

The National Hail Research Experiment (NHRE) was initiated in 1971; operated a randomized seeding experiment during the period 1972-74; completed important field tests of new instrumentation on the armored T-28 aircraft and carried out further data analysis and synthesis in 1975. The program is designed to assess the potential for altering hail and rainfall by cloud seeding, and the extent to which beneficial modification can be accomplished effectively on an operational basis. The approach taken involves: (1) the conduct of a broad-based but highly focused and integrated research program aimed at understanding the mechanisms of natural hail and rain development and the effects of seeding, (2) studies aimed at substantially improving the power of a statistical experiment in detecting seeding effects by the development of suitable covariates, followed by the conduct of a randomized seeding experiment, and (3) economic, social, legal and environmental studies associated with a technology of precipitation modification.

Highlights of the results obtained from the studies conducted are as follows: (1) The original techniques employed in NHRE were based on concepts developed in the Soviet Union which hypothesized that rapid hail growth took place in local regions of high liquid water content referred to as accumulation zones. A variety of physical evidence has led to the firm rejection of the Soviet model of hail formation as applied to northeast Colorado storms. (2) Observations within clouds and examination of thin sections of hailstones have shown that the ice crystal-rimming (graupel) process is dominant rather than the waterdrop-coalescence mode of precipitation formation. (3) Detailed case-study analyses of several hailstorms have confirmed that at least two different types of storms occur in northeast Colorado, and conceptual models based on data collected have given rise to new theories of how hail forms and grows in these different types of storms. (4) Based on these conclusions it is now postulated that rather than seeding in the maximum updraft core, as was done during the previous NHRE experiments, seeding should be carried out in the regions of weak updraft. This can be accomplished by seeding at cloud base in the fringes of the storm updraft or dropping artificial nucleant into newly growing cumulus towers from above. (5) Considerable effort was expended in the development of new instrumentation during the NHRE experiments and was based on the strong conviction that direct physical measurements of the characteristics of hail-producing storms were absolutely necessary to validate the concepts of hail suppression. Not only had the appropriate measurements never been made, but in most cases instruments to make the observations did not exist at the inception of NHRE. (6) Results from the randomized seeding experiment, which was carried out during the period 1972-74, do not permit one to conclude that seeding had any effect on hail or rainfall. The data are, however, extremely valuable for assessing the required density and extent of surface instruments in a future seeding experiment, as well as for estimating the length of time a future experiment would have to be carried out to detect a specified effect. (7) Studies of direct economic costs and benefits have estimated the break-even point for operational cloud seeding and reiterated the value of hail suppression capability if reductions in damage of at least 10% are attainable.

Present plans call for an intensive field experiment in 1976 with intensive analysis during the period 1976-77. These efforts are designed to focus on questions essential for the design, improvement and transferability of a

randomized seeding experiment. During the 1976 field season and the following analysis period high priority will be given to the following issues: (1) Where and in what quantities should seeding be carried out in northeast Colorado storms to prevent stones from growing to damaging sizes? (2) Which observable meteorological parameters or combinations thereof can be employed as hailfall covariates or as variables for data classification to increase the power of statistical tests and to determine whether suppression effects are present? (3) What methods should be used to disperse artificial nucleants? (4) Given a hail suppression effect, what instrumented surface network will reveal this effect in the shortest time given realistic resources? (5) Should operational hail suppression programs be undertaken in the northern Great Plains utilizing the knowledge gained and techniques developed in NHRE.

A unique capability is represented by the facilities that have been assembled by NHRE for hail suppression research. The principal research components of the 1976 field program will be the South Dakota (SDSM&T) T-28, the NCAR/NOAA sailplane, the University of Wyoming Queen Air, two Queen Airs and a Sabreliner from NCAR's Research Aviation Facility, the NCAR dual-wavelength radar system, the dual-Doppler radar system from NCAR's Field Observing Facility (FOF), the dual-Doppler radar system from NOAA's Wave Propagation Laboratory, surface meso-meteorological network (including the FOF Portable Automated Mesonet), three rawinsonde stations, cloud photography, two surface aerosol and nucleus measuring sites, and four mobile hail sampling teams. Data analysis will proceed on a case-study basis, with selected analysis teams made up of experts from various disciplines. These researchers will use the integrated data set to examine hailstorm mechanisms and validate conceptual models.

It is felt that before starting a new randomized seeding experiment confidence in the general applicability of new hypotheses must be increased by a focused program of direct observations and that the power of the statistical tests used in the randomized seeding experiment must be increased to the greatest extent possible in order to give a reasonable chance of detecting a seeding effect in an acceptable period of time. While answers to fundamental questions underlying the current ideas of precipitation growth and modification cannot be scheduled with precision, nor can it be predicted with confidence when suitable hailfall covariates will be established, the goal of NHRE investigators is to make sufficient progress in these areas so that an improved randomized seeding experiment can be initiated in summer 1978.

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