Planned and Inadvertent Weather Modification

(Adopted by AMS Council 2 October 1998)

This statement is concerned with the scientific status of planned and inadvertent weather modification on local and regional scales. The Society's policy on global climate change is separate and has previously been presented (*Bull. Amer. Meteor. Soc.,* **72,** 57).

1. Status of planned weather modification

a. Fog and stratus removal

Operations that dissipate supercooled fog and low stratus (clouds containing water droplets at subfreezing temperatures) by seeding with ice-forming agents (e.g., dry ice, liquid nitrogen, compressed air, silver iodide, etc.) have become routine at some airports. The dissipation of warm fogs can be accomplished by more expensive thermal techniques, but this has proven cost effective at only a few major airports.

b. Precipitation increase

There is statistical evidence that precipitation from supercooled orographic clouds (clouds that develop over mountains) has been seasonally increased by about 10%. The physical cause-and-effect relationships, however, have not been fully documented. Nevertheless, the potential for such increases is supported by field measurements and numerical model simulations.

Some experiments with warm-based convective clouds [bases about 10°C (~50°F) or warmer] involving heavy silver iodide seeding have suggested a positive effect on individual convective cells, but conclusive evidence that such seeding can increase rainfall from multicell storms has yet to be established. Many steps in the physical chain of events are not well understood at this time and have not been documented with observations nor simulated in numerical modeling experiments.

In recent years, the seeding of warm and cold convective clouds with hygroscopic chemical particles to augment rainfall has received renewed attention through model simulations and field experiments. A recent randomized experiment has reported statistical evidence of a rainfall increase that is supported by numerical modeling experiments. Nevertheless, measurements of key steps in the chain of physical events associated with hygroscopic particle seeding are needed to confirm the seeding hypothesis and the range of effectiveness of these techniques in increasing precipitation. Evidence that such seeding can increase rainfall over economically significant areas is not yet available.

There are indications that precipitation changes, either increases or decreases, can also occur at some distance beyond intended target areas (extra-area effects). Improved quantification of the associated hydrological impacts is needed to satisfy public concerns.

c. Hail suppression

Results of various operational and experimental projects and numerical modeling experiments provide a range of outcomes: some suggest decreases or increases in hail while others have produced inconclusive results. Statistical assessments of certain operational projects indicate

successful reduction of crop hail damage, but the physical basis for these results has not yet been established.

d. Severe storms modification

No sound physical hypotheses exist for the modification of hurricanes, tornadoes, or damaging winds in general, and no related scientific experimentation has been conducted in the past 20 years. Experiments have been carried out on lightning suppression but have not yielded methods for application.

2. Status of inadvertent weather modification

There is ample evidence that agricultural and industrial activities modify local and sometimes regional weather conditions. Improved environmental monitoring and atmospheric modeling capabilities have revealed that human activities have significant impacts on meteorological parameters and climatological mechanisms that influence our health, productivity, and societal infrastructure. The environmental impacts of acid rain on structures, vegetation, and lake water quality; of increased anthropogenic pollutants on air quality and visibility; and of urban effects on temperature, humidity, wind, and precipitation have all been well documented. In addition, atmospheric changes that might have passed unnoticed, or been dismissed as inconsequential just a few years ago, are now often found to have broader ramifications; for example, increased cloudiness associated with condensation trails from jet aircraft may modify the radiation budget at the ground.

3. Recommendations

Increasing population, shifting demographics, and the prospect of global climatic change require that food, fiber, and water resources be managed to best alleviate the chronic shortages that are already beginning to manifest themselves. Thus, there is considerable need and benefit to determine the scientific and economic feasibility of cloud-modification methods. Likewise, actions that inadvertently modify weather or climate need to be better understood, quantified, and (if necessary and feasible) mitigated. These are challenging tasks requiring well-focused, long-term efforts. Major breakthroughs in any of these areas are unlikely; progress will more probably continue to be evolutionary.

1) Planned weather modification programs are unlikely to achieve higher scientific credibility until more complete understanding of the physical processes responsible for any modification effect is established and linked by direct observation to the specific seeding methodology employed. Recent improvements in seeding agents, observational facilities and platforms, computer capabilities, numerical models, and physical understanding now permit more detailed examination of clouds and precipitation processes than ever before, and significant advances are consequently possible. Whereas a statistical evaluation is required to establish that a significant change resulted from a given seeding activity, it must be accompanied by a physical evaluation to confirm that the statistically observed change was due to the seeding.

2) Precipitation augmentation through cloud seeding should not be viewed as a drought relief measure. Opportunities to increase precipitation are usually few, if any, during droughts; consequently, the cost of mounting a cloud-seeding operation will far exceed the benefits that may be obtained. A program of precipitation augmentation is more effective in cushioning the impact of drought if it is used as part of a water management strategy on a year-round basis

whenever opportunities exist to build soil moisture, to improve cropland, and to increase water in storage.

3) Anthropogenic influences on meteorological and climatological conditions are far reaching and
significant. Economic development should be framed with an awareness of how each activity alters environmental processes and atmospheric conditions. Much is known about the physical processes involved in many aspects of inadvertent weather modification, but important questions remain. Continuing research and monitoring related to inadvertent weather modification is required, and the breadth of these studies must be extended to include new knowledge on natural feedbacks and societal ramifications, which will lead to policy decisions that reduce the chance of severe impacts.