7.1
THE WEATHER DAMAGE MODIFICATION PROGRAM

Steven M. Hunter *, Jon Medina and David A. Matthews

U.S. Bureau of Reclamation, Denver, CO

1. INTRODUCTION

The U.S. Bureau of Reclamation (Reclamation) has been engaged in weather modification research since the 1960s, although this research declined significantly in the late 1980s through 1990s. In Federal Fiscal Year (FY) 2002, however, Congress authorized funding of the Weather Damage Modification Program (WDMP) and specified that it be administered by Reclamation. The primary goal of the program is to improve and evaluate physical mechanisms to limit damage from weather phenomena such as drought and hail, and to enhance water supplies through regional weather modification research programs and transfer validated technologies for implementation within operational programs. The WDMP program received $1.2M for field research in FY 2002 and 0.8M in FY 2003, but was not funded in FY 2004 and beyond. These monies have supported research in seven states: Colorado, Texas (in cooperation with New Mexico and Oklahoma), Nevada, Utah, and North Dakota.

The WDMP focused on three intermediate targets associated with the overall goal: rainfall augmentation, snowfall augmentation, and hail suppression. Participating states were expected to match federal funding and "piggyback" their research on existing operational weather modification projects. This paper summarizes the science questions pursued, research approaches, and current status of each state project.

A recent report on weather modification research (NAS 2003) cites advances in observational, computational, and statistical technologies over the last few decades that could be applied to weather modification. Based partly on these advances, the report recommends initiation of a sustained national research program. Although the WDMP is not presently funded, the program may serve as a foundation for such a research program with Federal government support. Also, according to the NAS report, such research should be pursued because weather modification has the potential for relieving water resource stresses. Reclamation is the major wholesale supplier of water in the U.S. and operates in 17 western states, where such stresses are the most severe, owing in part to a multi-year drought and rapid population growth. As a result, Reclamation is being forced to make increasingly difficult choices regarding water allocation.

The WDMP represents the first federally supported attempt in the 21^{st} century to investigate some of the major lingering scientific questions about the efficacy of weather modification. Answers to these questions are crucial prerequisites to widespread use of weather modification to alleviate the burgeoning water supply crisis in the West.

2. RESEARCH BACKGROUND AND DESCRIPTION OF PROJECTS

2.1 Winter Orographic Seeding

Melt and runoff from snowpack contributes most of the reservoir storage in large portions of the Western U.S., so snowpack augmentation is an attractive target in the region. Accordingly, operational cloud seeding to augment snowpack in the mountains has a long history in several western states. Prior studies suggest that seeding of supercooled orographic clouds has worked, yielding seasonal precipitation increases on the order of 10% (AMS, 1998). More research and documentation is needed to buttress these findings, however.

Winter orographic seeding has been dominated by the use of silver iodide (AgI), delivered from ground-based generators or aircraft. The last federally-assisted cloud seeding project was a winter experiment in Utah during the 1990s (Super 1999). There are a number of other seeding technologies that have been put forward but not tested extensively.

* *Corresponding author address:* Steven M. Hunter, Bureau of Reclamation D-8510, P.O. Box 25007, Denver, CO, 80225-0007; e-mail: smhunter@do.usbr.gov

New chemical compositions, such as silver chloride-iodide complexes, may act more efficiently to produce ice particles at temperatures warmer than -5°C, where AgI is ineffective. Similar warm temperature results may be achieved by cost-effective liquid propane generators (Medina 2000). The Utah WDMP experiment operated such generators.

The use of tracer chemicals with the seeding materials affords a method to verify the targeting of those materials. Such chemicals were employed in the Nevada WDMP experiment, which even attempted to distinguish ground-based and aircraft seeding signatures. This experiment also included a Lagrangian particle dispersion model and windflow from the MM5 cloud model to further characterize seeding plume trajectories (Koracin et al. 1998). The Colorado experiment also used a Lagrangian transport model (Uliasz 1994) coupled with the RAMS cloud model (Cotton et al. 1994) to evaluate targeting of seeding material.

2.2 Convective Seeding

Research into warm-season seeding of convective clouds in the Western U.S. was conducted mostly in the late 1960s through early 1980s, notably through projects such as the National Hail Research Experiment (NHRE) and the High Plains Experiment (HIPLEX; Cooper and Lawson 1984). These experiments had mixed results for hail suppression and rainfall augmentation, respectively. Rosenfeld and Woodley (1989; 1993) reported increases in radar-estimated rainfall with AgI seeding in West Texas during the 1980s. Tracer studies were conducted in North Dakota in 1989 (Boe et al. 1992).

More recently, positive findings regarding hygroscopic seeding have been reported in several experiments, e.g., in South Africa (Mather et al. 1997), Thailand (Silverman and Sukarnjanaset 2000), Mexico (Bruintjes et al. 2001; Fowler et al. 2001), and India (Murty et al. 2000). Yin et al. (2000; 2001) have conducted modeling studies of hygroscopic seeding that offer plausible arguments for why such seeding may lead to rain increases.

2.3 Individual Project Goals

The states conducting WDMP research are shown in Fig. 1. Three projects, in Nevada, Utah and Colorado, are involved in cool-season, orographic seeding. The other two projects, one in North Dakota and the other in Oklahoma, Texas and New Mexico, seed convective clouds during the warm season. Specifically, individual project principal goals are as follows:

- *Nevada* – (1) Remotely sense supercooled cloud water to quantify cloud seeding potential in a selected watershed; (2) Apply mesoscale atmospheric and dispersion modeling to evaluate seeding effectiveness under a variety of storm conditions; (3) Evaluate seeding effectiveness through physical and chemical analyses of snow packs; (4) Use hydrologic modeling to estimate impacts of seeding-induced increases in snow packs on streamflow; (5) Characterize natural and seeded cloud regions with *in situ* aircraft microphysical measurements.
- *Utah* – (1) Conduct randomized cloud seeding on the Wasatch Plateau using propane dispensers to develop embryonic ice particles; (2) Explore impacts on precipitation by the cloud seeding.
- *Colorado* – (1) Configure the Colorado State University cloud model (RAMS) and conduct modeling over operational cloud seeding areas; (2) Implement algorithms simulating cloud seeding generators as sources of ice nuclei, (3) Simulate Lagrangian transport of seeding materials under different weather conditions; (4) Use RAMS to develop forecasts for seeded and nonseeded days; (5) Evaluate model predictions of precipitation.
- North Dakota – (1) Radar analysis of first echo detection; (2) Analysis of long-term cooperative observer network rainfall data; (3) Explore climatic rain gauge data for evidence of North Dakota Cloud Modification Project seeding effects on rainfall in western North Dakota; (4) Investigate CCN characteristics in western North Dakota; (5) Three-dimensional modeling of North

Dakota clouds using a new microphysical parameterization scheme, with explicit treatment of atmospheric aerosols and hygroscopic seeding effects

- Texas/Oklahoma/New Mexico – (1) Statistical analysis of historical precipitation events in the Oklahoma Mesonet; (2) Profile CCN by instrumented aircraft; (3) Study seeding influences on cloud evolution with radar data; (4) Conduct airborne experimental seeding with hygroscopic materials (milled salts) and AgI; (5) Track seeding plumes with a tracer gas.

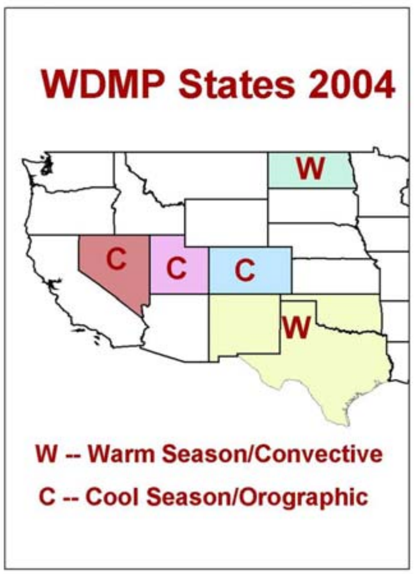

Figure 1. States conducting WDMP research, with indication of season and cloud type seeded. A single project sponsored activities in Texas, Oklahoma and New Mexico.

3. CONCLUSIONS AND FUTURE RESEARCH

Much of the Western U.S. has been experiencing a multi-year drought, creating water shortages that foment conflict between competing water users. This drought was particularly severe in 2002, when rainfall in the Colorado River basin was the lowest in recorded history. The drought has had far-reaching effects, including some of the worst forest fire seasons ever recorded. In response, bills were introduced in Congress to establish a National Drought Preparedness Act of 2003 and a National Drought Council within the Department of Agriculture (Western Governors Association 2004). The U.S. Department of the Interior recently started a "Water 2025" initiative (DOI, 2003). This initiative is intended to focus attention on increasing pressures on already-stressed water supplies by the West's explosive population growth, droughts, agriculture, recreation, and environmental concerns.

WDMP research will continue in 2005 to conclusion. No new funding has been received, however. The WDMP is the first federally-funded weather modification research field program in the 21st century. The program has demonstrated that the U.S. government can partner effectively with states and leverage scarce funds to carry out needed research, using resources already in place for operational weather modification projects. The program can serve as a model for future governmental cooperation and national initiatives such as the one proposed in the recent NAS report (section 1).

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