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TRANSACTIONS OF WORKSHOP ON TOTAL-AREA EFFECTS OF WEATHER MODIFICATION AUGUST 8-12, 1977 FORT COLLINS, COLORADO

SUBMITTED TO

NATIONAL SCIENCE FOUNDATION

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ABSTRACT

A workshop on the total-area effects of weather modification was held at Colorado State University, Fort Collins, Colorado, during August 8-12, 1977. The National Science Foundation sponsored the workshop which was conducted under Grant No. ENV 77-15038 by North American Weather Consultants of Goleta, California. The workshop considered the total-area effects from both planned and inadvertent weather modification and the social-legal-political implications posed by the dimensions of the area of effect.

Two areas of general agreement among the workshop participants were: 1) the importance of defining and understanding the total-area of effect of cloud seeding and applying this knowledge to the design and operation of all weather modification programs; and 2) the lack of firm evidence on which to draw conclusions as to extent and cause of these large-scale effects.

Statistical analyses, mostly of an a-posteriori nature, suggest that seeding effects from both planned and inadvertent weather modification may occur at least a few hundred kilometers away from the seeding source. These extended seeding effects may be in the form of either increases or decreases in precipitation, cloudiness, or other meteorological parameters.

A strong recommendation was made that government sponsored studies of the total-area effect of weather modification should receive a high priority in the future.

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DOWNWIND EFFECTS FROM THE ARIZONA CLOUD SEEDING EXPERIMENTS

By
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Randomized silver-iodide seeding of summer convective clouds was carried out over the Santa Catalina Mountains in southern Arizona in 2 programs---the first from 1957 through 1960, and the second in 1961, 1962, and 1964. Experimental days were taken in pairs; the decision to seed or not to seed was made after a day was considered as seedable. The second day of the pair was the opposite of the first. Each 2-day set was considered independently. If the second and third days were not considered seedable, the set was scrubbed. Seedability depended primarily on the available moisture in the morning.

The results of the first 4-year program indicated a statistically nonsignificant decrease in seeded rainfall of about 30%. Primarily because of the negative results, the experimental design was changed for the second program. Changes involved stricter limits on what was considered a seedable day (more moisture needed to be present), adding more rain gages to improve the estimates of rainfall amounts in the Santa Catalinas (assuming the original network might not be representative of the true rainfall), and seeding at varying altitudes depending on the height of the cloud base (seeding was just below the cloud base, rather than at a fixed altitude). Seeding for both programs began at 12:30 am and continued for 2 to 4 hours. Days were scrubbed if they were unable to seed for at least 2 hours, and this did happen quite a few times. I believe data for these seeded non-experimental days are available, but I don't think anyone has tried to use them.

The results of the second program were similar to that of the first--seeded rainfall was about 30% less than unseeded rainfall.

In 1970, Jerzy Neyman, Director, Statistical Laboratory, Department of Statistics, University of California, learned that the ARS-USDA operated a dense network of recording raingages on the Walnut Gulch Experimental Watershed about 70 miles south-southeast of the Santa Catalinas, and that many of these gages were in operation from 1957 through 1964. He contacted the ARS and a cooperative effort was initiated between the Statistical Lab and the ARS Southwest Watershed Research Center. I was the principal scientist from the ARS involved in the cooperative effort.

Without giving us any of the seeding information, other than the years when seeding was carried out, Dr. Neyman asked us to digitize hourly summer rainfall for all raingages on Walnut Gulch that were in continuous operation from 1957 through 1964. There were 26 such gages. When we had completed this step, we duplicated the cards and sent the original set to Dr. Neyman.

Simultaneously, he sent us the seeding information so that we could carry out our own independent analysis of the data. He also described the method that he would use in his analysis in advance of receiving the rainfall data. I think this is an important point. Analyses that are designed after experiments are completed are always more susceptible to bias than those that are designed in advance of the experiment.

Experimental days were divided into 2 groups, depending on whether Walnut Gulch was upwind or downwind from the Santa Catalinas based on the 5:00 am USWB radiosonde at Tucson. The other alternative would have been to use the 5:00 pm radiosonde. These were the only upper-level wind records available. Rainfall amounts were determined for 24-hour periods from noon of the experimental day to noon of the next day. Almost all rainfall on Walnut Gulch occurs between noon and midnight, with the largest incidence of rainfall in the evening hours. For all experimental days, there was 40% less rainfall on Walnut Gulch on seeded days than on nonseeded days, which was statistically significant at the 2.5% level. For experimental days when Walnut Gulch was downwind from the Santa Catalinas, there was 70% less rainfall on seeded than on non-seeded days, which was statistically significant at the 1% level. A further breakdown indicated that differences were much greater on the experimental second days than on the experimental first days, although decreases were indicated on both days.

The results were startingly and admittedly unexpected to me. At that time, the general belief was that there could be no effect from convective cloud seeding for any appreciable distance from the target. At least the people to whom I had been talking felt that way.

Following the publication of these results, Dr. Neyman and his colleagues at the University of California looked at all raingage records within 180 miles of the Santa Catalina Mountains. They used the moving grid method (mogrids) which they developed while working on the Whitetop data. In the Mogrid method, the region is divided into pie-shaped slices, with circular divisions at set distances from the target. In Arizona, because of the relative scarcity of rainfall data, they used 4 slices and divided the slices at 90 miles. Gages in the 4 sections within 90 miles were referred to as "near", and the 4 sections outside 90 miles as "far". The specific gages that were covered by each section varied with wind direction. Two different analyses were made---one based on wind directions from the 5:00 am radiosonde and the other based on wind directions from the 5:00 pm radiosonde.

Based on the 5:00 am radiosonde, there was 24 and 45% less rainfall in the near and far downwind cells, respectively, on seeded as opposed to non-seeded experimental days. Based on the 5:00 pm radiosonde, there was 29 and 34% less rainfall in the near and far downwind cells, respectively, on seeded as opposed to nonseeded experimental days. Three of the four values were statistically significant with one value highly significant.

Dr. Neyman and his colleagues also looked at first day and second day results, differing wind directions (based on different altitudes), and came up with a variety of values for the near and far downwind cells. Some of the values were significant, some were not, but all were negative.