ANNUAL EVALUATION REPORT 2003   **State of Texas**

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Cloud seeding operations 2003 began over Texas Weather Modification target area in March. This annual report serves as a summary of results. A total of **987 clouds** were seeded and identified by TITAN in **274 target area operational days**. Table 1 in page 1 summarizes the general figures:

Table 1 Generalities

First operational day: **March 15th, 2003 (WTWMA)**
Last operational day: **October 10th 2003 (SWTREA)**

Number of operational days: 274
(four in March, sixteen in April, twenty-three in May, seventy-nine in June, fifty in July, sixty-six in August, thirty-two in September, and four in October)

According to the daily reports operational days were qualified as:

Forty-six with excellent performance
One hundred and two with very good performance
Eighty-eight with good performance
Twenty-one with fair performance
Fourteen with poor performance
Three with non proper data

Number of seeded clouds: 987
(609 small seeded clouds, 141 large seeded clouds, 183 type B seeded clouds, and 54 npf))

Missed Opportunities: 28 (3 % of the seedable conditions)

Small Clouds

Table 2 shows the results from the classic TITAN evaluation for the 609 small seeded clouds which obtained proper control clouds.

Table 2. Seeded Sample versus Control Sample (609 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	70 min	55 min	1.27	27 (**15**)
Area	56.6 km^2	46.1 km^2	1.23	23 (**20**)
Volume	187.5 km^3	147.4 km^3	1.27	27 (**25**)
Top Height	8.3 km	7.7 km	1.08	8 (**4**)
Max dBz	47.6	45.7	1.04	4 (**3**)
Top Height of max dBz	4.1 km	4.3 km	0.95	- 5 (**-5**)
Volume Above 6 km	54.8 km^3	40.0 km^3	1.37	37 (**35**)
Prec.Flux	285.0 m^3/s	198.2 m^3/s	1.44	44 (**32**)
Prec.Mass	1342.7 kton	692.1 kton	1.94	94 (**81**)
CloudMass	115.6 kton	83.9 kton	1.38	38 (**31**)
η	11.6	8.2 (**8.4**)	1.41	41 (**38**)

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 2638 flares and 2453 generator minutes were used in this sub-sample with a very good timing (**73 %**), for an effective dose near **60 ice-nuclei per liter,** which might have reached higher levels in some individual cells. A very good increase of 81 % in precipitation mass together with an increase of 31 % 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 (15 %), area (20 %), volume (25 %), and volume above 6 km (35 %) are notable. There are slight increases in maximum reflectivity (3 %), and in top height (4 %). The seeded sub-sample seemed 38 % more efficient than the control sub-sample. Results are evaluated as very good.

An increase of 81 % in precipitation mass for a control value of 692.1 kton in 609 cases means:

$$\Delta_1 = 609 \times 0.81 \times 692.1 \text{ kton} = 341\ 406 \text{ kton} = 276\ 880 \text{ ac-f}$$

Large Clouds

The sub-sample of 141 large seeded clouds received a synergetic analysis. In average the seeding operations on these large clouds affected 85 % of their whole volume, with an excellent timing (82 % of the material went to the clouds in their first half-lifetime). A total of 2382 flares and 1018 generator minutes were used in this sub-sample for an effective dose near **50 ice-nuclei per liter**.

Also in average, large clouds were 30 minutes old when the operations took place; the operation lasted about 60 minutes, and the large seeded clouds lived 215 minutes (3 hours and 35 minutes).

Table 3 shows the corresponding results:

Table 3. Large Seeded Sample versus Virtual Control Sample (141 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	215 min	175 min	1.23	23
Area	592 km^2	526 km^2	1.13	13
Volume	2744 km^3	2385 km^3	1.15	15
Top Height	12.1 km	11.8 km	1.03	3
Max dBz	53.1	52.2	1.02	2
Top Height of max dBz	4.9 km	5.0 km	0.98	- 2
Volume Above 6 km	1335 km^3	1099 km^3	1.21	21
Prec.Flux	3494 m^3/s	2875 m^3/s	1.22	22
Prec.Mass	28 399 kton	18 762 kton	1.51	51

CloudMass	1949 kton	1475 kton	1.32	32
η	14.6	12.7	1.15	15

Timing for this sub-sample was excellent (82 %) and the increases are appreciable.

An increase of 51 % in precipitation mass for a control value of 18 762 kton in 141 cases may mean:

$$\Delta_2 = \textbf{141 x 0.51 x 18 762 kton = 1 349 175 kton = 1 094 181 ac-f}$$

Type B Clouds

The sub-sample of 183 type B seeded clouds received a synergetic analysis. In average the seeding operations on these type B clouds affected 55 % of their whole volume, with a good timing (55 % of the material went to the clouds in their first half-lifetime). A total of 2641 flares and 1590 generator minutes were used in this sub-sample for an effective dose near **35 ice-nuclei per liter.** .

Also in average, type B clouds were 120 minutes old when the operations took place; the operation lasted near 50 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 (183 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	265 min	235 min	1.13	13
Area	842 km^2	768 km^2	1.10	10
Volume	4198 km^3	3739 km^3	1.12	12
Top Height	12.1 km	11.9 km	1.02	2
Max dBz	52.4	51.9	1.01	1
Top Height of max dBz	5.2 km	5.3 km	0.98	- 2
Volume Above 6 km	2035 km^3	1706 km^3	1.19	19
Prec.Flux	4789 m^3/s	4090 m^3/s	1.17	17
Prec.Mass	42 339 kton	32 687 kton	1.30	30
CloudMass	2819 kton	2388 kton	1.18	18
η	15.0	13.7	1.09	9

Timing for this sub-sample was good (55 %) and some increases are appreciable.

An increase of 30 % in precipitation mass for a control value of 32 687 kton in 183 cases may mean:

$$\Delta_3 = \textbf{183 x 0.30 x 32 687 kton = 1 794 516 kton = 1 455 353 ac-f}$$

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3 =$ 2 826 414 ac-f

Main Teachings:

1) TITAN is underestimating the values of precipitation on the ground.
2) Maintenance seeding paid excellent dividends.
3) Timing and doses were better than last year.
4) Marginal seedable clouds seemed to give increases of about 30-35 %.
5) Top seeding operations should be done very carefully to avoid over-seeding problems.
6) Experts in Pleasanton showed that using TITAN side windows and a strong interaction among the meteorologists and the pilots allowed them to reach very systematically dynamic doses.
7) Local evaluations are between very good to excellent: we finally learnt how to seed clouds.
8) Trans-Pecos performed with excellence. It is a great surprise for a rookie.

Final Comments

1) Results are evaluated as very good. Operations on marginal seedable clouds seem not profitable.

2) Maintenance seeding usually paid excellent dividends. A very good general timing of 71 % implied a general effective dose about 55 ice-nuclei per liter. Timing and doses were better than those last year.

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

Reference

To refresh your knowledge about the evaluation in general and the synergetic analysis in particular you can visit:

Ruiz-Columbié, A., D.L. Bates, and O. Nuñez-Russis, 2003: **2002 Adventures, Ventures, and Misadventures of Weather Modification in Texas.** J. Wea. Mod., 35, 10-24