Southwest Texas Rain Enhancement Association
2005 Edwards Aquifer Authority Final Report

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The Year in Review

2005 marked the fourth year of operations for the Edwards Aquifer Authority (EAA) by Southwest Texas Rain Enhancement Association (SWTREA). The 2005 seeding season was an interesting one in terms of staff. The project under went some changes in terms of where planes and pilots were. The pilot and plane that was stationed in Uvalde County were moved to San Antonio at Stinson airport. A pilot from the South Texas Weather Modification Association (STWMA) project was used mainly for seeding in Uvalde County. The other two planes were stationed in Carrizo Springs. This pilot occasionally was used for seeding in Uvalde County. During the 2005 season, the cooperation between SWTREA and STWMA continued as SWTREA used pilots stationed in San Antonio for seeding operations. The working relationship between the two projects has allowed both projects to benefit.

Seeding in the Authority target area of Uvalde County saw a total of 21 flights for the 2005 operational year compared to 15 flights in 2004. Also, with the continued cooperation between the two seeding projects, SWTREA flew a total of 6 missions in Medina County. Five of these missions were flown in addition to another mission that was already taking place. One mission was launched specifically for Medina County due to technical difficulties with the SWTMA project on this particular day. As seen above, there were more missions in 2005 than 2004. 2005 was very dry for most parts of south Texas. As written in last year's report, seeding operations in 2004 were suspended for most of June due to excessive flooding across the area. However, when making a comparison with 2003, things seem more normal with a total of 20 flights in 2003.

At the conclusion of the 2005 operational season for the Authority EAA target area, October 31st, a radar evaluation was completed for the program. The findings were presented and discussed towards the end of this report.

The flight logs for the 2005 seeding season are below. This is just for Uvalde County. A separate table will be included for the seeding done in Medina County.

2005 Flight Log For SWTREA EAA Target Area

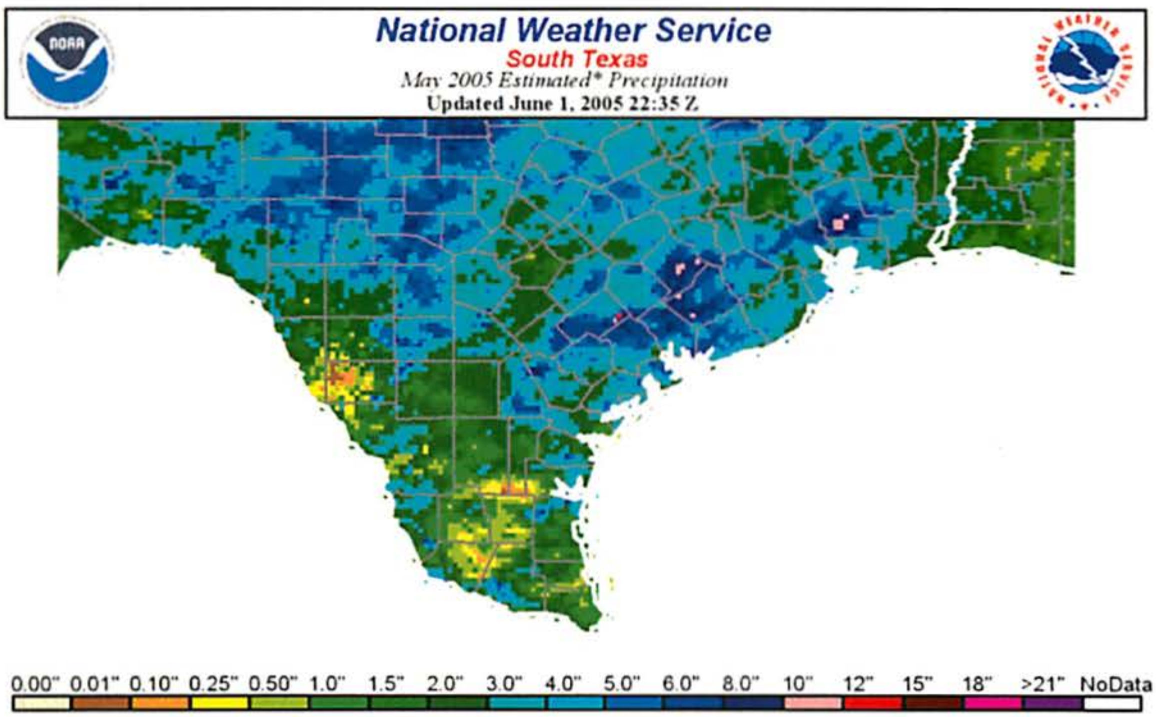
Flight #	Date	Aircraft	Total Time (hours)	Materials Used	Total Seeding Material AgI (g)
1	5/14/2005	498P	1.5	12 BIP Flares (40g)	560
2	5/28/2005	622X	0.5	5 BIP Flares (40g)	200
3	5/28/2005	622X	0.5	11 BIP Flares (40g)	440
4	7/5/2005	622Q	1	4 BIP Flares (40g)	160
5	7/9/2005	622X	1.25	7 BIP Flares (40g)	280
6	7/14/2005	622Q	1.85	7 BIP Flares (40g)	280
7	7/15/2005	622Q	0.75	8 BIP Flares (40g)	320
8	7/16/2005	370P	2	11 BIP Flares (40g)	440
9	7/28/2005	370P	0.9	2 BIP Flares (40g)	80
10	8/3/2005	622Q	0.25	3 BIP Flare (40g)	120
11	8/5/2005	370P	1	15 BIP Flares (40g)	600
12	8/9/2005	370P	1.1	12 BIP Flares (80g)	860
13	8/13/2005	622X	1	15 BIP Flares (40g)	600
14	8/15/2005	622X	0.5	2 BIP Flares (40g)	80
15	8/29/2005	370P	1	9 BIP Flares (40g)	360
16	9/11/2005	622X	0.1	2 BIP Flares (40g)	80
17	10/27/2005	622X	0.8	6 BIP Flares (40g)	280
18	10/31/2005	622X	1.25	10 BIP Flares (40g)	400
Totals **18**			**15.5**	**137 (40g) BIP Flares** **12 (80g) BIP Flares**	**6.780**

2005 Flight Log For EAA (Medina County)

Flight #	Date	Aircraft	Total Time (hours)	Materials Used	Total Seeding Material AgI (g)
1	7/9/2005	162X	0.2	4(40g) BIP flares	160
2	7/14/2005	162X	0.5	5 (40g) BIP flares	200
3	7/24/2005	162X	0.25	8(40g) BIP flares	320
4	7/28/2005	370P	0.1	5(40g) BIP flares	200
5	8/3/2005	162X	0.10	1(40g) BIP flares	40
Totals			1.15	22 (40g) BIP flares	920

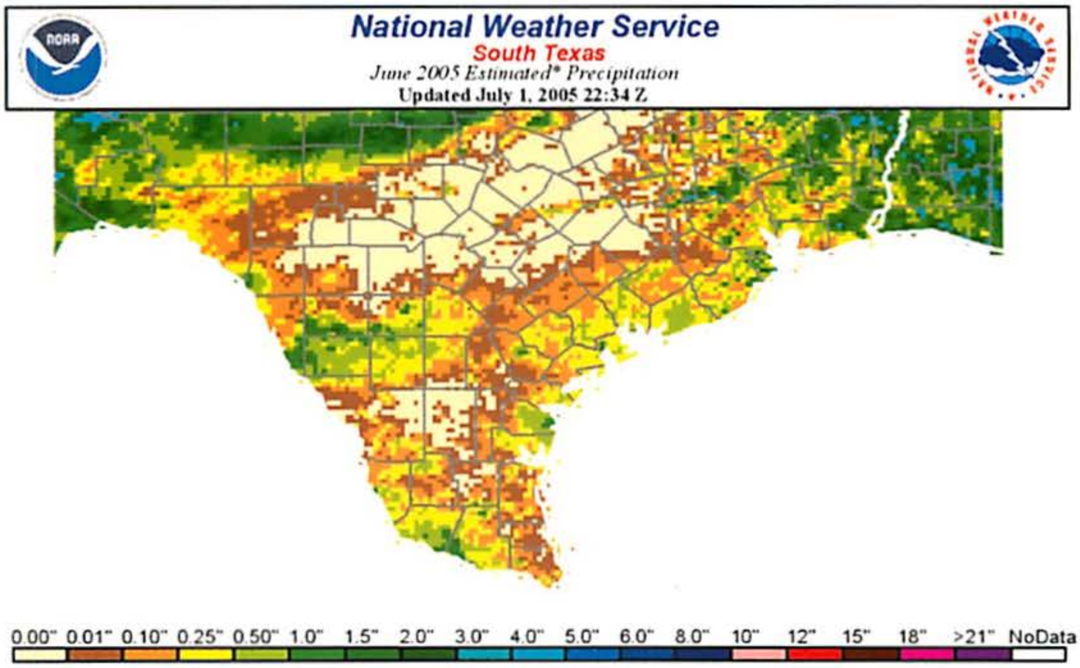
May 2005

The first two weeks of May were unusually quiet for this time of year for the South Texas area. An area of high pressure and an associated mid to upper level ridge caused a very hot and dry weather pattern for the area during this time period. However, this did change for the second half of the month. A total of three missions were flown for the EAA for the Month of May in the SWTREA target area. Also, SWTREA did have part of its mission in Medina County on the 29th due to the movement of the system that was being flown on. The main weather phenomena was a MCC on the 14th and a batch of MCS's that battered the target area and parts of South Texas for the Memorial day weekend.



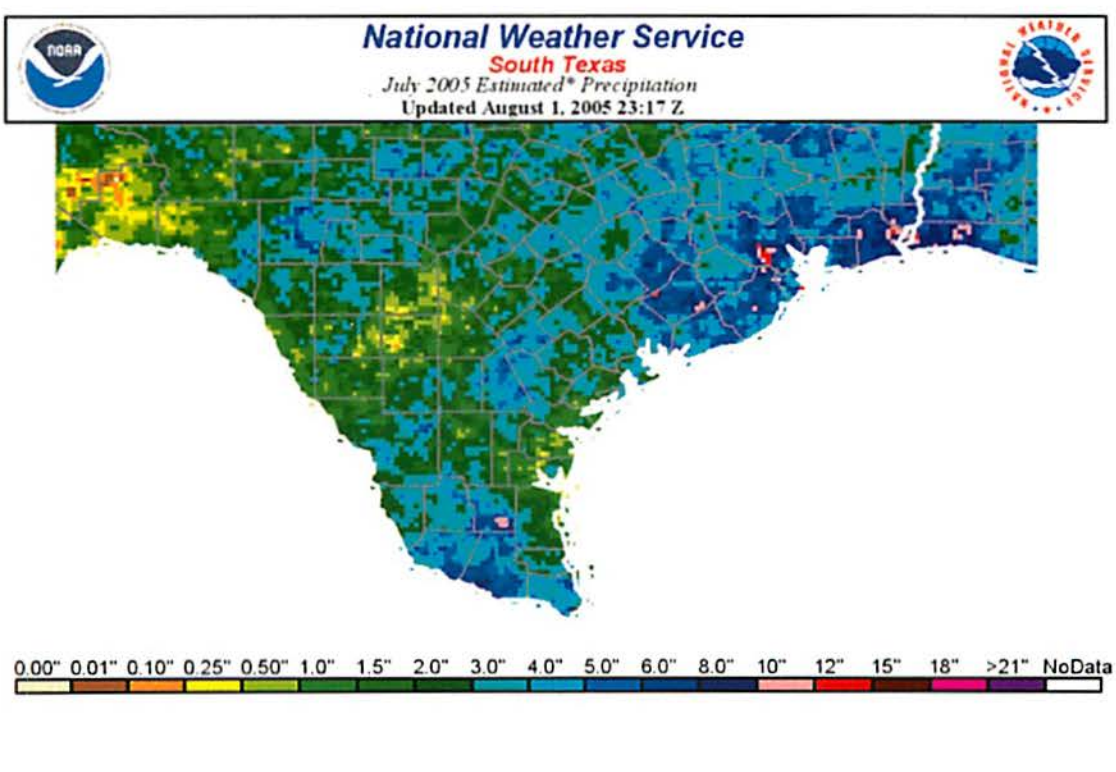
June 2005

June for the South Texas area was unusually dry. A high pressure ridge dominated for most of the month and thus no opportunities for seeding missions in the month of June for Uvalde County were present. Additionally, the association only had one mission due to a shortwave that emerged from Mexico, which was a nocturnal event. The combination of hot and sunny days during the month resulted in almost a total lack of convection over the EAA target area. No missions were flown for the month of June for the EAA target area.



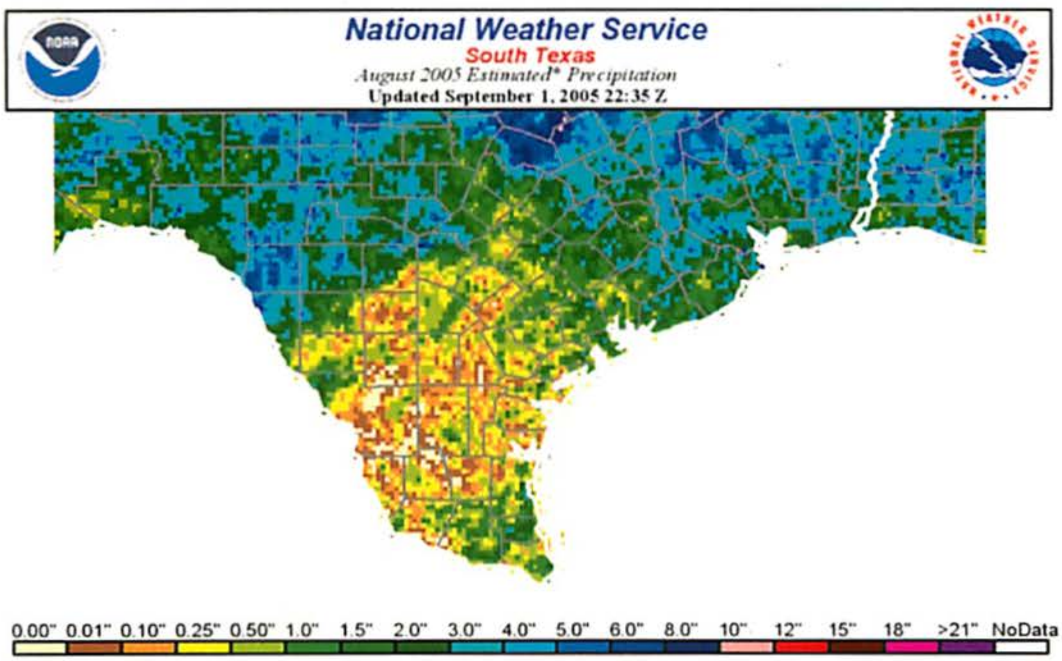
July 2005

Unlike June, July produced a very active weather pattern across most of South Texas. The ridge of high pressure that dominated the weather during June finally broke down at the beginning of July. A series of upper level disturbances, ample moisture and even a hurricane brought much needed rains to the area for most of the month. The seabreeze on a few occasions was enhanced by a very moist and unstable atmosphere which gave San Antonio and surrounding areas ample rainfall. Overall, the month of July was very active in the EAA target area compared to the first two months of seeding operations.



August 2005

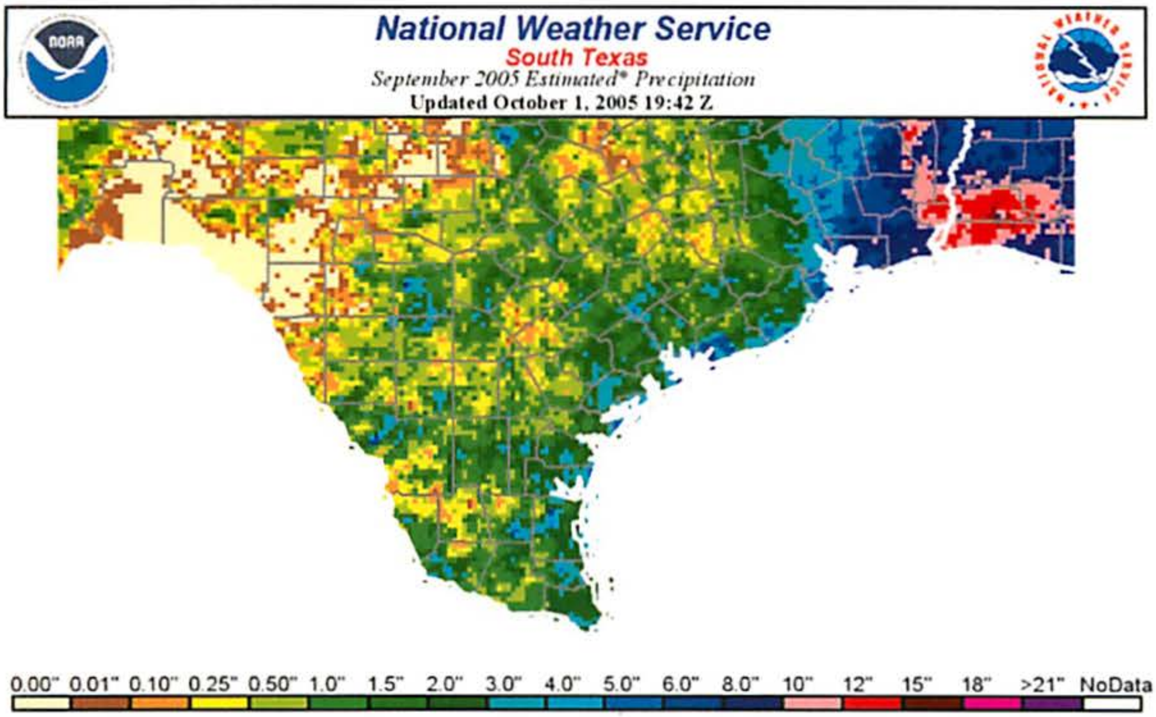
August, which was very different from July, produced numerous opportunities for cloud seeding in Uvalde County. The main reason for the change from very few opportunities to numerous opportunities was a drastic change in the weather pattern. While June offered a very hot and dry month for most of South Texas due to unusually strong high pressure over the area, August was very different. August gave way to several upper level disturbances moving quite close or stalling north of the area and allowed convection to have a chance to get started. A very moist and tropical atmosphere was the setup for most of the days that there was seeding in Uvalde County. A number of upper level troughs provided ample lift for these thoroughly saturated environments to produce scattered convection. Also, with an upper level trough pretty much stationary over West Texas for the first week of August, this allowed ample convection to either invade the target area or allowed outflow boundaries to pass through the area. A total of 6 seeding days took place in Uvalde County in August.



September 2005

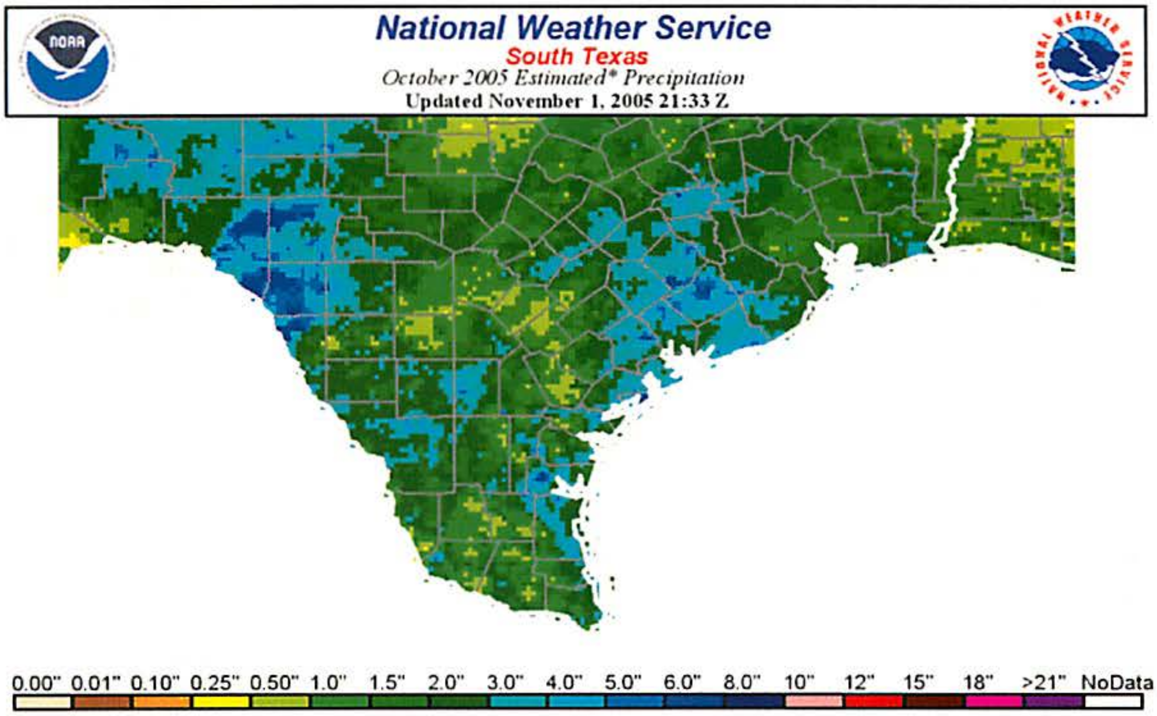
September started out as a very active month in terms of rainfall over most of south Texas. For the first two weeks of the month, seeding missions were conducted almost every day in the SWTREA target area. This however only translated into a few flights for the EAA target area due to the fact that most convection was confined to the coast and the Rio Grande Plains. A total of two missions were flown in the EAA target area. The reason for so few flights was a combination of tropical type activity during the first part of the month that limited convection to coastal counties and the onset of high pressure that brought record temperatures to the area for the last two weeks of September.

Autumn officially began close to the end of the month, but the thermometer across the area stood well above the century mark for at least four straight days. Towards the end of the month, the first cold front of the season made its way into the area but only offered a small cool off and no rain chances with its frontal passage. One of the missions was flown in Medina County, so Uvalde County only had one seeding mission for the month of September



October 2005

October overall was a very quiet time for most of South Texas. An upper level ridge was dominated during the first couple week of the month. A few cold fronts did pass through the area during the month but most of these fronts were moisture deprived due to the pattern of the upper level flow. Near the end of the month and the end of the EAA's seeding season for Uvalde County a couple seeding missions were conducted, adding only two missions for the entire month.



2004/2005 EAA COMPARISON

YEAR	2004			2005		
MONTH	# of flights	Total Seeding Material	# of seeding days	# of flights	Total Seeding Material	# of seeding days
MAY	0	0g AgI	0	3	1,100g AgI	2
JUNE	6	2,120g AgI	6	0	0g AgI	0
JULY	1	80g AgI	1	6	2,120g AgI	6
AUGUST	6	2,440g AgI	6	6	2,280g AgI	6
SEPTEMBER	2	720g AgI	2	1	80g AgI	1
OCTOBER	0	0g AgI	0	2	640g AgI	2
TOTAL	15	5,360g AgI	15	19	5,360g AgI	18

The preceding table gives a historical glance at a comparison of the Authority seeding activities for 2004 and 2005. This is useful to see what kind of activity has been ongoing throughout the last two years of the Authority project.

Meteorological Perspective of Seeding in 2005

This section will be a summary of perceived efforts of cloud seeding as determined by radar trends.

Most convection for the year in Uvalde County did produced positive results according to radar trends. A few events did not offer very good seeding due to large complexes of rain having undefined bases.

May offered a total of three missions, one of which was classified as hail suppression for Uvalde County. The severe weather season which is usually in full swing during this time of the year offered very little in the way of intense convective formation. Typically severe weather is very active in May, but was inhibited this year due to intense high pressure and its associated ridge that built into the area.

June was a very quiet month and no missions took place in the EAA target area. This was due to an unusual area of high pressure that settled over the central U.S for most of the month. This caused a ridge to build and created subsidence which inhibits the formation of clouds and thus not allowing any kind of rain to occur across the area.

July offered a number of chances for seeding missions due to the breaking down of the subtropical ridge over the area. This was replaced with a series of troughs and their associated shortwaves. This very active pattern continued nearly for the entire month and a seeding mission took place for 21 or the 31 days of the month. A total of seven missions took place in Uvalde County. This is very unusual for July, typically high pressure builds in and dry conditions prevail. Most of the activity in Uvalde County was intensified by very tropical conditions that occurred and gave convection more moisture to work with. The weather phenomena this month included mostly sea breeze activity and upper level troughs.

August was also a very active month for Uvalde County. The upper level troughs and associated shortwaves produced a couple MSC's and gave much needed rainfall the area. These moisture filled systems did help the area make up for some of the conditions that prevailed earlier in the year.

In September, activity dwindled, as tropical moisture and the rather active pattern that was felt in July and August decreased over the area. Very warm temperatures prevailed over the area, especially at the end of the month where temperatures were over 100 degrees for five days. This was due to an area of high pressure that produced a strong cap over the region. A total of six missions were flown, mostly at the beginning of the month.

October was the last month in which seeding operations were conducted for the EAA target area. A total of two missions were flown. The small amount of flight activity was due to a strong upper level ridge pattern that was in place for most of south Texas. A strong cold front did move into the area near the 31st but little moisture was available for the front even through a mission was still launched.

Overall, with a total of 19 flights for the EAA target area, the season is summarized as very good. Most of the flights that did occur in the EAA target were rated as excellent or very good. The clouds in the target area seemed to respond well when seeding was conducted. For the months where activity was at a minimum, the upper level ridge and associated high pressure at the surface were the contributing factors to the lack of clouds and convection.

ANNUAL EVALUATION REPORT 2005
EAA

Arquímedes Ruiz-Columbié
Active Influence & Scientific Management

Cloud seeding operations 2005 began over EAA target area in May. This annual report serves as a summary of results. A total of **48 clouds** were seeded and identified by TITAN in **26 operational days**. Table 1 in page 1 summarizes the general figures:

Table 1: Generalities

First operational day: **May 14th 2005**
Last operational day: **October 31st 2005**

Number of operational days: 26
(Two in May, one in June, eleven in July, seven in August, three in September, and two in October)

According to the daily reports operational days were qualified as:

Eleven with excellent performance
Seven with very good performance
Six with good performance
One with poor performance

One without proper data

(One operational day did not obtain proper data; this evaluation considered only days with proper data)

Number of seeded clouds: 48
(30 small seeded clouds, 7 large seeded clouds, 9 type B seeded clouds, and 2 seeded clouds did not get proper files)

Missed Opportunities: none (with lifetime longer than 45 minutes)
Small Clouds

Evaluations were done using TITAN and NEXRAD data.

Table 2 shows the results from the classic TITAN evaluation for the 30 small seeded clouds which obtained proper control clouds.

Table 2: Seeded Sample versus Control Sample (30 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	65 min	45 min	1.44	44 **(30)**
Area	59.9 km^2	39.1 km^2	1.53	53 **(28)**
Volume	163.7 km^3	97.7 km^3	1.68	68 **(31)**
Top Height	7.6 km	7.2 km	1.05	5 **(2)**
Max dBz	49.8	47.9	1.04	4 **(3)**
Top Height of max dBz	4.2 km	4.2 km	1.00	0 **(-1)**
Volume Above 6 km	12.1 km^3	4.8 km^3	2.52	152 **(83)**
Prec.Flux	459.5 m^3/s	257.3 m^3/s	1.79	79 **(26)**
Prec.Mass	1947.0 kton	787.7 kton	2.47	147 **(99)**
CloudMass	143.8 kton	78.0 kton	1.84	84 **(29)**
η	13.5	10.1	1.34	34 **(56)**

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 136 flares were used in this sub-sample with an excellent timing (80 %) for an effective dose about 105 ice-nuclei per liter. An excellent increase of 99 % in precipitation mass together with an increase of 29 % 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 (30 %), area (28 %) volume (31 %), volume above 6 km (83 %), and precipitation flux (26 %) are notable. There were slight increases in maximum reflectivity (3 %), and in top height (2 %). The seeded sub-sample seemed 56 % more efficient than the control sub-sample. Results are evaluated as excellent.

An increase of 99 % in precipitation mass for a control value of 787.7 kton in 30 cases means:

$$\Delta_1 = 30 \times 0.99 \times 787.7 \text{ kton} = 23\,394.7 \text{ kton} = 18\,973 \text{ ac-f}$$

Large Clouds

The sub-sample of 7 large seeded clouds received a synergetic analysis. In average, the seeding operations on these large clouds affected 65 % of their whole volume; with a perfect timing (100 % of the material went to the clouds in their first half-lifetime). A total of 85flares were used in this sub-sample for an effective dose about 90 ice-nuclei per liter.

Also in average, large clouds were 25 minutes old when the operations took place; the operation lasted about 50 minutes, and the large seeded clouds lived 145 minutes.

Table 3 shows the corresponding results:

Table 3: Large Seeded Sample versus Virtual Control Sample (7 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	145 min	120 min	1.21	21
Area	854 km^2	761 km^2	1.12	12
Prec.Mass	29 806 kton	21 107 kton	1.41	41

An increase of 41 % in precipitation mass for a control value of 21 107 kton in 7 cases may mean:

$$\Delta_2 = 7 \times 0.41 \times 21\,107 \text{ kton} = 60\,577 \text{ kton} = 49\,128 \text{ ac-f}$$

Type B Clouds

The sub-sample of 9 type B seeded clouds received a synergetic analysis. In average, the seeding operations on these type B clouds affected 30 % of their whole volume; with a very good timing (72 % of the material went to the clouds in their first half-lifetime). A total of 203 flares were used in this sub-sample for an effective dose about 110 ice-nuclei per liter.

Also in average, type B clouds were 100 minutes old when the operations took place; the operation lasted about 45 minutes, and the type B seeded clouds lived 225 minutes.

Table 4 shows the results:

Table 4: Type B Seeded Sample versus Virtual Control Sample (7 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	225 min	220 min	1.02	2
Area	1122 km^2	1079 km^2	1.04	4
Prec.Mass	72 808 kton	63 311 kton	1.15	15

An increase of 15 % in precipitation mass for a control value of 63 311 kton in 9 cases may mean:

Δ_3 **= 9 x 0.15 x 63 311 kton = 85 470 kton = 69 316 ac-f**

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3$ **= 137 417 ac-f**

(Increase due mainly to the initial seedings done over EAA target area)

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)	Radar (season value)	% (increase)
Bandera	13	15	9 000	0.21	15.93 in	1.3

Medina	13	18	47 300	0.67	8.30 in	8.1
Bexar	6	12	41 200	0.62	9.58 in	6.5
Uvalde	16	18	85 600	1.03	6.02 in	17.1
Total	**48**	**63**	**183 100**			
Average				**0.63**	**9.96 in**	**8.3**

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

Final Comments

1) Results are evaluated as excellent;

2) The micro-regionalization analysis showed increases per county; seedable conditions were more frequent over the western zones of the target area where greater increases in PrecMass were obtained although the other zones received downwind benefits; the average increase in precipitation, referred to radar seasonal value, is about **8.3 %**;

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

APPENDIX

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

Shortwave, or shortwave trough, refers to a small-scale area of lower pressure, 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.

Radar analysis numbers came from Archie Ruiz's final report of the 2005 season for the EAA.

Acknowledgements

2005 was another successful season for the cloud seeding in the Edwards Aquifer Authority target area. The assessment was done and showed positive effects. This project could not be possible without the hard work and dedication of many people. In this section those appropriate parties will be thanked.

Also, to the SWTREA project manager, chief pilot and secretary, Ed Walker and Debbie Farmer. Also to the SWTMA pilots Ron Merks and Mickey Chadwell which have enabled our project to continue to operate in the absence of one of our pilots near the end of the season. There are others I would also like to thank that are involved with the STWMA including, Tommy Shearrer, Tim Pickens, as well as many others. These people have made the transition of working here and adapting to new surroundings very easy.

I am very sure that I have left out some people that have helped in the project and without them it would not be what it is. So to those of you, who know who you are, thanks so much for making my first experience with weather modification a very productive and good one! I look forward to working with everyone mentioned and not mentioned and learning even more.