**ANNUAL EVALUATION REPORT 2020 TPWMA (Trans-Pecos)**

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Cloud seeding operations 2020 began over Trans-Pecos Weather Modification target area in April. This annual report serves as a summary of results. **30 clouds** were seeded and identified by TITAN in **15 operational days**. Table 1 in page 1 summarizes the general figures:

**Table 1 Generalities**

First operational day: **April 27th, 2020**

Last operational day: **September 17th, 2020**

**Number of operational days: 15**

(One in April, five in May, four in June, one in July, two in August, and two in September)

According to the daily reports operational days were qualified as:

**Ten with excellent performance**

**Three with very good performance**

**Two with good performance**

**Number of seeded clouds: 30**

(16 small-seeded clouds, 6 large-seeded clouds, and 8 type B-seeded clouds)

**Missed Opportunities: one (with lifespan longer than 1 hour): ~ 3 % of resources.**

July 5th: Storm # 1508 on Culberson and Reeves County (22:04 - 01:08 UTC)

**Small Clouds**

Table 2 shows the results from the classic TITAN evaluation for the 16 small-seeded clouds which obtained proper control clouds.

**Table 2. Seeded Sample versus Control Sample (16 couples, averages)**

**Variable Seeded Sample Control Sample Simple Ratio Increases (%)**

**Lifetime**  75 min 55 min 1.36 36 (**25**)

**Area**  90.8 km 77.5 km 1.17 17 (**22**)

**Volume**  368.9 km 305.2 km 1.21 21 (**23**)

**Top Height**  9.8 km 9.5 km 1.03 3 (**1**)

**Max dBz** 51.0 46.5 1.10 10 (**2**)

**Top Height**

**of max dBz**  4.8 km 5.6 km 0.86 - 14 (**-9** )

**Volume**

**Above 6 km**   153.8km**** 138.3 km**** 1.11 11 (**26**)

**Prec.Flux**  470.1 m/s 307.4 m/s 1.53 53 (**28**)

**Prec.Mass**  2270.4 kton 1108.2 kton 2.05 105 (**99**)

**CloudMass** 235.7 kton 161.6 kton 1.46 46 (**40**)

  **η**  9.6 6.9 1.39 39 (**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 88 flares were used in this sub-sample with an excellent timing (**91 %),** for an effective dose near **30 ice-nuclei** **per liter**. An excellent increase of 99 % in precipitation mass is an indication of the use of quasi-dynamic doses for small clouds. The seeded sub-sample seemed 9 % more efficient than the control sub-sample. Results are evaluated as **excellent** for this subsample.

An increase of 99 % in precipitation mass for a control value of 1108.2 kton in 16 cases means:

** = 16 x 0.99 x 1108.2 kton ≈ 17 554 kton ≈ 14 236 ac-f (layer: 12.1 mm ≈ 0.48 in)**

**Large Clouds**

The sub-sample of 6 large-seeded clouds received a synergetic analysis. On average the seeding operations on these large clouds affected 65 % of their whole volume, with a perfect timing (100 % of the material went to the clouds in their first half-lifetime). A total of 91 flares were used in this sub-sample for an effective dose near **30 ice-nuclei per liter**.

On average, large clouds were 35 minutes old when the operations took place; the operation lasted about 29 minutes, and the large-seeded clouds lived 300 minutes.

Table 3 shows the corresponding results:

**Table 3. Large Seeded Sample versus Virtual Control Sample (6 couples, averages)**

**Variable Seeded Sample Control Sample Simple Ratio Increases (%)**

**Lifetime**  385 min 250 min 1.14 14

**Area**  1442 km 1276 km 1.13 13

**Volume**  9806 km 8453 km 1.16 16

**Volume**

**Above 6 km**  5785 km**** 5030km**** 1.15 15

**Prec.Flux**  12870 m/s 10815 m/s 1.19 19

**Prec.Mass**  113 643 kton 76 786 kton 1.48 48

An increase of 48 % in precipitation mass for a control value of 76 786 kton in 6 cases may mean:

** = 6 x 0.48 x 76 786 kton ≈ 221 144 kton ≈ 179 348 ac-f**

 **(layer: 25.6 mm ≈ 1.01 in)**

**Type B Clouds**

The sub-sample of 8 type B seeded clouds received a synergetic analysis. On average the seeding operations on these type B clouds affected 15 % of their whole volume, with an excellent timing (91 % of the material went to the clouds in their first half-lifetime). A total of 68 flares were used in this sub-sample for an effective dose of about **20 ice-nuclei per liter** .

On average, type B clouds were 100 minutes old when the operations took place; the operation lasted about 21 minutes, and the type B seeded clouds lived 300 minutes.

Table 4 shows the results:

**Table 4. Type B Seeded Sample versus Virtual Control Sample (8 couples, averages)**

**Variable Seeded Sample Control Sample Simple Ratio Increases (%)**

**Lifetime**  300 min 290 min 1.03 3

**Area**  5683 km 5529 km 1.03 3

**Volume**  21348 km 20749 km 1.03 3

**Volume**

**Above 6 km** 6119 km**** 5884km**** 1.04 4

**Prec.Flux**  28005 m/s 26928 m/s 1.04 4

**Prec.Mass** 248 575 kton 225 978 kton 1.10 10

An increase of 10 % in precipitation mass for a control value of 85 765 kton in 14 cases may mean:

** = 8 x 0.10 x 225 978 kton ≈ 180 782 kton ≈ 146 615 ac-f**

 **(layer: ~ 4 mm ≈ 0.16 in)**

**The total increase: =+ +  = 340 199 ac-f**

 **(average layer: ~ 0.50 in)**

 **(~ 890 ac-f per small storm; ~ 29 891 ac-f per large storm; ~ 18 327 per B storms)**

**Micro-regionalization (information per county)**

 **seeded seeded ac-f increase (in) seasonal (in) %**

 **(initial) (extended) (Δ) (δ) (April-Sept.)**

**Culberson 3 3 10 500 0.04 3.54 1.1 %**

**Reeves 9 12 82 500 0.51 3.95 12.9 %**

**Pecos 12 15 190 300 0.79 5.53 14.3 %**

**Ward 3 6 31 200 0.72 3.75 19.2 %**

**Loving 3 4 19 300 0.53 2.83\* 18.7 %**

 (\*) interpolated value

**Outside 5 6 400 (~ 2 % of the total increase)**

 **(downwind effect)**

**Total 30 45 340 200**

**Averages 0.52 in 4.12 in 13.2 %**

**Final Comments**

1. Results are evaluated as **excellent;** an excellent average timing of about **93 %**, an average dose of about **30 ice-nuclei per liter**, and **fifteen operational days** seemed to have great impacts, especially on Ward, Reeves and Pecos Counties. A relative increase a little over 13 % for the whole target area is an excellent signal.
2. It is recommended to introduce hygroscopic seeding in the operations, especially in those operational days when the cloud bases are colder than 10 °C. The goal is to enhance the collision-coalescence mechanism.
3. Radar estimations of precipitation should be considered as measurements of trend. Nevertheless, according to the results reported, seeding operations did improve the dynamics of seeded clouds.
4. Only one missed opportunity indicated a great weather watch system. However, data still suggest the need of a second operational aircraft during active convective periods. A second aircraft may help to increase the seeding doses.

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