ANNUAL EVALUATION REPORT 2011 STWMA (Pleasanton)

Dr. Arquímedes Ruiz-Columbié
Active Influence & Scientific Management

Cloud seeding operations 2011 began over South Texas Weather Modification Association target area in June. This annual report serves as a summary of results. A total of **57 clouds** were seeded and identified by TITAN in **24 operational days**. Table 1 in page 1 summarizes the general figures:

Table 1: Generalities

First operational day: **June 4th 2011**
Last operational day: **September 29th 2011**

Number of operational days: 24
(Four in June, seven in July, four in August, and nine in September)

According to the daily reports operational days were qualified as:

Twelve with excellent performance
Six with very good performance
Three with good performance
Two with fair performance
One experimental

Number of seeded clouds: 57
(36 small seeded clouds, 15 large seeded clouds, 6 type B seeded clouds)

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 36 small seeded clouds which obtained proper control clouds.

Table 2: Seeded Sample versus Control Sample (36 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	60 min	40 min	1.50	50 (**36**)
Area	58.7 km^2	42.3 km^2	1.39	39 (**36**)
Volume	158.3 km^3	112.9 km^3	1.40	40 (**39**)
Top Height	7.4 km	7.2 km	1.03	3 (**1**)
Max dBz	52.5	51.4	1.02	2 (**1**)
Top Height of max dBz	3.5 km	3.5 km	1.00	0 (**1**)
Volume Above 6 km	22.3 km^3	13.0 km^3	1.71	71 (**55**)
Prec.Flux	469.2 m^3 /s	302.3 m^3 /s	1.55	55 (**56**)
Prec.Mass	2089.2 kton	925.5 kton	2.26	126 (**120**)
CloudMass	147.1 kton	96.9 kton	1.52	52 (**53**)
η	14.2	9.5	1.48	48 (**43**)

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 **159 flares** were used in this sub-sample with an excellent timing (**86 %)** for an effective dose about **70 ice-nuclei per liter**. The seeding operation for small clouds lasted about **8.9 minutes** in average. An excellent increase of 120 % in precipitation mass together with an increase of 53 % 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 (36 %), area (36 %) volume (39 %), volume above 6 km (55 %), and precipitation flux (56 %) are notable. Slight increases in top height (1 %) and in maximum reflectivity (1 %) are reported.

The seeded sub-sample seemed 43 % more efficient than the control sub-sample. Results are evaluated as **excellent**.

An increase of 120 % in precipitation mass for a control value of 925.5 kton in 36 cases means:

Δ^1 = 36 x 1.20 x 925.5 kton = 39 982 kton = 32 425 ac-f

Large Clouds

The sub-sample of 15 large seeded clouds received a synergetic analysis. In average, the seeding operations on these large clouds affected 56 % of their whole volume; with a perfect timing (100 % of the material went to the clouds in their first half-lifetime). A total of 216 flares were used in this sub-sample for an effective dose about **110 ice-nuclei per liter**.

Also in average, large clouds were 35 minutes old when the operations took place; the operation lasted about 41 minutes, and the large seeded clouds lived 300 minutes.

Table 3 shows the corresponding results:

Table 3: Large Seeded Sample versus Virtual Control Sample (15 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	170 min	150 min	1.13	13
Area	1317 km^2	1122 km^2	1.17	17
Volume	4704 km^3	3965 km^3	1.19	19
Volume Above 6 km	1241 km^3	994 km^3	1.25	25
Prec.Flux	5156 m^3/s	4125 m^3/s	1.25	25
Prec.Mass	36 022 kton	25 015 kton	1.44	44

An increase of 44 % in precipitation mass for a control value of 25 015 kton in 15 cases may mean:

Δ_2 = 15 x 0.44 x 25 015 kton = 165 099 kton = 133 895 ac-f

Type B Clouds

The sub-sample of 6 type B seeded clouds also received a synergetic analysis. In average, the seeding operations on these type B clouds affected 23 % of their whole volume with an excellent timing (83 % of the material went to the clouds in their first half-lifetime). A total of 86 flares were used in this sub-sample for an effective dose about **145 ice-nuclei per liter.**

Also in average, type B clouds were 160 minutes old when the operations took place; the operation lasted about 27 minutes, and the type B seeded clouds lived 260 minutes.

Table 4 shows the results:

Table 4: Type B Seeded Sample versus Virtual Control Sample (6 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	260 min	250 min	1.04	4
Area	1736 km^2	1630 km^2	1.07	7
Volume	24140 km^3	22582 km^3	1.07	7
Volume Above 6 km	1739 km^3	1595 km^3	1.09	9
Prec.Flux	14192 m^3/s	13020 m^3/s	1.09	9
Prec.Mass	38 541 kton	33 514 kton	1.15	15

An increase of 15 % in precipitation mass for a control value of 33 514 kton in 6 cases may mean:

Δ_3 = 6 x 0.15 x 33 514 kton = 30 163 kton = 24 462 ac-f

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3$ = 190 782 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)
Bandera	**7**	**9**	**20 500**	**0.51**	**3.66 in**	**14.0**
Medina	**3**	**9**	**18 300**	**0.23**	**3.64 in**	**6.3**
Frío	**3**	**5**	**15 500**	**0.26**	**2.91 in**	**8.8**
Bexar	**2**	**4**	**9 500**	**0.14**	**4.61 in**	**3.0**
Atascosa	**8**	**15**	**23 200**	**0.35**	**5.04 in**	**7.0**
McMullen	**5**	**9**	**17 200**	**0.29**	**4.35 in**	**6.7**
Wilson	**5**	**7**	**14 200**	**0.33**	**5.11 in**	**6.5**
Karnes	**10**	**12**	**13 500**	**0.34**	**3.35 in**	**10.1**
Live Oak	**6**	**9**	**13 800**	**0.25**	**3.48 in**	**7.2**
Bee	**5**	**6**	**10 800**	**0.23**	**1.72 in**	**13.5**
Uvalde		1	5 500			
La Salle	1	3	11 300			
Zavala		1	5 400			
Webb			2 200			
Dewitt	1	1	800			
Goliad	1	1	100			
Total	**57**	**86**	**181 800**			
Average (only for the bold values)				**0.29**	**3.79 in**	**8.3**

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

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 7 cases were achieved (5 small storms, 3 large storms, and 1 type B storm).

Table 6 below shows the results of the TITAN evaluation for the small 3 cases:

Table # 6 Seeded Sample versus Control Sample (3 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	80 min	35 min	2.29	129 (**130**)
Area	53.0 km^2	39.5 km^2	1.34	34 (**44**)
Volume	144.3 km^3	96.0 km^3	1.50	50 (**55**)
Top Height	7.0 km	6.7 km	1.04	4 (**2**)
Max dBz	51.7	51.1	1.01	1 (**2**)
Top Height of max dBz	3.4 km	3.5 km	0.97	-3 (**3**)
Volume Above 6 km	19.7 km^3	8.2 km^3	2.40	140 (**76**)
Prec.Flux	399.8 m^3 /s	278.1 m^3 /s	1.44	44 (**55**)
Prec.Mass	1543.1 kton	624.6 kton	2.47	147 (**150**)
CloudMass	130.2 kton	81.4 kton	1.60	60 (**66**)
η	11.9	7.7	1.55	55 (**51**)

Results appear to be explosive in some variables (see lifetime, area, volume, volume above 6 km, precipitation flux and precipitation mass). However, the sub-sample was seeded also with 21 BIP AgI-flares and a perfect timing for an effective average silver iodide dose of 85 ice-nuclei per liter and therefore credits cannot go alone to the hygroscopic seeding. Additionally, this sub-sample is too small (only 3 cases) and the

results might be due to high variability. More cases are needed to get some confidence, but these results are very promising. The maritime/continental index for this sample was -4.9.

Average results for the 7 large cases 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 (7 large cases averaged)

Average Case	Before Hyg.	During Hyg.	30 min after Hyg.
n	5	8	8
PrecMass/scan	1 822 kton	2 690	2 951
Top maxdBz	3.8 km	4.2	4.1
Centroid h	4.8 km	4.8	4.9

78 BIP, 12 hygroscopic flares, AgI dose: 90 ice-nuclei per liter; timing 100 %, 47 % affected

Corresponding Increases:

	Seeded	Control	Simple Ratio	Increase (%)
Area	1838 km^2	1574 km^2	1.17	17
PrecMass	36 765 kton	26 450 kton	1.39	39

Δ = 7 x 0.39 x 26 450 kton = 72 209 kton = 58 561 ac-f

No average increase in the number of cells but an increase in precipitation mass per scan after the hygroscopic seeding seems to indicate that the hygroscopic material did affect those large storms. However, there is a slight decrease in top of max reflectivity and a slight increase in Centroid height during the 30 minutes after hygroscopic seeding suggesting that some impacts in the upper part of the clouds might have taken place. However, it is hard to interpret the possible meaning of those small changes.The sample is too small for any conclusive argument but pinpoints some possible positive results.

Similar analysis was done for the one type B case:

Table # 8 (1 type B case)

Variable	Before Hyg.	During Hyg.	30 min after Hyg.
n	2	1	1

PrecMass/scan	**279 kton**	**286**	**254**
Top maxdBz	**3.1 km**	**3.0**	**3.0**
Centroid h	**3.5 km**	**3.5**	**3.5**

6 BIP, 4 hygroscopic flares, AgI dose: 25 ice-nuclei per liter; timing 100 %, 100% affected

Corresponding Increases:

	Seeded	Control	Simple Ratio	Increase (%)
Area	**161 km^2**	**112 km^2**	**1.44**	**44**
PrecMass	**3054 kton**	**1222 kton**	**2.50**	**150**

Δ = 1 x 1.50 x 1222 kton = 1833 kton = 1487 ac-f

In this type B case, the possible modification signal was not clear. Once again, only one case does not allow for confidence, although it is suggestive.

Final Comments

1) Results are evaluated as **excellent**;

2) The micro-regionalization analysis showed increases per county; different zones received downwind benefits; the average increase in precipitation, referred to rain gage seasonal value, is about **8 %**;

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

4) In 2011, the total increase in the region, estimated in about 0.2 million acre-feet, should be considered a great help to fresh water natural resources.

5) This year hygroscopic seeding was continued at a exploratory level and the results are again intriguing and promissory, although inconclusive. However, the results obtained for the seeded small clouds point out in favor of the idea that there may be a strong synergy between the hygroscopic and the glaciogenic seeding.