ANNUAL EVALUATION REPORT 2018 EAA

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Cloud seeding operations 2018 began over EAA target area in May. This annual report serves as a summary of results. A total of **23 clouds** were seeded and identified by TITAN in **13 operational days**. Table 1 in page 1 summarizes the general figures:

Table 1: Generalities

First operational day: **May 20th, 2018**
Last operational day: **September 6th, 2018**

Number of operational days: 13
(One in May, two in June, four in July, three in August, and three in September)

According to the daily reports operational days were qualified as:

Ten with excellent performance
Three with very good performance

Number of seeded clouds: 23
(14 small seeded clouds, 2 large seeded clouds, 7 type B seeded clouds)

Missed Opportunities: six (with lifetime longer than 60 minutes) ~ 21 % of resources

June 9: # 650 over Bexar County
June 13: # 401 over Bexar County
June 15: # 692 over Medina County
July 7: # 3368 over Bexar, Medina and Uvalde Counties
August 5: # 1432 over Uvalde County
September 6: # 3007 over Bexar and Medina Counties

Small Clouds

Evaluations were done using TITAN and NEXRAD data.

Table 2 shows the results from the classic TITAN evaluation for the 14 small seeded clouds which obtained proper control clouds.

Table 2: Seeded Sample versus Control Sample (14 couples, averages)

Variable (%)	Seeded Sample	Control Sample	Simple Ratio	Increases
Lifetime	65 min	40 min	1.63	63 (**48**)
Area	74.1 km^2	48.8 km^2	1.52	52 (**37**)
Volume	206.9 km^3	122.8 km^3	1.68	68 (**45**)
Top Height	7.5 km	7.2 km	1.04	4 (**1**)
Max dBz	52.5	50.1	1.05	5 (**0**)
Top Height of max dBz	3.6 km	3.6 km	1.00	0 (**-3**)
Volume Above 6 km	28.7 km^3	11.7 km^3	2.45	145 (**37**)
Prec.Flux	584.1 m^3/s	305.9 m^3/s	1.91	91 (**51**)
Prec.Mass	2633.7 kton	845.0 kton	3.12	212 (**160**)
CloudMass	192.2 kton	98.1 kton	1.96	96 (**50**)
η	13.7	8.6	1.59	59 (**76**)

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 92 AgI-BIP and 4 hygroscopic flares were used in this sub-sample with a good timing (**77 %)** for an average effective silver iodide dose about **120 ice-nuclei per liter**. The seeding operations lasted in average about 6 minutes. An excellent increase of **160 %** in precipitation mass together with an increase of 50 % 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 (37 %), and precipitation flux (51 %)

are noticeable. There was no increases in maximum reflectivity (0 %) and a slight increase in top height (1 %). The seeded sub-sample seemed 76 % more efficient than the control sub-sample. Results are evaluated as **excellent**.

An increase of **160 %** in precipitation mass for a control value of 845 kton in 14 cases means:

Δ_1 = 14 x 1.60 x 845.0 kton ≈ 18 928 kton ≈ 15 351 ac-f (layer: 18.2 mm ≈ 0.72 in)

Large Clouds

The sub-sample of 2 large seeded clouds received a synergetic analysis. On average, the seeding operations on these large clouds affected 43 % of their whole volume with a very good timing (85 % of the material went to the clouds in their first half-lifetime). A total of 36 AgI-BIP and 1 hygroscopic flare were used in this sub-sample for an effective glaciogenic dose about **105 ice-nuclei per liter**.

Also on average, large clouds were 20 minutes old when the operations took place; the operation lasted about 36 minutes, and the large seeded clouds lived 210 minutes.

Table 3 shows the corresponding results:

Table 3: Large Seeded Sample versus Virtual Control Sample (2 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	210 min	190 min	1.11	11
Area	478 km^2	422 km^2	1.13	13
Prec.Mass	80 367 kton	59 101 kton	1.36	36

An increase of 36 % in precipitation mass for a control value of 59 101 kton in 2 cases may mean:

Δ_2 = 2 x 0.36 x 59 101 kton ≈ 42 553 kton ≈ 34 510 ac-f
(layer: 44.5 mm ≈ 1.75 in)

Type B Clouds

Seven type B clouds over EAA target area were seeded during the season. On average, the seeding operations on these type B clouds affected 10 % of their whole volume with a good timing (77 % of the material went to the clouds in their first half-lifetime). A total of 124 AgI-BIP and 21 hygroscopic flares were used in this sub-sample for an effective dose about **50 ice-nuclei per liter**.

Also on average, type B clouds were 100 minutes old when the operations took place; the operation lasted about 20 minutes, and the B seeded clouds lived 275 minutes.

Table 4: Type B Seeded Sample versus Virtual Control Sample (7 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	275 min	265 min	1.04	4
Area	897 km^2	870 km^2	1.03	3
Prec.Mass	124 076 kton	116 441 kton	1.07	7

Δ_3 = 7 x 0.07 x 116 441 kton ≈ 57 056 kton ≈ 46 272 ac-f

(layer: 9.1 mm ≈ 0.36 in)

The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3$ = 96 133 ac-f

(1 097 ac-f/small, 17 255 ac-f/large, 6 610 ac-f/B)

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)
Uvalde	**8**	**11**	**36 100**	**0.43**	**3.94 in**	**10.9**
Bandera	**2**	**3**	**12 800**	**0.35**	**13.87 in**	**2.5**
Medina	**11**	**15**	**28 700**	**0.38**	**9.44 in**	**4.0**
Bexar	**2**	**5**	**11 500**	**0.17**	**7.17 in**	**2.4**
Total	**23**	**34**	**89 100**			
Average				**0.33 in**	**8.61 in**	**5.0 %**

(**Initial seeding** means the number of clouds seeded when the operations began; whereas **extended seeding** means the counties favored by seeding after the initial operations took place.

Note: the difference between the TITAN estimation by cloud comparison and the TITAN estimation by precipitation print is due to the fact that seeded clouds migrated to counties nearby and therefore the calculated increases were distributed on a larger area.

Final Comments

Results are evaluated as **very good**;

1) The micro-regionalization analysis showed increases per county; different zones received downwind benefits; the average increase in precipitation, referred to rain gage seasonal value, is about **5 %**;

2) Radar estimations of precipitation should be considered as measurements of trend. Nevertheless, seeding operations improved the dynamics of seeded clouds;

3) In 2018, the total increase in the region, estimated in 89 100 acre-feet, should be considered a great help to the fresh water natural resources.