Comparison of First Radar Echoes in Seeded and Unseeded Convective Clouds in North Dakota

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ABSTRACT

First radar echoes on a randomized cloud seeding project in North Dakota appeared closer to cloud base and at higher temperatures on seed days than on no-seed days. The average first echo temperature was near −11°C on no-seed days and −7°C on seed days.

1. Introduction

Dennis and Koscielski (1972) reported that first echoes in convective clouds in South Dakota seeded with either silver iodide or salt formed closer to cloud base and at warmer temperatures than first echoes in unseeded clouds. This note provides some additional evidence from a randomized cloud seeding project in North Dakota, which tends to support their earlier findings.

2. Reduction of radar data

The North Dakota Pilot Project was operated from Watford City in western North Dakota from 1969 to 1972 (Dennis *et al.*, 1975). Clouds were seeded, principally from below base, by aircraft equipped with silver iodide generators in attempts to stimulate showers and suppress hail. In 1972 a few clouds were also seeded with powdered salt (NaCl).

A quantitative 10 cm weather radar was operated in the summer of 1972 with data recorded on magnetic tape. The data included raster scans of convective clouds in the area, which permit a detailed study of first radar echoes in the clouds.

The identification of first echoes was carried out by one of the present authors (Koscielski), who was not engaged on the project and who worked on the radar data without knowledge of which days were seed or no-seed days. The data were first reduced by a computer. By viewing microfilm printouts of computed values of Z_e, the equivalent radar reflectivity factor, at different elevation angles, the analyst identified heights of first echoes in completely new showers and of new echoes around existing showers.

It should be noted that the analyst, working without reference to seeding logs, could not tell which clouds occurring on seed days were actually seeded. It is likely that some of the echoes on seed days developed in clouds which were not seeded, but any such are treated as seed cases in this note.

One seed day with identifiable first echoes was dropped from the seed sample when a check of operational logs showed that only salt seeding was done, leaving a sample of 10 no-seed and 14 seed days (Table 1). It is thought that the remaining seed days, shown in Table 1, should be comparable to the silver iodide cases of the earlier study, since silver iodide was the primary seeding agent.

3. Results

In the previous study, first echo height was related to cloud model output, particularly to predictions of maximum updraft speed. Lack of detailed information on cloud bases and tops precludes fitting models to the clouds scanned in the present study. However, comparisons of the seed and no-seed data samples are instructive.

The average height of the first echo above cloud base for the no-seed sample of Table 1 is 2.6 km, compared to 2.0 km for the seed sample. This is somewhat less than the 1.0 km difference between no-seed and silver iodide cases found for the Rapid City area by Dennis and Koscielski (1972), but still indicates lower first echoes for silver iodide seeded clouds. A t-test suggests the difference in means is significant at the 0.03 level.

The average temperature of first echo formation for the no-seed sample is −11.4°C compared to −7.1°C for the seed sample. The corresponding values for the earlier study were −14.8°C for no-seed cases and −7.4°C for silver iodide seed cases, which again agree quite well with the new data. A t-test on the new data indicates the difference in mean temperature of first echo formation is significant at the 0.001 level.

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4. Discussion

The apparent occurrence of a few echoes at temperatures above 0°C may signify either lack of precision in the radar measurements or the formation of some echoes through coalescence of cloud droplets. Either factor would tend to obscure differences between the seed and no-seed samples related to activity of silver iodide. The existence of significant differences between the seed and no-seed samples suggests 1) that the ice (Bergeron) process is important in initiation of precipitation in many cumulus clouds of the northern Great Plains (compare Dye *et al.*, 1974), and 2) that silver iodide seeding as practiced in the North Dakota Pilot Project in 1972 speeded the initiation of the process in a substantial fraction of the clouds occurring on seed days.

The results of the present and the previous study by Dennis and Koscielski (1972) indicate that effects of silver iodide seeding in North Dakota and western South Dakota are quite similar, in that the seeding is associated with an average temperature of first echo formation around −7°C. The echoes presumably indicate the presence of graupel of several hundred microns in diameter. It is not immediately apparent how the silver iodide crystals from acetone generators burning a solution of AgI and NH_4I, which become active around −5°C (Blair *et al.*, 1973), could produce such particles at −7°C if the entire process took place in an updraft of, say, 5 m s^{-1}. A partial explanation may be that the warmest first echoes form by coalescence and that the echoes produced by silver iodide seeding actually average a few degrees colder. Further investigations of the internal circulations and microphysics of cumulus congestus clouds may in time clarify the complex relationships involved.

TABLE 1. Summary of identified first echoes for 1972 listed in order of appearance.

Date	Cloud base height (km MSL)	Heights of first echoes (km above cloud base)	Temperatures of first echoes (°C)
		No-Seed Days	
21 May	2.7	4.1, 4.2, 4.2, 3.7	−24, −24, −24, −20
25 May	2.0	2.2, 2.7, 2.5, 2.2, 2.9, 4.3, 1.2, 1.4, 1.2, 2.6	−6, −10, −8, −6, −12, −23, −1, −2, −1, −9
1 Jun	3.2	0.1, 0.1	5, 5
4 Jun	2.1	1.5, 5.9, 5.9, 2.0	0, −29, −29, −3
7 Jun	2.5	5.5	−28
17 Jun	2.1	2.6, 1.6, 3.4, 3.1	−4, 2, −8, −8
17 Jul	2.1	1.7	−7
27 Jul	2.4	2.9	−11
5 Aug	3.3	3.5, 3.7, 1.2, 2.5	−23, −22, −5, −14
11 Aug	3.4	2.2, 1.6, 1.6, 2.0, 0.4, 2.0, 2.0, 2.1, 1.7	−12, −8, −8, −11, 0 −11, −11, −12, −8
		Seed Days	
11 Jun	2.2	3.2, 4.8, 3.5	−10, −20, −11
23 Jun	3.0	0.7, 0.8, 1.8, 1.8, 0.1, 1.3	2, 1, −7, −7, 8, −2
25 Jun	1.5	2.9, 1.3, 0.9, 2.8, 1.0, 3.3, 2.3, 2.2, 1.1	−6, 6, 9, −5, 8, −8, −2, −1, 7
27 Jun	2.2	2.3, 1.8, 2.2, 2.3, 1.7, 1.8, 2.0, 2.5, 2.3, 2.0, 2.1, 2.3, 2.3, 1.0, 1.0, 1.8	−10, −7, −10, −10, −6, −7, −9, −12, −10, −9, −9, −10, −10, −3, −3, −7
7 Jul	2.5	2.7, 1.8, 1.8, 0.5, 1.3, 1.1	−11, −7, −7, 2, −5, −4
10 Jul	3.5	1.9, 0.5, 0.5, 1.5, 1.5	−11, −2, −2, −8, −8
13 Jul	3.0	1.0, 0.5, 1.0, 0.8, 0.1	−1, 3, −1, 1, 7
14 Jul	2.4	1.2, 0.6, 0.5, 0.5	−2, 2, 2, 2
15 Jul	1.7	2.0, 1.3, 2.5, 1.1, 2.8, 2.0, 2.5, 1.1	−5, 0, −8, 2, −10, −5, −8, 2
22 Jul	1.6	3.2, 4.2, 3.2, 5.4, 4.4, 4.6, 3.4	−8, −14, −8, −22, −16, −17, −9
1 Aug	2.4	1.6, 2.8, 3.1, 3.2, 2.6	−3, −11, −12, −13, −9
12 Aug	4.0	1.2, 3.3, 2.4	−8, −22, −15
17 Aug	2.5	2.9, 1.8, 1.9, 2.5, 1.5, 1.0, 0.9, 2.4, 2.8, 2.0, 4.0	−12, −3, −4, −9, −2, 1, 1, −8, −10, −5, −17
20 Aug	1.5	2.4, 2.5, 1.7, 2.3, 2.3	1, 0, 6, 2, 2

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