ANNUAL EVALUATION REPORT 2011 **State of Texas**

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Cloud seeding operations 2011 began over Texas Weather Modification target area in April. This annual report is a compilation of the evaluation reports already made and published for five local projects. SOAR program did not ask for an evaluation. Therefore, this annual report serves as a summary of the results obtained over Panhandle, Trans-Pecos, WTWMA, STWMA, and SWTREA target areas (EAA target area is included in the last two). A total of **288 clouds** were seeded and identified by TITAN in **124 target area operational days**. Table 1 in page 1 summarizes the general figures:

Table 1: Generalities

First operational day: **April 20th, 2011 (WTWMA)**
Last operational day: **October 11th, 2011 (WTWMA)**

Net Number of operational days: 124
Most active period: July to September: 106 ~ 85 % of the operational days,
Less active months: October: 1 ~ 1 % of the operational days
April: 3 ~ 2 % of the operational days
May: 3 ~ 2 % of the operational days)

According to the daily reports, operational days were qualified as:

Fifty-two with excellent performance
Thirty-eight with very good performance
Seventeen with good performance
Six with fair performance

Additionally, six experimental days and five days with non proper data

Number of seeded clouds: 288
(154 small seeded clouds, 58 large seeded clouds, 72 type B seeded clouds, 4 npf)

Missed Opportunities: 3 (~ 1 % of the seedable conditions)

Note: During its first half, Season 2011 was affected by La Niña conditions which may explain why only 6 operational days took place between April and June. ENSO neutral conditions dominated during the summer when most of the operational days occurred. As La Niña conditions reappeared in October, only one more operational day came about.

Small Clouds

Table 2 shows the results from the classic TITAN evaluation for the 154 small seeded clouds which obtained proper control clouds.

Table 2: Seeded Sample versus Control Sample (154 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	63 min	41 min	1.54	54 (**39**)
Area	60.8 km^2	43.2 km^2	1.41	41 (**37**)
Volume	205.5 km^3	139.4 km^3	1.47	47 (**41**)
Top Height	8.5 km	8.0 km	1.06	7 (**3**)
Max dBz	55.7	53.7	1.04	4 (**2**)
Top Height of max dBz	3.9 km	3.9 km	1.00	0 (**2**)
Volume Above 6 km	58.3 km^3	35.3 km^3	1.65	65 (**47**)
Prec.Flux	428.0 m^3/s	277.3 m^3/s	1.54	54 (**47**)
Prec.Mass	1941.8 kton	858.1 kton	2.26	126 (**103**)
CloudMass	152.2 kton	96.6 kton	1.58	158 (**45**)
η	12.8	8.9	1.44	44 (**41**)

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 **755 flares** were used in this sub-sample with an excellent timing (**84 %),** for an effective dose about **45 ice-nuclei per liter,** which might have reached slightly higher levels in some individual cells. An excellent increase of 103 % in precipitation mass together with an increase of 41 % 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 (39 %), area (37 %), volume (41 %), volume above 6 km (47 %), and precipitation flux (77 %) are notable. There are slight increases in maximum reflectivity (2 %), and in top height (2%). The seeded sub-sample seemed 41 % more efficient than the control sub-sample. Results are evaluated as **excellent** for this sub-sample.

An increase of 103 % in precipitation mass for a control value of 858.1 kton in 154 cases means:

Δ_1 = 154 x 1.03 x 858.1 kton = 136 112 kton = 110 387 ac-f

Large Clouds

The sub-sample of 58 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 (96 % of the material went to the clouds in their first half-lifetime). A total of **1023 flares** were used in this sub-sample for an effective dose near **80 ice-nuclei per liter**.

Also in average, large clouds were 29 minutes old when the operations took place; the operation lasted about 37 minutes, and the large seeded clouds lived 230 minutes (3 hours and 50 minutes).

Table 3 shows the corresponding results:

Table 3: Large Seeded Sample versus Virtual Control Sample (58 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	230 min	195 min	1.18	18
Area	1229 km^2	1019 km^2	1.21	21
Volume	4916 km^3	3928 km^3	1.25	25
Volume Above 6 km	1677 km^3	1327 km^3	1.26	26
Prec.Flux	7368 m^3/s	5778 m^3/s	1.28	28
Prec.Mass	73 066 kton	48 345 kton	1.51	51

An increase of 51 % in precipitation mass for a control value of 48 345 kton in 58 cases may mean:

Δ_2 = 58 x 0.51 x 48 345 kton = 1 430 045 kton = 1 159 767 ac-f

Type B Clouds

The sub-sample of 72 type B seeded clouds also received a synergetic analysis.
In average the seeding operations on these type B clouds affected 24 % of their whole volume with an excellent timing (83 % of the material went to the clouds in their first half-lifetime). A total of **1345 flares** were used in this sub-sample for an effective dose about **90 ice-nuclei per liter.** .

Also in average, type B clouds were 135 minutes old when the operations took place; the operation lasted about 39 minutes, and the type B seeded clouds lived 290 minutes (4 hours and 50 minutes)

Table 4 shows the results:

Table 4: Type B Seeded Sample versus Virtual Control Sample (72 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	290 min	280 min	1.04	4
Area	1855 km^2	1754 km^2	1.06	6
Volume	9807 km^3	9126 km^3	1.07	7
Volume Above 6 km	3493 km^3	3268 km^3	1.07	7
Prec.Flux	26856 m^3/s	25284 m^3/s	1.06	6
Prec.Mass	80 581 kton	71 236 kton	1.13	13

An increase of 13 % in precipitation mass for a control value of 71 236 kton in 72 cases may mean:

Δ_3 = 72 x 0.13 x 71 236 kton = 666 769 kton = 540 750 ac-f

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3$ = 1 810 904 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:

Table 5: Results per county

County	Initial seeding	Extended seeding	Acre-feet (increase)	Inches (increase)	Rain gage (season value)	% (increase)
PGCD						
Armstrong	**10**	**13**	**53 200**	**1.07**	**4.75 in**	**23**
Carson	**8**	**13**	**56 300**	**1.14**	**5.69 in**	**20**
Donley	**4**	**8**	**36 200**	**0.73**	**3.38 in**	**22**
Gray	**3**	**9**	**39 400**	**0.82**	**4.83 in**	**17**
Potter	**6**	**12**	**30 500**	**0.63**	**2.98 in**	**21**
Roberts	**5**	**9**	**56 500**	**1.14**	**4.97 in**	**23**
Wheeler	**2**	**5**	**33 900**	**0.69**	**4.79 in**	**14**
Hemphill		1	1 300			
Hutchinson		1	8 200			
Ochiltree		1	2 100			
Moore			2 200			
Collingsworth			3 000			
Sub-total	**38**	**69**	**322 800**			
Partial Averages (only for the bold values)				**0.89**	**4.48 in**	**20 %**

WTWMA

Glascock	**9**	**11**	**53 400**	**1.11**	**4.88 in**	**23 %**
Sterling	**12**	**14**	**66 100**	**0.84**	**4.18 in**	**19 %**
Reagan	**8**	**15**	**61 400**	**0.98**	**3.91 in**	**25 %**
Irion	**17**	**22**	**79 700**	**1.42**	**6.87 in**	**21 %**
Tom Green	**9**	**14**	**62 600**	**1.54**	**6.83 in**	**23 %**
Crocket	**21**	**28**	**114 800**	**0.77**	**3.37 in**	**23 %**
Schleicher	**29**	**34**	**96 000**	**1.37**	**5.48 in**	**25 %**
Sutton	**23**	**31**	**69 400**	**0.90**	**4.08 in**	**22 %**
Total	**128**	**169**	**603 400**			
Outside TA			~ 180 000			
Partial Average (only for the bold values)				**1.11**	**4.95 in**	**23 %**

TRANS-PECOS

Reeves	13	15	17 000	0.12	0.58	21
Culberson	1	2	3 500	0.02	0.13	16
Loving	1	4	46 500	0.18	0.78	23
Ward	2	4	10 400	0.19	0.85	22
Pecos	6	8	53 200	0.21	0.88	24
Winkler		3	22 000			
Total	**23**	**36**	**152 600**			
Partial Average (only for the bold values)				**0.14**	**0.64 in**	**21 %**

STWMA

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**			
Partial Average (only for the bold values)				**0.29**	**3.79 in**	**8 %**

SWTREA

Uvalde	**8**	**13**	**68 600**	**0.82**	**6.40 in**	**12.8**
Zavala	**4**	**5**	**20 700**	**0.30**	**5.10 in**	**6.0**
Dimmit	**4**	**11**	**41 700**	**0.58**	**4.23 in**	**13.7**
La Salle	**6**	**8**	**68 500**	**0.86**	**4.29 in (*)**	**20.0**
Webb	**13**	**17**	**52 900**	**0.29**	**2.98 in**	**9.7**
Real	4	4	13 600			
Frio		1	2 100			
Medina		1	7 100			
McMullen	1	1	1 600			
Duval	2	3	5 400			
Total	**42**	**64**	**282 200**			
Partial Average				**0.57**	**4.60 in**	**12 %**

Total	**288**	**424**	**1 542 400 ac-f**			
Averages				**0.60 in**	**3.69 in**	**17 %**

No hail suppression operations were developed during the season 2011

Exceptional drought conditions in South Texas during the cloud seeding season, and especially during the spring, inhibited the formation of storms with the subsequent shortage of seedable clouds and severe weather.

Final Comments

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

2) The micro-regionalization analysis showed increases per county; the average increase in precipitation, referred to an average seasonal value, is about **17 %**;

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

4) 2011 cloud seeding operations in Texas were strongly impacted by the intense drought that affected the State (this drought has been the most intense one-year drought in record, more than a hundred years since recorded data begin in 1895). La Niña conditions seemed to inhibit seedable conditions during the spring and when neutral conditions took place during the summer months more seedable clouds appeared. However, the return of La Niña conditions by October brought an early end to the campaign. It is important to point out that exploratory hygroscopic seeding operations continued during 2011 with promissory results (a report on dual seeding will be out soon).

5) No hail suppression operations were developed during the season 2011