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Cloud seeding operations 2012 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: Panhandle, Trans-Pecos, WTWMA, STWMA, and SWTREA target areas (EAA target area is included in the last two). A total of 353 clouds were seeded and identified by TITAN in 162 target area operational days. Table 1 summarizes the general figures:

Table 1: Generalities

First operational day: March 19th, 2012 (WTWMA)
Last operational day: October 13th, 2012 (WTWMA) Season: 209 days

Net Number of operational days: 162

Most active period: May to September: 143 ~ 88 % of the operational days,

Less active months: March: 5 ~ 3 % of the operational days

 April: 9 ~ 6 % of the operational days

 October: 5 ~ 3 % of the operational days

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

Ninety with excellent performance

Thirty-four with very good performance

Twenty-six with good performance

Eight with fair performance

Additionally, eight days with non proper data

Number of seeded clouds: 353

(169 small seeded clouds, 56 large seeded clouds, 128 type B seeded clouds)

Missed Opportunities: 6 (~ 1.7 % of the seedable conditions)

Small Clouds

Table 2 shows the results from the classic TITAN evaluation for the 169 small seeded clouds which obtained proper control clouds.

Table 2: Seeded Sample versus Control Sample (169 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	65 min	45 min	1.45	45 (40)
Area	75.2 km ²	49.3 km ²	1.52	52 (47)
Volume	271.5 km ³	174.3 km ³	1.56	56 (47)
Top Height	8.9 km	8.4 km	1.05	5 (2)
Max dBz	52.8	51.0	1.04	4 (2)
Top Height of max dBz	3.9 km	3.8 km	1.03	3 (0)
Volume Above 6 km	83.2 km ³	54.6 km ³	1.52	52 (41)
Prec.Flux	589.3 m ³ /s	335.8 m ³ /s	1.76	76 (56)
Prec.Mass	2644.3 kton	1123.6 kton	2.35	135 (124)
CloudMass	254.5 kton	228.1 kton	1.67	67 (53)
η	10.4	4.9	2.12	112 (48)

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 687 AgI and 84 hygroscopic flares were used in this sub-sample with an excellent timing (87 %), for an effective AgI dose about 40 ice-nuclei per liter, which might have reached slightly higher levels in some individual cells. An excellent increase of 124 % 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 (40 %), area (47 %), volume (47 %), volume above 6 km (41 %), and precipitation flux (56 %) are notable. There are slight increases in maximum reflectivity (2 %), and in top height (2%). The seeded sub-sample seemed 48 % more efficient than the control sub-sample. Results are evaluated as excellent for this sub-sample.

An increase of 124 % in precipitation mass for a control value of 1123.6 kton in 169 cases means:

$$\Delta_1 = 169 \times 1.24 \times 1123.6 \text{ kton} \approx 235\,462 \text{ kton} \approx 190\,959 \text{ ac-f}$$

Large Clouds

The sub-sample of 56 large seeded clouds received a synergetic analysis. In average the seeding operations on these large clouds affected 66 % of their whole volume, with an excellent timing (98 % of the material went to the clouds in their first half-lifetime). A total of 617 AgI and 48 hygroscopic flares were used in this sub-sample for an effective silver iodide average dose near 70 ice-nuclei per liter.

Also in average, large clouds were 32 minutes old when the operations took place; the operation lasted about 29 minutes, and the large seeded clouds lived 225 minutes (3 hours and 45 minutes).

Table 3 shows the corresponding results:

Table 3: Large Seeded Sample versus Virtual Control Sample (56 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	225 min	190 min	1.18	18
Area	1207 km ²	931 km ²	1.30	30
Volume	4814 km ³	3723 km ³	1.29	29
Volume Above 6 km	1817 km ³	1468 km ³	1.24	24
Prec.Flux	9812 m ³ /s	7523 m ³ /s	1.30	30
Prec.Mass	88 973 kton	59 599 kton	1.49	49

An increase of 49 % in precipitation mass for a control value of 59 599 kton in 56 cases may mean:

$$\Delta_2 = 56 \times 0.49 \times 59\,599 \text{ kton} \approx 1\,635\,397 \text{ kton} = 1\,326\,307 \text{ ac-f}$$

Type B Clouds

The sub-sample of 128 type B seeded clouds also received a synergetic analysis.

In average the seeding operations on these type B clouds affected 19 % of their whole volume with an excellent timing (84 % of the material went to the clouds in their first half-lifetime). A total of 1648 AgI and 135 flares were used in this sub-sample for an effective silver iodide average dose about 100 ice-nuclei per liter. .

Also in average, type B clouds were 130 minutes old when the operations took place; the operation lasted about 36 minutes; and the type B seeded clouds lived 300 minutes (5 hours)

Table 4 shows the results:

Table 4: Type B Seeded Sample versus Virtual Control Sample (128 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	300 min	290 min	1.03	3
Area	2271 km ²	2118 km ²	1.07	7
Volume	8885 km ³	8384 km ³	1.06	6
Volume Above 6 km	3012 km ³	2807 km ³	1.07	7
Prec.Flux	16846 m ³ /s	15507 m ³ /s	1.09	9
Prec.Mass	125 850 kton	113 784 kton	1.11	11

An increase of 11 % in precipitation mass for a control value of 113 784 kton in 128 cases may mean:

$$\Delta_3 = 128 \times 0.11 \times 113\,784 \text{ kton} = 1\,602\,079 \text{ kton} = 1\,299\,286 \text{ ac-f}$$

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3 = 2\,746\,552 \text{ ac-f}$

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	6	7	63 500	1.28	15.88 in	8.1
Carson	2	10	84 400	1.71	11.74 in	14.6
Donley	5	8	112 000	2.26	14.78 in	15.3
Gray	7	11	138 600	2.88	15.68 in	18.4
Potter	11	11	45 700	0.94	12.18 in	7.7
Roberts	2	3	23 300	0.47	12.75 in	3.7
Wheeler	2	7	49 000	1.00	16.68 in	6.0
Hemphill		1	8 100			
Hutchinson		1	2 500			
Collingsworth		3	27 000			
Randall		1	700			
Sub-total	35	61	544 800			
Partial Average (only for the bold values)				1.50 in	14.24 in	10.5

WTWMA

Glascock	9	16	146 000	3.03	15.53 in	19.5 %
Sterling	16	21	169 200	2.15	19.96 in	11.8 %
Reagan	9	19	166 800	2.66	13.97 in	19.0 %
Irion	23	31	122 000	2.17	13.66 in	15.9 %
Tom Green	26	31	121 300	2.98	18.77 in	15.9 %
Crocket	12	18	142 200	0.94	12.80 in	7.4 %
Schleicher	27	35	161 800	2.31	14.10 in	16.4 %
Sutton	9	15	81 600	1.06	11.00 in	9.6 %

Sub-total	131	186	1 110 900			
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Outside TA			30 000			
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Partial Average (only for the bold values)				2.16	14.97 in	14.4 %
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TRANS-PECOS

Culberson	2	2	3700	0.02	4.30*	0.5
Reeves	13	13	32600	0.23	5.10	4.5
Pecos	5	7	40100	0.16	9.68	1.7
Ward	1	1	8400	0.19	7.40*	2.6
Loving	1	1	4400	0.12	6.40*	1.9
Winkler		1	5600	0.12	7.48	1.6
Brewster		1	1300			
Crane		1	2800			
Ector		1	1400			

Sub-total	22	28	100 300
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Partial Averages	0.14	6.73	2.1 %
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*** interpolated values**

STWMA

Bandera	6	7	47 100	1.17	24.71 in	4.7
Medina	7	11	26 700	0.34	20.40 in	1.7
Frío	7	13	74 900	1.26	21.48 in	5.9
Bexar	1	5	3 800	0.63	25.02 in	2.5
Atascosa	18	24	89 400	1.35	23.56 in	5.7
McMullen	12	17	72 700	1.22	19.33 in	6.3
Wilson	7	9	17 800	0.42	22.46 in	1.9
Karnes	12	17	40 400	1.02	20.07 in	5.1
Live Oak	25	29	94 400	1.71	19.31 in	8.9
Bee	26	31	81 500	1.73	17.04 in	10.2
Uvalde		1	1 000			
La Salle	3	5	10 900			
Kendall		2	3 500			
Goliad		1	400			
Sub-total	124	172	564 500			
Partial Average (only for the bold values)				1.09	21.34 in	5.3 %

SWTREA

Uvalde	21	21	86 600	1.04	14.02 in	7.4
Webb	20	22	138 400	0.76	7.57 in	10.0
La Salle		1	1800			
Frio		2	900			
Medina		1	900			
Atascosa		1	400			
McMullen		1	600			
Duval		1	600			
Karnes		1	800			
Sub-total	41	51	231 000			
Partial Average				0.90	10.80 in	8.7%

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 **8.2 %**;
- 3) Radar estimations of precipitation should be considered as measurements of trend. Nevertheless, **seeding operations appeared to improve the dynamics of seeded clouds**.
- 4) During the 2012 cloud seeding campaign in Texas two projects introduced hygroscopic seeding as an important component of the operations (WTWMA and STWMA). The results corroborated the idea that a synergy between hygroscopic and glaciogenic seeding can improve even more the dynamic of seeded clouds. Details can be seen in the corresponding two local 2012 reports.

5) One hail suppression operation was conducted during the season 2012 on May 10th over Webb County. The operation was evaluated as successful because the seeded storm seemed to slightly diminish its potential for hail. However, the dose used was considered not high enough (80 ice-nuclei per liter).

