What Do We Need in Weather Modification?

BERNARD A. SILVERMAN

Bureau of Reclamation, Denver, Colo. 80225

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ABSTRACT

The needs of weather modification are examined from the vantage point of a manager, from the Federal sector, of applied research and development in precipitation management. Several problems in the perspective with which weather modification is viewed in the scientist, user and political communities are discussed. This image of weather modification has given rise to a credibility gap which hinders its technological development. Several courses of action are suggested to improve this image and move the field of weather modification forward both scientifically and socially.

1. Introduction

The question, "What do we need in weather modification?" is one that responsible managers, researchers and users of weather modification must continually ask themselves. Significant events of the last few years make this question particularly relevant at this time. Among the more important events are the following:

1) Great concern over the widespread drought in the United States has triggered an unprecedented number of state and locally supported weather modification programs, and along with it, reaction that has ranged from a total lack of credibility in its effectiveness to the ill-informed perception that any seeding-induced precipitation in the intended target area will inevitably be at the expense of precipitation that would have fallen in "downwind" areas.

2) Reduction in the number of Federal agencies with active weather modification research programs and a steady decrease in the level of funding by those Federal agencies that are still active.

3) Recent completion of several large-scale weather modification programs, i.e., the Colorado River Basin Pilot Project (CRBPP), the National Hail Research Experiment (NHRE), and the Florida Area Cumulus Experiment (FACE), the results of which are being perceived as having fallen short of projected expectations, despite the fact that they have made significant contributions to the science of weather modification.

4) Launching of two new major research programs by the Bureau of Reclamation, i.e., the High Plains Cooperative Program (HIPLEX) and the Sierra Cooperative Pilot Project (SCPP).

5) Passage by the U.S. Congress of Public Law 94-490, the National Weather Modification Policy Act of 1976 and the creation of an auspicious Weather Modification Advisory Board thereunder which is charged with recommending a national weather modification policy, a national program of research and development and an organizational structure for carrying out the policy and program.

What, indeed, do we need in weather modification?

I will attempt to respond to this difficult question by first commenting briefly on some problems in, what I term, the perspective with which weather modification is viewed in the scientist, user and political communities. Then, I will suggest several courses of action which I feel will move the field of weather modification forward both scientifically and technologically. I will discuss the needs of weather modification from the vantage point of a manager, from the Federal sector, of applied research and development in precipitation management and will confine my remarks to this important area of weather modification.

2. Problems in perspective

The past and present image of the field of weather modification has given rise to a credibility gap which constantly places obstacles in the path of its technological progress. Three main problems in perspective are, in my estimation, responsible for the creation of this credibility gap.

a. The drought-relief fallacy

There are too many potential users and policy makers who view weather modification only as a drought-relief measure. Funding and operational programs increase during drought periods, apparently with the expectation that water deficits that took years to develop will be quickly replenished. Weather modification is often invoked as a desperation measure,

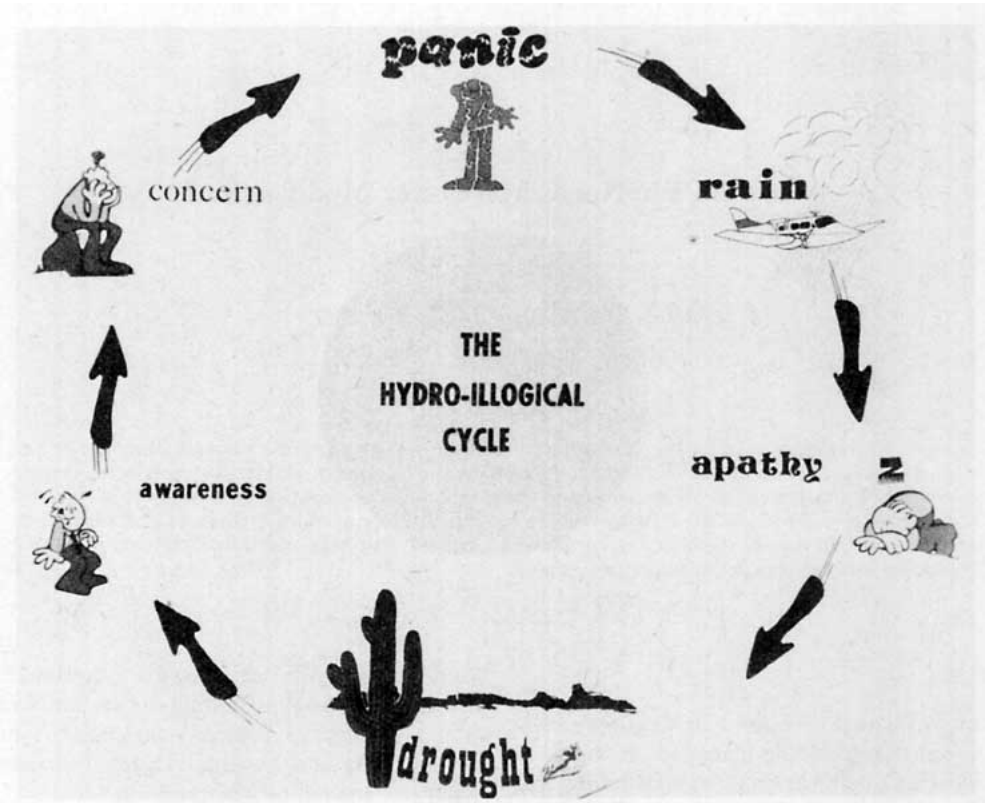

FIG. 1. The hydro-illogical cycle.

perpetuating the hydro-illogical cycle (see Fig. 1). This is encouraged, in part, by the quick reaction time and relatively low cost of weather modification operations in contrast to other potential drought-relief measures.

This is, of course, a "no win" situation for weather modification. The use of weather modification during drought periods is generally limited by less frequent opportunities. If all of these opportunities were exploited and if the most optimistic estimates of weather modification effectiveness were realized, the drought, while somewhat mitigated, would still persist and the effort would be viewed as falling short of expectations, if not a failure. The short history of weather modification contains ample evidence of the consequences of such apparent failures—a loss of public confidence in the claims and expectancies of weather modification.

Precipitation management should be promoted as a water resource tool to be managed on a year-round basis as any other component of the total water management system. Weather modification should be used to recharge and augment water supplies whenever the opportunities arise and the situation warrants. It should be used in concert with modern agricultural and soil conservation practices to maximize much needed agricultural production during both adequate and rain-short years. It should be considered for application at any stage of crop or forage growth when additional water would be beneficial and also during vegetatively dormant periods to increase the moisture of the soil in preparation for planting.

Apathy in the hydro-illogical cycle must be replaced by constructive planning and preparation for drought to lessen its impact. Weather modification can and should play an important role in such a water management system.

b. Research and/or operations?

The lack of credibility for weather modification is contributed to and aggravated by the diverse opinions of scientists on the state-of-the-art of weather modification. The strong proponents, mainly commercial operators, believe that certain areas of weather modification are fully operational technologies capable of producing considerable economic benefits and that further research is a threat to their adoption. The cautious optimists believe that promising results have been obtained in some cases but further experimentation should be required before operational programs are allowed to proceed. Some of the research scientists in this group also believe that premature adoption of operational programs is a threat to the continued research required to develop and verify weather modification techniques. Still others believe that the effects of weather modification may be so far-reaching that it is too risky to even experiment in the atmosphere until all of the effects are identified and evaluated.

Diversity of opinion is healthy for a developing science as long as it is constructive. It should, however, be realized that research and operations are not mutually exclusive activities. Rather, they can and must proceed together, interacting with each other and with the society it is meant to serve if we are to develop a technology that is acceptable both scientifically and socially.

Users of weather modification are shrewd business people. They understand that they are, in many cases, taking a gamble when they use weather modification, but it is no greater risk than they take in other aspects of their business. Operational weather modification will, therefore, proceed, and by proceeding on this basis it provides an opportunity for learning and progress that cannot otherwise be achieved. Working with the user community we can investigate aspects of the emerging technology that cannot be realistically studied in research programs. We can investigate the societal and political issues of weather modification which, in the final analysis, will decide the true fate of weather modification. We can investigate and develop the institutional framework for incorporating precipitation management into the overall water resources management policy of each climatic and socioeconomic region, recognizing and accommodating the needs and rights of all who are affected. Several states are already doing this under the Bureau of Reclamation's HIPLEX program.

If properly structured, operational programs can also contribute to scientific development, and, in a subsequent section, I will suggest how this might be done. Research programs must, at the same time, improve on our understanding of how, when and where to apply these techniques and develop overall scientific confidence in them. Research alone can develop a technique but research in concert with operations and its ramifications is needed to develop a technology. If users are willing to risk application of a scientifically unproven technology in the strictest sense, scientists should attempt to maximize the learning potential of the effort.

c. The oversimplistic image

A major source of friction between researchers and operators which fuels the fire of diversity is the image of weather modification operations that has developed which makes it appear that cloud seeding techniques are simple and inexpensive to apply with probable success. This image of simplicity is, to a large extent, conveyed by the structure of most operational programs which usually consist of ground or airborne seeding systems, non-quantitative radar (or no radar at all) mainly for directing aircraft, and operationally trained, but not necessarily meteorologically trained, personnel.

Most programs are launched with no provision for reliable evaluation or feedback. Some are directed at both hail suppression and rain augmentation and give the appearance of being able to switch from one to the other by a mere change in seeding rate. The results of research, on the other hand, indicate that weather modification is a complex science.

There is growing support for the thesis that the seeding of clouds may at different times result in positive, negative or no effect and that there is insufficient confidence in our ability to determine when and under what circumstances each will occur. It has been shown that rain and hail are integral and interrelated components of the precipitation process of cloud systems and that you cannot affect one without affecting the other, but there is conflicting evidence on the nature and sign of these effects. There is also increasing recognition of the fact that promising, or even proven, techniques may not be readily transferable from one area to another, even over small distances. And we are only beginning to investigate and understand the size of the area affected by cloud seeding.

I am confident that commercial operators are and have been aware of the complexities of their trade and do not believe that the application of weather modification is simple. What, then, has given rise to and acts to perpetuate the image of simplicity? I believe that four related factors have contributed to the problem:

1) The commercial and scientific communities have allowed the submarginal operators, who are better salesmen then scientists, to establish the market price and standards for the industry. The responsible operators have, therefore, had to compromise between what they believe is necessary and what the market would bear in order to be competitive.

2) A major casualty of this compromise has been evaluation, which could have provided the necessary feedback to rectify the situation.

3) Given the relatively low price of operations, many more potential users have been willing to take the gamble, most of them believing that the only outcomes of their gamble are either positive or no effect.

4) The scientific community has not provided the convincing evidence that any more than was already being done was really needed. They have, in general, been critical of operations or at best aloof, when constructive suggestions and support were needed.

I believe that operational programs should proceed with the input and support of the scientific community. There are some weather modification techniques, although imperfect, that can be applied operationally in the proper context not only for potential economic benefits but also to increase scientific understanding. These programs must use the appropriate tools and skilled manpower. Such

programs will be more expensive than existing ones and users should, in their own interest, pay the price to reap the full, long-term benefits of weather modification.

3. Suggested courses of action

a. Technology assessment

Operational application of weather modification, whether warranted or not, has revealed a number of user-oriented issues, some perceived and some real, that are as important as the traditional scientific issues if not overriding. Weather modification, whether it be research or operations, will not progress wisely or perhaps at all, unless it is considered in a context that includes everyone that may be affected. We must develop and promote a new public and scientific image of weather modification.

It is my opinion that the fastest and most effective way of achieving a new perspective for weather modification is by means of a comprehensive technology assessment. Technology assessment is a method of systematically exploring the direct and indirect consequences of employing an emerging technology. Several technological scenarios are usually followed, from conservative to optimistic, so the value of additional scientific advancement is determined. It examines both the technology's impact on society and society's impact on the development of the technology. If focuses on all key issues, both perceived and real. It does not necessarily answer all questions but does identify the important questions that must be answered.

A well-conceived, comprehensive technology assessment of precipitation management will provide the factual information to shape a new and proper image for weather modification. It will place the benefits, risks and disbenefits in proper perspective and, thereby, allow the public, users and decision makers to make informed judgments concerning its development and application rather than being ruled by unfounded fears. It will confront and clarify such key issues as liability, compensation of disbeneficiaries, water rights, environmental effects, etc. A fine example of such a technology assessment is the one developed for hail suppression which stated as one of its public policy recommendations, "We recommend that a national technology assessment study on the modification of precipitation be conducted. Based on our findings that rainfall effects were more important than hail effects in economic and socio-political impact, we feel strongly that a technology assessment on precipitation modification is needed" (Changnon *et al.*, 1977). The technology assessment on the modification of precipitation will, of course, be more complex than that for hail suppression because of its greater importance and impact on society and, for those reasons, it must be done.

b. Scientifically upgraded operational programs

As I mentioned before, operational programs, if property conducted, can be a source of scientific learning and technique development as well as potential economic benefit. Each operational program should include two basic ingredients: 1) the proper personnel and equipment to execute the seeding technique and 2) a standard set of basic measurements by which to assess the effects of seeding. While more costly than presently conducted operational programs, it is in the users' best interest to upgrade the quality of their programs. They will attract more knowledgeable and experienced scientists, improve the efficiency of their operation, improve feedback to research and further development, and in a larger sense maximize the future return on their investment.

The first set of ingredients is already within the power of most responsible commercial operators who, I am sure, would make them available if the market would bear it. As I pointed out before, weather modification is complex and the tools for its execution should be commensurate with its complexity. If the user community can be made to realize this fact, I am confident they will pay for it. The higher price of operations may result in fewer programs but they would be more productive. It might also make it more difficult for submarginal operators to ply their trade.

The second set pf ingredients is more difficult to specify but is equally important. I am not, and I emphasize *not*, necessarily calling for randomized seeding operations. I am encouraged by the recent National Science Foundation grant to the Illinois State Water Survey to develop techniques for assessing the effectiveness of nonrandomized experiments. I am eagerly looking to this work to provide guidelines for a standard minimum set of appropriate measurements. It should, however, be understood that the *assessment* of results obtained in this manner will take longer in years and be lower in confidence than the *evaluation* of results obtained through randomization. It is, nevertheless, imperative to take this important step in assessing operational programs in order to maintain and expand taxpayer trust, safeguard the professionalism of the operations and expand our base of scientific information.

Both the American Meteorological Society and Weather Modification Association can play an important role in establishing the above-mentioned standards.

c. Funding

No commentary on the needs of weather modification would be complete unless it included some mention of funding. Traditionally we ask for an expansion of research support that is commensurate with the mag-

nitude of the problem and the potential reward, usually tens-to-hundreds of millions of dollars. It is, however, not realistic to think that this will happen very soon. I do not think it will even be possible until a new perspective of weather modification is developed and accepted. I firmly believe that substantially higher levels of funding than are currently being provided; that is, steadily increasing budgets attaining about an order-of-magnitude increase in ten years, will be justified by technology assessments such as the one I recommended for precipitation management. We should, for the time being, strive for adequate and sustained levels of funding, with the emphasis on the latter (I sometimes feel that the funding of weather modification is as variable as the hydrological fluctuations but 180° out of phase).

Because of the complexity and variability in atmospheric processes, weather modification research requires carefully coordinated efforts over a considerable number of years. These programs should be based on obtaining a clear understanding of the most critical scientific, technical and sociopolitical problems which, in turn, establish the base level of funding for the efforts. Researchers must be assured of stability of at least this base level of funding if they are to wisely plan and execute such programs. Given that opportunity, I believe we will succeed in demonstrating by field experimentation the feasibility and value of weather modification which, in the final analysis, will be the most convincing argument in earning expanded financial support for further research and application.

4. A final comment

It is my strong belief that researchers, operators and users of weather modification should join in a deliberate and concerted effort to resolve the above-mentioned problems in perspective and thereby change the public image of weather modification that exists today. We will progress and succeed in our individual endeavors only as long as the field of weather modification in general is respected and considered beneficial. We must never lose sight of the fact that weather modification is not an end in itself. It is a valuable set of tools in an arsenal of tools that can and should be used effectively to serve many of society's important needs, such as food, fiber and energy production, recreation, environmental enhancement and life sustenance itself. The new and proper image of weather modification should be promoted on this basis, and activities and their priorities established accordingly.

It occurs to me that a good place to start in creating a new image for weather modification is to abandon the name "weather modification" itself. A more descriptive, appealing name having a positive connotation is needed. The term weather modification does not express the sense of desirability and public good that we are trying to convey. Therefore, it enables radical opponents to prey on the emotions of the uninformed public by conjuring up specters related to religion, weather disasters and the like.

A positive step forward would be to refer, whenever possible, to the particular activity in terms of its intended purpose, i.e., rain and winter orographic snowpack augmentation (or collectively as precipitation management as the Bureau of Reclamation prefers to call it), hail suppression, fog dispersal, etc., and avoid such ambiguous terms as precipitation modification, hurricane modification, etc. Reference to the collection of such activities as a general field of research and technology in more positive terms is, however, the major problem. Mr. Harlan Cleveland, Chairman of the Weather Modification Advisory Board under PL 94-490, referred to it during his banquet address at the Sixth Conference on Planned and Inadvertent Weather Modification (10–13 October, 1977, Champaign-Urbana, Ill.) as a "program to enhance the atmospheric environment." In this context I would like to advocate the use of "atmospheric resources management" as a frame of reference, which is how the Bureau of Reclamation views weather modification. Our atmospheric resources, e.g., precipitation, wind and sunshine, are renewable and/or inexhaustible components of our nation's natural resources. It should, therefore, be included as a part of a total, integrated system of managing our nation's natural resources along with land, water, minerals, etc.

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