"REVIEWED"

EMERGENCY CLOUD SEEDING IN GEORGIA, SUMMER, 1977

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Abstract. Three drought relief cloud seeding programs were conducted in Georgia during the summer of 1977 by on-site meteorologists who flew on specially equipped seeding aircraft. Suitable clouds, actively growing cumulus towers reaching at least the -5°C level, were seeded with ejectable silver iodide pyrotechnic flares. The seeding technique was patterned after the National Oceanic and Atmospheric Administration's Florida Area Cumulus Experiment (FACE) in southern Florida, and followed a dynamic seedability hypothesis.

In limited evaluation of one of the three programs, a target/control comparison indicated an excess of 27 percent in actual July-August precipitation over that predicted from control area precipitation. A one tailed Student's t test indicated less than five chances in 100 that this difference could be attributed to chance.

1. INTRODUCTION

The impacts of a drought, which was affecting much of the southeastern United States during the Spring and early Summer of 1977, prompted concerned citizens in the Dawson, Georgia area to consider a cloud seeding program. By late June most of the corn crops in this area had been lost and the continuing drought was beginning to affect peanuts and soybeans. At a public meeting on June 22 the pros and cons of a cloud seeding program were discussed, and an emergency program was initiated with funding to be provided through voluntary contributions of one dollar per acre of peanuts or soybeans. A program name was selected (Southwest Georgia Rain Gain) and a committee raised the needed funds with considerable dispatch and contracted with North American Weather Consultants to conduct the seeding program.

Interest in cloud seeding generated by this program and the on-going drought led to the establishment of two additional seeding programs in Georgia - near Statesboro and near Waynesboro. See Figure 1 for location map. Both programs also were conducted by North American Weather Consultants (NAWC) with funding supplied on a similar voluntary basis.

2. PROJECT DESIGN

All three seeding programs were designed to transfer the techniques used and knowledge gained from the Florida Area Cumulus Experiment (FACE) to Georgia. A similar drought relief program had been conducted by NAWC in Jamaica with encouraging results (Griffith and Brown, 1976). FACE is an on-going research program sponsored by the National Oceanic and Atmospheric Administration (NOAA) in southern Florida. FACE began in 1970 following some preliminary experiments conducted in 1968 and 1970 which indicated precipitation from single cumulus clouds could be increased as much as 300% (Simpson and Woodley, 1971). The goal of FACE is to determine whether rainfall over a large area can be increased by seeding. Results from previous FACE experimentation indicate rainfall over an area can be increased by 20 to 50% although these results are currently going through a confirmation experiment (Woodley et al., 1977).

The seeding technique used on FACE consists of flying through the upper portions of actively growing cumulus clouds with tops colder than -10°C. A specially equipped plane drops silver iodide pyrotechnics into updraft regions

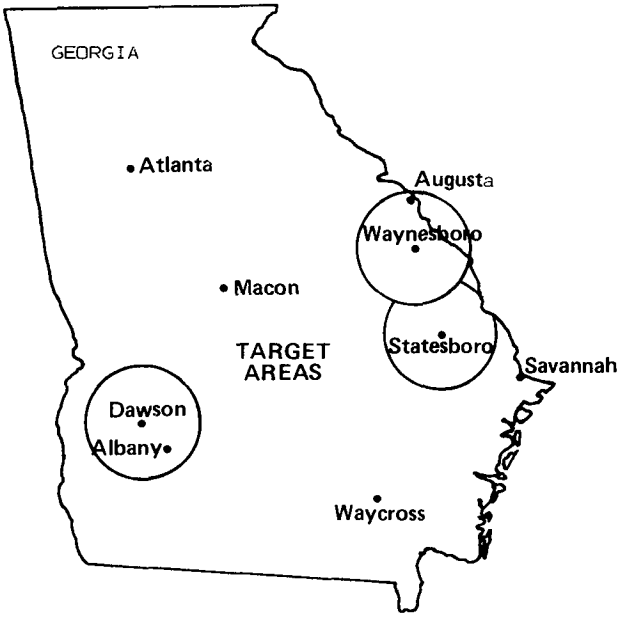

Fig. 1 Target areas of the three seeding projects, July-August 1977

of clouds which contain significant quantities of supercooled water droplets. Ignited as they are released from the plane, the flares fall 3000 to 5000 feet before being completely consumed. Artificial freezing nuclei produced when the silver iodide impregnated pyrotechnic material burns cause formation of ice crystals while the supercooled water droplets within the cloud evaporate. Heat of fusion released within the cloud by this conversion causes the cloud to grow larger than it would have naturally, which in turn produces more rainfall since cloud size and rainfall are closely related. The effects of adding additional heat to clouds through seeding is normally referred to as dynamic seeding.

This same dynamic seeding technique was used by NAWC in Georgia in 1977. Twin-engine Cessna aircraft were fitted with racks holding 102 pyrotechnic silver iodide flares, containing 20 grams of silver iodide. Figures 2 and 3 provide photographs of one of the seeding aircraft and of a seeding rack. A NAWC project meteorologist flew with each aircraft and selected the cumulus clouds to be seeded. Clouds were seeded within a 30 mile radius of Dawson, Statesboro, and Waynesboro. Target size was selected based on an estimate of how large an area one aircraft could cover effectively.

Fig. 2 Turbocharged seeding aircraft

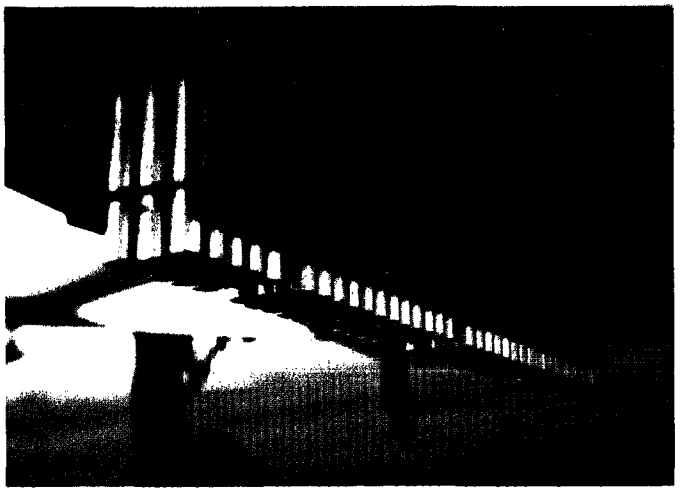

Fig. 3 Seeding flare rack

3. OPERATIONS

The FACE seeding techniques were utilized except that the minimum cloud top temperature criteria were revised upward from $\leq$ -10°C to $\leq$ -5°C. The -5°C level was normally located near 5500 m (18,000 ft MSL). No observations of liquid water content were available so the on-board meteorologist subjectively assessed the cloud's water content through visual observation. Most clouds during the operational periods were lower than the -5°C level and were therefore not seedable. Clouds reaching this height did occur, however, on an average of one day out of every two or three. These favorable clouds seemed to occur more frequently in the Dawson area than in the other two project areas. The reason for the difference in seeding opportunities between the western project (Dawson) and the two eastern projects is uncertain. The consensus of the meteorologists involved was that there were more air mass occurrences in the western project while suitable clouds in the eastern projects seemed to occur primarily with synoptic disturbances. Table 1 summarizes the operations on the three projects.

Table 1 Summary of operations of the three projects

Target Area	Operational Dates, 1977	Seeding Days	Number of Seeding Flights	Number of Flares Fired
Dawson	07/13-09/06	24	27	751
Statesboro	07/29-08/29	14	15	176
Waynesboro	07/26-09/02	16	16	196

4. RESULTS

Determining any effects of seeding on these three programs is difficult. The reasons are basically threefold: 1) seeding was normally conducted during periods when rain occurred naturally, 2) summer rainfall is highly variable both in time and space, and 3) the effects of seeding are generally smaller than precipitation variability. The combination of these three factors renders it difficult to determine the effects of seeding on a given day or usually even on a given month or season of seeding. Several seasons of seeding are often required before the magnitude of any effects of seeding can be estimated.

Research programs approach this evaluation problem through a random selection of days on which seeding will be conducted while leaving other days unseeded. After a number of cases are collected, differences between the seeded and unseeded days can be determined and the statistical significance of the results determined. Such a technique is utilized on FACE. Normally, supporters of operational programs (like those in Georgia) are unwilling to allow about half of the favorable days for seeding to go by to determine the effects of seeding. Consequently, other evaluation techniques are often used to attempt to assess the effects of seeding on operational programs.

A commonly used technique compares rainfall in the "target" area to rainfall in a nearby "control" area. The control area selected should be an area as close to the target area as possible without being affected by the seeding. A mathematical relation is developed (usually a linear regression based on historical rainfall amounts without any seeding programs). This relation is then used to estimate the amount of rainfall that should occur during the seeding program in the target area based on the control area rainfall. The calculated rainfall can then be compared to the actual rainfall in the target area to estimate the effects of seeding.

The Dawson project was selected for evaluating since it was conducted for the longest period of time of the three programs, and seemed to have the most frequent seeding opportunities. Figure 4 provides the location of the target and control precipitation gages used in the analysis. A control area was selected primarily south of the target, since the prevailing winds were out of the south through east. A linear regression of July, August rainfall, 1956 to 1975, gave a correlation coefficient of .79.

At the seven target stations the July-August rainfall exceeded the precipitation predicted using the control area by 27 percent. This is equivalent to about 63 mm (2.5 in.) of additional rainfall during the July-August period. The possibility that these differences were due only to chance (in other words no seeding effect) was estimated to be only four to five chances out of 100 from a one-tailed Student's t statistical test. Figure 5 provides a graph of the target versus control precipitation from this analysis.

These apparent positive results are encouraging, especially considering that the first 12 days of July were not seeded and that the program was begun during a drought period when fewer seedable clouds would be expected than in a more normal precipitation season. From these preliminary indications, it appears that the seeding techniques used on FACE may well be transferable to Georgia and that cloud seeding should be considered as one source of supplemental water in this region.

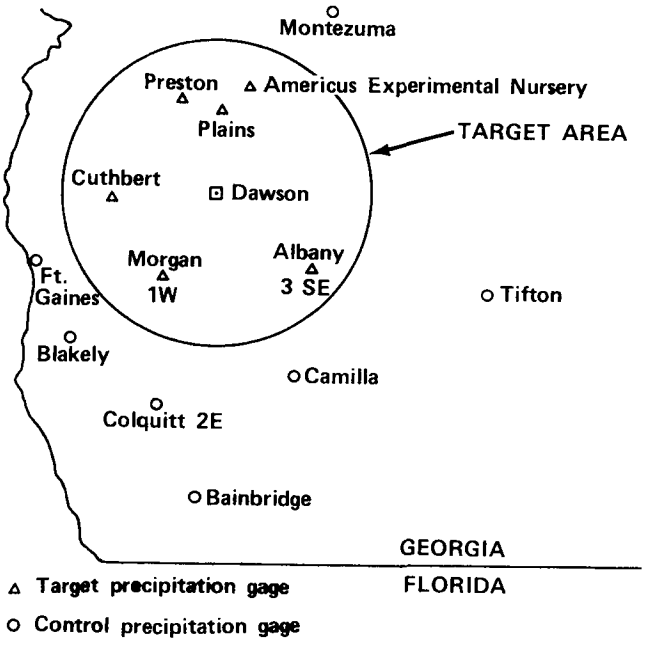

Fig. 4 Location of target and control precipitation stations

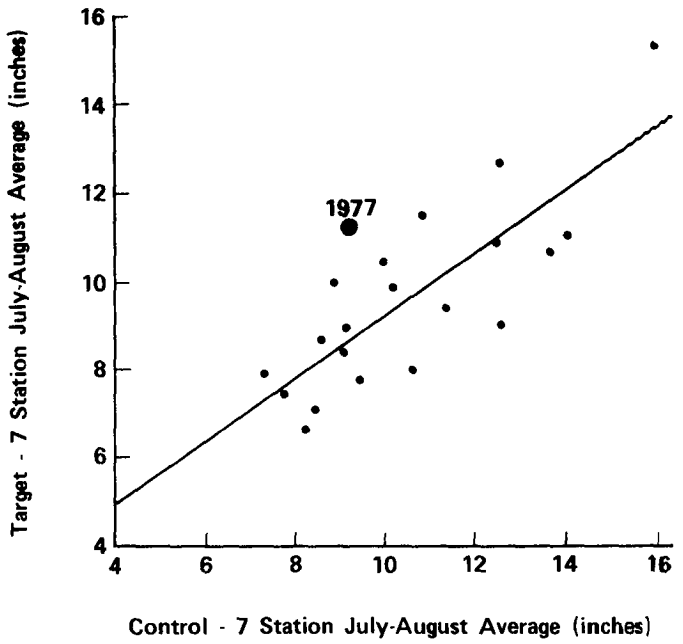

Fig. 5 Average target versus control precipitation

5. REFERENCES

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