EASTERN REGION TECHNICAL ATTACHMENT
No. 71-6-28
June 28, 1971

PREFACE

NOAA IS NOW ENGAGED IN CLOUD SEEDING EFFORTS, THE MOST PUBLICIZED OF WHICH IS A PROGRAM THAT INVOLVES THE SEEDING OF HURRICANES. IN OUR OWN EASTERN REGION, NOAA'S ATMOSPHERIC AND CHEMISTRY LABORATORY HAS BEEN WORKING ON THE GREAT LAKES PROJECT, THE PURPOSE OF WHICH IS TO LEARN HOW TO MODIFY, BENEFICIALLY, LAKES INDUCED SNOWFALLS WHICH OFTEN PARALYZE TRAFFIC AND THE ACTIVITIES OF CIVILIZATION. THIS TECHNICAL ATTACHMENT IS INTENDED TO PRESENT EASTERN REGION PERSONNEL WITH A BRIEF DESCRIPTION OF THE BASIC THEORY BEHIND EFFORTS TO EFFECT PRECIPITATION BY CLOUD SEEDING. THIS ARTICLE ORIGINALLY APPEARED IN THE AIR WEATHER SERVICE PUBLICATION, AEROSPACE SCIENCES REVIEW, NUMBER 71-1, MAY 1971.

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THE SCIENCE OF RAINMAKING

Lt. Robert I. Sax

As the title implies, the modification of clouds to enhance rainfall is no longer just an "art" to be practiced badly by smooth-talking individuals weighted down with a wagonload of worthless chemicals. Today, cloud seeding is considered by many experts to be an exacting science which, under the proper environmental conditions, can be utilized to produce needed rainfall and replenish thirsty watersheds in many regions of the world. This short article is intended to convey to the reader the basic theory behind efforts to increase rainfall by cloud seeding, as well as give an insight into some of the problems which might be encountered in such an operation.

Although at first glance it may seem intuitively obvious, the fact that there can be no cloud seeding without the presence of clouds cannot be emphasized strongly enough. It is not within anyone's capability to produce rain from a cloudless sky. If the large-scale synoptic weather pattern is such as to lead to conditions inhibiting any cloud formation, there is absolutely nothing to be gained from cloud-seeding operations.

The mere presence of clouds is, by itself, not a sufficient condition for making rain. For seeding to be effective, it is necessary for at least some of the cloud water to be converted from a metastable supercooled liquid state to the stable ice phase. With silver iodide (AgI) as the nucleating agent, this requires that portions of the cloud grow at least to the height of the -5°C temperature level, but no higher than to about the -15°C level (where significant conversion of water to to ice begins to occur naturally). Opportunities for successful cloud-seeding operations are therefore limited, in the first instance, to days during which natural cloud growth ceases within the layer of the atmosphere bounded by the -5°C and -15°C isotherms.

Two physical consequences emerge from the conversion of a water droplet into an ice crystal, and each has provided the theoretical basis for rain augmentation experiments. Firstly, because the vapor pressure over water is greater than that over ice at the same supercooling temperature, any ice crystals present in a mixed-phase cloud will grow faster than the neighboring water droplets. In theory, then, the introduction of a few (a concentration of the order, one per liter) AgI ice forming nuclei should enhance the coalescence process (and hence, rainfall) by causing a broadening of the particle-size spectrum within the cloud. This can be termed "static" seeding because its purpose is to alter the cloud's microphysical structure in order to induce collidal instability. This has been the seeding approach most often used in past years, usually with conflicting results.

Secondly, and, as it turns out, more importantly, every gram of water converted into ice releases about 80 calories of heat to the surrounding environment. This, along with the additional heating created by the direct deposition of water vapor onto the ice particles, can increase the temperature within the updraft region of a typical cumulus congestus cloud by two or three degrees Centigrade, thus supplying enough energy to double its buoyancy. The idea behind "dynamical" cloud seeding is, by causing glaciation, to release suddenly a sufficient amount of heat to make the cloud buoyant enough to penetrate a capping inversion layer and extend its vertical and horizontal dimensions. This should lead to a longer cloud lifetime, a better-organized circulation with a stronger, more-sustained updraft, and a more efficient rain-producing coalescence mechanism. A "dynamical" seeding operation requires a concentration of about two orders of magnitude more AgI nuclei than that needed for "static" seeding.

It should be appreciated that distinctly separate scientific principles are involved in the two different seeding techniques described above. Given a set of environmental conditions, a choice must be made as to which method is more likely to enhance rainfall. Neither technique is likely to produce a significant increase in rainfall from layer clouds, because these are either too dry or else are part of a large-scale, natural rain-producing, synoptic disturbance. However, cloudiness induced by orographic effects, though not containing very much liquid water at any given instant, remains staionary over a location (usually a watershed area) for long periods of time and may lend itself to "static" seeding aimed at increasing rainfall by inducing colloidal instability.

In most regions of the world it is supercooled convective clouds which offer, by far, the greatest potential for increasing rainfall, and it is with this type that the "dynamical" seeding technique moves into the forefront. Recent observations have tended to indicate that, at temperatures colder than -5°C in convective clouds, nature can produce the concentrations of ice-forming nuclei needed to induce colloidal instability, so at those temperatures, little is to be gained from a "static" seeding approach. The initiation of the coalescence process is therefore not the problem in convective clouds - the problem is sustaining coalescence long enough for the cloud droplets to grow to a precipitable size. The cloud's lifetime is the critical factor. Short-lived, shallow, convective clouds will precipitate very inefficiently, if at all. Under the proper environmental conditions seeding to increase cloud bucyancy can lead to deep, long-lasting convective clouds from which it is possible to more than double the amount of rainfall reaching the ground.

It is this "dynamical" seeding technique which has been undergoing testing by the National Oceanic and Atmospheric Administration (NOAA). Results from experiments conducted in the Caribbean in 1965 and in Florida in 1968 and 1970 were very encouraging. The first operational seeding program using this technique will be conducted this spring in central Florida by NOAA's Experimental Meteorology Laboratory. Their intent is to replenish some of the watersheds which are presently at dangerously low levels in that area due to a prolonged period of below-normal rainfall. A careful analysis of past upper-air soundings indicates that enough suitable clouds should be available for seeding to cause a statistically-noticeable increase in precipitation.

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SCIENTIFIC SERVICES DIVISION, ERH
June 28, 1971