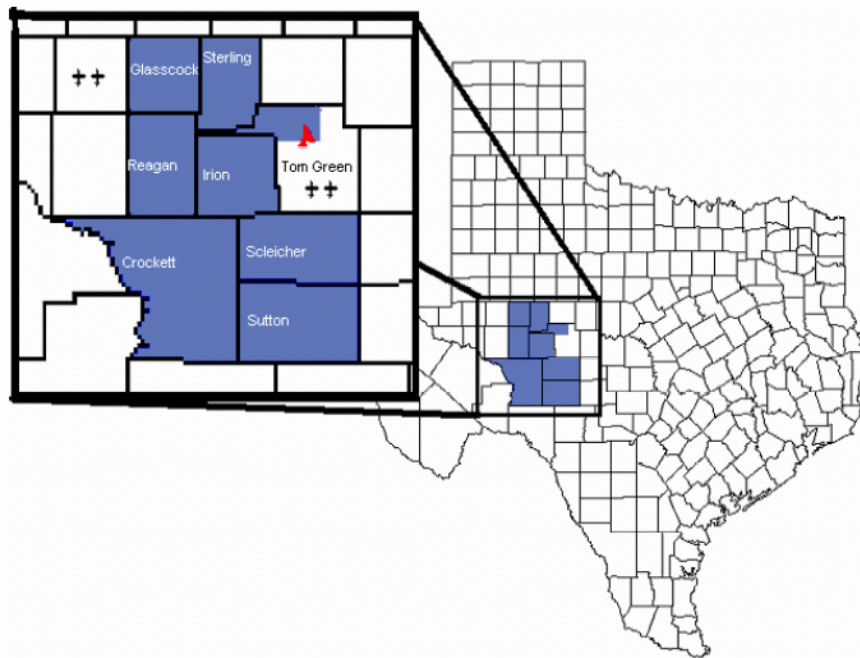


# 2006 ANNUAL REPORT WEST TEXAS WEATHER MODIFICATION ASSOCIATION



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West Texas Weather  
Modification Association  
2006 Annual Report

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Seeding operations started on March 7<sup>th</sup> and ended on October 9<sup>th</sup> with 61 operational days. Eight days were not sufficient for analysis and only one day a data was corrupted. A new meteorologist was hired, beginning the end of June. A few repairs on aircraft did not affect operations. TITAN software operated without any major issues.

2006 was a very dry year with a value at San Angelo under normal by 2.65 inches. August was the most active this season with 14 operational days. Precipitation and percent of normal maps show various regions which received rainfall and those which did not. The mid-summer pattern was influenced largely by the Southwest Monsoon.

Excellent timing for seeding clouds and very good flare usage allowed for the project to operate under budget.

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Meteorologist

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Active Influence & Scientific Management

Cloud seeding operations 2006 began over the West Texas Weather Modification Association target area in March. This annual report serves as a summary of results. A total of **157 clouds** were seeded and identified by TITAN in **53 operational days**. Table 1 in page 1 summarizes the general figures:

**Table 1: Generalities**

First operational day: **March 8<sup>th</sup> 2006**  
Last operational day: **October 9<sup>th</sup> 2006**

**Number of operational days: 53**  
(One in March, six in April, eleven in May, ten in June, eight in July, fourteen in August, two in September, and one in October)

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

**Twenty-three with excellent performance**  
**Seventeen with very good performance**  
**Eleven with good performance**  
**Two with fair performance**

**One with corrupted data: May 2<sup>nd</sup>**

**Number of seeded clouds: 157 (78 small, 33 large, and 45 type B seeded clouds)**

**Missed Opportunities: 2 (1.3 %)**

**April 1<sup>st</sup>: Cloud # 24 over Crocket County (lifetime 68 minutes)**  
**August 23<sup>rd</sup>: Cloud # 207 over Schleicher (lifetime 184 minutes)**

## Small Clouds

Evaluations were done using TITAN and NEXRAD data.

Table 2 shows the results from the classic TITAN evaluation for the 78 small seeded clouds which obtained proper control clouds.

**Table 2: Seeded Sample versus Control Sample (78 couples, averages)**

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
<b>Lifetime</b>	70 min	45 min	1.56	56 ( <b>40</b> )
<b>Area</b>	71.1 km <sup>2</sup>	46.6 km <sup>2</sup>	1.52	52 ( <b>45</b> )
<b>Volume</b>	225.7 km <sup>3</sup>	145.9 km <sup>3</sup>	1.55	55 ( <b>48</b> )
<b>Top Height</b>	8.8 km	8.2 km	1.07	7 ( <b>5</b> )
<b>Max dBz</b>	50.3	48.8	1.03	3 ( <b>4</b> )
<b>Top Height of max dBz</b>	4.3 km	4.3 km	1.00	0 ( <b>0</b> )
<b>Volume Above 6 km</b>	37.2 km <sup>3</sup>	20.7 km <sup>3</sup>	1.80	80 ( <b>54</b> )
<b>Prec.Flux</b>	559.1 m <sup>3</sup> /s	337.4 m <sup>3</sup> /s	1.66	66 ( <b>67</b> )
<b>Prec.Mass</b>	2704.9 kton	1118.9 kton	2.41	141 ( <b>126</b> )
<b>CloudMass</b>	171.7 kton	108.6 kton	1.58	58 ( <b>58</b> )
<b><math>\eta</math></b>	15.8	10.3	1.53	53 ( <b>44</b> )

Bold values in parentheses are modeled values, whereas  $\eta$  is defined as the quotient of Precipitation Mass divided by Cloud Mass, and is interpreted as efficiency. A total of 474 flares were used in this sub-sample with an excellent timing (**78 %**) for an effective dose about **85 ice-nuclei per liter**. The seeding operation for small clouds lasted about **12 minutes** in average. An excellent increase of **126 %** in precipitation mass together with an increase of 58 % 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 (45 %)

volume (48 %), volume above 6 km (54 %), and precipitation flux (67 %) are notable. There are slight increases in maximum reflectivity (4 %), and in top height (5 %). The seeded sub-sample seemed 44 % more efficient than the control sub-sample. Results are evaluated as **excellent**.

An increase of 126 % in precipitation mass for a control value of 1118.9 kton in 78 cases means:

$$\Delta_1 = 78 \times 1.26 \times 1118.9 \text{ kton} = 109\,965 \text{ kton} = 89\,182 \text{ ac-f}$$

## Large Clouds

The sub-sample of 33 large seeded clouds received a synergetic analysis. In average, the seeding operations on these large clouds affected 67 % of their whole volume; with an excellent timing (94 % of the material went to the clouds in their first half-lifetime). A total of 574 flares were used in this sub-sample for an effective dose about **80 ice-nuclei per liter**.

Also in average, large clouds were 29 minutes old when the operations took place; the operation lasted about 35 minutes, and the large seeded clouds lived 180 minutes.

Table 3 shows the corresponding results:

**Table 3: Large Seeded Sample versus Virtual Control Sample (33 couples, averages)**

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	180 min	150 min	1.20	20
Area	777 km <sup>2</sup>	615 km <sup>2</sup>	1.26	26
Volume	3563 km <sup>3</sup>	2789 km <sup>3</sup>	1.28	28
Volume Above 6 km	1256 km <sup>3</sup>	960 km <sup>3</sup>	1.31	31
Prec.Flux	10805 m <sup>3</sup> /s	7901 m <sup>3</sup> /s	1.37	37
Prec.Mass	75 576 kton	47 235 kton	1.60	60

An increase of 60 % in precipitation mass for a control value of 47 235 kton in 33 cases may mean:

$$\Delta_2 = 33 \times 0.60 \times 47\,235 \text{ kton} = 935\,253 \text{ kton} = 758\,490 \text{ ac-f}$$

## Type B Clouds

The sub-sample of 45 type B seeded clouds received a synergetic analysis. In average, the seeding operations on the type B clouds affected 32 % of their whole volume; with a good timing (60 % of the material went to the clouds in their first half-lifetime). A total of 762 flares were used in this sub-sample for an effective dose ~ **135 ice-nuclei per liter**.

Also in average, type B clouds were 125 minutes old when the operations took place; the operation lasted about 38 minutes, and the type B seeded clouds lived 200 minutes.

Table 4 shows the results:

**Table 4: Type B Seeded Sample versus Virtual Control Sample (45 couples, averages)**

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	200 min	190 min	1.05	5
Area	1548 km <sup>2</sup>	1395 km <sup>2</sup>	1.10	10
Volume	5874 km <sup>3</sup>	5264 km <sup>3</sup>	1.12	12
Volume Above 6 km	1499 km <sup>3</sup>	1330 km <sup>3</sup>	1.13	13
Prec.Flux	14456 m <sup>3</sup> /s	12600 m <sup>3</sup> /s	1.15	15
Prec.Mass	124 020 kton	101 655 kton	1.22	22

An increase of 22 % in precipitation mass for a control value of 101 655 kton in 45 cases may mean:

$$\Delta_3 = 45 \times 0.22 \times 101\,655 \text{ kton} = 1\,006\,385 \text{ kton} = 816\,178 \text{ ac-f}$$

$$\text{The total increase: } \Delta = \Delta_1 + \Delta_2 + \Delta_3 = 1\,663\,850 \text{ ac-f}$$

## 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:

County Seeding	Initial Seeding	Extended (increase)	Acre-feet (increase)	Inches (increase)	Rain (season value)	% (increase)
<b>Glascock</b>	<b>18</b>	<b>24</b>	<b>105 900</b>	<b>2.20</b>	<b>13.53 in*</b>	<b>16.3</b>
<b>Sterling</b>	<b>18</b>	<b>28</b>	<b>158 400</b>	<b>3.22</b>	<b>13.58 in</b>	<b>23.7</b>
<b>Reagan</b>	<b>17</b>	<b>23</b>	<b>177 800</b>	<b>2.84</b>	<b>12.44 in*</b>	<b>21.5</b>
<b>Irion</b>	<b>26</b>	<b>31</b>	<b>267 400</b>	<b>4.77</b>	<b>13.05 in*</b>	<b>36.5</b>
<b>Tom Green</b>	<b>16</b>	<b>22</b>	<b>140 000**</b>	<b>1.72</b>	<b>16.01 in</b>	<b>21.5</b>
<b>Crocket</b>	<b>24</b>	<b>33</b>	<b>352 500</b>	<b>2.35</b>	<b>11.35 in</b>	<b>20.7</b>
<b>Schleicher</b>	<b>24</b>	<b>30</b>	<b>239 500</b>	<b>3.43</b>	<b>15.71 in</b>	<b>21.8</b>
<b>Sutton</b>	<b>14</b>	<b>24</b>	<b>256 800</b>	<b>3.31</b>	<b>12.51 in</b>	<b>26.5</b>
<b>Total</b>	<b>157</b>	<b>215</b>	<b>1 698 300</b>			
<b>Average</b> (only for the bold values)				<b>2.98</b>	<b>13.52 in</b>	<b>23.6</b>

(\*) Missed data recreated by spatial interpolation

(\*\*) One half of the Tom Green Area considered

(**Initial seeding** means the counties where the operations began, whereas **extended seeding** means the counties favored by seeding after the initial operations took place).

## **Final Comments**

- 1) Results are evaluated as **excellent**; only one operational day was lost due to corruption of data (May 2<sup>nd</sup>);
- 2) The micro-regionalization analysis showed increases per county; seedable conditions were more frequent over the central zone of the target area; the average increase in precipitation, referred to seasonal value, is about **23.6 %**;
- 3) Radar estimations of precipitation should be considered as measurements of trend. Nevertheless, seeding operations appeared to improve the dynamics of seeded clouds.