211
"1977"

INTERIM REPORT: State-of-the-Art in Weather Modification in the Pacific Southwest

TASK FORCE

Herbert B. Osborn, USDA, Chairman
Curtis W. Bowser, USBR
Olin H. Foehner, USBR
David P. Hale, New Mexico Interstate Stream Commission
Harold Meyer, USBR
James Sears, Corps of Engrs.

INTRODUCTION

Wendall A. Mordy, Center for the Study of Democratic Institutions and the Center for the Future, Santa Barbara, California, presented a paper at the IUGG general assembly in France in August, 1974, summarizing weather modification efforts from 1971 through 1974. His summary of current research efforts in weather modification is as follows:

> "Current weather modification research is aimed at hazard mitigation, precipitation modifications, and the understanding of inadvertent weather and climate changes. Much of it in the United States in the 1970's has been concentrated on five major efforts, with the following objectives: (1) to determine whether hailstorms can be modified to suppress hail damage in the high plains of the United States (National Hail Research Experiment, directed by the National Center for Atmospheric Research and sponsored by the National Science Foundation); (2) to determine whether the maximum wind speeds in tropical cyclones (hurricanes) can be modified by cloud seeding and thus reduce the damage potential (Project Stormfury, sponsored by the U.S. Department of Commerce, NOAA); (3) to determine whether practical benefits from increased precipitation or snowfall displacement can be secured with existing weather modification technology or by development of improved technology (Project Skywater, sponsored by the U.S. Department of Interior, Bureau of Reclamation); (4) to determine whether mesoscale precipitation bands entering the West Coast can be seeded to produce substantial increases in precipitation (Santa Barbara Project, sponsored by the U.S. Navy and National Science Foundation); and (5) to determine the reality, extent, and causes of the reported precipitation anamoly produced by the city of St. Louis (Metromex, sponsored by the National Science Foundation)."

The efforts that are of greatest interest in the Pacific Southwest are those listed under (3) and (4). Specifically, these are the efforts to increase snowfall in the higher mountains of the Pacific Southwest, to increase rainfall within the mesoscale precipitation bands entering the West Coast, and to increase rainfall from convective clouds in the Southwest. Experiments to decrease hail damage and modify hurricanes are of considerably less interest in the Pacific Southwest, as is inadvertent weather modification.

At present, water shortages in the Pacific Southwest are not critical, but by all estimates they soon will be. For example, most reports indicate that the Colorado River Basin will experience critical water shortages within 25 years. Cloud seeding efforts will increase during these 25 years because of increasing demand on available water supplies. Experimental evidence already lags behind operational cloud seeding programs, and increased demand brought on by approaching shortages may widen this gap. More evidence is needed on both specific and general weather modification efforts before public pressure, rather than scientific knowledge, dictates weather modification programs.

There are diverse opinions within the professional and scientific communities on weather modification in general as well as on specific weather modification efforts or programs. In the remainder of this progress report, we use the phrase "atmospheric scientist involved in weather modification," or simply, "atmospheric scientists." These terms refer to university teacher/scientists who are devoting significant time and efforts in weather modification and attended the NSF Workshop on Weather Modification and Agriculture in Ft. Collins, Colorado, July, 1975.

Orographic Precipitation

The greatest interest in weather modification in the Pacific Southwest has been in enhancing orographic precipitation. Most of these efforts have been to increase the snowpack, primarily in the Sierra Nevada Mountains. Atmospheric scientists involved in weather modification, agree almost unanimously that snowfall can be increased in mountainous regions up to 300 square miles. Estimates vary from 5 to 30%, but 10% is about the average prediction based on current technology. Scientists are divided as to whether future techniques will improve appreciably on this 10%. Uncertainties in this area of weather modification range from question of conservation mass and energy and the complexities of natural precipitation to social aspects. The concept of natural limits on increases is extremely important in long range planning.

Two relatively large-scale experiments to augment snowfall (the Colorado River Basin Pilot Project and the Pyramid Lake Pilot Project), have been carried out in recent years. Both have been completed and the data are being analyzed. Final results from these 2 experiments are not as yet available. Initial information indicates that unexpected natural and man-made problems have made the analyses of the projects more difficult than was expected. Currently, the USBR is reanalyzing results from several relatively small-scale randomized experiments to augment snowfall which were carried out independently at several state universities, in the West (Montana State, Fresno State, New Mexico State, Colorado State, and Utah State). The original results of these projects were inconclusive but all suggested increases in snowfall from seeding.

A considerable effort also has gone into increasing rainfall within frontal systems approaching the West Coast. There is less agreement among atmospheric scientists as to the success or significance of these efforts. A major difficulty is that increases are reported for selected bands of moisture within the storm system, and such selectivity makes independent analyses of reported results much more difficult. In general, a major difficulty in analyzing many weather modification efforts is the policy of reporting increases in percent of natural precipitation in sub-systems within a broader precipitation type. This is particularly true in reporting results of seeding of convective clouds, which will be discussed later.

Convective Precipitation

Most seeding to augment snowfall is accomplished with ground based silver iodide generators. On the other hand, convective clouds are seeded by both ground based and aircraft based generators. The principle rationale for seeding convective clouds from aircraft is that seeding can increase rainfall from small convective cells, but may decrease rainfall from larger systems; so it should be more selective. Commercial operators who seed from ground based generators cannot be as selective; and in this respect, the two methods are contradictory.

The majority of atmospheric scientists feel that current technology is adequate to increase rainfall from small convective clouds. However, these increases, although large percent-wise, may be small volume-wise in respect to natural, annual or seasonal rainfall. Generally, natural orographic rainfall occurs in large enough volumes that a 10% increase would be significant. This is not necessarily true with convective storms. For example, in most of the arid and semiarid Southwest, a 100% increase from .05 to .10 inch from a convective cell would be insignificant because of high evaporation rates.

Most atmospheric scientists feel that the present state-of-the-art is too uncertain to seed isolated large convective systems (including squall lines), and the opinions are about evenly divided as to whether such seeding will ever be safely operational. There are several uncertainties in seeding larger convective systems including the fear of increasing intense rain or hail damage. Also, experimental design, instrumentation, and analysis of efforts to modify such systems are extremely costly, so information on modification of such systems is lacking.

Droughts

There are basically two types of drought--one occurring from several years of below-average precipitation, and the other from several dry weeks during, for example, a critical growing period. Long term droughts are of greatest interest in regions such as the Pacific Southwest, where most irrigation and municipal water supplies come from snowmelt. Augmentation of winter snowfall should help to alleviate moderate long-term droughts, but water users should understand the magnitude of possible increases and the uncertainty that future technology will increase this magnitude. Also, the question of whether or not we can increase snowfall from a given storm system as it crosses each of several mountain ranges has not been satisfactorily answered.

Most atmospheric scientists do not believe that convective rainfall can be significantly increased during periods of severe drought during specific growing seasons. Comments usually suggest some probability of success for moderate droughts and little chance of success during extreme droughts. Large percentage increases during dry periods may be meaningless since the volume increases may be very small. The problem of severe short term droughts while critical in the Great Plains, is not as important in the Pacific Southwest. In the Southwest, the greatest need for convective rainfall is in the spring and early summer, when the chances of rains that can be seeded are the least likely. For example, when clouds are rare or nonexistant, then weather modification based upon seeding individual clouds cannot be expected to increase rainfall. Weather modification under these conditions cannot alleviate the seasonal droughts in the Southwest.

Other

Scientists are divided on the possible modification of violent convective storms that produce squall lines, hail, and intense rainfall. Future technology in weather modification of violent storms is also uncertain. However, such storms are of considerably less significance in the Pacific Southwest than in the Great Plains.

The Forest Service has experimented on lightning suppression in Montana and Wyoming with considerable success. However, several investigators in Arizona and New Mexico have pointed out the high correlation between lightning and rainfall, so lightning suppression in the Southwest might also mean decreasing rainfall.

Comments

The following comment on the present state-of-the-art appears in "Workshop for an Assessment of the Present and Potential Role of Weather Modification in Agricultural Production" compiled by Grant and Reid at Colorado State University in August, 1975:

> Weather Modification has made modest but significant gains during the past 25 years. It can now have at least moderate effects on the solution of food production problems. The technology has clearly not been proven for many applications. Numerous scientific questions remain.

In the discussions at this workshop, it appeared that most of the "modest" gain had been made in modifying orographic storms, particularly snowfall.

Also, it should be emphasized that conclusive experimental data are lacking in all major areas of weather modification, and that rudimentary evidence is lacking in many. A significant number of atmospheric scientists feel that there is still a need for more experimentation in all areas of weather modification.

One area in which experimental data are needed is in downwind or large-scale effects of convective cloud seeding. Large-scale positive and negative effects have been tentatively identified as resulting directly from contamination by a seeding agent or indirectly from changing growth patterns within a part of a larger air mass system. In general, these results have been reported "after-the-fact," and the experimental design only included the target areas. Such wide-scale effects, if substantiated, could have contaminated many of the weather modification experiments in the United States. Most recently, some investigators have included downwind effects in the project design, so some more definitive information should be available in the future.

The National Academy of Science Committee on Atmospheric Science in a 1973 report recommended a large increase in funds for weather modification experiments. With the increase in funds, the committee felt that many of the major questions in weather modification could be answered by 1980. The emphasis of the report was on the need for more scientific knowledge in all aspects of weather modification. At this time, there is no indication that there will be a significant increase in funds for weather modification.

Finally, we have listed 30 selective references on weather modification. These references provide a good sample of the available documentation in weather modification. Some of the listed publications are quite lengthy, but most are shorter articles and would provide the reader with a good diverse background in weather modification efforts pertinent to the Pacific Southwest.

Summary

There is still considerable controversy in all areas of weather modification in the Pacific Southwest. The most widespread support is in the area of snow augmentation, and the most controversy in the area of convective rainfall augmentation. Questions of possible widespread and downwind effects of cloud seeding remain.

SELECTED REFERENCES

Battan, L. J. Silver-Iodide Seeding and Rainfall from Convective Clouds. J. Applied Meteorology Vol. 5(5):669-683, 1966.

Battan, L. J. Harvesting the Clouds--Advances in Weather Modification. Doubleday & Co., Garden City, 148 pp., 1969.

Battan, L. J., and A. R. Kassander. Summary of Results of a Randomized Cloud Seeding Project in Arizona. Proc. Fifth Berkeley Sym. on Math. Stat. and Prob., University of California Press, Vol. 5, 1965-1966, pp. 29-33, 1967.

Brook, M. Weather Modification in New Mexico. Talk given at the Meeting of the Water Council Representing the Eleven Western States, January 5, 1973.

Brown, K. J., R. D. Elliot, J. R. Thompson, P. St. Amand, and S. D. Elliot, Jr. The Seeding of Convection Bands. Proc. Fourth Conference on Weather Modification. Amer. Meteorol. Soc., Ft. Lauderdale, Florida, November, 1974.

Brown, J. J., R. D. Elliot, and J. R. Thompson. Large Scale Effects of Cloud Seeding, Final Report. Aerometric Res. Inc., USBR, Oct. 1973.

Elliot, R. D., et al. Twelve Basins Investigation: Analysis of Potential Increases in Precipitation and Streamflow Resulting from Modification of Cold Orographic Clouds in Selected River Basins of the Western United States. North Amer. Weather Consultants. USBR, Vol. I, May 1973, Vol. II, December 1973.

Elliot, R. D., A. Court, R. W. Shaffer, and J. F. Hannaford. Colorado River Basin Pilot Project: Second Interim Report Covering an Appraisal of the First Three Years. USBR, June, 1974.

Grant, L. O. Priority Problems for Modifying Cumulus Precipitation. Proc. ASCE Specialty Conf., Fort Collins, Colorado, 16 pp., 1973.

Grant, L. O., J. M. Fritsch, and P. W. Mielke, Jr. Randomized Seeding of Continental Convective Clouds Near Climax, Colorado, Proc. Third Conf. on Weather Mod., Rapid City, S. Dakota, June, 1974.

Grant, L. O., and J. D. Reid. Workshop for an Assessment of the Present and Potential Role of Weather Modification in Agricultural Production. Atmos. Sci. Paper No. 236, Colorado State Univ., Ft. Collins, Colorado, August, 1975.

Grant, L. O., et al. Weather Modification--A Pilot Project: San Juan Mountain River Basin, Final Report. USBR, Feb. 1974.

I.C.A.S. Analysis of the Federal Effort in Weather Modification, ICAS Report No. 18-A, 1974.

Keyes, et al. Jemez Atmospheric Water Resources Research Project: Final Report, Vol. I, Summary and Accomplishments. USBR, January, 1974.

Lovasich, J. L., J. Neyman, E. L. Scott, and J. A. Smith. Statistical Aspects of Rain Simulation Problems and Prospects. Statistical Lab., University of California, Tech. Report to ONR, 1970.

McDonald, J. E. Evaluation of Weather Modification Field Tests, University of Washington Press, 1969.

Mordy, W. A. Weather--Climate Modification. Review of Geophysics and Space Physics. U. S. National Report, I.U.G.G., Vol. 13(3):746-752, 1975.

National Academy of Science, National Research Council, Committee on Atmospheric Science, Weather and Climate Modification: Problems and Progress, Washington, D. C., 1973.

Neyman, J. and H. B. Osborn. Evidence of Widespread Effect of Cloud Seeding at Two Arizona Experiments. Proc. Nat. Acad. Science, Vol. 68:649-652, 1971.

Neyman, J., H. B. Osborn, E. L. Scott, and M. A. Wells, Reevaluation of the Arizona Cloud Seeding Experiment. Proc. Nat. Acad. Science, Vol. 69:1348-1352, 1972.

Simpson, J., and A. S. Dennis. Cumulus Clouds and Their Modification. NOAA Tech. Memo. ERL OD-14, 1972.

Steinhoff, et al. The San Juan Ecology Project, Interior Progress Report, USBR, March 1975.

USBR. Proceedings: Skywater Conference VII, March, 1972.

USBR. Proceedings: Skywater Conference VIII, October, 1973.

USBR. 1972 Annual Report: Project Skywater, November, 1973.

USBR. Western U. S. Water Plan: Augmentation Potential Through Weather Modification, February, 1975.

Weinstein, A. I., and P. B. McCready. Isolated Cumulus Cloud Modification. USBR Proj. Report, 1968.

Weisbecker, L. W. The impacts of Snow Enhancement: Technology Assessment of Winter Orographic Snowpack Augmentation in the Upper Colorado River Basin, Stanford Research Inst., 1974.

Weisbecker, L. W. Snowpack, Cloud Seeding, and the Colorado River: A Technology Assessment of Weather Modification, Stanford Res. Inst., 1974.