Meetings and Societies

Scientific Basis of Weather Modification

Shortly after the 1946 discovery of the Dry-Ice cloud seeding technique by Schaefer (Schenectady) and during the first rush of amateur and commercial rain makers who were showering a bewildered public with a variety of claims of success for turning supercooled clouds into precipitating snow and rain, a whimsical but unknowingly pertinent cartoon appeared in a national magazine. It showed two clergymen quizzically gazing through a church window at the raindrops spattering outside, with one asking the other, "I wonder if its theirs or ours?" Ten years later, the clergyman's problem is still very much the meteorologist's problem, but the latter is steadily narrowing the range of his uncertainty. In the course of his efforts to so delimit his uncertainty, the meteorologist has virtually developed a whole new branch of his field, cloud physics, and the past decade's effort to learn useful techniques of modifying clouds has entrained the services of chemists, physicists, statisticians, and even astronomers.

In an attempt to take stock of the present position of cloud modification and related fields, an international Conference on the Scientific Basis of Weather Modification Studies was held 10–12 Apr. at the University of Arizona's Institute of Atmospheric Physics. This conference brought together at one time and in one place scientists representing nearly every one of the world's leading cloud modification research groups. Nine foreign scientists (whose travel to the conference was supported through a grant from the Rockefeller Foundation) and 26 U.S. scientists presented research results on all aspects of the problem, ranging from the physics and chemistry of nucleation through the seeding of large cyclonic storms and on into the intricacies of statistical evaluation of seeding results.

If a discerning layman had come to this conference with a primary interest in the question of whether scientists had yet found a practicable way of increasing precipitation, his conclusion after listening to their papers and discussions for 3 days would have to be that, as yet, whatever successes they have are confined to certain very favorable situations. In contrast to the often glowing claims that have emanated in recent years from some commercial cloud-seeders, the observer would have heard from this gathering of researchers a long series of still unsettled questions that bear crucially on the techniques and economics of artificial cloud nucleation.

The only indications of substantial positive results from the usual commercial-type seeding operations, using ground-based silver iodide generators, for which present statistical significance was claimed at the conference were the results of an evaluation made by the staff of President Eisenhower's Advisory Committee on Weather Control. The evaluations dealt with a number of commercial rain-making operations carried out in selected winter storms in the mountainous West Coast region during the past few years. These evaluations were subjected to rather strong criticisms by some of the statisticians present, on the basis that it was not possible to draw valid conclusions from this type of operation owing to lack of randomization in the tests, and secondarily because of certain possible errors in the statistical model used in the analysis (a point that did not become quite clear to nonstatisticians present but whose resolution appears to be in sight).

It was pointed out, however, by Thom (Washington), who supervised the evaluations, that the Advisory Committee for Weather Control had been required, by virtue of its statutory obligations, to use such data, and had sought to extract therefrom what statistical information it could, notwithstanding the lack of scientific design in the original operations. He urged that the positive indications obtained should be considered primarily as suggesting further research on the seeding potentialities in the areas studied.

The difficulties encountered by the advisory committee in carrying out its responsibilities were generally recognized by the conferees; however, there was the feeling expressed that because of these technical statistical uncertainties, some implications of recent committee communications and press statements may not have been warranted. This question hinges in part on statistical questions that are still to be settled. All other conference reports of scientific efforts to appraise the effects of past cloud-seeding efforts seemed to fall into one or the other of the following categories: (i) experiments on a small scale (on individual clouds or cloud groups) in which some indisputable positive effects have been observed; (ii) large-scale experiments which have not so far yielded clearly established positive results of recognized significance, either because the technique used was inefficient or because the sensitivity of the statistical tests employed was low owing to lack of adequate observational data.

Notwithstanding the fact that no dramatic research results on rain-making techniques were reported, an observer would have found in the proceedings of this conference a number of indications of cautious optimism on the part of the scientists regarding *future* developments and could have seen clearly that the decade of research which was being reviewed had brought real progress in the form of greatly increased knowledge of the physics of clouds and precipitation. It seemed agreed that recent progress has been nowhere more significant than in the recognition, just within the past few years, that the growth of raindrops by collision and coalescence is as important as the classical ice-crystal process for natural precipitation. And one cloud-seeding technique in particular, that directed at dissipating stratus cloud decks, seemed to be accepted as an accomplished fact, based especially on work summarized by aufm Kampe and Weickmann (Belmar).

Optimism was expressed by many conferees relative to the prospects of inducing significant increases of precipitation under certain restricted types of weather conditions in regions where a broad air current is forced to rise over an extensive mountain barrier. Under such conditions, clouds tend to form more or less continually and, equally important, strong air currents are present to transport into the clouds seeding agents (notably silver iodide particles) released from ground generators. Conference attention seemed to center on such mountain-barrier regions, chiefly because recent experiments in several parts of the world have cast certain doubts on the extent to which ground-released nuclei reach cloud altitudes over any other types of terrain before photolytic decay or surface changes deactivate the nuclei, although much more work is still required on these questions. Ludlam (London and Stockholm) mentioned forthcoming tests to be made under essentially these mountain-barrier conditions in Sweden. Bowen (Sydney) described seeding experiments now in progress, wherein aircraft are releasing silver iodide in a randomized time sequence at cloud altitudes upwind from

the Snowy Mountains in southeastern Australia. In the latter case, the first year's results showed substantial positive effects, but Bowen emphasized the lack of statistical significance at this stage.

Neumann (Tel Aviv) reported seeding trials that have been underway in Israel for 3 years but have not been well known in this country. Seeding with ground-based silver iodide generators is conducted on a randomized basis. The accumulated experience of the first 3 years' work suggested that something of the order of 50 years of such randomized trials would be needed to detect a 20-percent increase at the 5-percent confidence level using the original statistical design, so efforts are now being made to incorporate a more efficient design into the tests.

Braham, Battan, and Byers (Chicago) discussed several aspects of still another randomized seeding experiment in which aircraft released large amounts of water spray (drops of the order of 100 μ in diameter) into clouds over Puerto Rico and obtained statistically significant radar evidence that this treatment *initiated* precipitation processes in the tradewind clouds. Rough calculations suggest economic difficulties in consequence of the inherently high expense of flying thousands of gallons of water to cloud-top altitudes. This experiment, nevertheless, stands out as the first in which a clear-cut positive effect of cloud seeding has been demonstrated in a carefully designed randomized treatment scheme.

There has long been recognition that existing methods of generating silver iodide (*e.g.*, burning acetone solutions of silver iodide) may be very far from optimal. However, uncomfortably little truly careful work to examine the generator processes and output has been done in the past decade. It was, therefore, most encouraging to hear Mason (London) report current studies wherein electron diffraction and x-ray diffraction techniques are being used to study the nature of the particles produced by several basic methods. Mason reported that almost none of them contained the simple hexagonal (icelike) crystalline silver iodide, as had always been assumed, but rather that mixed crystals, often of cubic lattice, predominated. Mason believes that their poor crystalline structure is a result of reduction of AgI to metallic silver under the influence of the hydrogen present in the combustion atmosphere of generators. His findings document the need for intensive study of nuclei generators and hold out, implicitly, hope that research could yield marked improvements in this phase of seeding technology. Sänger (Zürich) reported interesting evidence that he has recently found which suggests that cupric sulfide may be equal in effectiveness to silver iodide as an ice-nucleating material and less subject to decay effects.

A number of papers on many of the more detailed problems now confronting cloud-modification research added greatly to the success of the conference, but they will not be summarized here, since they are of somewhat less general interest. The proceedings of the conference are being published in the form of a collection of mimeographed 500- to 1000-word summaries of the papers presented. A limited number of copies will be available to educational and research institutions in this country and abroad. Requests should be addressed to the Institute of Atmospheric Physics, University of Arizona, Tucson.

It seemed to me that this conference did fulfill very well its intended purpose of taking stock of the present status of research in cloud modification and cloud physics. From it, the conclusion may be drawn that the past decade of effort counsels greater conservatism regarding the extent to which clouds may be made to yield precipitation than was initially manifested by enthusiastic exponents of seeding. The present seeding techniques may fall short of producing increases that can easily be identified, the number of situations in which real effectiveness of seeding potentially exists may be more limited than originally hoped, or the large natural variability of precipitation may be obscuring statistical discrimination of even substantial increases. Perhaps all three of these factors play a part in the still existing uncertainty regarding the efficacy of man's most recent rain-making efforts. This still leaves room for what Reichelderfer (Washington) described in his conference paper as "realistic optimism," a term in which the adjective connotes due respect for the many complexities of the natural processes that occur within clouds and the noun connotes a feeling that we cannot possibly have optimized seeding techniques yet and much remains to be learned.

In all, there was quite complete agreement among the conferees that a strong case can be made for still more vigorous cloud-modification and cloud-physics research. A considerable measure of agreement was reached at the conference concerning the chief lines along which such research might best be directed in the near future.

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Meeting Notes

■ An international symposium on particle accelerators, detection techniques and high-energy physics, which was arranged by the European Organization for Nuclear Research, was held 11–22 June at the Institut de Physique in Geneva, Switzerland. The following countries were represented at the conference: Australia, Belgium, Canada, Czechoslovakia, Denmark, France, Federal Republic of Germany, Greece, India, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, U.S.S.R., United Kingdom, U.S.A., and Yugoslavia. UNESCO also sent an observer.

The first week of the symposium was devoted entirely to high-energy particle accelerators. During that period, about 50 papers were given on the chief problems raised by the construction of modern accelerators, such as the theoretical aspects of the question, the study of magnets, the radio-frequency accelerating system, the injection and ejection of particles, the operation of the machines, and so forth. The technical features of the large accelerators now in operation or being built were explained in detail, and finally, entirely new principles were put forward whose practical application would considerably improve the performance of existing accelerators.

During the second week of the symposium, attention was focussed on detection methods and on the theoretical aspects and experimental techniques of the physics of elementary particles. The 70 papers delivered dealt with a wide variety of questions, such as Wilson chambers, bubble chambers, over-compression and counting techniques, experimental and theoretical physics concerning mesons, nucleons and antiprotons, quantum field theories, the structure of the proton, mesic atoms, and so forth. A news report from Geneva states that the exchanges of views that took place between participants, both inside and outside the conference room, proved extremely fruitful, and that the frankness shown by all concerned bodes well for the possibility of future international cooperation in physics.

■ The 28th meeting of the Pan American Sanitary Organization Executive Committee ended on 13 June with the signing of its final report embodying 16 resolutions. The meeting opened on 5 June under the chairmanship of Jorge Jiménez Gandica, director of the Division of Public Health of Colombia. Manuel A. Sanchez Vigil, director of the National Institute of Hygiene, Nicaragua, was vice-chairman. Most of the resolutions adopted will be presented for final action to the PASO Directing Council at its ninth meeting, which is scheduled to convene on 16 Sept. in Antigua, Guatemala.

The $2,400,000 budget proposed by Fred L. Soper, director of the Pan American Sanitary Bureau, Regional Office of the World Health Organization, for the bureau's operations in 1957 was ap-