ANNUAL EVALUATION REPORT 2006 **State of Texas**

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Cloud seeding operations 2006 began over Texas Weather Modification target area in March. This annual report is a compilation of the evaluation reports already made and published for five local projects. The SOAR and Trans-Pecos projects did not provide any data during 2006. Therefore, this annual report serves as a summary of the results obtained over NPGCD, Panhandle, WTWMA, STWMA, and SWTREA target areas (EAA target area is included in the last two), A total of **551 clouds** were seeded and identified by TITAN in **218 target area operational days**. Table 1 in page 1 summarizes the general figures:

Table 1 Generalities

First operational day: **March 8th, 2006 (WTWMA)**
Last operational day: **October 12th, 2006 (STWMA)**

Net Number of operational days: 199
(Most active months May to August: ~ 80 % of the operation days,
Less active month: March: ~ 1 % of the operation days)

According to the daily reports operational days were qualified as:

Sixty-five with excellent performance
Seventy-four with very good performance
Forty-nine with good performance
Eleven with fair performance

Twelve with non proper data

Seven experimental days

Number of seeded clouds: 551
(298 small seeded clouds, 116 large seeded clouds, 131 type B seeded clouds, and 6 npf))

Missed Opportunities: 3 (0.5 % of the seedable conditions)

Small Clouds

Table 2 shows the results from the classic TITAN evaluation for the 298 small seeded clouds which obtained proper control clouds.

Table 2: Seeded Sample versus Control Sample (298 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	65 min	40 min	1.63	63 (**48**)
Area	65.0 km^2	42.3 km^2	1.54	54 (**37**)
Volume	188.8 km^3	115.6 km^3	1.63	63 (**45**)
Top Height	8.2 km	7.7 km	1.07	7 (**4**)
Max dBz	49.7	48.3	1.03	3 (**2**)
Top Height of max dBz	4.2 km	4.3 km	0.98	- 2 (**0**)
Volume Above 6 km	29.6 km^3	14.9 km^3	1.99	99 (**67**)
Prec.Flux	493.6 m^3/s	297.7 m^3/s	1.66	66 (**50**)
Prec.Mass	2217.4 kton	873.2 kton	2.54	154 (**120**)
CloudMass	150.6 kton	91.1 kton	1.65	65 (**49**)
η	14.9	9.6	1.56	56 (**50**)

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 **1344 flares** were used in this sub-sample with an excellent timing (**84 %),** for an effective dose near **90 ice-nuclei per liter,** which might have reached slightly higher levels in some individual cells. A very good increase of 120 % in precipitation mass together with an increase of 49 % 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 (48 %), area (37 %), volume (45 %), volume above 6 km (67 %), and precipitation flux (50 %) are notable. There are slight increases in maximum reflectivity (2 %), and in top height (4 %). The seeded sub-sample seemed 50 % more efficient than the control sub-sample. Results are evaluated as **excellent** for this sub-sample.

An increase of 120 % in precipitation mass for a control value of 873.2 kton in 298 cases means:

Δ_1 = 298 x 1.20 x 873.2 kton = 312 256 kton = 253 240 ac-f

Large Clouds

The sub-sample of 116 large seeded clouds received a synergetic analysis. In average the seeding operations on these large clouds affected 62 % of their whole volume, with an excellent timing (96 % of the material went to the clouds in their first half-lifetime). A total of **1784 flares** were used in this sub-sample for an effective dose near **90 ice-nuclei per liter**.

Also in average, large clouds were 31 minutes old when the operations took place; the operation lasted about 41 minutes, and the large seeded clouds lived 205 minutes (3 hours and 25 minutes).

Table 3 shows the corresponding results:

Table 3. Large Seeded Sample versus Virtual Control Sample (116 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	205 min	175 min	1.17	17
Area	1051 km^2	887 km^2	1.18	18
Volume	3734 km^3	3022 km^3	1.24	24
Volume Above 6 km	1186 km^3	911 km^3	1.30	30
Prec.Flux	9652 m^3/s	7600 m^3/s	1.27	27
Prec.Mass	63 869 kton	53 590 kton	1.19	19

An increase of 19 % in precipitation mass for a control value of 53 590 kton in 116 cases may mean:

Δ_2 = 116 x 0.19 x 53 590 kton = 1 181 124 kton = 957 891 ac-f

Type B Clouds

The sub-sample of 131 type B seeded clouds received a synergetic analysis.
In average the seeding operations on these type B clouds affected 26 % of their whole volume with a very good timing (74 % of the material went to the clouds in their first half-lifetime). A total of **2100 flares** were used in this sub-sample for an effective dose near **115 ice-nuclei per liter.** .

Also in average, type B clouds were 125 minutes old when the operations took place; the operation lasted near 39 minutes, and the type B seeded clouds lived 265 minutes (4 hours and 25 minutes)

Table 4 shows the results:

Table 4. Type B Seeded Sample versus Virtual Control Sample (131 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	265 min	250 min	1.06	6
Area	1774 km^2	1654 km^2	1.07	7
Volume	6319 km^3	5809 km^3	1.09	9
Volume Above 6 km	1586 km^3	1431 km^3	1.11	11
Prec.Flux	14626 m^3/s	13339 m^3/s	1.10	10
Prec.Mass	152 740 kton	132 500 kton	1.15	15

An increase of 15 % in precipitation mass for a control value of 132 500 kton in 131 cases may mean:

Δ_3 = 131 x 0.15 x 132 500 kton = 2 603 625 kton = 2 111 540 ac-f

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3$ = 3 322 671 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)
Dallam	**10**	**13**	**128 000**	**0.59**	**12.75 in**	**12.3**
Hartley	**11**	**18**	**153 200**	**1.96**	**8.06 in**	**24.3**
Sherman	**10**	**15**	**57 000**	**1.15**	**13.70 in**	**8.3**
Moore	**19**	**29**	**245 100**	**3.30**	**9.34 in**	**35.3**
Hansford	**11**	**16**	**86 700**	**1.76**	**14.45 in**	**12.2**
Hutchinson	**8**	**23**	**89 800**	**4.46**	**14.37 in**	**31.0**
Ochiltree	**5**	**8**	**76 700**	**1.57**	**12.22 in**	**12.8**
Limpscomb	**2**	**5**	**65 200**	**1.31**	**10.79 in**	**12.1**
Hemphill		7	80 050			
Potter	**17**	**21**	**202 200**	**4.17**	**14.68 in**	**28.4**
Randall	3	11	116 200			
Carson	**19**	**34**	**205 200**	**4.16**	**17.25 in**	**24.1**
Armstrong	**15**	**23**	**158 200**	**3.25**	**14.24 in**	**22.8**
Roberts	**9**	**19**	**151 300**	**3.08**	**11.42 in**	**27.0**
Gray	**2**	**18**	**137 100**	**2.77**	**15.74 in**	**17.6**
Donley	**11**	**19**	**80 400**	**1.62**	**15.25 in**	**10.6**
Wheeler	**1**	**9**	**54 300**	**1.11**	**14.19 in**	**7.8**

Glascock	**18**	**24**	**105 900**	**2.20**	**13.53 in***	**16.3**
Sterling	**18**	**28**	**158 400**	**3.22**	**13.58 in**	**23.7**
Reagan	**17**	**23**	**177 800**	**2.84**	**12.44 in***	**21.5**
Irion	**26**	**31**	**267 400**	**4.77**	**13.05 in***	**36.5**
Tom Green	**16**	**22**	**140 000****	**1.72**	**16.01 in**	**21.5**
Crocket	**24**	**33**	**352 500**	**2.35**	**11.35 in**	**20.7**
Schleicher	**24**	**30**	**239 500**	**3.43**	**15.71 in**	**21.8**
Sutton	**14**	**24**	**256 800**	**3.31**	**12.51 in**	**26.5**
Bandera	**5**	**6**	**7 800**	**0.18**	**16.59 in**	**1.1**
Medina	**5**	**7**	**8 400**	**0.12**	**7.69 in**	**1.6**
Frío	**5**	**6**	**20 500**	**0.35**	**6.32 in***	**5.5**
Bexar	**4**	**6**	**24 500**	**0.37**	**10.36 in**	**3.6**
Atascosa	**27**	**33**	**128 200**	**1.96**	**11.83 in**	**16.6**
McMullen	**14**	**21**	**53 300**	**1.32**	**14.48 in**	**9.1**
Wilson	**6**	**11**	**39 300**	**0.92**	**20.73 in**	**4.4**
Karnes	**22**	**29**	**106 200**	**2.65**	**15.81 in**	**16.8**
Live Oak	**12**	**21**	**50 400**	**0.91**	**21.32 in**	**4.3**
Bee	**26**	**30**	**37 000**	**0.79**	**23.44 in**	**3.4**
Goliad	4	6	3 200	0.06		
Guadalupe	2	3	7 500	0.21		
Gonzalez	7	7	16 300	0.29		
Uvalde	**19**	**23**	**89 400**	**1.07**	**13.70 in**	**7.8**
Zavala	**14**	**19**	**160 700**	**2.32**	**12.78 in**	**18.2**

Dimmit	**13**	**17**	**124 200**	**1.75**	**9.57 in**	**18.3**
La Salle	**19**	**23**	**113 000**	**1.42**	**14.54 in**	**9.8**
Webb	**33**	**35**	**114 500**	**0.64**	**19.53 in**	**4.4**
Total	**551**	**815**	**3 244 400**			
Average				**1.89 in**	**13.82 in**	**15.8 %**

Final Comments

Results are evaluated as **excellent**. The main problem detected was the loss of radar data (12 operational days did not get proper files, last year 31 operational days were lost);

The micro-regionalization analysis showed increases per county; the average increase in precipitation, referred to an average seasonal value, is about **15.8 %**;

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