



Utah Cloud Seeding *Symposium Report*

Snowbird Ski Resort
September 28, 2023

Prepared by the Utah Division of Water Resources



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Cover image: recharge of Utah's water systems, from precipitation to snowpack to runoff

Report written by Carly Payne and Jake Serago

Background and objectives

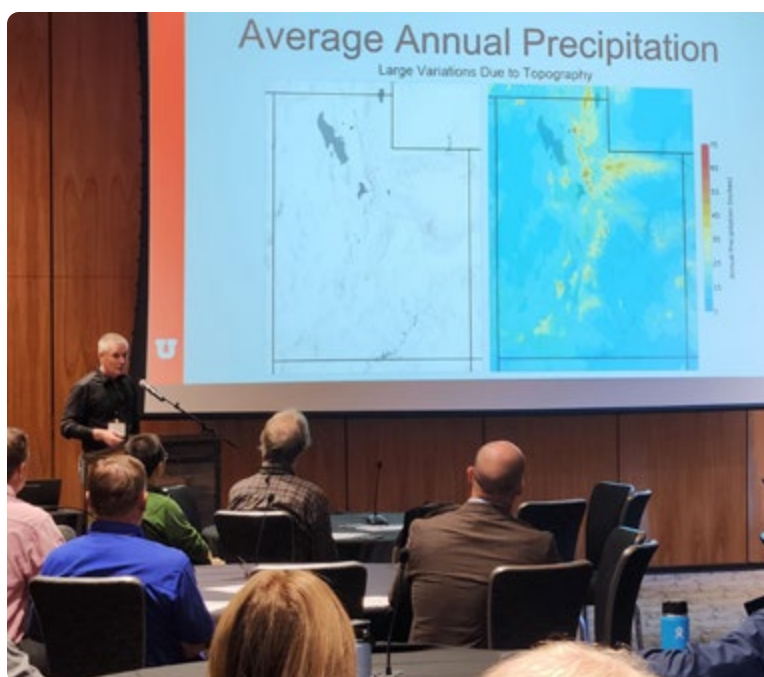
Utah's first Cloud Seeding Symposium — organized by Utah Department of Natural Resources staff — convened in Salt Lake City, Utah on September 28, 2023 at Snowbird Ski Resort. The symposium provided a forum for networking and information exchange between legislators, decision-makers, local program sponsors, journalists and scientists. Given the unprecedented investment in the state cloud seeding program during the 2023 legislative session, the Division of Water Resources needed to understand from stakeholders how best to support program enhancements, including operations, contracting processes, communications and research. Bringing people together from across Utah and surrounding states fostered greater collaboration, transparency and advancement of the practice.

The symposium's objectives included:

- Providing a setting where legislators and media could meet, speak with and learn about cloud seeding from expert scientists and experienced program managers.
- Allowing the Division of Water Resources to gather input from operators and program sponsors about how to improve and better coordinate the statewide program.
- Offering ideas and suggestions to the Division of Water Resources from researchers and program sponsors about what type of research is needed and how best to conduct it.

Seventy people from a range of organizations attended the meeting. Participants included people from the Utah Legislature, the Governor's Office, Department of Natural Resources, Department of Environmental Quality, water districts, ski resorts and other private industries, environmental groups, research organizations, county commissions, universities, media outlets, as well as cloud seeding specialists from California, Idaho, Colorado and Nevada. The full participant list is included in [Appendix B](#).

Joel Ferry, Executive Director of the Utah Department of Natural Resources, opened the symposium. He thanked those who traveled and Snowbird for providing the venue. The director also thanked North American Weather Consultants (NAWC) for their contributions, organizations that have advanced research and operations, and the Utah Legislature for their unwavering support



Jim Steenburgh of University of Utah presenting on cloud physics

of cloud seeding initiatives, especially the allocation of \$12 million in one-time funding and an annual budget of \$5 million to expand the program. The symposium's intention was to demystify cloud seeding by hearing from experts on the science, operations and environmental implications of cloud seeding. Over the past few years, there has been unprecedented interest in cloud seeding across the globe and people are recognizing the critical role it can play in water resource management. He affirmed that Utah is committed to enhancing cloud seeding operations and supporting cutting-edge research in an effort to ensure our programs are as effective and efficient as possible. Lastly, he encouraged attendees to engage, learn and connect.



Symposium attendees at the cloud seeding remote generator demonstration

Symposium structure

The symposium was structured to induce informed discussion on how to improve program management and operational research. Presentations during the first half of the day focused on the natural snow process, how cloud seeding operations are conducted, the state of the science and environmental impacts, as well as information on the cloud seeding programs in Utah, Idaho, Nevada and California.

NAWC gave a remote generator demonstration during the mid-morning break.

All symposium attendees participated in two workshops during the afternoon. The first workshop gathered input and ideas on what functions well about the state cloud seeding program and recommendations for improvement. The main improvements were related to communications, contracting terms and evaluations. The second workshop addressed research gaps, needs and priorities.

The symposium agenda is included in [Appendix A](#).

Conclusions and recommendations

Water-related issues

Stakeholders throughout Utah and the Western states are facing myriad water-related challenges. The issues brought to the symposium included the shrinking Great Salt Lake, aging water infrastructure, population growth and associated water demands, climate change, drought and more.

Communication and support from the Department of Natural Resources

Local participants and potential participants in Utah's cloud seeding program would like to see increased communication between the Division of Water Resources and state citizens. There are high levels of interest in attending more symposiums and workshops like this one.

In addition, current program sponsors would like to receive more frequent reports on active cloud seeding progress during the season. NAWC sends monthly reports to various water entities. How can we get these to a wider range of people? One possibility would be the development of a software that is compatible with remote generators and would allow people to access real-time data as the generators run. The Utah Division of Water Resources could also utilize its communication team in developing a communications strategy.



Symposium attendees at the first workshop, facilitated by Jake Serago, discussing existing program logistics and communication

Public education and outreach

Some participants feel that their communities don't believe in or understand cloud seeding science, which may contribute to their hesitance to participate in the program. Participants and NAWC mentioned increasing outreach efforts to educate the public and local officials on the benefits of cloud seeding, including the science, environmental concerns, and the process to get involved. Suggested places to present included the county commissioners' "Cowboy Caucus," water districts, cities, counties and other local groups and events. To make this happen, the state and NAWC need to be informed of these meetings with potential program sponsors.

The state could also work closely with local newspapers to share information on the cloud seeding program. Watershed councils could be used as an avenue of receiving and disseminating this information. The state and NAWC could work to have small-scale forums, similar to this symposium, across the state by region. Such forums would be more accessible and perhaps more interesting to local groups and governments. It would allow for peers to hear from one another on their opinions, concerns and needs for the cloud seeding program.

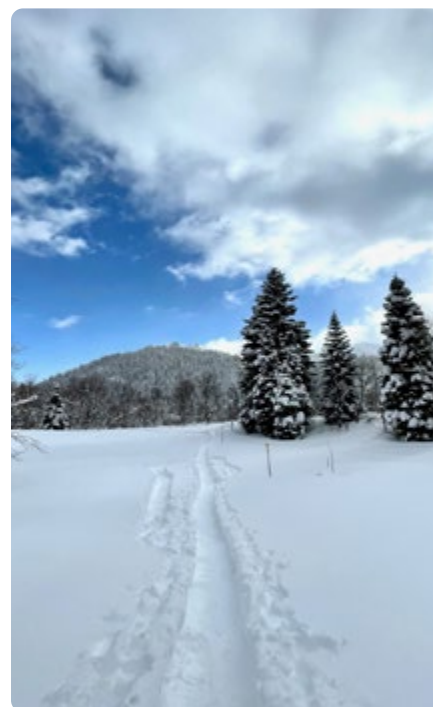
Simplification of the sponsorship process

Cloud seeding sponsors would like to simplify the necessary steps on their end, including a reduction in the number of letters sent and received. There were high levels of interest in moving from a one-year contract to a multi-year contract. Long-term contracts can provide additional security and sustainability to the program and ease the education burden on the state. NAWC already has multi-year contracts with many of the sponsors.

Research challenges

Cloud seeding researchers and professionals face many challenges, including the need for dedicated money in research and observational systems. Conclusions from early research at the Desert Research Institute were presented about how research should be approached, with the cloud seeding "chain of events" described as including the following questions:

- Is cloud seeding material successfully and reliably produced?
- Is seeding material transported into a region of cloud that has supercooled liquid water (SLW)?
- Is seeding material dispersed sufficiently in the SLW cloud so that a significant volume is affected?
- Are temperatures cold enough for substantial new ice production?
- Does the new ice remain in the SLW cloud long enough to gain significant mass and fall out as snow in the target area?



Predictions for snowfall and ice production are further complicated by a changing climate

Research questions

There are gaps in the understanding of both natural precipitation processes and artificial precipitation processes. The symposium discussed many important, yet unanswered questions related to these processes, some of which are listed here:

- How does air pollution impact snowfall and precipitation?
- What is the role of natural dust?
- How can we better understand background aerosol concentrations?
- What are secondary ice production mechanisms, and how might cloud seeding be contributing to secondary ice production?
- What factors drive snowfall variability from year to year, and how can we improve seasonal forecasts?
- How will precipitation change under current and future climate conditions? Is there opportunity to extend the seeding season?
- What are the impacts of gravity waves, turbulence and other small-scale factors?
- What is the full life cycle of natural precipitation, from cloud activation or ice nucleation to snowfall on the ground?
- Can valleys or areas that aren't near mountains benefit from cloud seeding?
- What are the downwind or extra area impacts of cloud seeding?
- If the goal of cloud seeding is to increase snowmelt-driven streamflow in the spring, is there a benefit to seeding earlier in the season, or do sublimation, wind and other factors reduce that benefit?
- What is the optimal number of cloud seeding generators and where should they be placed to be effective?
- How effective is cloud seeding at increasing runoff?
- What other seeding agents can be used to enhance precipitation?
- How can we improve and quantify cloud seeding impact?
- How much seeding material is needed to be effective?
- What are the most favorable and unfavorable conditions for seeding?
- How can we understand the impacts of seeding based on spatial variability?
- Can target-control analysis be used as seeding target areas increase across the West?
- How can we better analyze cold pools and stable layers in valleys and basins?



The effectiveness of remote generators like this one can be enhanced with further research

Research tools

The symposium acknowledged the lack of many research and observational tools and observations necessary to answer these outstanding questions, including:

- Cloud radars
- Lobby for additional NWS (NEXRAD) radar
- Expansion of models
- Observational platforms that measure cloud in a lagrangian sense
- Observing the three-dimensional structure of the atmosphere
- Mountain cloud microphysics measurements
- Ice nuclei measurements
- High temporal and high fidelity precipitation measurements
- Techniques to more confidently measure the contributions of cloud seeding to precipitation and runoff
- Visualization models to be used as an education tool
- Ability to track the additional water throughout the system, including to streams and headgates
- Can the MesoWest network be used more or expanded?

Due to unprecedented funding for cloud seeding improvements from its Legislature, the state of Utah is uniquely positioned to acquire the necessary tools to better support the investigation of these research questions.

Research themes

The symposium noted that many of the listed questions and tools related to two themes: evaluation and optimization of cloud seeding programs. Some primary suggestions to focus on to better quantify seeding impacts under the program evaluation theme included increased use of model guidance and additional instrumentation, such as radars and radiometers. For the program optimization theme, suggestions included greater collaboration and partnership between organizations, utilization of MesoWest for observation analysis and data assimilation into models, utilization of long-term model simulations (e.g., CONUS404) for feasibility and design, seeding parameterization model guidance, and sharing of equipment, particularly radars, between organizations.

Formation of a technical advisory committee

The symposium discussed the possible formation of a technical advisory committee to share information, identify priorities and create a plan to fund research. This committee would investigate which research questions are possible and would lead to increased optimization and evaluation, who could perform the studies, and what instruments may be necessary to help set up the experiments. This would ensure the best use of the state's money. Said committee would include scientists, state officials, stakeholders and experts from Utah State University and the University of Utah.

Symposium Report

Appendices

Appendix A: Symposium Agenda

Morning Session

- 8 a.m.....Breakfast
- 8:30 a.m Welcome and introduction
Joel Ferry, Department of Natural Resources Executive Director
- 8:45 a.m Symposium purpose and agenda
Candice Hasenyager, Division of Water Resources Director
- 9 a.m..... Cloud Seeding Information
- *Cloud Physics — Jim Steenburgh, University of Utah*
 - *State of the Science — Sarah Tessendorf, National Center for Atmospheric Research*
 - *Operations — Todd Flanagan, North American Weather Consultants*
 - *Environmental Impacts — Patrick Golden, Heritage Environmental Consultants*
- 10:15 a.m Remote generator demonstration
- 10:45 a.m State Programs
- *Utah — Jake Serago (Utah Division of Water Resources)*
 - *Idaho — Kayla Golden (Idaho Department of Water Resources)*
 - *Nevada — Frank McDonough (Desert Research Institute)*
 - *Lower Colorado River Basin — Tom Ryan (Metropolitan Water District of Southern California)*
- 12 p.mLunch
Sponsored by North American Weather Consultants

Appendix A: Symposium Agenda

Afternoon Session

1:15 p.m.Workshop 1: Expanding Utah’s Cloud Seeding Program: Operational & Funding Improvements

Facilitator — Jake Serago

Local sponsors of cloud seeding programs, both current and potential, are encouraged to attend this discussion of program enhancements and funding models. Input is sought from sponsors on how the Utah Department of Natural Resources can support their needs.

2:45 p.m. Break

3 p.m. Workshop 2: Cloud Seeding Research Needs

Facilitator — Sarah Tessendorf

Researchers in atmospheric, meteorology and cloud seeding are encouraged to attend to discuss current research gaps, improve collaboration, discuss funding and explore the possibility for a large-scale field research campaign in Utah.

4:45 p.m. Concluding remarks

Candice Hasenyager

5 p.m. Symposium concluded

An exposition of cloud seeding equipment will be available throughout the day.

Appendix B: Symposium Attendees

Name	Agency or Interest
Todd Adams	Utah Department of Natural Resources
Gay Lynn Bennion	Utah House of Representatives
Desiree Bravo	County of San Luis Obispo Department of Public Works
Garrett Cammans	North American Weather Consultants
Parker Cammans	North American Weather Consultants
Bobbijo Casper	Central Utah Water Conservancy District
Shannon Clough	Utah Division of Water Resources
Evan Curtis	Governor's Office of Planning and Budget
Nathan Daus	Cache Water District
Lynn DeFreitas	Friends of Great Salt Lake
Ivan Djambov	Legal Fiscal Analysts Office
Rachel Edie	Utah Division of Air Quality
Joel Ferry	Utah Department of Natural Resources Executive Director
Dave Fields	Snowbird
Todd Flanagan	North American Weather Consultants
Kade Garner	ABC 4 News
Kala Golden	Idaho Department of Water Resources
Patrick Golden	Heritage Environmental Consultants
Amy Green	Rural Water Technology Alliance
Jim Grover	Governor's Office of Economic Opportunity
Gannet Hallar	University of Utah
Jared Hansen	Central Utah Water Conservancy District
Candice Hasenyager	Utah Division of Water Resources Director
Timothy Hawkes	Great Salt Lake Brine Shrimp Cooperative
Darren Hess	Weber Basin Water Conservancy District
Charles Holmgren	Utah Board of Water Resources
Brad Horrocks	Uintah County Commissioner
Jay Mark Humphrey	Emery Water Conservancy District
Curtis Hurley	Deer Valley Resort
Bryce Jackson	Utah Water Resource Development Corp.
Steve Krueger	University of Utah
Leia Larsen	The Salt Lake Tribune
Michael Larson	Utah Association of Conservation Districts
Frank McDonough	Desert Research Institute
Devin McKrola	Central Utah Water Conservancy District


Appendix B: Symposium Attendees


Name	Agency or Interest
William Merkley	Uintah Water Conservancy District
Craig Miller	Utah Division of Water Resources
Jeremy Miller	The Economist 1843 Magazine
Riley Olsen	Weber Basin Water Conservancy District
Jay Olsen	Utah Department of Agriculture and Food
Cole Osborne	North American Weather Consultants
Scott Paxman	Weber Basin Water Conservancy District
Carly Payne	Utah Division of Water Resources
Tammy Pearson	Beaver County Commissioner
James Reese	Utah Division of Water Rights
Crystal Ross	Utah Division of Water Resources
Tom Ryan	Metropolitan Water District of Southern California
Jake Serago	Utah Division of Water Resources
Mark Sghiatti	Utah Division of Air Quality
Gene Shawcroft	Central Utah Water Conservancy District
Jared Smith	North American Weather Consultants
TJ Somers	Deer Valley Resort
Jim Steenburgh	University of Utah
Jesse Stewart	Salt Lake City Department of Public Utilities
Todd Stonely	Utah Division of Water Resources
Sarah Tessoroff	National Center for Atmospheric Research
Jacob Treadwell	Snowbird
Jeff Tuttle	Emery Water Conservancy District
Laura Vernon	Utah Division of Water Resources
James Walter	Salt River Project
Clyde Watkins	Duchesne County Water Conservancy District
Paulette Webster	Central Utah Water Conservancy District
Marisa Weinberg	Utah Division of Forestry, Fire and State Lands
Kim Wells	Utah Department of Natural Resources
Ben Winslow	KSTU Fox 13
Dex Winterton	Duchesne County Water Conservancy District
Jaime Wolff	National Center for Atmospheric Research
Kevin Workman	Central Utah Water Conservancy District
Lulin Xue	National Center for Atmospheric Research
Edward Zipser	University of Utah



Utah's snowpack is the heart of our water system, and cloud seeding can enhance it

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