Weather Modification

See Science, *22 September 1967, for details about registration and hotel reservations for the AAAS Annual Meeting.*

Even in ancient times man dreamed of modifying his environment, but it was not until that auspicious day in July of 1946 that Vincent Schaefer provided the first clear-cut evidence that man could modify the weather on a major scale by his dry-ice seeding of supercooled stratus clouds. The art and science of weather modification has now developed into an accepted industry. Even with this growth and acceptance, many questions remain unanswered and most responses to cloud seeding have not been proven beyond some reasonable doubts.

A symposium organized by the AAAS Committee on Arid Lands and scheduled to be held 30 December during the AAAS annual meeting in New York City will review the status of and some of the problems involved in Weather Modification in Arid Lands. Reports will be presented by scientists who have been closely associated with the development and advancement of weather modification as a science and as an industry. While there are many aspects of weather modification (lightning control, suppression of hail, temperature amelioration, and other factors) the symposium will be limited to those aspects associated with the increase of precipitation in arid regions.

From the early preliminary work by Langmuir, Schaefer, and Vonnegut through "Project Cirrus" (1952) the emphasis was on the physical processes involved in nucleation and the propagation of these processes. No sooner had it been shown that the cold action of dry ice caused the "explosion" of crystals throughout a cloud, than the search for other and better agents to "seed" were sought. Soon many commercial companies were selling "precipitation." The great majority of these firms were reputable and honest and it is to these stalwarts that we owe so many advances in the science of weather modification. On the other hand, because the projects were designed as operations programs, evaluation from a research standpoint was difficult.

Research projects during the early periods were very limited, consequently most of the work was done by commercial interests who learned the techniques of operation and shared their findings with others. With the creation of government programs in 1953, research on weather control was expanded under projects "Skyfire" and "Overseed" until today silver iodide is the most widely utilized cloud-seeding agent. It was also during this second phase of the development of weather modification that the "Santa Barbara Project" was created to statistically evaluate the effects of cloud seeding as contrasted with the earlier optical or visual evaluation of the early work.

In 1958, the National Science Foundation was directed to advance funds for weather modification research in the forms of contracts and grants. Other federal agencies also had programs during this period.

The most recent program increase in the United States was centered in the U.S. Bureau of Reclamation where an organized program of investigations of atmospheric water resources in the Western states is being conducted.

Other weather modification programs in arid lands have been operating in Australia, Japan, Mexico, Colombia, Russia, and Israel. Reports from the various localities indicate increases in precipitation ranging up to values well in excess of 100 percent.

The present state of the science seems to be somewhat as follows:

1) Nearly all workers agree that seeding under certain conditions increases precipitation.

2) There is no unanimity of opinion as to the relative effectiveness of aircraft, rocket, or ground generators as source and distribution vehicles for seeding agents.

3) No effective, economic method for accurately locating seeding-agent smoke plumes is known.

4) The situation regarding the legal aspects of cloud seeding is extremely hazy.

5) Little is known about the human ecological effects of cloud seeding.

6) No completely satisfactory method for evaluating the effects of cloud seeding has been devised.

7) The physical properties of ice and the ice-forming processes are only very sketchily understood.

8) The warm cloud process is not well understood.

9) The degree of inadvertent cloud seeding is unknown.

10) Little is known about seeding agents other than dry-ice or silver iodide.

11) No effective method for tracing the location of the effects of cloud seeding has been devised.

12) Little is known about the performance of seeding agents under detailed storm types and subtypes.

13) Very little is known about micro- and mesoscale meteorology during and following cloud seeding.

14) The effects of modifying precipitation on other meteorological phenomena are unknown.

15) The general socioeconomic effects of weather modification remain relatively unknown.

16) Only preliminary information on the effects of augmentation of precipitation on the socioeconomic conditions within the affected area is available.

17) The hydrologic implications of modifying the precipitation have only been surmised on theoretical grounds.

18) Little is known about the effects of weather modification on animal and plant life in the affected area.

19) The political implications of the international movement of seeding agents and effects can only be surmised.

20) The political implications of conducting large operations and research programs within a county are un-

known. Competition between agencies may be difficult to avoid.

21) Lack of public understanding of weather modification has led and will lead to legislation handicapping the research and development of weather modification in many areas.

22) The state of the instrumentation art must be greatly advanced before many of the environmental factors associated with cloud seeding can be measured.

23) Practically nothing is known about the effects of cloud seeding on the quality of water obtained at point of use.

24) The field of analytical chemistry as applied to ultramicro techniques is not prepared to meet the needs of weather modification.

25) Some silver iodide smokes are much better nucleating agents than others. Many of the reasons for this are unknown.

26) Seeding cap-clouds with silver iodide causes precipitation where none would have occurred naturally.

27) Seeding of cirrus clouds causes precipitation to fall hours before it would have fallen naturally as well as increasing the total quantity of precipitation.

28) Periodic seeding of cirrus clouds produces a like periodicity in the precipitation.

29) Seeding of convective storms has produced very erratic results. At times well-defined increases of precipitation occur, while at other times no changes or even decreases in precipitation have occurred.

30) Seeding greatly modifies the energy of many storms, shifting the energy from smaller to larger scale circulations.

31) Silver iodide nuclei do not remain active in the atmosphere for prolonged periods of time.

32) Seeding of winter orographic storms preponderantly produces increases in precipitation.

33) Under stratus conditions a continuous supply of nuclei must be provided to sustain precipitation.

The New York symposium will feature such speakers as Vincent J. Schaefer, Werner A. Baum, Roscoe R. Braham, Jr., Charles F. Cooper, Lyle D. Calvin, Emery N. Castle, J. B. Stevens, Archie M. Kahan, Eugene L. Peck, and Robert B. Ellert.

JOEL E. FLETCHER
Utah Water Research Laboratory, Utah State University, Logan

Cumulus clouds drift to the northeast from the San Francisco Peaks (Arizona) as seen from Gray Mountain, looking south. The clouds to the left of the Peaks were emerging from a cloud-seeding target and probably contained silver iodide. [W. L. Rusho, Bureau of Reclamation, Denver, Colorado]