

## AUGMENTATION OF 1968-1972 WINTER STORMS IN NEW MEXICO<sup>a</sup>

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Augmentation of winter storms in the West is certainly an important research area, and results of such augmentation attempts should be documented and reported. However, in this case the author has implied positive results from an unsuccessful experimental program. His paper should have been a report on the difficulties involved in developing and carrying out a weather modification program.

The writers have several comments and questions concerning both general and specific statements and omissions in the paper. The discussion follows the outline of the paper.

**Introduction.**—In the environmental objectives of the 4-yr cloud-seeding program, Item (3), management and evaluation of randomized seeding, and Item (6), preliminary studies of downwind effects, are most relevant to this discussion. In Ref. 4, Keyes, et al. reported the results of the program in greater detail. This reference is essential in evaluating the paper.

**Operation of Mesoscale Observation Network and Data Processing.**—The author stated that "the full-scale experimental program was operational during the last winter season," which the reader should remember while studying the remainder of the paper.

**Meteorological Analyses of Storms.**—The author's statement that subjective forecasting techniques were better than objective ones, while undoubtedly true, suggests bias in his evaluation of these results. This, along with changes in seeding agent and delivery rates, and "softening" the statistical hardline procedure makes the project more of an uncontrolled augmentation effort than a viable experiment.

**Diffusion Processes of Artificial Nucleants.**—The author questioned possible uncontrolled influences that might have invalidated the experiment. The preliminary analyses showed that all but one precipitation station was contaminated, if the 10,000-ft wind did vary within 210°-330°. In Ref. 4, the author indicated probable contamination from the San Juan Project on at least 1 experimental day. The writers are uncertain as to whether outside influences could have been, or were, significant.

**Downwind Effects.**—The author does not cover downwind effects in the paper, but he does in Ref. 4. Since possible downwind effects were included in the

<sup>a</sup>December, 1976, by Conrad G. Keyes, Jr. (Proc. Paper 12616).

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planned experiment. (Item 6 of the objectives list) he should have discussed them in the paper. Downwind effects, during the program, were apparently negative but generally not statistically significant with a nonsignificant decrease in both mountain and plains areas and a dramatic decrease (no significance indicated) in the rain shadow area (4). There was a significant decrease at Clayton, in northeastern New Mexico, and the overall wide area decrease was given as significant at the 9% level (4). Although the writers appreciate that only widely scattered data were available for downwind analysis, they suspect that if the overall indication had been positive, the analysis would have been included in this paper.

**Evaluation of Randomized Seeding.**—Table 1 is misleading. Were the seeding rates given from the observed data, or were they anticipated as if all "favorable" 6-hr analysis units had been seeded? In Ref. 4, the author stated that of the total 7046-hr analysis units, 425 met selected criteria (selected after the culmination of 4 yr of seeding). Thus, the 425 cases analyzed were those in which the seeding should have had maximum effect. Analyzing these cases, the overall effect from 4 yr of seeding was a nonsignificant 0.42% decrease in total seeded precipitation. The remaining 279 events, which were stratified out of the analysis, "were measurably unaffected by the artificial seeding" (4). What was the overall effect of seeding if all of the data had been analyzed.

Table 1 suggests positive results of seeding as observed during the experiment. However, these are results based on "stratified" and "generated" data, in effect, on the most favorable conditions. Only during the 1970-1971 winter were significant positive results indicated (4), and this was in the third year of the program, not in the fourth year, when the program was fully operational and the seeding agent and rates were changed.

The writers are not sure what things the author is comparing in the "statistical" tests. The author called the statistical results "psuedo-significant" in Ref. 4, and "significant" (in quotes) in the paper under discussion. Also, since the hypothetical results were based on the most idealistic conditions, reporting values to 3 decimal places is certainly misleading.

**Preliminary Studies of Economics of Precipitation Management.**—The reported results are based on an assumed operational program expected to produce results comparable to the most favorable results of the experiment. However, the results are hypothetical.

#### Summary and Conclusions.

1. The author implied that an extension of the 4-yr program would have led to more concrete results, but later stated that a "sufficient amount of data" were collected. The writers feel that the former statement is more accurate than the latter.

2. Manipulation of the complexing agent and the rate of generating material in the fourth year of the project did not give the desired results (4), thus, the author's statements that such a combination could prove valuable in the future is an unproved assumption.

3. A section is missing on one of the original purposes, study of possible downwind effects.

4. The reference list is selective and incomplete.

The writers appreciate the author and others work. However, a paper detailing

the difficulties in such a project would have been more beneficial than this paper. The subject paper is misleading—data gathered were stratified and then, apparently, more data were generated based on only a part of the 4-yr program. "Significant" results were reported based on a hypothetical situation. Possible downwind effects were ignored. Although there is literature elsewhere to support augmentation of winter orographic precipitation, this paper does not add to the evidence. Experiments are still needed in seeding of winter orographic precipitation, especially to analyze possible off-target effects of such seeding.