Comments on Current Dual Cloud Seeding Operations in Texas

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ABSTRACT: Within the past three years, the weather modification programs in Texas have occasionally used hygroscopic flares as a complement for glaciogenic cloud seeding operations. Introduced at an exploratory level, those dual seeding (hygroscopic plus glaciogenic) operations have been systematically evaluated using TITAN in an attempt to obtain evidence of possible greater impacts on storm radar signals than those obtained only using AgI flares. This article presents a summary of those evaluations.

1. Introduction

Operational programs in Texas have a relatively long history using glaciogenic seeding. In 1997 the already operating local programs introduced the use of the TITAN (Thunderstorm Identification Tracking Analysis and Nowcasting) software package which permitted a better interaction between the radar information and the operational meteorologists. Since TITAN also has an evaluation software package, corresponding quantitative evaluations were first introduced in 2000 in order to compare radar-derived properties of seeded and unseeded storms. The results have been systematically reported and have indicated positive signals in the radar variables associated with increases in precipitation for the seeded storms in comparison with their controls. In general terms, the cloud seeding operations have seemed to improve the dynamics of seeded storms.

The final conceptual model for glaciogenic cloud seeding operations in Texas was created after a research program led by the late W. G. Finnegan (2001), although it also owned features to previous research programs. In summary, seedable cells are selected among those with top temperatures about -5^0 C but warmer than -15^0 C. The glaciogenic material is released during the early stages of cell development, dosages are expected to reach the dynamic mode of seeding (~ 100 ice-nuclei per liter), and the operations should have a massive character (seeding of all possible seedable cells). Those operations are expected to modify the natural regime of the supercooled water in the seeded cells, empowering mainly the formation of ice-aggregates about -5^0 C (Bates and Ruiz, 2002). As mentioned before, TITAN evaluations during the last 12 years have demonstrated positive results associated with the operations.

2. DUAL SEEDING

In August 1996, a case study and a non-randomized cloud seeding experiment were conducted on five convective clouds in Texas (Woodley and Rosenfeld, 1999 a and b).

The experiment offered an occasion to observe and compare radar measurements of seeded storms under different treatments (glaciogenic, hygroscopic or none). The authors reported that "the cloud seeded with hygroscopic flares 'out performed' the other three by a large margin and was anomalous relative to all other non-seeded clouds within the scan of the radar". The aforementioned case study (August 11th, 1996) involved a dual seeding operation with ejectable AgI flares near the cloud top (- 8^{o} C) while hygroscopic flares were released at the base level. The test was evaluated as highly successful from an operational point of view. Although those results only allowed for heuristic interpretations, they suggested then that dual seeding (hygroscopic plus glaciogenic) might result in greater impacts than those expected with only one type of seeding.

Current dual cloud seeding operations in Texas are still at the exploratory level. There is a growing body of evidence that environmental conditions, like dust and other pollutants may be hurting the cloud efficiency for rain, especially at the warm levels (where the collision-coalescence mechanism dominates). An increased colloidal stability of natural clouds may also lead to a higher inception of precipitation at cold levels, with the subsequent higher probability for anvils (losses of humidity) and severity (intense precipitation, hail and gust at the surface). If this is the case, the hygroscopic part of the dual seeding action might help to alleviate those symptoms and also might allow for the formation of more graupel (soft hail about – 5^{o} C) instead of hard hail at colder levels (about - 25^{o} C).

However, some observations are pertinent here. Seeding with hygroscopic materials in principle should conduce to slightly colder levels of droplet freezing, with a freezing point depression which is proportional to the number of solute particles per mole in the droplet (the van 't Hoff factor). Additionally, the high concentration of ions might slow down the natural nucleation rate of ice crystals, especially if Mg^{++} and Ca^{++} are present (Finnegan, 1998). Those counter effects might be detrimental for the purpose of empowering aggregation about – 5^{o} C; therefore, a glaciogenic material would be necessary to reach the desired result. These statements constitute the basis for the current dual cloud seeding operation concept used in Texas:

1) Hygroscopic material is released in order to improve the collision-coalescence mechanism in seedable convective clouds, which in turn will produce larger droplets and eventually more graupel;

2) Glaciogenic material is simultaneous released with the purpose of counteracting the detrimental effects hygroscopic agents might have on ice-aggregation.

3. EVALUATION RESULTS AND BRIEF DISCUSSION

Within the past three years a total of 58 storms have received dual seeding in Texas. The details of this figure are offered on Table 1 below:

Table 1: Distribution of dual seeded cases per target area during the period 2009-2011 in Texas.

Project	Year	Dual Cases	Small Storms	Large Storms	Type B Storms
WTWMA (San Angelo)	2009	5	3	1	1
	2010	4	1	1	2
	2011	4	1	2	1
STWMA (Pleasanton)	2010	7	3	3	1
	2011	9	5	3	1
SWTREA (Carrizo Springs)	2010	12	6	1	5
	2011	17	5	2	10
Total		58	24	13	21

As Table 1 indicates, only 24 dual seeded cases (~ 41 %) were small clouds (precipitation mass less than 10 000 kton). Those are the clouds that usually get proper control matches by the TITAN evaluation (unseeded clouds with similar dynamics during their first 20 minutes of their evolution after TITAN assigns a track number) (see Ruiz-Columbié, 2004). Large and Type B storms (usually also large) rarely coexist in their regions with similar unseeded storms. For this reason, only the small seeded cases constitute the sample under analysis here. Table 2 shows the comparison with the sample of corresponding control cases:

Variable	Seeded Sample	Control Sample	Simple Ratio	Increases (%)
Lifetime	73 min	45 min	1.62	62 (60)
Area	69.9 km^2	45.9 km^2	1.52	52 (42)
Volume	247.7 km^3	150.4 km^3	1.65	65 (45)
Top Height	8.3 km	7.6 km	1.09	9 (7)
Max dBz	53.5	51.9	1.03	3 (3)
Top Height of max dBz	3.6 km	3.5 km	1.02	2 (1)
Volume Above 6 km	74.7 km^3	38.7 km^3	1.93	93 (50)
Precipitation Flux	549.6 m^3/s	332.9 m^3/s	1.65	65(54)
Precipitation Mass	2590.5 kton	979.2 kton	2.65	165 (141)
Cloud Mass	204.8 kton	126.8 kton	1.62	62 (52)
η	12.3	7.8	1.58	58 (56)

Table 2: Seeded sample versus control sample (24 couples, averages)

A total of 111 BIP AgI flares and 24 hygroscopic flares were used in the sample with an excellent timing (98% of the seeding materials went into the targets in their first half-lifetime). The comparison seems to indicate that the seeded sample was favored by the seeding operations; whereas the dual character of those operations appears to favor the seeded clouds even with higher impacts than those usually reported in the evaluations of glaciogenic seeding. The increase in precipitation mass (141%) deserves special attention since typical increases are in a range around 100%. The increases observed here might indicate the existence of synergy due to the dual character of the seeding operation. Of course, this interpretation should be considered only heuristically because of the small sample, its pool nature, and the fact that the AgI dose was, on average about 55 ice-nuclei per liter which seems to be enough to produce a dynamic response by its own. However, the dual seeding operation seems to have clearly improved the dynamics of the seeded sample when compared with its corresponding control sample.

CONCLUSIONS

Exploratory dual seeding operations in three target areas of Texas were conducted on 58 convective storms during the seasons 2009, 2010, and 2011. The results of the TITAN evaluation for the 24 small seeded storms that obtained proper control storms appear to indicate that increases in precipitation mass might expect to be higher than those habitually observed in glaciogenic seeded cases. However, this preliminary result should be carefully handled and interpreted only as evidence and not proof of any potential synergy between hygroscopic and glaciogenic materials. There is a need for a randomized experiment using dual seeding in order to demonstrate its efficacy; such experiment should also have a strong microphysical component to prove the impacts that the hygroscopic action may have on the ice-phase.

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