2002 Adventures, Ventures, and Misadventures of Weather Modification in Texas

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Abstract. Texas'2002 cloud seeding operations, which began in March, were aided by daily and monthly evaluation reports using the TITAN evaluation software package. By comparison with unseeded control clouds, the evaluation program estimated the modifications that had occurred in particular seeded clouds in regards to timing, dosages, missed opportunities, etc. This paper serves as an annual summary of these results. A total of **897 clouds** were seeded and identified by TITAN in **237 t**arget**-a**rea **o**perational **days (tao days)**. A sub-total of 599 seeded clouds was evaluated with the classic TITAN tool; 56 seeded clouds did not obtain proper data files, and **242 clouds were reserved for the synergetic analysis** (135 large and 107 type B clouds).

0. Introduction

Year 2002 was a very peculiar year in relationship to cloud seeding operations in Texas. Ten projects started the 2002 season. The **Edward Aquifer Authority** (EAA) was no longer an independent entity, but the new **Southern Ogallala Aquifer Rainfall** program was added when it split from **High Plains Water District** program (HPWD) and included the 3 New Mexico counties. In August, HPWD suddenly closed due to the opposition in 3 of its counties. Moreover, the process of evaluation, whose results are the core of this paper, became more complex with the addition of the called **"synergetic analysis"**, a tool designed to analyze large and type B clouds, which usually do not receive proper control partners from the TITAN evaluation (Ruiz et al, 2002; Mittermaier and Dixon, 2000). Synergetic analysis consists in making the comparisons of different periods of the same cloud to estimate the response to the seeding operation and later to construct a virtual control cloud. Details are explained later.

The exhaustive study of every seeded cloud and its corresponding control cloud (real or virtual) allowed us to understand the nature of the Weather Modification actions. From the data generated during this second year of scientific management in Texas we were able to estimate increases of rainfall leaving the clouds and the cost per acre-foot, a cost figure easily understood in Texas. An intense program of public information has begun which gives interested parties these data and figures.

1. Classic TITAN evaluation

A total of 897 clouds were seeded and identified by TITAN on 237 target area operational days during the period March-October 2002. Fifty-six clods did have incomplete data files and were, therefore, not considered in the evaluations; consequently a final sample of 841 seeded clouds was analyzed (low tracking threshold 32 dBz, Bates and Ruiz, 2002). However, 242 seeded clouds (135 large and 107 type B cases) were extracted from the classic TITAN evaluation and reserved for synergetic analyses. Thus, we had 599 small seeded clouds and clusters (precipitation mass smaller than 10^7 ton), which obtained proper control clouds in the evaluation process. Table 1.1 shows the results.

Table 1.1 Small Seeded Clouds versus Small Control Clouds (599 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	85 min	55 min **(61)**	1.55 (**1.39**)	55 (**39**)
Area	58.2 km^2	46.7 km^2	1.25 (**1.18**)	25 (**18**)
Volume	193.2 km^3	140.1 km^3	1.38 (**1.22**)	38 (**25**)
Top Height	8.0 km	7.5 km	1.07 (**1.04**)	7 (**4**)
Max dBz	47.3	45.6	1.04 (**1.02**)	4 (**2**)
Top Height of max dBz	4.2 km	4.3 km	0.98 (**1.00**)	-2 (**0**)
Volume Above 6 km	55.4 km^3	34.8 km^3	1.59 (**1.33**)	59 (**33**)
Prec.Flux	289.0 m^3/s	190.7 m^3/s	1.52 (**1.36**)	52 (**36**)
Prec.Mass	1439.3 kton	667.4 kton	2.16 (**1.89**)	116 (**89**)
CloudMass	119.8 kton	79.5 kton	1.51 (**1.35**)	51 (**35**)
η	12.0	8.4 (**8.5**)	1.43 (**1.41**)	43 (**41**)

Bold values in Table 1.1 are modeled values (Ruiz et al, ibid), whereas η is defined as the quotient between Precipitation Mass and Cloud Mass and is interpreted as efficiency. A total of 3225 flares and 3480 generator-minutes were used in this sub-sample with a very good timing (69 % of the seeding agent went to the clouds during their first half-lifetime), for an effective dose around **40 ice-nuclei per liter** (8 % of the seeding agent came from generators) in relationship to the average volume above 6 km, but should have reached dynamical levels in the aimed new developments by judging the results. A very good increase of 89 % in precipitation mass together with an increase of 35 % in cloud mass illustrates that the seeded clouds grew at expenses of the environmental moisture and used only a fraction of this moisture for their own maintenance. The increases in lifetime, in volume, in volume above 6 km, and in precipitation flux are appreciable, whereas the increase in area (18 %) is around the radar uncertainty. There is a slight increase in maximum reflectivity (2 %), and a little greater increase in top height (4 %), but both are within the respective radar uncertainties. The seeded sub-sample seemed **41 % more efficient** than the control sub-sample.

Our cluster analysis was extended to different other sub-samples. For instance, Table 1.2 shows the results for 267 cases where the couple is composed of "a single seeded case versus a single control case" (267 couples):

Table 1.2 Single Seeded Clouds versus Single Control Clouds (267 couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	40 min	30 min **(33)**	1.33 (**1.21**)	33 (**21**)
Area	29.0 km^2	25.5 km^2	1.14 (**1.08**)	14 (**8**)
Volume	82.8 km^3	69.3 km^3	1.19 (**1.12**)	19 (**12**)
Top Height	7.3 km	7.0 km	1.04 (**1.01**)	4 (**1**)
Max dBz	45.9	44.8	1.02 (**1.01**)	2 (**1**)
Top Height of max dBz	4.0 km	4.2 km	0.95 (**0.98**)	-5 (**-2**)
Volume Above 6 km	18.9 km^3	14.3 km^3	1.32 (**1.07**)	32 (**7**)
Prec.Flux	146.2 m^3/s	105.0 m^3/s	1.39 (**1.20**)	39 (**20**)
Prec.Mass	368.8 kton	203.2 kton	1.81 (**1.57**)	81 (**57**)
CloudMass	52.1 kton	38.5 kton	1.35 (**1.17**)	35 (**17**)
η	7.1	5.3 (**5.3**)	1.34 (**1.34**)	34 (**34**)

A total of 958 flares and 1477 generator-minutes were used in this sub-sample with a very good timing (68 %), for an effective dose around 60 ice-nuclei per liter (10 % of the seeding agent came from generators). Here there are only slight increases in area, in volume, in volume above 6 km, and in precipitation flux, whereas the increases in lifetime (21 %) and precipitation mass (57 %) are appreciable, above the corresponding radar uncertainties.

Results in single-cell cloud evaluation indicate that the expected dynamical response did not occur but that microphysical changes promoted the increase in precipitation mass presumably through an appreciable increase in lifetime, the only primary variable with appreciable increase. The seeded sub-sample appeared to be 34 % more efficient.

A new concept was introduced to analyze some impacts of the seeding actions in the upper levels of the seeded clouds. We defined **top debris** as the echoes at the top level with reflectivity below 32 dBz and at the end of the cloud lifetime. For the seeded sub-sample of single-cell clouds and its control sub-sample, an analysis of top debris (sometimes anvil losses) indicated that at the end of their lifetime the top debris of the seeded clouds had a height of 9.2 km, while the control sample had a value of 9.1 km, a difference of 0.1 km = 328 feet. The top debris of the single-cell seeded clouds was, on average, higher than the top debris of the corresponding control clouds, a feature that points out the undesired losses of moisture at the top level.

A similar analysis of top debris for the single-cell clouds seeded only with generators (cases which occurred only in Abilene and Cotulla target areas) showed that these losses were worse for these cases (29 couples). The average top debris for these 29 seeded cases was 8.5 km, whereas for the control cases average was 7.8 km. The difference 0.7 km = 2295 feet was seven times greater than the value obtained for the sub-sample of 267 cases.

The extension of the cluster analysis to multi-cell cases led to Table 1.3, which shows the results of the evaluation for the sub-sample of multi-cell small seeded clouds and clusters matched with multi-cell control clouds (205 couples).

Table 1.3 Multi-cell Seeded Clouds versus Multi-cell Control Clouds
(205 multi-cell couples, averages)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	120 min	80 min (**88**)	1.50 (**1.36**)	50 (**36**)
Area	93.0 km^2	77.7 km^2	1.20 (**1.19**)	20 (**19**)
Volume	323.7 km^3	244.3 km^3	1.33 (**1.27**)	33 (**27**)
Top Height	8.9 km	8.2 km	1.09 (**1.09**)	9 (**9**)
Max dBz	48.9	46.7	1.05 (**1.03**)	5 (**3**)
Top Height of max dBz	4.3 km	4.5 km	0.96 (**0.98**)	-4 (**-2**)
Volume Above 6 km	95.9 km^3	65.0 km^3	1.48 (**1.41**)	48 (**41**)
Prec.Flux	462.2 m^3/s	314.9 m^3/s	1.47 (**1.41**)	47 (**41**)
Prec.Mass	2818.6 kton	1385.7 kton	2.03 (**2.13**)	103 (**113**)
CloudMass	201.4 kton	140.5 kton	1.43 (**1.39**)	43 (**39**)
η	14.0	9.9 (**9.1**)	1.41 (**1.54**)	41 (**54**)

A total of 1865 flares and 1040 generator-minutes were used in this seeded sub-sample, with a very good timing (70 %), for an effective dose around 40 ice-nuclei per liter, which should have reached dynamical levels in many particular clouds by judging the results. Only 5 % of the seeding material came from generators). Appreciable increases in the main variables but area indicate the occurrence of dynamical responses, with an excellent increase in precipitation mass (113 %). The seeded sub-sample appeared to be 54 % more efficient than its corresponding control.

Table 1.3.1 shows the results of the evaluation of the clouds (singles and multi-cells) that were seeded only with generators:

Table 1.3.1 Seeded Sample versus Control Sample (38 couples, averages)
(Single and Multi-cell clouds seeded only with generators versus their control clouds)

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	70 min	40 min (**44**)	1.75 (**1.59**)	75 (**59**)
Area	47.6 km^2	43.2 km^2	1.10 (**1.01**)	10 (**1**)
Volume	122.3 km^3	113.1 km^3	1.08 (**1.00**)	8 (**0**)
Top Height	6.9 km	6.6 km	1.05 (**0.99**)	5 (**-1**)
Max dBz	45.2	44.1	1.02 (**0.98**)	2 (**-2**)
Top Height of max dBz	3.7 km	3.8 km	0.97 (**1.03**)	-3 (**3**)
Volume Above 6 km	17.8 km^3	19.7 km^3	0.90 (**0.81**)	-10 (**-19**)
Prec.Flux	190.7 m^3/s	154.3 m^3/s	1.24 (**1.08**)	24 (**8**)
Prec.Mass	819.4 kton	547.0 kton	1.50 (**1.36**)	50 (**36**)
CloudMass	65.1 kton	57.0 kton	1.14 (**1.02**)	14 (**2**)
η	12.6	9.6 (**9.4**)	1.31 (**1.34**)	31 (**34**)

A total of 1065 generator-minutes were used in this sub-sample with a good timing (58 %), for an effective dose around **35 ice-nuclei per liter**. Now, only the increases in lifetime (59 %), and precipitation mass (36 %) are appreciable, whereas the increases in area and precipitation flux are very small, within the radar uncertainties. There is not increase in volume, and a decrease in volume above 6 km, which may indicate that the extension of the seeded clouds at the upper levels occurred with values of reflectivity below the tracking threshold, mainly as top debris (**blown top effect**).

The dose is considered intermediate, which is not bad, but it seems like the very small ice particles made a counter-effect.

Coming back to the sub-sample of 205 multi-cell couples, a further analysis of multiplicity using the information about the amount of cells in each scan for every case shows very interesting features. Table 1.4 summarizes these issues:

Table 1.4 Analysis of multiplicity using the amount of cells (n)
(Multi-cell Seeded Clouds versus their Multi-cell Control Clouds)

	<n>	**abs. maximum**	**<maximum>**	**<max. occurrence>**	**<transition>**
Seeded Sample	**1.9**	**16**	**3.8**	**34 min**	**18 min**
Control Sample	**1.7**	**15**	**3.1**	**24 min**	**12 min**

Here, **<n>** is the average of existing cells in the multi-cells, **abs. maximum** is the absolute maximum in the amount of cells, **<maximum>** is the average of maximum number of cells, **<max.occurrence>** is the average time of the maximum occurrence, and **<transition>** is the average time of transition from the single stage to the multi-cell stage.

According to these results, the multi-cell seeded clouds showed a greater multiplicity in average than the control clouds, with a greater absolute maximum, and a greater averaged maximum. The maximum occurrence seemed to be delayed by 10 minutes later in the seeded cases (perhaps because the maximums were usually greater), whereas the transition to a multi-cell stage had a difference of 6 minute. This difference indicates that if the first updraft of a future multi-cell system is seeded it will last longer than expected naturally, producing a little delay in the transition to the multi-cell stage. These results are to some extension slightly different from those obtained during the season 2001, but the use of a lower reflectivity threshold (32 dBz in 2002 versus 39 dBz in 2001) may have affected the final issues.

It is worth noting that the seeded clouds lasted longer in the single-cell stage than their corresponding control clouds. This supports the notion that our seeding activities generally modified the internal dynamic of the clouds. Further study is recommended, and could include an analysis of the relationship between spatial extent of the dynamic forcing that results from seeding versus the magnitude of this forcing.

This year we made a preliminary investigation of the relationship between synoptic conditions and the efficiency of the seeding operations using our data set for the small clouds and clusters in every local project. For the whole state, a sub-total of "172 extra-tropical seeded clouds", and "427 tropical seeded clouds" were identified. An extra-tropical case was defined as a cloud formed in a predominant extra-tropical air-mass, whereas a tropical case was defined as a cloud formed in a predominant tropical air-mass (the opposite case). Extra-tropical cases represented the 29 % of the small clouds and cluster, and were predominant over the Texas Panhandle during the season, while the tropical cases were predominant in the rest of the target areas. There were slightly better responses to the seeding operations from the extra-tropical cases in the Texas Panhandle projects and in Plains and San Angelo target areas, although very close to the radar uncertainties, and no meaningful differences in the rest. An interesting situation was detected in Pleasanton target area, where the very small differences between extra-tropical and tropical cases may be indicating that clouds formed under strong maritime influence, but inland, received a quick continental imprint; this imprint rapidly "continentalized" the clouds, which gave us better opportunities for weather modification actions. However, since there were a few cases in these samples, all of these conclusions are preliminary. Another interesting realization is that tropical conditions had a great influence during the season for all the target areas but the Panhandle projects.

2. The synergetic analysis

We know the limitations that TITAN has to track properly seeded cloud systems. At least in Texas, these limitations have transcended to real problems in the determination of proper control clouds for large clouds (Bates and Ruiz, ibid). Furthermore, the TITAN authors (Mittermaier and Dixon, ibid) have always advised that the use of the TrackMatch facility to obtain control candidates should be limited to "type A" seeded clouds (clouds seeded before they are too old, we selected in Texas 1 hour-period, Bates and Ruiz, ibid). These facts leave out of the analysis the large clouds (precipitation mass greater than 10 000 kilotons) and the "type B" clouds (seeded when they were one hour old or older). The synergetic analysis is a tool designed to evaluate these cases (large and type B clouds), which studies scan by scan the properties of the clouds, making statistical calculations for the periods before, during, and after seeding, and for the whole lifetime. This analysis provides at the end the opportunity to build a virtual control cloud (a model that estimates how the seeded cloud would have evolved as an unseeded cloud). The basis of this analysis is well known, **clouds working in a system are more efficient**, and produce more precipitation than isolated clouds. Additionally, for large and more complex system we need to know the whole history of the system to figure out how its natural evolution would have been. For small clouds and clusters the control cases obtained with TITAN are appropriate enough, but for large and type B systems they are not.

Furthermore, it is very important to know whether or not the seeding operation took place in a cloud already in a steady state situation, when the temporal evolution of some variables in the TITAN side windows appeared to reach a plateau. If this is the case, the period before the seeding operation may be used as belonging to "a control cloud" which had a lifetime shorter than the seeded case, determined using the results in Table 1.1. Type B clouds usually fall in this category. It is important always to determine what percent of the cloud was really affected by the seeding operation. If the cloud was seeded before reaching a steady state, the percent of the cloud affected is considered as a system seeded in its early stages, normalized, taking away the period before seeding, to build a control case. The values obtained are later subtracted to the seeded cloud to construct its final virtual control case. In both cases we construct a virtual control cloud by a method that may be named **"of the normalized increases".**

The analysis for large clouds with precipitation mass greater than 10 000 kton (135 cases) offered the results shown below:

Table 2.1 A summary of the temporal evolution for some variable in large clouds

Variable	Before seeding	During seeding	After seeding	Whole lifetime
<n>	3.4	5.2	4.9	4.7
dn/dt	1.3	2.0	-1.2	0.0
PrecMass/scan	586 kton	1177 kton	1903 kton	1292 kton
PrecMass/cell. scan	186 kton	226 kton	388 kton	275 kton

(<n> is the average of cells; dn/dt is the rate of increase in the amount of cells every 20 minutes; PrecMass/scan means precipitation mass per scan, PrecMass/cell.scan means per cell and per scan)

These values indicate an increase of 53 % in the amount of cells during the seeding operation in large clouds (5.2/3.4 = 1.53), accompanied by an increase in precipitation mass per scan of 101 % (1177/586 = 2.01). For the entire lifetime respective increases were 38 % and 120 %. However, these increases must be normalized before being used in the construction of the virtual control cases. It is very important to point out that the rate of production of cells did increase during the operations, and later became negative in association with the processes of merging and dissipation.

For type B clouds (107 cases), the corresponding results were:

Table 2.2 A summary of the temporal evolution for some variable in type B clouds

Variable	Before seeding	During seeding	After seeding	Whole lifetime
<n>	4.7	6.3	5.0	5.2
dn/dt	0.8	0.2	-1.1	0.0
PrecMass/scan	594 kton	992 kton	1258 kton	892 kton
PrecMass/cell. scan	126 kton	157 kton	252 kton	172 kton

These values show an increase of 34 % (6.3/4.7 = 1.34) in the amount of cells during the seeding operations of type B clouds, together with an increase of 67 % in precipitation mass per scan (992/594 = 1.67). For the entire lifetime the respective increases were 11% and 50 %. In average type B clouds lasted 255 minutes, while large clouds lasted 210 minutes, and this difference in 45 minutes seems decisive.

As we have said, during the 2002 season 242 seeded clouds deserved synergetic analyses, 135 type A large cases, and 107 type B cases. However, 5 large clouds and 6 type B clouds were discarded for different reasons: four were seeded too late during their senescence period (after full maturity, without **S**torm **S**everity **S**tructure index signs, a feature in TITAN), two were very maritime and seeded relatively late, and five received really marginal doses (around 1 ice-nucleus per liter). These 11 cases did not show responses to the seeding operations.

Table 2.3 shows the results for the large clouds, whereas table 2.4 corresponds to the type B clouds.

Table 2.3 Seeded Sample versus Virtual Control Sample (130 couples, averages)
(Large Seeded Clouds versus their Virtual Large Control Clouds)

Variable	Seeded Sample	Virtual Control	Simple Ratio	Increases (%)
Lifetime	210 min	185 min	1.14	14
Area	856 km^2	812 km^2	1.05	5
Volume	4285 km^3	3975 km^3	1.08	8
Top Height	13.2 km	12.6 km	1.05	5
Max dBz	53.4	52.4	1.02	2
Top Height of max dBz	5.4 km	5.4 km	1.00	0
Volume Above 6 km	2165 km^3	1966 km^3	1.10	10
Prec.Flux	5435 m^3/s	4940 m^3/s	1.10	10
Prec.Mass	82324 kton	70282 kton	1.17	17
CloudMass	3166 kton	2871 kton	1.10	10
η	26.0	24.5	1.06	6

A total of 3496 flares and 1165 generator-minutes were used in this sub-sample for an average dose around 30 ice-nuclei per liter, which may have reached higher levels in some individual turrets (4% of the seeding agent came from generators).

For the 101 type B cases:

Table 2.4 Seeded Sample versus Virtual Control Sample (101 couples, averages)
(Type B Seeded Clouds versus their Virtual Control Clouds)

Variable	Seeded Sample	Virtual Control	Simple Ratio	Increases (%)
Lifetime	255 min	245 min	1.04	4
Area	702 km^2	657 km^2	1.07	7
Volume	3399.3 km^3	3138 km^3	1.08	8
Top Height	11.8 km	11.2 km	1.05	5
Max dBz	50.3	49.9	1.01	1
Top Height of max dBz	4.9 km	5.0 km	0.98	-2
Volume Above 6 km	1761 km^3	1603 km^3	1.10	10
Prec.Flux	3616 m^3/s	3328 m^3/s	1.09	9
Prec.Mass	59639 kton	52399 kton	1.14	14
CloudMass	2330 kton	2101 kton	1.11	11
η	25.6	24.9	1.03	3

A total of 1409 flares and 1165 generator-minutes were used in this sub-sample for an average dose around 20 ice-nuclei per liter, which may have reached higher levels in some particular turrets.

Increases are very similar in table 2.3 and in table 2.4. Type B clouds in average lasted more than large type A clouds, but offered less precipitation. Most of the virtual increases in the last two tables are within the radar uncertainties and therefore are undetectable with our actual tools. Nevertheless, the synergetic analysis and its derivate results allow us to approach the evaluation of the seeding operations on seeded clouds that did not get proper controls and to obtain estimations about the values of the possible increases in the radar variables. In fact, we have now a better idea about how proper control clouds must be for large seeded clouds. The problem might be partially solved with an improved TITAN version that might evaluate individual convective seeded clouds without considering a family tracking number. However, for large single clouds, which are rare events, the problem would persist.

Probably the interpretation of results from the different tables presented in this report might be more clarified with the presentation of the different precipitation masses as water layers. We can define these layers with the variable "layer depth", D,

D = Precipitation Mass (kton) / Area (km^2), which has unit of millimeters.

(One inch is equal to 25.4 millimeters)

Table 2.5 shows the corresponding values for small clouds and clusters (from Table 1.1):

Table 2.5 Values of "D" for small cloud and cluster samples

	Seeded Sample	Control Sample	Increase	% to Seeded Sample
D	**0.97 inch**	**0.56 inch**	**0.40 inch**	**41 %**

It is important to notice that the increase in this case is not the arithmetic difference between the seeded and the control values because different values of area are in the calculations. The values of D simulate depth values of layers below an average cloud for each sample and the equivalent layer for the increase calculated from the radar data. Here the percent of increase referred to the seeded sample is 41 %, and might be a close figure to the values that may be obtained by a proper rain gage network.

For large clouds (from table 2.3):

Table 2.6 Values of "D" for large clouds

	Seeded Sample	Control Sample	Increase	% to Seeded Sample
D	**3.79 inches**	**3.40 inches**	**0.55 inch**	**14 %**

A 14 % of increase is reported in the depth of a virtual layer below the average large seeded cloud.

For type B clouds (from table 2.4):

Table 2.7 Values of "D" for type B clouds

	Seeded Sample	Control Sample	Increase	% to Seeded Sample
D	**3.34 inches**	**3.13 inches**	**0.41 inch**	**12 %**

A 12 % of increase is reported in the depth of a virtual layer below the average type B seeded cloud.

The average figure for **all the seeded clouds**:

Table 2.8 Values of "D" for all the clouds

Seeded Sample	Control Sample	Increase	% to Seeded Sample

D	**1.70 inches**	**1.32 inches**	**0.42 inch**	**25 %**

A 25 % of increase is reported in the depth of a virtual layer below the average seeded cloud of the season 2002.

3. A glance to the local assessments

A further evaluation of performance based on a scale of 1 to 5 was done under daily bases. An **excellent operational day** is defined as one with an excellent timing (75 % or higher), an excellent dosage (dynamic levels), an excellent increase in precipitation mass (90 % or more), and no missed opportunities. Excellent days receive a mark of 5. A very **good operational day** is defined as one with a very good timing (between 65 and 74%), a **very** good dose (intermediate to dynamic levels), a very good increase in precipitation mass (between 60 and 89 %), and 15 % or less missed opportunities. Very good days receive a mark of 4. A **good operational day** is defined as one with a good timing (between 55 and 64 %), a good dose (intermediate), a good increase in precipitation mass (between 30 and 59 %), and between 16 and 30 % missed opportunities. Good days receive a mark of 3. Days with a mixture of excellent, very good, and good marks for the different indexes are evaluated according with the predominant nuance, determined by using the median, and more qualitative criteria. Days with lower performance than those described in this paragraph but with some increases in variables as area, volume, volume above 6 km, precipitation flux, and precipitation mass are classified as **fair**, which sometimes means failure, and receive a mark of 2. Days with decreases in precipitation mass and other variables are classified as **poor** and receive a mark of 1. Using this scale to classify the 237 target area operational days reported, the following distribution was obtained:

Thirty excellent target area operational days, seventy-nine very good target area operational days, eighty-six good target area operational days, and thirty-two fair target area operational days, for a median of three (ten of these days were out of data)

A total of **93 missed opportunities** (990 seedable clouds were present over the whole state target area during the operations) were distributed as table 4.1 shows below together with other managing indexes:

Table 3.1: An Analysis of Performance

Missed Opportunities (M.O), Efficiency using Seedable Conditions, Timing, Dosages used, and Increase

Project	**M.O**	**Efficiency (%)**	**Timing (%)**	**Dosage (in/ l)**	**Layer increase (%)**
CRMWD (Big Spring)	2 (10 %)	90	70	25	23
HPUWCD (Littlefield)	14 (17 %)	86	63	40(1)	17
NPWMA (Dumas)	7 (10 %)	90	84	20	26
PGWD (White Deer)	9 (10 %)	90	73	20	24
SOAR (Plains)	11 (18 %)	82	69	20	27

STWMA (Pleasanton)	6 (12 %)	88	74	55	31
SWTREA (Cotulla)	14 (20 %)	80	55	35(2)	13
TBWMA (Del Río)	9 (8 %)	92	70	120(3)	28
WCTWMA (Abilene)	4 (3 %)	97	65	40(4)	21
WTWMA (San Angelo)	17 (6 %)	94	69	40	29
TEXAS	**93 (9%)**	**91**	**69**	**40**	**25**

(1) Problems of over-seeding during top seeding operations (too many flares per turrets)
(2) Pale increases in seeded clouds mainly due to generators that promoted "blown top" effects
(3) Slight over-seeding during base seeding operations which did not hurt the clouds
(4) Pale increases in seeded clouds mainly due to generators that promoted "blown top" effects

4. Conclusions and comments

There are many features that deserve final comments. First of all, the system of scientific management implanted in Texas in 2001 has paid off its initial inversion (Bates and Ruiz, ibid). Daily, monthly and annual evaluations have allowed us to improve the performances in each local project, a sort of continuing education that challenges the personnel to stay proficient in the positions they are working at.

Second, there are more statistical evidences that acetone generators are very limited seeding tools, at least for convective clouds. Despite better doses and timing than last year, the increases obtained in 2002 with them were pale, and the losses as top debris appear to be significant (see table 1.3.1 and the comments associated).

Third, we also realized first-hand the well know need for meteorologists and pilots to maintain excellent inter-personnel communications during the operational flights. Over-seeding problems can be minimized with a more intelligent use of TITAN side windows and a better pilot-meteorologist communication link. The over-seeding factor is more probable in top seeding operations, which aim small turrets, undetectable by radar, when the meteorologist needs more information from the pilots.

Four, the interaction with experts in other atmospheric disciplines, and with the general public taught us that there is a long road to walk before outsiders understand the nature of our job. We are facing a great handicap because **Classic Meteorology's** main concern about storms is that they are sources of bad weather, and has focused study in order to describe the processes from **a macroscopic point of view, as well as mechanical.** We know now how to appeal to their instability to promote distinct behaviors, which occur far from equilibrium. Storms are not totally determined by environmental conditions. **Storms are a dynamic product of their environment, are conditioned by the environment, but also they condition the**

environment. With this conception, the passive and contemplative style of Classic Meteorology can be removed. Additionally, Advertent Weather Modification operations do not compete energetically with the weather systems but they trigger a chain of events using **catalysts** (such as silver iodide), which help release latent energy. Talk of the impossibility of modifying weather systems because of their huge energy levels does not recognize that small causes can produce great effects, the base of Thermodynamics two centuries ago. A rigorous mechanical point of view has become too mechanistic, thereby neglecting the existence of thermodynamic machines and engines where a little spark serves to release latent chemical energy.

When the seeding operations take place the chain of events triggered allows the cells to receive additional moisture from the environment, which eventually feeds the ice in place. Unseeded clouds do not receive this additional moisture, but continue to grow 'naturally', because the seeding operations in other cells do not block the confluence of moisture in the neighbor clouds. All convective clouds start as thermals that promote the formation of **micro-scale low-pressure centers** in low levels, which are the cause of the aforementioned confluence. If the environment is rich enough in moisture, the described process will occur, otherwise clouds will not exist. The **"Robbing from Peter to pay Paul argument"** ignores these facts and the evidence that favorable effects downstream are also associated with the seeding operations (see also DeFelice, 2002).

Current quantitative evaluations in Texas (Ruiz, 2002) show that there are no great increases either for top height or for maximum reflectivity in the seeded clouds, two variables very related with severe weather. These variables illustrate that operations do not increase the risks of severe weather. Besides, operations target seedable cells, which are very young, contain plenty of supercooled water and are iceless. We attempt to use dynamic doses, with a maximum around **100 ice-nuclei per liter**, far from overseeding levels (1000 ice-nuclei per liter). The aforementioned results in this paragraph additionally show that the increases in precipitation mass (at the bottom of seeded clouds) are greater than the increases in cloud mass for the same clouds, illustrating that seeded clouds grow at the expenses of environmental moisture which is abundant for all other nearby convective clouds as well. The mechanistic conceptions that clouds are like "pitchers" should be replaced with one that is more realistic and recognizes that clouds are open systems with a very strong interaction with the environment that import mass and energy from it, and export entropy. Clouds then can grow in structural and functional complexity, can reach steady states far from equilibrium, can produce synergy… This new conception permits to recognize the **Weather Modification facts**. The **World Meteorological Organization** has slowly evolved every year toward a more favorable opinion of planned weather modification. From very skeptical statements in the early 90's, passing on to an encouraging policy statement in 1998, to a more optimistic actual view, which includes not only axiological statements but also guidelines to develop operational programs, this evolution points to a growing recognition of the **Weather Modification facts** (WMO statement, 2002).

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