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Preliminary Field Experiments of Snomax^{TM} on Cumulus Mediocris Clouds to Artificially Induce the Production of Ice Particles.

James A. Jung in conjunction with Snomax Technologies
North Dakota Atmospheric Resource Board
P. O. Box 1833
Bismarck, ND 58502

Snomax Technologies
95 Allens Creek Rd.
Rochester, NY 14618

ABSTRACT

Snomax^{TM} Snow Inducer, Pseudomonas syringae, has undergone preliminary field studies to determine its ability to produce ice particles in cumulus type clouds. Initial results show the production of ice particles at concentrations of 100's/liter within 8 minutes after seeding with Snomax^{TM} at temperatures near -5°C.

1. Introduction

The presence or absence of ice particles in continental cumulus clouds generally determines its efficiency to produce rain on the ground. Typically, except for the low concentrations of biogenic ice nuclei (Schnell and Vali, 1976; Levin and Yankosky, 1988; Vali et al., 1976) the atmosphere has a very limited supply of active ice nuclei at temperatures warmer than -15°C. Even at -20°C the average number of effective ice nuclei in the atmosphere is only about 1 liter^{-1} (Pruppacher and Klett, 1980). Consequently this deficiency of effective ice nuclei in continental convective clouds, with cloud top temperatures greater than about -12°C, produce little or no rain (Pruppacher and Klett 1980).

It is known that large numbers of living and dead microorganisms can be found in rain, hail and snow (Gregory, 1967; Parker, 1968; Parker and Barsolm, 1970; Mandrioli et al., 1973). These microorganisms were assumed to be swept out or collected by falling hydrometeors until Schnell and Vali (1972, 1973) reported that some of these microorganisms were actually used as freezing nuclei.

Vali et al. (1976) isolated a bacterial culture from decomposing leaves which was the most effective in producing freezing nuclei. Maki et al., (1974) identified the bacteria as Pseudomonas syringae, a bacteria normally found on plant surfaces as an epiphyte. This ice nucleation-active bacteria was found to be active at temperatures between -2° and -10°C (Maki and Willoughby, 1978; Lindow et al., 1978; Yankofsky et al., 1981b; Lindow et al., 1982). Figure 1 compares the bacterial freezing spectrum of Snomax to AgI and dry ice. AgI activates between -8° and -12°C, while Snomax will initiate the the formation of ice at significantly warmer temperatures (Ward and DeMott 1989).

Snomax (Pseudomonas syringae) aerosols were found to be highly efficient and fast acting, apparently nucleating ice by a

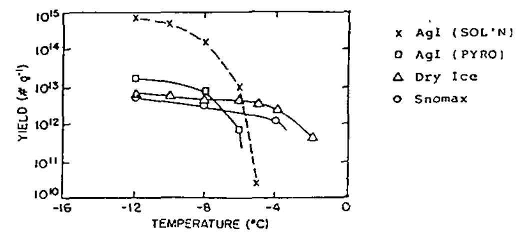

Figure 1. Comparison of the ice crystal yield versus temperature for Snomax, dry ice, and two of the more efficient AgI-type ice nucleating aerosols from solution combustion and pyrotechnic formulation. (from Ward and DeMott, 1988)

condensation freezing mechanism and at rates comparable to those of dry ice (Ward and DeMott, 1988). Preliminary field tests with Snomax showed visible glaciation effects at temperatures as warm as -5°C (Ward and DeMott, 1988). These results suggest a great potential for Snomax as another ice nucleating agent for use in weather modification.

This paper reports some initial results of seeding cumulus clouds with Snomax for the purpose of ice production for weather modification purposes.

2. PROCEDURE

2.1 Seeding Hypothesis

To study the effects of Snomax as a cloud-ice initiating agent, cumulus type clouds were used. These cumulus had cloud top temperatures warmer than -6°C and had little or no natural ice. These clouds were seeded with a mixture of 80% Pseudomonas syringae and 20% silica base at the rate of 20 g min^{-1} during the entire time the aircraft was in-cloud. After seeding, subsequent penetrations were made through the cloud near the same height to measure the number of ice particles. The liquid water content of the cloud was also to be measured, but a malfunction with the liquid water probe made this impossible. A series of clouds at different temperatures were to be used to determine the effects of Snomax as an ice nucleant at temperatures between -2° and -6°C. To do this a relatively large field of cumulus mediocris to cumulus humilis were necessary.

2.2 Instrumentation

Quantitative measurements of the number of ice particles and general atmospheric conditions were accomplished by using a SPEC model III ice particle counter, Rosemont Temperature Probe, EG+G system dew point hygrometer and a Loran position indicator. These values were acquired and recorded by an airborne data system using a Z-80 based microprocessor. This system was designed to record data at one second intervals and be written to floppy disks.

The ice particle counter (IPC) is a cross polarized ice particle counter which uses the concept reported by Turner and Radke (1973) and is explained by Lawson and Stewart (1983). The measurements with the higher particle counts were smoothed by using a 5 second average for that point similar to Lawson and Stewart (1983).

The Rosemont temperature probe uses a platinum resistance temperature element and has a range of +50° to -50°C with an accuracy of 0.5°C and a resolution of 0.1°C. Comparison of this instrument with others during the North Dakota Thunderstorm Project (Boe et al., 1989) showed a consistent error of 1.0°C colder than the actual temperature. For the purpose of this paper the graphs have been adjusted to show the actual temperature (1°C has been added to the measured temperature).

The aircraft used was a Beechcraft Duke which has been suitably modified to accommodate the instruments for weather modification experiments.

3. RESULTS

A total of five different clouds were seeded with Snomax. The first two candidates were within a series of clouds which were approximately 3 to 4 km apart. Analysis of the flight track shows that after seeding the initial flight path was not intercepted. Consequently there were no measurements made of the seeded areas.

The third candidate was seeded at temperatures between -1.5° and -2.5°C of which there were no ice particles detected before seeding. Subsequent penetrations were conducted at 3 and 5 minutes after seeding. Little or no airframe icing occurred during any of the penetrations. There were also no signs of growth by the cloud during the duration of the experiment. Ice particles were not expected at this temperature because according to Fig. 1 the activation temperature of Snomax was not reached.

After climbing back to the -5°C level a fourth candidate was chosen for seeding. On subsequent passes at 3, 6 and 11 minutes after seeding no significant amounts of ice particles were detected. Airframe icing occurred on each of the 3 penetrations. This cloud grew and eventually formed an anvil. Determination of ice crystal concentrations at cloder temperatures higher in the cloud was not attempted.

The fifth candidate was similar to the fourth, and was seeded on the first two passes through the cloud with a total of 30g of Snomax. On the first pass through the cloud there were very few ice particles detected (Fig 2a). Cloud temperature was somewhat variable, and the ride was moderately turbulent (fig. 2b). The second pass, 3 minutes later, was smoother with a more consistent updraft. There were more ice particles detected, but still not in high concentrations, and with a more uniform cloud temperature (Fig. 3). During both the first and second passes the aircraft accumulated as much as 7 mm of ice on each pass.

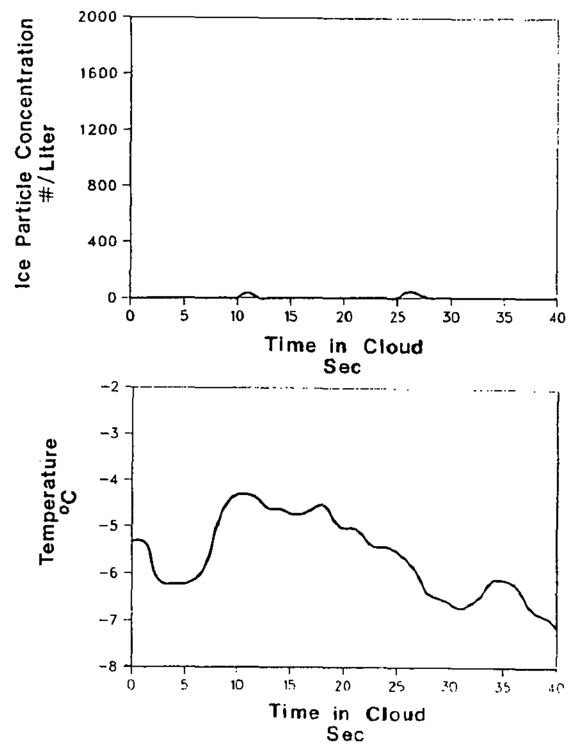

Figure 2. a) Ice particle concentration and b) cloud temperature of initial seeding penetration.

There were some definite changes in the cloud by the time of the third pass (7 minutes after initial seeding). The cloud had grown approximately 2000 ft in height since seeding. Upon entering the cloud the ride became turbulent with varying degrees of updraft and downdraft intensity. Significant numbers of ice particles were detected along with warmer temperatures as shown in Fig. 4. During this pass the aircraft accumulated only small amounts of airframe ice. These

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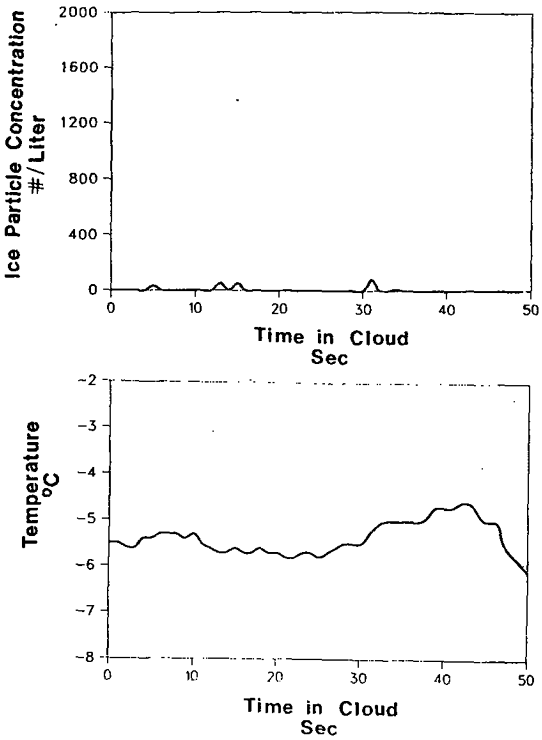

Figure 3. a) Ice particle concentration and b) cloud temperature of second seeding penetration, 3 minutes after initial seeding.

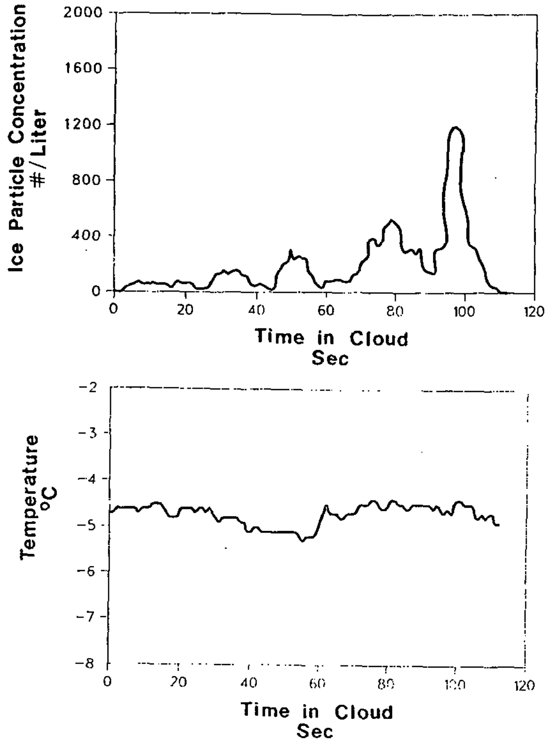

Figure 5. a) Ice particle concentration and b) cloud temperature 12 minutes after initial seeding.

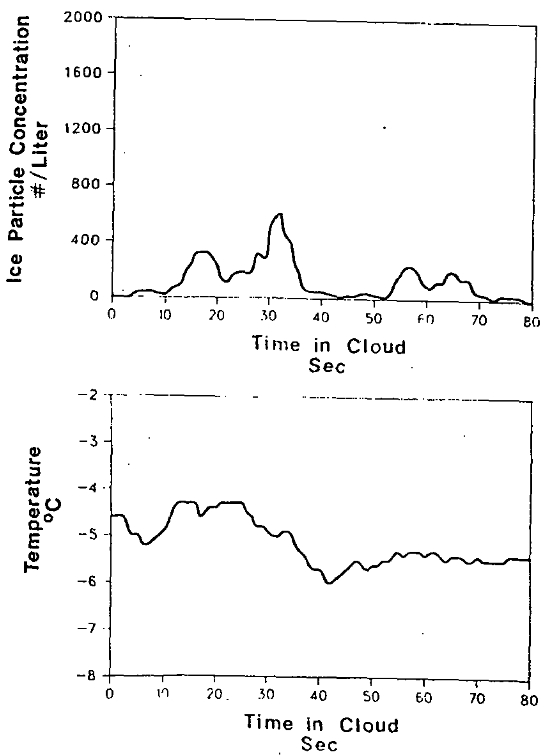

Figure 4. a) Ice particle concentration and b) cloud temperature, 7 minutes after initial seeding.

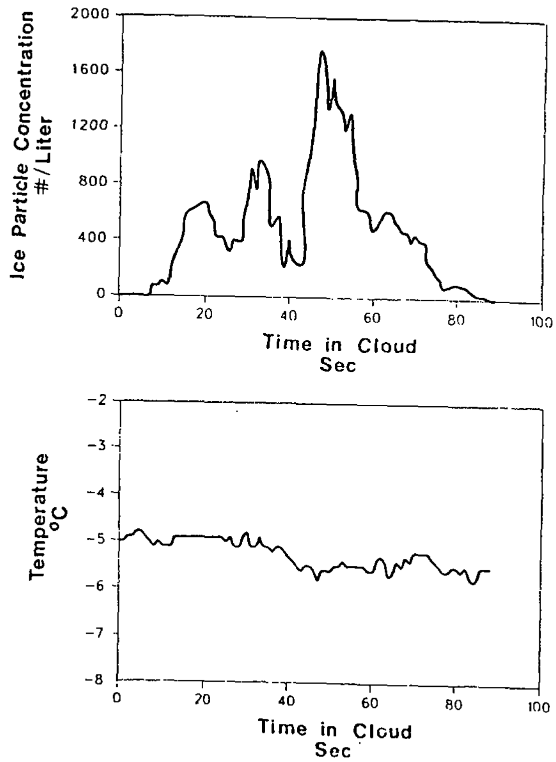

Figure 6. a) Ice particle concentration and b) cloud temperature 17 minutes after initial seeding.

observations are consistent with the 200 seconds required for the dry bacteria to grow to a 15-20 um diameter hydrometeor found by Levin et al., (1987) and the 3 to 5 minutes required for 90% nucleation found by Ward and DeMott (1988).

During the fourth pass through the cloud (12 minutes after initial seeding) there were no major changes except there was a greater concentration of ice particles shortly before exiting the cloud (Fig. 5). Airframe icing was again minimal. At this time the cloud had started to show signs of forming an anvil and had grown approximately 6000 ft above its original seeding height.

The final pass through this cloud was 17 minutes after the initial seeding pass. At this time graupel and raindrops were hitting the windshield along with high concentrations of ice particles (Fig. 6). This cloud had now grown into a small cumulonimbus with an anvil. Subsequent passes through this cloud were not attempted due to its size and nature.

The field of cumulus around these two seeded clouds was still relatively the same as when we started. The two seeded clouds eventually ingested some of the neighboring smaller clouds. Two other cumulus clouds near the seeded clouds were penetrated at the -5°C level, looking for natural ice with only small amounts found (similar to Fig. 2a and 3a). These "control" clouds were monitored for approximately 10 minutes without signs of growth or natural ice production.

Upon descent past cloud base the fourth and fifth seeded clouds were producing rain to the ground with occasional cloud to ground lightning strokes.

4. CONCLUSION AND COMMENTS

Snomax is a bacterial protein which has an ice nucleating activation temperature between -2° and -5°C. While inconclusive, seeding at temperatures near -2°C did not produce any detectable ice crystals while ice particles were detected in concentrations of 100 liter^{-1} 8 minutes after seeding at temperatures near -5°C. It is not clear why ice particles were not detected in the fourth cloud but it is speculated that penetrations at higher altitudes and colder temperatures would have revealed at least some traces of ice particles.

Snomax shows a potential for use in rain enhancement type weather modification operations on cumulus clouds, although further research needs to be conducted regarding its feasibility for the use in hail suppression operations. The major concern here is the two orders of magnitude less ice particles possible per gram of Snomax as compared to AgI-AgCl-NaCl aerosols at temperatures colder than -12°C (see Fig. 1). Snomax being active at warmer temperatures may prove to be of greater importance, than total number of particles produced. Further studies should be conducted to determine the importance of both factors.

5. ACKNOWLEDGMENTS

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