**ANNUAL EVALUATION REPORT 2017 EAA**

**Dr. Arquímedes Ruiz-Columbié**
Active Influence & Scientific Management

Cloud seeding operations 2017 began over EAA target area in May. This annual report serves as a summary of results. A total of **94 clouds** were seeded and identified by TITAN in **23 operational days**. Table 1 in page 1 summarizes the general figures:

**Table 1: Generalities**

First operational day: **May 1st, 2017**
Last operational day: **October 3rd, 2017**

**Number of operational days: 23**
(Three in May, five in June, seven in July, three in August, four in September, and one in October)

According to the daily reports operational days were qualified as:

**Seventeen with excellent performance**
**Five with very good performance**
**One with fair performance**

**Number of seeded clouds: 94**
(70 small seeded clouds, 14 large seeded clouds, 10 type B seeded clouds)

**Missed Opportunities: none** (with lifetime longer than 60 minutes)

## Small Clouds

Evaluations were done using TITAN and NEXRAD data.

Table 2 shows the results from the classic TITAN evaluation for the 15 small seeded clouds which obtained proper control clouds.

**Table 2: Seeded Sample versus Control Sample (70 couples, averages)**

| Variable | Seeded Sample | Control Sample | Simple Ratio | Increases (%) |
|---|---|---|---|---|
| Lifetime | 70 min | 40 min | 1.75 | 75 (**56**) |
| Area | 69.2 $km^2$ | 44.6 $km^2$ | 1.55 | 55 (**51**) |
| Volume | 198.1 $km^3$ | 127.0 $km^3$ | 1.56 | 56 (**52**) |
| Top Height | 7.8 km | 7.4 km | 1.05 | 5 (**3**) |
| Max dBz | 53.0 | 51.9 | 1.02 | 2 (**2**) |
| Top Height of max dBz | 3.5 km | 3.5 km | 1.00 | 0 (**0**) |
| Volume Above 6 km | 38.4 $km^3$ | 24.2 $km^3$ | 1.59 | 59 (**41**) |
| Prec.Flux | 572.6 $m^3/s$ | 336.8 $m^3/s$ | 1.70 | 70 (**47**) |
| Prec.Mass | 2403.3 kton | 1001.4 kton | 2.40 | 140 (**121**) |
| CloudMass | 179.4 kton | 111.3 kton | 1.61 | 61 (**50**) |
| η | 13.4 | 9.0 | 1.49 | 49 (**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 554 AgI-BIP and 28 hygroscopic flares were used in this sub-sample with an excellent timing (**93 %)** for an average effective silver iodide dose about **80 ice-nuclei per liter**. The seeding operations lasted in average about 10 minutes. An excellent increase of **121 %** 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 (56 %), area (51 %), volume (52 %), volume above 6 km (41 %), and precipitation flux (47 %) are noticeable. There were slight increases in maximum

reflectivity (2 %) and in top height (3 %). The seeded sub-sample seemed 48 % more efficient than the control sub-sample. Results are evaluated as **excellent**.

An increase of **121 %** in precipitation mass for a control value of 646.5 kton in 15 cases means:

**$\Delta_1$ = 70 x 1.21 x 1001.4 kton ≈ 84 819 kton ≈ 68 788 ac-f (layer: 17.5 mm ≈ 0.69 in)**

## Large Clouds

The sub-sample of 14 large seeded clouds received a synergetic analysis. In average, the seeding operations on these large clouds affected 80 % of their whole volume with an excellent timing (99 % of the material went to the clouds in their first half-lifetime). A total of 276 AgI-BIP and 34 hygroscopic flares were used in this sub-sample for an effective glaciogenic dose about **100 ice-nuclei per liter**.

Also in average, large clouds were 25 minutes old when the operations took place; the operation lasted about 30 minutes, and the large seeded clouds lived 230 minutes.

Table 3 shows the corresponding results:

**Table 3: Large Seeded Sample versus Virtual Control Sample (14 couples, averages)**

| Variable | Seeded Sample | Control Sample | Simple Ratio | Increases (%) |
|---|---|---|---|---|
| Lifetime | 230 min | 190 min | 1.21 | 21 |
| Area | 1100 km$^2$ | 902 km$^2$ | 1.22 | 22 |
| Prec.Mass | 65 750 kton | 41 614 kton | 1.58 | 58 |

An increase of 58 % in precipitation mass for a control value of 41 614 kton in 14 cases may mean:

**$\Delta_2$ = 14 x 0.58 x 41 614 kton ≈ 337 906 kton ≈ 274 042 ac-f**
**(layer: 21.9 mm ≈ 0.86 in)**

## Type B Clouds

Ten type B clouds over EAA target area were seeded during the season. In average, the seeding operations on these type B clouds affected 25 % of their whole volume with a very good timing (86 % of the material went to the clouds in their first half-lifetime). A total of 61 AgI-BIP and 10 hygroscopic flare were used in this sub-sample for an effective dose about **105 ice-nuclei per liter**.

Also in average, type B clouds were 110 minutes old when the operations took place; the operation lasted about 25 minutes, and the B seeded clouds lived 300 minutes.

**Table 4: Type B Seeded Sample versus Virtual Control Sample (6 couples, averages)**

| Variable | Seeded Sample | Control Sample | Simple Ratio | Increases (%) |
|---|---|---|---|---|
| Lifetime | 300 min | 285 min | 1.05 | 5 |
| Area | 950 km$^2$ | 896 km$^2$ | 1.06 | 6 |
| Prec.Mass | 48 578 kton | 42 241 kton | 1.15 | 15 |

**$\Delta_3$ = 10 x 0.15 x 42 241 kton ≈ 63 362 kton ≈ 51 387 ac-f (layer: 6.7 mm ≈ 0.26 in)**

**The total increase: $\Delta = \Delta_1 + \Delta_2 + \Delta_3$ = 394 217 ac-f (~ 33% drifted into other counties)**
**(983 ac-f/small, 19574 ac-f/large, 5139 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** | **33** | **39** | **83 100** | **0.97** | **16.33 in** | **5.9** |
| **Bandera** | **14** | **15** | **51 500** | **1.42** | **17.05 in** | **8.3** |
| **Medina** | **40** | **52** | **106 500** | **1.39** | **13.51 in** | **10.3** |
| **Bexar** | **7** | **9** | **21 800** | **0.33** | **12.14 in** | **2.7** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Total | **94** | **115** | **262 900** | | | |
| **Average** | | | | **1.02 in** | **14.76 in** | **6.9 %** |

(**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 outside the EAA target area.**

## Final Comments

Results are evaluated as **excellent**;

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 **7 %**;

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

3) In 2017, the total increase in the region, estimated in 262 900 acre-feet, should be considered a great help to the fresh water natural resources.

4) This year hygroscopic seeding was continued as an important component of the operations. Results are indicating a stronger synergy between the hygroscopic and the glaciogenic actions (see the 2017 STWMA Evaluation Report for details).