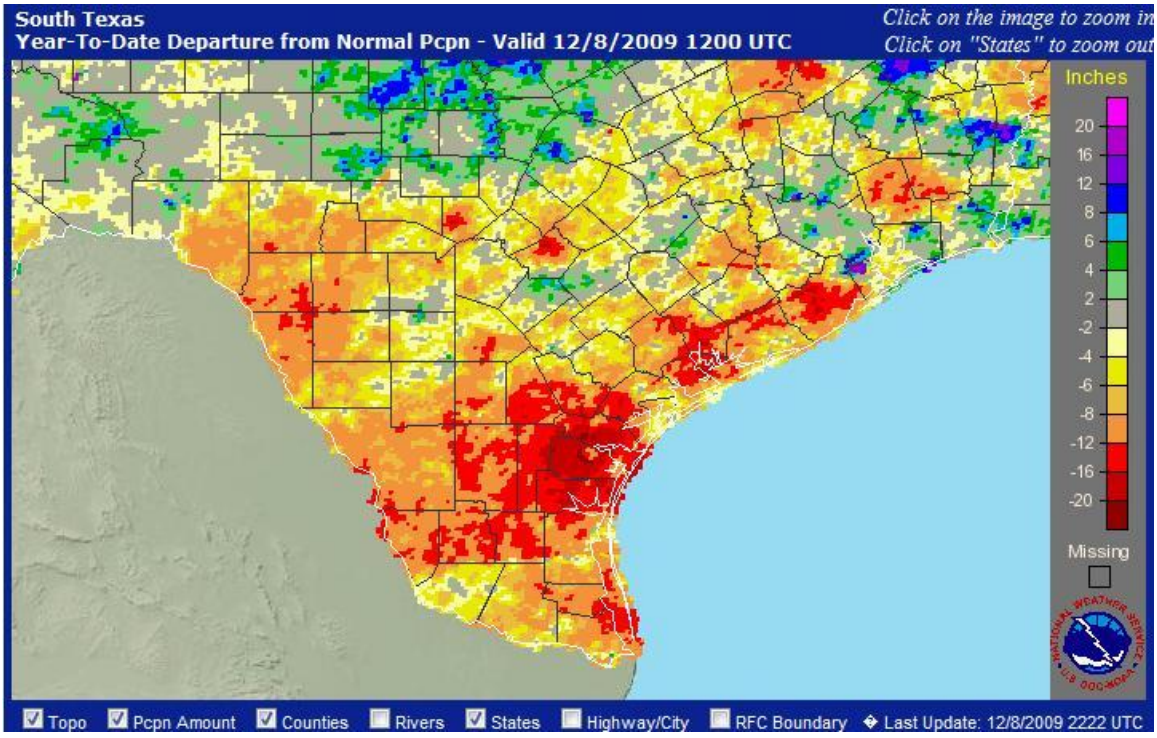
As was true last year, no missions were conducted in the month of November due to the total lack of any seedable convection.

Climatology of 2009

The first graphic below shows the 2009 estimated rainfall for South Texas through December. The second graphic below shows the departure from normal from precipitation across south Texas. This continues to show the precipitation trends for the year and how south Texas remained mostly dry in 2009.



Going county by county, starting in the northern target area, Uvalde County saw anywhere between 10 inches in the southwestern corner of the county and up to 20 inches on the eastern side of the county. As you go south in Zavala, Dimmit, and Webb counties, anywhere from 10 to 20 inches fell, but some portions of western Zavala County and southwestern Webb County received less than 10 inches through most of 2009. Locations well to the east/northeast seemed to fair much better than the target area.

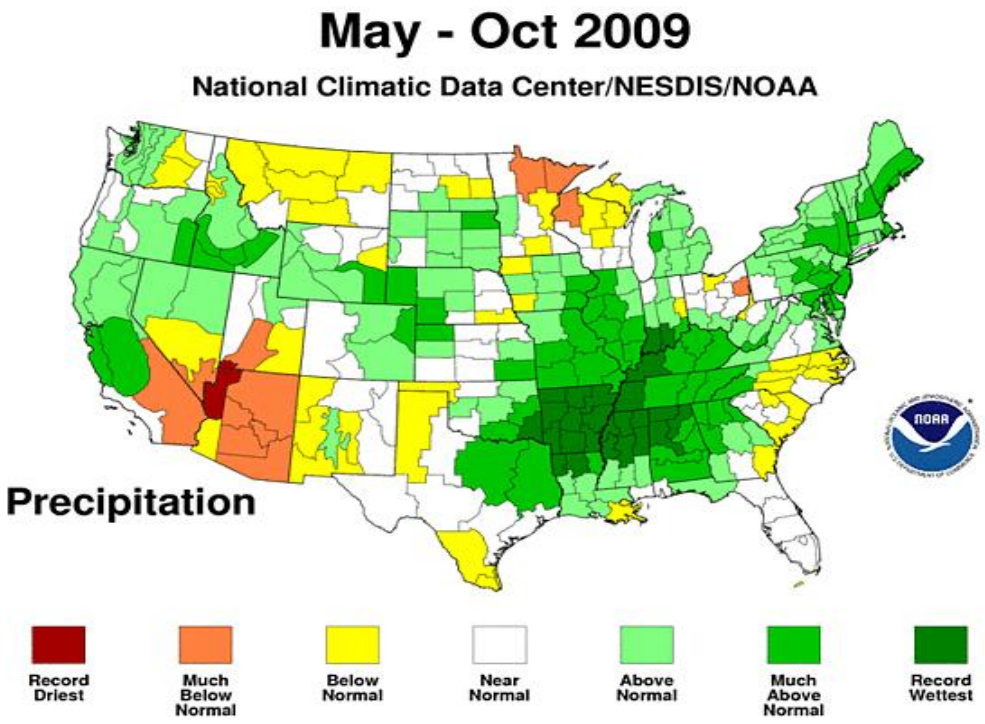


This graphic really helps to make sense of the rainfall totals from the last graphic. It shows that the entire target area was below normal in regards to precipitation for the year. The driest areas of the target area were mostly in southern Webb County, with deficits on the order of 12 inches. Locations in eastern Dimmit, southeastern Zavala, and northern Zavala ~~faired~~ fared the best with deficits only around 2 inches. However, believe it or not, other locations were drier than the Southwest Texas target area, mainly the coastal areas where deficits as large as 20 inches were recorded this year. Just to the north of the Edwards Aquifer recharge zone, rainfall totals were above normal, showing a sharp contrast between drought over south Texas and a normal precipitation year for locations to the north.

The next two figures take another look at how south Texas compared to the rest of the country in terms of precipitation in 2009.

The next figure is a color coded picture of the United States. This graph represents precipitation from a time of May of 2009 to October 2009. This essentially depicts the average seeding season in South Texas, with the exception of the early spring months, March and April. This graphic shows how Texas compared to the rest of the U.S during the summer of 2009. It seemed that the southwestern U.S was even in worse shape than Texas, with record dryness occurring in southern California and into Arizona. In contrast, most of the southeast U.S. into the Tennessee River Valley saw record rainfall over the same time frame. This pattern shows a persistent high over the southwestern U.S into the southern Plains, which includes Texas. Transversely, a persistent trough was located over the southeastern US and eastern U.S.

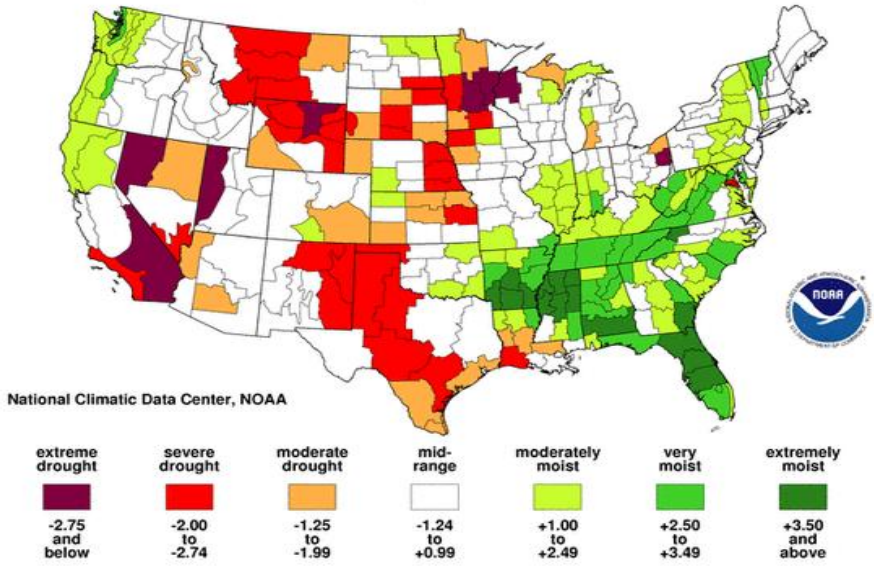
For people who are unfamiliar with a trough and ridge, an explanation will follow of these common weather systems. A trough or as it is commonly referred to, a trough of low pressure, usually induces rising air, which allows cooler and warmer air to interact and create a temperature and pressure difference. These temperature and pressure differences usually create weather, most commonly in Texas, showers and thunderstorms. When a ridge or a ridge of high pressure is present, air is generally sinking, creating subsidence, or drying of the air. This eliminates most of the moisture from the air including clouds. High pressure is usually associated with fair weather and warm temperatures during the summer, whereas low pressure is usually associated with cooler temperatures and more precipitation.



The next three images will further illustrate the dryness of the summer of 2009 and uses the Palmer Drought Severity Index (PDSI). The PDSI is a meteorological index of drought. This takes into account hydrological factors such as precipitation, evaporation, and soil moisture. This series of graphics will show the progression of the drought into the summer and finally the easing of the drought by the end of the seeding season. The first graphic shows the PDSI during the month of May. It shows the south Texas region classified as in intense drought, with locations to the south in a moderate drought. The second graphic shows the PSDI during the month of July. This shows extreme over most all of south Texas with exceptional drought conditions to the east of the target area. Finally, the last graphic shows much improved conditions over almost all of south Texas for September, with much wetter conditions reported over much of the area.

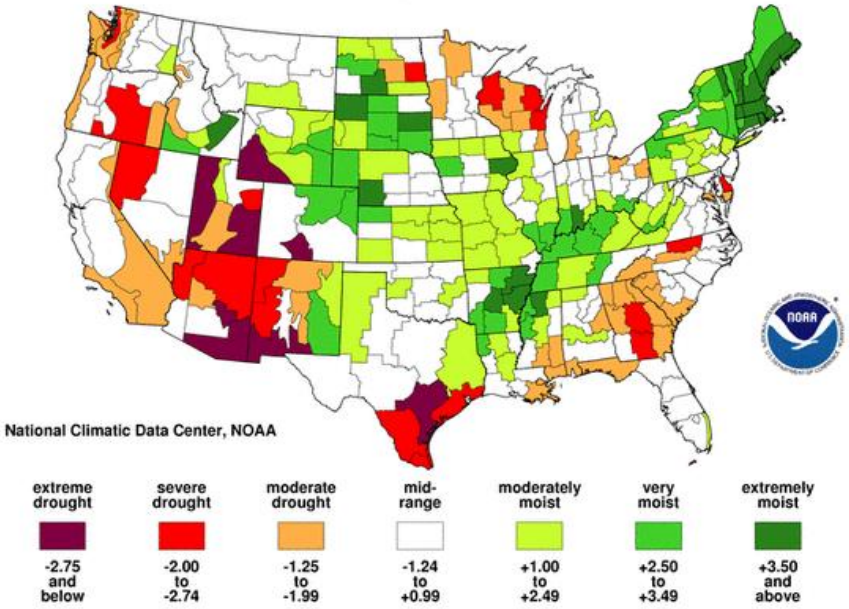
Palmer Z Index
Short-Term Conditions

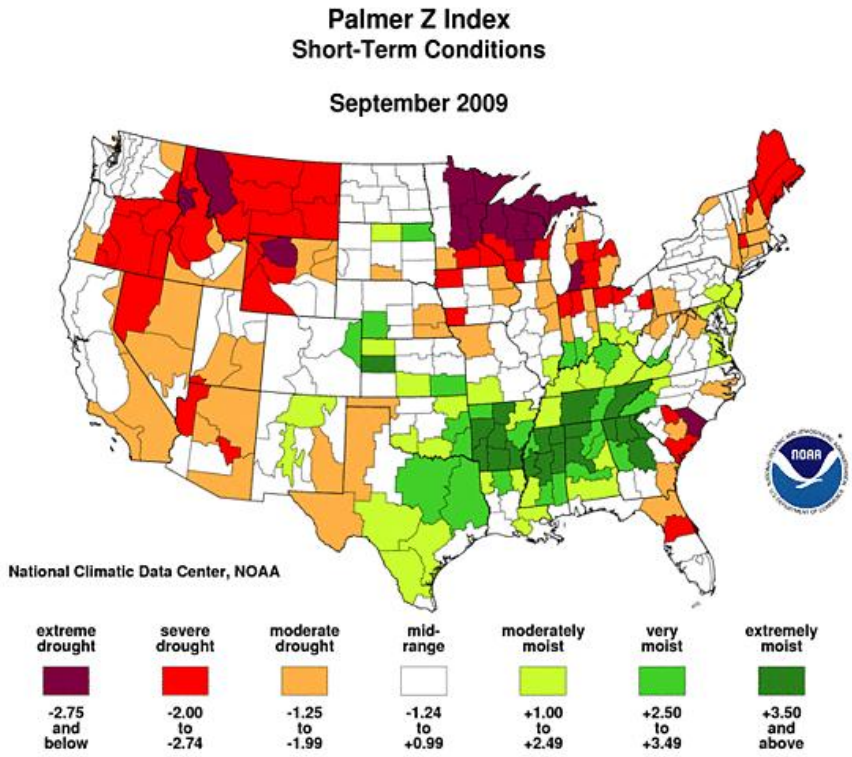
May 2009



Palmer Z Index
Short-Term Conditions

July 2009





Monthly Flight Activity

Below is a collection of the monthly totals for the project. These tables were included on the web page throughout the seeding season. These tables will give a statistical glance at the season. Also, as done in previous final reports, a historical table will be provided so a comparison can be made from previous years of the project.

March 2009 Flight Activity

Flight	Date	Aircraft	Start time	End time	Total time (hours)	Counties	Materials used	Total Seeding Material	Purpose
S-1	3/11/2009	622X	5:50 PM	7:05 PM	1.15	Zavala	3(40g) BIP Flares	120g AgI	Rain Enhancement
R-1	3/25/2009	622X	5:30 PM	6:45 PM	1.15	Webb	N/A	N/A	Recon
S-2	3/26/2009	622X	11:00 AM	12:00 PM	1	Zavala	28(40g) BIP Flares	1120g AgI	Hail Suppression

April 2009 Flight Activity

Flight	Date	Aircraft	Start time	End time	Total time (hours)	Counties	Materials used	Total Seeding Material	Purpose
S-3	4/17/2009	622X	10:15 PM	11:40 PM	1.45	Webb	53(40g) BIP Flares	2120g	Hail Suppression
R-2	4/29/2009	622X	9:55 PM	11:25 PM	1.5	Zavala	N/A	N/A	Hail Suppression No inflow found

May 2009 Flight Activity

Flight	Date	Aircraft	Start time	End time	Total time (hours)	Counties	Materials used	Total Seeding Material	Purpose	Reason
R-3	5/15/2009	57AA	4:55 PM	5:40 PM	0.85	Webb	N/A	N/A	Recon	Poorly developed clouds; no inflow
R-4	5/15/2009	57AA	7:30 PM	8:55 PM	1.25	Dimmit	N/A	N/A	Recon	Couldn't find inflow with storms
S-4	5/15/2009	622X	8:35 PM	9:35 PM	1	Dimmit Webb	16(40g) BIP Flares	640g AgI	Rain Enhancement	
S-5	5/16/2009	622X	9:30 AM	12:20 PM	2.95	Frio LaSalle Uvalde Webb	38(40g) BIP Flares	1520g AgI	Rain Enhancement	
R-5	5/22/2009	370P	2:45 PM	3:05 AM	0.5	Uvalde	N/A	N/A	Recon	Flares would not fire
S-6	5/23/2009	57AA	11:35 PM	12:35 PM	1	Uvalde	4(40g) BIP Flares	160g AgI	Rain Enhancement	
S-7	5/23/2009	622X	4:45 PM	6:15 PM	1.5	LaSalle	6(40g) BIP Flares	240g AgI	Rain Enhancement	
S-8	5/23/2009	622X	9:00 PM	11:15 PM	2.15	Dimmit Webb	12(40g) BIP Flares	480g AgI	Rain Enhancement	
S-9	5/24/2009	622X	3:15 PM	5:35 PM	3.2	Uvalde	26(40g) BIP Flares	1040g AgI	Rain Enhancement	
S-10	5/27/2009	622X	4:00 PM	5:55 PM	1.95	Edwards	8(40g) BIP Flares 46(40g) BIP Flares	320g AgI 1840g AgI	Rain Enhancement Hail Suppression	
S-11	5/27/2009	847P	6:10 PM	8:00 PM	1.9	Uvalde	50(40g) BIP Flares	2000g AgI	Hail Suppression	
S-12	5/27/2009	622X	7:55 PM	8:55 AM	1	Zavala	6(40g) BIP Flares 33(40g) BIP Flares	240g AgI 1320g AgI	Rain Enhancement Hail Suppression	
S-13	5/29/2009	622X	1:05 AM	3:05 AM	2	Uvalde	13(40g) BIP Flares	520g AgI	Rain Enhancement	
S-14	5/29/2009	622X	1:50 PM	4:30 PM	2.8	Dimmit Zavala	39(40g) BIP Flares	1560g AgI	Rain Enhancement	
S-15	5/29/2009	622X	6:30 PM	8:15 PM	1.75	Uvalde Webb	13(40g) BIP Flares	520g AgI	Rain Enhancement	
R-6	5/30/2009	847P	5:00 PM	7:30 PM	2.5	LaSalle	N/A	N/A	Recon	No inflow Weak convection
S-16	5/31/2009	370P	5:35 PM	8:00 PM	2.55	Dimmit Zavala	54(40g) BIP Flares	2160g AgI	Hail Suppression	

June 2009 Flight Activity

Flight	Date	Aircraft	Start time	End time	Total time (hours)	Counties	Materials used	Total Seeding Material	Purpose
S-17	6/1/2009	622X	6:05 PM	7:15 PM	1.1	Webb	8(40g) BIP Flares	320g AgI	Rain Enhancement
R-7	6/1/2009	622X	8:45 PM	9:25 PM	0.7	LaSalle	N/A	N/A	Recon / Very weak cells
S-18	6/2/2009	622X	9:35 PM	11:00 PM	1.45	Uvalde Zavala	22(40g) BIP Flares	880g AgI	Rain Enhancement
R-8	6/3/2009	370P	3:20 PM	3:55 PM	0.5	LaSalle	N/A	N/a	Recon No inflow
S-19	6/3/2009	370P	4:50 PM	7:05 PM	2.15	Dimmit LaSalle Zavala	41(40g) BIP Flares	1640g AgI	Rain Enhancement
S-20	6/25/2009	178M	3:53 PM 4:36 PM	4:00 PM 5:00 PM	0.5	Uvalde	4(40g) BIP Flares	160g AgI	Rain Enhancment
S-21	6/30/2009	622X	2:25 PM	3:35 PM	1.1	Real	6(40g) BIP Flares	240g AgI	Rain Enhancement
S-22	6/30/2009	622X	6:25 PM	8:25 PM	2	Dimmit Maverick Webb	55(40g) BIP Flares	2200g AgI	Rain Enhancement
S-23	6/30/2009	622X	9:00 PM	10:50 PM	1.9	Dimmitt Webb	15(40g) BIP Flares	600g AgI	Rain Enhancement

July 2009 Flight Activity

Flight	Date	Aircraft	Start time	End time	Total time (hours)	Counties	Materials used	Total Seeding Material	Purpose
R-9	7/1/2009	622X	9:10 PM	10:05 PM	0.95	LaSalle	N/a	N/a	Recon
S-24	7/2/2009	622X	4:00 PM	7:05 AM	3.05	LaSalle	29(40g) BIP Flares	1160g AgI	Rain Enhancement
						Live Oak			
						McMullen			
						Atascosa			
						Frio			
S-25	7/6/2009	370P	3:50 PM	5:00 PM	1.1	Uvalde	8(40g) BIP Flares	320g AgI	Rain Enhancment
			5:35 PM	5:45 PM	0.1	Uvalde	4(40) BIP Flares	160g AgI	Rain Enhancment
			6:10 PM	6:20 PM	0.1	Zavala	6(40) BIP Flares	240g AgI	Rain Enhancment
S-26	7/6/2009	498P	5:45 PM	8:55 PM	2.9	Webb	5(40g) BIP Flares	200g AgI	Rain Enhancement
R-10	7/7/2009	370P	3:25 PM	4:15 PM	0.5	Webb	N/A	N/A	Recon
S-27	7/7/2009	160P	4:45 PM	5:30 PM	0.75	Uvalde	4(40g) BIP Flares	160g AgI	Rain Enhancement
S-28	7/7/2009	498P	5:55 PM	7:45 PM	1.9	Maverick	24(40g) BIP Flares	960g AgI	Rain Enhancement
						Zavala			
R-11	7/10/2009	370P	4:55 PM	6:35 PM	1.8	Webb	N/A	N/A	Recon/No inflow
R-12	7/11/2009	370P	3:15 PM	5:00 PM	1.75	Webb	N/A	N/A	Recon/No inflow
S-29	7/17/2009	498P	4:35 PM	6:05 PM	1.5	Uvalde	22(40g) BIP Flares	880g AgI	Rain Enhancment
S-30	7/17/2009	370P	6:00 PM	7:50 PM	1.9	Zavala	13(40g) BIP Flares	520g AgI	Rain Enhancment
S-31	7/18/2009	370P	6:30 PM	8:15 PM	1.75	Webb	15(40g) BIP Flares	600g AgI	Rain Enhancement
S-32	7/20/2009	622X	4:40 PM	6:35 PM	2.05	Uvalde	10(40g) BIP Flares	400g AgI	Rain Enhancment
						Zavala			
S-33	7/30/2009	622X	12:45 PM	3:25 PM	2.4	Uvalde	53(40g) BIP Flares	2120g AgI	Rain Enhancment
						Kinny			
						Maverick			
						Zavala			
S-34	7/31/2009	622X	11:55 PM	2:00 PM	2.95	Uvalde	38(40g) BIP Flares	1520g	Rain Enhancment
						Dimmit			
						Webb			
						Zavala			

August 2009 Flight Activity

Flight	Date	Aircraft	Start time	End time	Total time (hours)	Counties	Materials used	Total Seeding Material	Purpose
S-35	8/12/2009	622X	4:25 PM	6:00 PM	2.55	Uvalde	3(40g) BIP Flares	120g AgI	Rain Enhancment
S-36	8/12/2009	622X	8:50 PM	10:00 PM	1.1	Dimmit	3(40g) BIP Flares	120g AgI	Rain Enhancement
S-37	8/13/2009	847P	4:50 PM	6:40 PM	1.9	Kinney	2(40g) BIP Flares	80g AgI	Rain Enhancment Flares would not fire
S-38	8/13/2009	622X	6:00 PM	8:00 PM	2	Dimmit Duval LaSalle Webb	38(40g) BIP Flares	1520g AgI	Rain Enhancement
S-39	8/18/2009	622X	4:15 PM	5:40 PM	1.25	Dimmit Webb	7(40g) BIP Flares	280g AgI	Rain Enhancment
S-40	8/27/209	622X	4:45 PM	6:10 PM	1.35	Uvalde	7(40g) BIP Flares	280g AgI	Rain Enhancment
S-41	8/28/2009	622X	2:25 PM	4:45 PM	2.2	Uvalde LaSalle Zavala	6(40g) BIP Flares	240g AgI	Rain Enhancement
S-42	8/28/2009	498P	4:00 PM	7:00 PM	3	Real Uvalde Dimmit Zavala	23(40g) BIP Flares	920g AgI	Rain Enhancement
S-43	8/30/2009	847P	3:00 PM	5:40 PM	2.4	LaSalle Webb	11(40g) BIP Flares 30(40g) BIP Flares	440g AgI 1200g AgI	Rain Enhancement Hail Suppression
R-13	8/31/2009	370P	7:05 PM	8:15 PM	1.1	Webb	N/A	N/A	No inflow found

September 2009 Flight Activity

Flight	Date	Aircraft	Start time	End time	Total time (hours)	Counties	Materials used	Total Seeding Material	Purpose
S-44	9/1/2009	622X	3:10 PM	4:05 PM	0.95	Dimmit	7(40g) BIP Flares	280g AgI	Rain Enhancement
						Zavala			
S-45	9/1/2009	622X	5:40 PM	7:15 PM	1.35	LaSalle	10(40g) BIP Flares	400g AgI	Rain Enhancement
						Uvalde	1(1000g) BIP Flare	1000g CaCl	
S-46	9/4/2009	622X	7:20 PM	9:10 PM	1.9	Dimmit	25(40g) BIP Flares	1000g AgI	Rain Enhancement
						LaSalle			
						Webb			
						Zavala			
S-47	9/5/20098	847P	3:05 PM	4:55 PM	1.9	LaSalle	15(40g) BIP Flares	600g AgI	Rain Enhancement
R-14	9/6/2009	847P	2:35 PM	3:40 PM	1.05	Uvalde	N/A	N/A	Could not find Inflow
S-48	9/7/2009	847P	5:35 PM	6:45 PM	1.1	Zavala	2(40g) BIP Flares	80g AgI	Rain Enhancement
S-49	9/9/2009	370P	1:50 PM	3:35 PM	1.75	Uvalde	6(40g) BIP Flares	240g AgI	Rain Enhancement
S-50	9/9/2009	622X	5:20 PM	6:15 PM	0.95	Zavala	7(40g) BIP Flares	280g AgI	Rain Enhancement
S-51	9/9/2009	622X	10:25 PM	12:00 PM	2.25	Maverick	15(40g) BIP Flares	600g AgI	Rain Enhancement
						Zavala			
R-15	9/19/2009	370P	3:00 PM	4:35 PM	1.55	Webb	N/A	N/A	Recon Absent of bases and no inflow
S-52	9/22/2009	622X	7:10 AM	8:40 AM	1.5	Uvalde	12(40g) BIP Flares	480g AgI	Rain Enhancement
S-53	9/28/2009	622X	10:25 PM	11:40 PM	1.15	Uvalde	8(40g) BIP Flares	320g AgI	Rain Enhancement
R-16	9/29/2009	622X	11:20 AM	11:55 AM	0.55	Webb	N/A	N/A	No inflow
S-54	9/29/2009	622X	2:20 PM	3:50 PM	1.5	Dimmit	11(40g) BIP Flares	440g AgI	Rain Enhancement
						LaSalle			

Historical SWTREA Flight Information

The table below shows a history of the seeding project since it became operational in 1999. This table shows an increase in flights and material used in 2009 compared to 2008. As well, 2009 showed a large jump in reconnaissance flights from previous years. The increased flight activity, both seeding and reconnaissance, indicated an aggressive approach to seeding during this very dry year over south Texas.

Year	Recon flights	Seeding flights	Flight hours	Seeding agents distributed		No. Aircraft Assigned	
				AgI Flare (gms)	AgI Liquid (gms)	Base	Top
1999	2	55	115	26,340	3,743	2	0
2000	8	69	99	15,040	10,322	2	0
2001	21	99	222	37,160	10,322	3	0
2002	26	67	222	34,900	34,231	3	0
2003	26	74	195	49,096	1,446	3	0
2004	19	76	185	45,720	0		
2005	3	62	124	40,720	0		
2006	6	75	160	45.920	0		
2007	6	32	54	17.000	0		
2008	7	47	78	35,400			
2009	16	51	113	43,280			
Total for 10 years	119 Flights	509 Flights	1,452 Hours	364,236 Grams AgI	56,321 Grams AgI		

DAILY FLIGHT TRACKS

Each day that operations took place, a flight track was created on the TITAN computer that is used for radar and tracking purposes. There are a number of these flight tracks generated throughout the seeding season. In order to save some paper, the flight tracks will be included on a CD which is located on the back cover of this report. This will enable anyone who wishes to read the operational summary for a particular day then look at where the plane actually flew.

Conclusions and Evaluations

The Southwest Texas Rain Enhancement Association has just now completed its tenth year of operations and the ninth full year of 24-hour 7-day per week cloud seeding. This year saw an increase in flight activity even though drought conditions existed for most of the seeding season. 2009 was another dry year over south Texas, continuing an extended drought from 2008. Exceptional drought conditions existed over the area but this did not stop weather modification activities over the target area, with a rather busy season occurring between May and September. 2009 was actually wetter than 2008 but not by much. This did not only affect the Southwest Texas project but the South Texas project. The neighboring project to the east, the South Texas Weather Modification Association, dealt with the same dry conditions as the target area in southwest Texas. They as well had a very active season due to aggressive seeding operations during the dry summer. For the Southwest Texas project, there were sixty-seven flights during this year's 8-month season. Of the sixty-seven flights, there were fifty-one seeding flights and sixteen reconnaissance missions that took place in 2009. The Southwest Texas Rain Enhancement Association continues to serve as a demonstration program to many of the other weather modification programs in Texas, demonstrating effective rain enhancement and hail suppression techniques on many different types of storms at any time of the day or night.

The annual evaluation for the project is included under appendix A. The evaluation includes the radar analysis for the cloud seeding project. The analysis is broken into various parts. The first part analyzes the type of system that was being seeded. An explanation of what a different system is considered is included in the report. The micro-regionalization includes a county-by-county breakdown of seeding efforts. This evaluation shows increase in precipitation, with some radar error, for each county for 2009. At the end, the increase per acre feet of water is determined by adding the totals for the different cloud systems seeded.

Acknowledgements

People behind the 2009 SWTREA project

The SWTREA has now completed its ninth year as a self-sufficient weather modification project. As a result of many hours of consultation, hard work, training, and perseverance, we are confident in our abilities to continue seeding storms in 2009 and beyond, exhibiting the same aggressive and determined manner as this year's performance.

Our Association would like to acknowledge the many individuals that guided and encouraged us during the 2009 season. Thanks to our newest pilot, Mathew Pope that spent countless hours flying the skies of southwest Texas during the 2009 season. As well, I would like to thank Ed Walker, our pilot in command and project manager, who has made this project what is it and made it extremely successful. Without these two pilots, the project would not be anything near what it is currently. Debbie Farmer, clerical for the project who makes certain everything is in order administrative wise.

As well, I would like to thank many members of the South Texas Weather Modification Association. In particular, the project staff that we not only share an office with, but ideas, skill, and experience that makes the Southwest Texas project even better.

The Southwest Texas Rain Enhancement Association Board of Directors:
Bill Martin, Chairman
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Matthew Pope, Pilot
Debbie Farmer, Wintergarden Underground Water District clerical

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Tommy Shearrer, SWTMA President
Todd Flanagan, Project Meteorologist
Craig Funke, PIC
Candi Gonzales, Evergreen Underground Water District clerical

Appendix A

ANNUAL EVALUATION REPORT 2009

Arquímedes Ruiz-Columbié
Active Influence & Scientific Management

Cloud seeding operations 2009 began over South West Texas Rain Enhancement Association target area in April. This annual report serves as a summary of results. A total of **82 clouds** were seeded and identified by TITAN in **34 operational days.** One of these operational days did not get proper data (April 17th). Table 1 in page 1 summarizes the general figures:

Table 1: Generalities

First operational day: **March 11th 2009**
Last operational day: **September 29th 2009**

Number of operational days: 34
(two in March, one in April, six in May, five in June, eight in July, five in August, and seven in September)

According to the daily reports the twenty-three operational days with proper data were qualified as:

Twenty-three with excellent performance
Three with very good performance
Four with good performance
One with fair performance

Two days classified as experimental (June 25th, August 27th)
One with corrupted data (April 17th)

Number of seeded clouds: 82
(37 small seeded clouds, 14 large seeded clouds, 29 type B seeded clouds, 2 npf)

Missed Opportunities: one (~ 1 %) (with lifetime longer than 45 minutes)

August 12th: Cloud # 1142 over Webb County

Small Clouds

Evaluations were done using TITAN and NEXRAD data.

Table 2 shows the results from the classic TITAN evaluation for the 37 small seeded clouds which obtained proper control clouds.

Table 2: Seeded Sample versus Control Sample (37 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	60 min	40 min	1.50	50 (**33**)
Area	74.8 km^2	45.4 km^2	1.64	64 (**39**)
Volume	225.2 km^3	128.8 km^3	1.75	75 (**41**)
Top Height	7.9 km	7.2 km	1.10	10 (**3**)
Max dBz	51.6	49.4	1.04	4 (**2**)
Top Height of max dBz	3.6 km	3.5 km	1.03	3 (**2**)
Volume Above 6 km	39.5 km^3	21.9 km^3	1.80	80 (**40**)
Prec.Flux	513.2 m^3/s	278.2 m^3/s	1.84	84 (**28**)
Prec.Mass	1952.4 kton	735.9 kton	2.65	165 (**95**)
CloudMass	189.5 kton	98.9 kton	1.92	92 (**54**)
η	10.3	7.4	1.39	39 (**17**)

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 164 flares were used in this sub-sample with an excellent timing (**91 %)** for an effective dose about **45 ice-nuclei per liter**. The seeding operation for small clouds lasted about **8 minutes** in average. An excellent increase of **95 %** in precipitation mass together with an increase of 54 % 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 (33 %), area (39 %) volume (41 %), volume above 6 km (40 %), and precipitation flux (28 %) are notable. There are slight increases in top height (3 %) and maximum reflectivity (2 %). The seeded sub-sample seemed 17 % more efficient than the control sub-sample. Results are evaluated as **excellent** for this sub-sample.

An increase of 95 % in precipitation mass for a control value of 735.9 kton in 37 cases means:

Δ_1 = 37 x 0.95 x 735.9 kton = 25 867 kton = 20 978 ac-f

Large Clouds

The sub-sample of 14 large seeded clouds received a synergetic analysis. In average, the seeding operations on these large clouds affected 65 % of their whole volume; with an excellent timing (93 % of the material went to the clouds in their first half-lifetime). A total of 97 flares were used in this sub-sample for an effective dose about **65 ice-nuclei per liter**.

Also in average, large clouds were 25 minutes old when the operations took place; the operation lasted about 15 minutes, and the large seeded clouds lived 225 minutes.

Table 3 shows the corresponding results:

Table 3: Large Seeded Sample versus Virtual Control Sample (14 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	225 min	195 min	1.15	15
Area	882 km^2	783 km^2	1.13	13
Volume	3,011 km^3	2,442 km^3	1.23	23
Volume Above 6 km	917 km^3	746 km^3	1.23	23
Prec.Flux	6,515 m^3/s	5,588 m^3/s	1.17	17
Prec.Mass	53,581 kton	36,613 kton	1.46	46

An increase of 46 % in precipitation mass for a control value of 36 613 kton in 14 cases may mean:

Δ_2 = 14 x 0.46 x 36 613 kton = 235 788 kton = 191 224 ac-f

Type B Clouds

The sub-sample of 29 type B seeded clouds also received a synergetic analysis. In average, the seeding operations on these type B clouds affected 16 % of their whole volume with an excellent timing (83 % of the material went to the clouds in their first half-lifetime). A total of 567 flares were used in this sub-sample for an effective dose about **125 ice-nuclei per liter**.

Also in average, type B clouds were 150 minutes old when the operations took place; the operation lasted about 37 minutes, and the type B seeded clouds lived 285 minutes.

Table 4 shows the results:

Table 4: Type B Seeded Sample versus Virtual Control Sample (29 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	285 min	275 min	1.04	4
Area	2,032 km^2	1,976 km^2	1.03	3
Volume	6,558 km^3	6,253 km^3	1.05	5
Volume Above 6 km	1,904 km^3	1,817 km^3	1.05	5
Prec.Flux	17,157 m^3/s	16,557 m^3/s	1.04	4
Prec.Mass	144,546 kton	133,279 kton	1.09	9

An increase of 9 % in precipitation mass for a control value of 133 279 kton in 28 cases may mean:

Δ_3 = 28 x 0.09 x 133 279 kton = 347 858 kton = 282 113 ac-f

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3$ **= 494 315 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 Gage (season value)	% (increase)
Uvalde	**21**	**24**	**98,300**	**1.18**	**9.94 in**	**11.9**
Zavala	**16**	**24**	**47,000**	**0.68**	**7.16 in**	**9.5**
Dimmit	**15**	**17**	**61,500**	**0.86**	**8.47 in**	**10.2**
La Salle	**12**	**14**	**45,500**	**0.57**	**8.63 in**	**6.6**
Webb	**13**	**17**	**97,100**	**0.53**	**7.65 in**	**6.9**
Frio	1	7	44,200			
Maverick	2	9	9,400			
Medina	1	4	16,100			
Bandera	1	2	17,000			
Total	**82**	**118**	**436,100**			
Average				**0.76**	**8.37 in**	**9.0**

(**Initial seeding** means the counties were the operations began, whereas **extended seeding** means the counties favored by seeding after the initial operations took place).

Some considerations on hail suppression operations

Four case studies are presented here to illustrate the evaluation of hail suppression operations. In summary, four operational days were dedicated to this type of operations but one of those days (April 17th) did not get proper data. Previous observations of hail storms have suggested that two derivate variables defined below seem to be very useful for hail signatures (particularly when their values approach unity). Variable D1 is defined as the quotient between the mass of the storm in kton and the corresponding volume in cubic kilometers as offered by the generated TITAN files. Variable D2 is defined in an analogous form using the same variables above 6 km altitude. Both variables have density dimensions, but it should be pinpointed that they are radar variables which only take in consideration what the radar sees. The following table # 6 shows the behaviors of these variables for three storms cases for three different periods in the storms lifetimes (before seeding, during seeding, and after seeding):

Table # 6: Analysis of anti-hail seeding operations (three case studies)

	Before seeding	during seeding	after seeding
Case 1: variable D1	**1.05**	**1.07**	**0.94**
variable D2	**1.01**	**1.00**	**0.83**

(March 26th, Storm ID: # 004, 28 flares used, dose: 65 ice-nuclei per liter)

Case 2: variable D1	**0.86**	**1.21**	**1.08**
variable D2	**0.73**	**1.18**	**0.93**

(May 27th, Storm ID: # 1215, 43 flares used, dose: 300 ice-nuclei per liter)

Case 3: variable D1	**1.24**	**1.31**	**0.93**
variable D2	**1.17**	**1.27**	**1.00**

(May 27th, Storm ID: # 1571, 50 flares used, dose: 300 ice-nuclei per liter)

Case 4: variable D1	**1.10**	**1.22**	**1.23**
variable D2	**0.98**	**1.10**	**1.13**

(May 31st, Storm ID: # 14, 56 flares used, dose: 90 ice-nuclei per liter)

Average: variable D1	**1.06**	**1.17**	**1.05**
variable D2	**0.97**	**1.14**	**0.97**

(177 flares used (44.25 per storm), average dose: ~ 190 in/ l)

Data in table # 6 suggest that the seeding operations appeared to diminish the values of variables D1 and D2 for all the cases but one (case # 4) which seemed to continue to grow after seeding; however, the corresponding TITAN file stopped abruptly and did not record the whole storm evolution, and therefore it is impossible to enounce a fair conclusion. However, the seeding operations seemed to have in the other three cases under analysis some favorable impacts in mitigating the hail. Doses in general were very dynamic with an average about **190 ice-nuclei per liter** (almost twice the value in 2008).

Considerations on Hygroscopic Seeding

Some hygroscopic seeding operations were done in order to explore its potentialities**.** These operations took place as a complement of the main glaciogenic seeding operations. A total of 4 cases were achieved (3 type B storms, 1 large storm). Results are described below using the following variables: n (# of cells), precipitation mass per scan, top height of maximum reflectivity, and height of the Centroid.

Table # 7

Case #1	**Before Hyg**	**during Hyg**	**30 min after Hyg**
n	9	10	20
PrecMass/scan	4,551 kton	9,554	55,391
Top maxdBz	4.5 km	3.0	5.4
Centroid h	4.5 km	4.5	4.5

AgI dose: 90; timing 100 %

Case # 2

n	4	9	15
PrecMass/scan	2,532 kton	5,581	28,878
Top maxdBz	4.6 km	5.0	5.7
Centroid h	4.6 km	4.7	4.6

AgI dose: 80; timing 100 %Case # 3

n	4	3	3
PrecMass/scan	10,698 kton	29,673	32,844
Top maxdBz	4.0 km	5.0	3.1
Centroid h	4.5km	4.7	4.1

AgI dose: 290; timing 100 %

Case # 4

n	**4**	**7**	**5**
PrecMass/scan	1,890 kton	6,989	11,325
Top maxdBz	3.1 km	3.0	3.0
Centroid h	3.7 km	3.6	3.7

AgI dose: 100; timing 100 %

Average Case

n	4	7	11
PrecMass/scan	4,918 kton	12,949	32,110
Top maxdBz	4.1 km	4.0	4.3
Centroid h	4.3 km	4.4	4.2

AgI dose: 140; timing 100 %

The average increases in the number of cells and in precipitation mass per scan seem to indicate that the hygroscopic material went into the storms with excellent timing since the target units were still growing at the time of seeding. Additionally, the average top height of maximum reflectivity slightly decreased during the seeding actions, whereas the average reflectivity Centroid height was increasing at the time of seeding but in the next 30 minutes decreased 0.2 km (~ 650 feet), suggesting that a seeding signal were probably present due to the hygroscopic material (although not at supercooled levels). However, the sample is too small to have any statistical significance, and maybe supports the idea that the hygroscopic material might have affected the target units.

An additional comment is perhaps pertinent. The evaluation of weather modification actions always brings back the question about causality (the sequence cause-effect and the explanation of what is happening). Hygroscopic seeding is not an exception. In our case, causal relationships are complex and subtle because the complexity of the processes that produce precipitation involves numerous factors from different scales (planetary, synoptic, mesoscale, and microscale). **Cloud seeding should be considered as a contributory cause,** whereas cloud seedability has to be regarded as the main cause responsible for the precipitation events. It is probably hard to understand, but this distinction is vital for any evaluation to be objective: **the contributory cause is only partly responsible for the final effect**.

Final Comments

1) Results are evaluated as **excellent**; only one operational day was lost due to data corruption (TITAN problems).

2) The micro-regionalization analysis showed increases per county; seedable conditions were relatively more frequent over the northern zones although the other zones received downwind benefits; the average increase in precipitation, referred to rain gage seasonal value, is about **9 %**.

3) Radar estimations of precipitation should be considered as measurements of trend. Nevertheless, seeding operations appeared to improve the dynamics of seeded clouds.

4) Anti-hail suppression operations during the spring seemed to have some success in mitigating hail activity within the seeded clouds. Doses were higher than in previous campaigns.

5) This year hygroscopic seeding was done at a exploratory level and the results are intriguing and promissory. More actions on this direction are advisable, especially on small clouds which usually get proper control clouds and therefore facilitate the contrastive analysis.

Appendix B

GLOSSARY

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, 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 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 µm (10^{-4} 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**.**