INCREASES IN SILVER IODIDE ATTRIBUTABLE TO GROUND GENERATORS: HIGHLIGHTS OF THE 1975 ALBERTA GROUND GENERATOR EXPERIMENT

K. L. Grandia and D. S. Davison
Intera Environmental Consultants Ltd.

1. INTRODUCTION

During the summer of 1975, Intera Environmental Consultants conducted a field research program to investigate the cloud seeding potential from a network of ground-based silver iodide generators. The purpose of this study was to determine the heights and concentrations of silver iodide by means of selected aircraft traverses at different levels. This program was part of an evaluation of the potential for cloud seeding from ground-based sources (Intera, 1975 a,b), directed by the Alberta Weather Modification Board, (AWMB).

The area of the ground generator study is shown in Figure 1 which is from the Alberta Hail Project Field Program, 1975 (Deibert, 1976). Also shown in Figure 1 is the area of the aircraft-based cloud seeding experiment discussed further by Deibert and Renick (1975). Within the ground-based generator study area 17 silver iodide generators were operated under contract to the AWMB from the period June 1 to August 20, 1975.

2. MEASUREMENT SYSTEM

The aircraft used in this study was a Piper PA-32-300 'Cherokee Six', which was capable of carrying the necessary equipment, pilot, and flight technician to a ceiling of at least 15,000 feet. There was a total of 130 hours, on 88 flights, flown for this study. Of these 88 flights there were 41 case study days for analysis in this study.

The aircraft was equipped with an NCAR Acoustical Ice Nuclei Counter (Langer, 1975) which is designed to sample a known volume of air and detect the number of ice nuclei within the volume. Basically, the air is directed to a pre-cooled cloud chamber. Ice crystals are created on the sampled ice nuclei, grow and settle to the bottom of the chamber, and are drawn through an acoustical sensor. This sensor detects the ice crystal, and the signal is fed to an integrating counter and recorder. The output data were left in counts per minute which corresponds approximately to ice nuclei per litre.

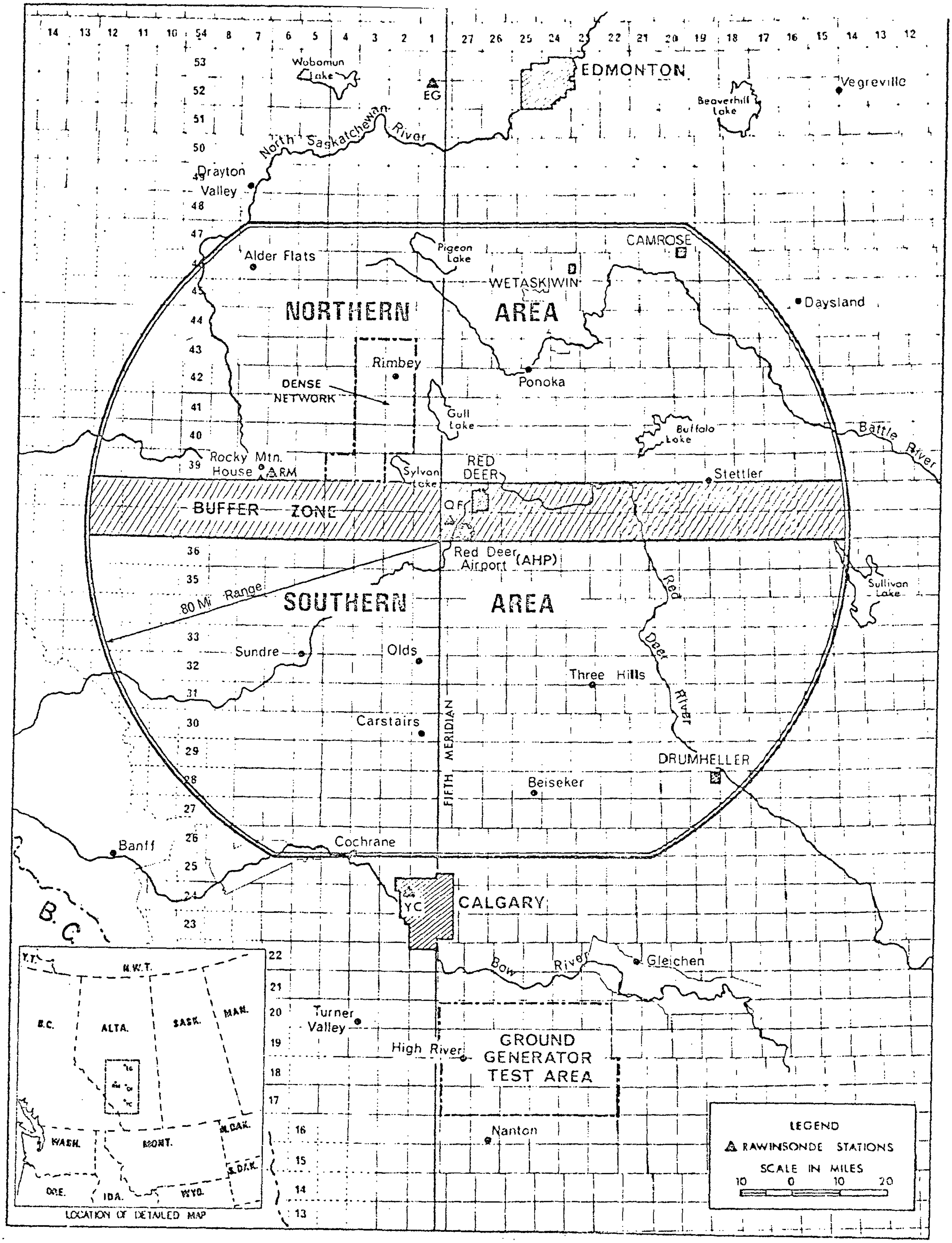

Figure 1 1975 Alberta Hail Project and Ground Generator Test Area.

The recording platform on the aircraft was the Metrodata M8 Airborne Meteorological System and the Metrodata 620 Recorder. The M8 system is capable of measuring Temperature, Relative Humidity, Indicated Airspeed, Pressure Altitude, VOR Azimuth and DME Distance. These data are then recorded onto 1/2" cassette tape via the 620 recorder.

The ground support equipment included a pickup truck, a pilot balloon theodolite and balloons, a Taylor weatherscope, and a sling psychrometer. The Taylor weatherscope provided a readout of wind speed and direction, and barometric pressure, and the psychrometer was used for accurate dry and wet bulb temperatures. Both systems were lab-calibrated prior to the field operation.

Single theodolite tracking of pilot balloons provided a measure of the winds aloft during the study period. The observer used a worksheet and hand calculator to derive the winds for selected releases. The winds were then relayed to the aircraft controller via a radio-telephone installed in the truck. It was necessary to have the pibal winds to update the aircraft position, so the dispatch of the operator and the launch of pibals was under the direction of the aircraft controller.

3. DESIGN OF ANALYSIS PROCEDURES

The ultimate concern of this study was the possibility of effective seeding of storms from an area source of ground based generators. This analysis considered the ice nuclei measurements from the point of view of what would influence a hail-producing storm. Estimates made from comprehensive studies of a super-cell in northeastern Colorado indicated an entrainment rate of about 10^{14} liters of air per minute (Foote and Fankhauser, 1973). Thus a storm is influenced by the average concentration over a huge volume of air. It is not influenced by an isolated peak value which occurs in a very small volume of air.

The viewpoint of what influences a storm is in marked contrast to a plume study. Usually in a plume study one is concerned with maximum concentrations often related to air pollution problems. A high concentration even if in a small volume of air is important for a plume study, but not from the viewpoint of what influences a large storm.

Hail suppression by ground generators is an approach based on the concept of air mass seeding. The most important question to answer is:

> What are the average concentrations of ice nuclei at various heights within the whole region containing ground generator under the types of meteorological conditions associated with hailstorms?

In order to simulate the average concentrations that a storm would 'see' and to treat all case days in as consistent and objective a way as possible, a standardized averaging technique was adopted.

Since there was roughly one generator per township, it is reasonable

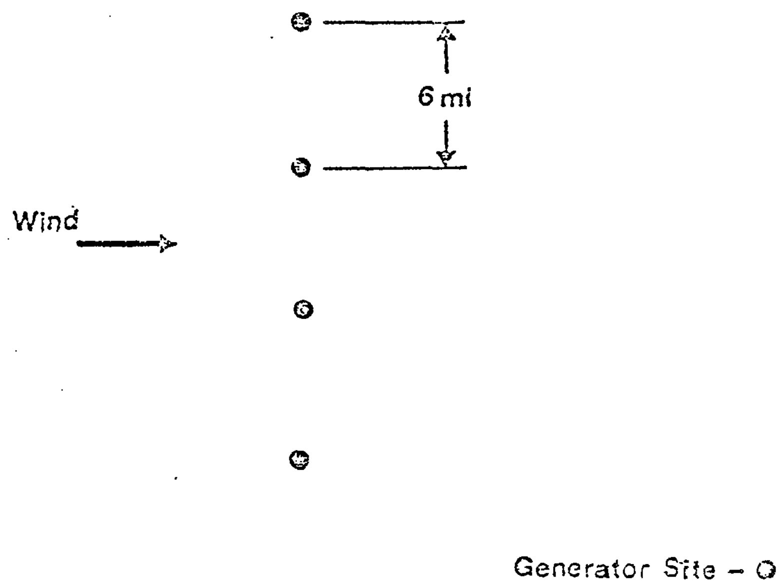

Figure 2 An Idealized ground generator network.

to adopt a six-mile path length as a standard averaging path length. Furthermore, this is a suitable size scale for the inflow of cumulus clouds.

In the idealized generator network shown in Figure 2, the areal average across the whole length of generators would be the same as across the path of a single generator averaged over six miles. Thus, a six-mile path length is averaging over each generator's share of the downwind region.

In practice, the generators were not so regularly spaced so that in most cases proper areal averages over long path lengths past many generators could not be directly measured. Using a standard averaging path length for cross-wind traverses through regions of high concentrations associated with generators assured consistent and uniform treatment of data regardless of whether there were generators operating at single sites, at a row of sites, or at irregularly spaced sites.

On most days, there was at least one generator site at which more than one generator was operating. In order to treat all the data consistently the data presented included the reduction of the observed concentrations (averaged over standard path lengths) to those concentration levels corresponding to single generators at each site. The reduction of concentrations was done by dividing the observed average concentrations by two if there are two generators per site; by three if there are three generators per site, and so forth.

4. EXPERIMENTAL RESULTS

Using the analysis procedures outlined in Section 3, the case days were classified according to meteorological conditions and to distances downwind from the source.

Morning (pre-inversion break-up) and afternoon background concentrations of ice nuclei were determined. Also, those days on which hail was reported in the vicinity of the study area were compared with non-hail days. It was noteworthy that hail days showed background concentration that were not consistently higher or lower than the afternoon background averages (see Table 1). Furthermore, the morning background levels were typically less than half of the afternoon levels.

The overall standarized average concentrations for afternoon traverses downwind of the generator network are shown in Table 2, along with the number of runs making up the average. Also shown in the table are the average concentrations for the runs flown greater than three miles downwind from the generators.

These average concentrations are plotted on Figure 3, together with the average afternoon background concentrations.

The ground generators can be seen to have caused an increase in the areally-averaged ice nuclei concentrations by a factor of 2 to 4 over background up to a height of 10,000 feet, msl. which is a typical cloud base for Alberta hailstorms.

There is a slight decrease in the lower level standarized ice nuclei concentrations for the samples further downwind, although this decrease is probably not significant.

HEIGHT (1000's ft. MSL)	AVERAGE BACKGROUND CONCENTRATIONS		HAIL DAY BACKGROUND CONCENTRATIONS	
	Value (c/min)	Number of samples	Value (c/min)	Number of samples
4	2.1	5	1.4	4
6	2.4	6	1.6	2
8	1.7	6	1.5	2
10	1.4	4	0.8	2

The ground elevation in the test area is 3400 ± 200 ft. MSL

Table 1 Average afternoon background concentrations of ice nuclei.

HEIGHT 1000's ft. MSL	Average Concentration for All Runs (except 4 stable/inversion cases)		Average Concentration Excluding Near Generator Cases	
	Value (c/min)	Number of Runs	Value (c/min)	Number of Runs
4	7.2	19	5.8	15
5	5.8	14	5.3	12
6	8.1	17	8.4	16
7	5.8	10	5.8	10
8	3.3	14	3.4	13
9	5.8	4	5.8	4
10	3.4	5	3.4	5

The ground elevation on the test area is 3400 ± 200 ft. MSL. Near generator cases are cases where the flight path was less than three miles downwind from the generators.

Table 2 Average standardized concentrations of ice nuclei in the region affected by ground generators.

The apparent elevated maximum around 2500' agl. is not inconsistent with recent laboratory modeling experiments reported by Willis & Deardorff (1976). The physical basis of the elevated maximum is believed to be due to the differences in upward and downward mixing under convective conditions. A more detailed paper of this feature is under preparation.

A fundamental assumption in this entire experiment is that observations of ice nuclei concentrations in an undisturbed non-storm environment can measure the effectiveness of ground generators in making more ice nuclei available for storms. However, a storm is not simply superimposed on a non-disturbed atmosphere. Rather the storm circulation patterns can reach the ground level to high up into the atmosphere (up to 40,000 feet) over a wide horizontal region. Throughout the summer there were occasional flights in the vicinity of storms which evidenced the effect of storm circulation patterns on ice nuclei concentrations.

5. CONCLUSIONS

The previous discussion has outlined the highlights from the analysis and interpretation of the entire data set presented in INTERA (1975b). From these results, certain conclusions were reached. However, there are uncertainties in the numerical values of both the background concentrations and concentration increases attributed to the generators. These

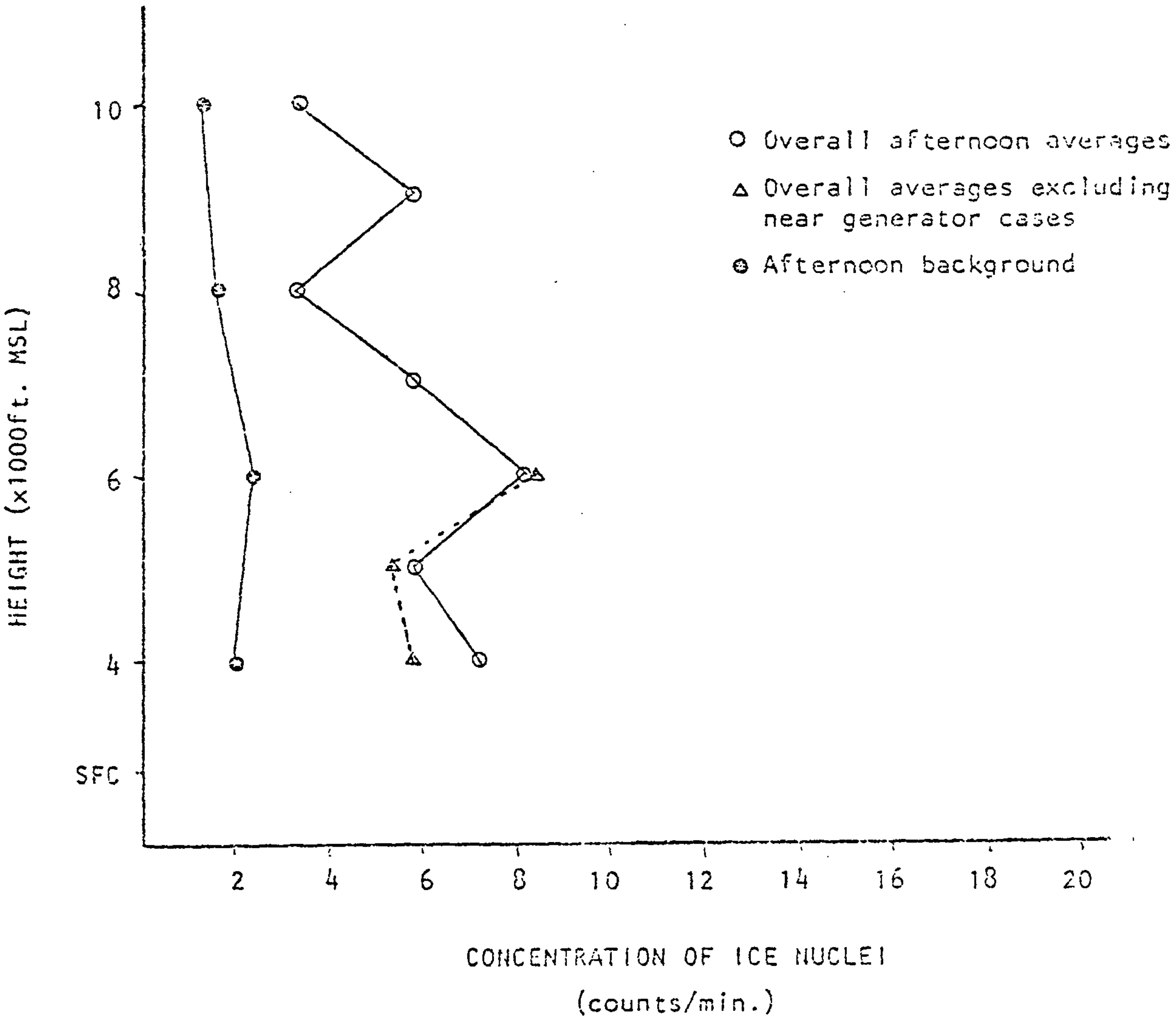

Figure 3 Overall standardized average concentrations for afternoon traverses downwind of the generators.

uncertainties arise due to the limited number of suitable cases and to inherent instrumental limitations of response and resolution of the NCAR counter. Notwithstanding these limitations the following points can be concluded:

1) Investigations of afternoon background ice nuclei measurements reveal an average of approximately two per liter, but this appears to be a function of stability and wind shear. The morning background was approximately 0.5 per liter, or a factor of about 3 to 4 less than the afternoon value.

2) The concept of a network of ground generators for cloud seeding is predicated on an areal, or air mass seeding of the clouds. Thus it is necessary to treat the effluent in a manner that is consistent with how the material

influences the clouds. A supercell storm entrains approximately 10^{14} liters of air per minute. Based on the measured background concentrations, natural ice nuclei are entrained at the rate of about 2×10^{14}/min; thus, the influence of AgI seeding must be superimposed on this number.

3) Within the limitations of the data set, a network of ground generators with approximately one generator per township was shown to lead to average concentrations of 5 to 10 c/min or 2-4 times over background, decreasing slightly with height up to typical cloud base heights. In comparison, an aircraft continually burning one flare produces 10^{16} ice nuclei per minute which leads to an average concentration of 100 c/min for a supercell storm entraining 10^{14} liters of air per minute.

4) Measurements made in the updraft of one thunderstorm showed a variable concentration within the updraft ranging from background to a factor of three over background.

5) Morning inversion tests showed the trapping of the AgI beneath the inversion surface. These observations were consistent with documented pollutant-trapping beneath the inversion.

6) Four cases in this study suggested that the local circulation due to the thunderstorm induces large variability in the spatial distribution of AgI. It is uncertain as to the extent of this influence, but it does point out the need for a better understanding of the thunderstorm-environment interaction.

Significant conclusions were reached and presented in this study as to the concentrations of natural and artificial ice nuclei up to typical cloud base height. These results answered the questions originally posed at the outset of this experiment. However, by themselves, these results do not provide the basis for an evaluation of ground generators as a seeding technique.

The following uncertainties must be addressed prior to an effective design for any operational program. There must be an understanding as to the effectiveness of the concentrations of AgI on the thunderstorm. Furthermore, it is vital to understand the effects of the local thunderstorm wind circulation patterns on entrainment of natural and artificial nucleating agents into the thunderstorm.

Without the answers to these two questions proper design of ground generator network cannot be accomplished.

6. ACKNOWLEDGEMENTS

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