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WINTER GROUND OPERATIONS 2021-2022

WYOMING WEATHER MODIFICATION

WIND RIVER MOUNTAINS

Final Operations Summary prepared for the Wyoming Water Development Office



WEATHER MODIFICATION
INTERNATIONAL

Ground-Based Cloud Seeding Operations 2021-2022 Winter Operations Report

For the

Wind River Mountain Range, Wyoming

Prepared By



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MARCH 2023



WYOMING WEATHER MODIFICATION PROGRAM

Wind River Mountain Range



EXECUTIVE SUMMARY

Funding for cloud seeding operations in the Wind River Range for the winter of 2021-2022 was provided in part by the 2021 Wyoming State Legislature's *Omnibus Water Bill – Construction*. The Wyoming State Legislature has mandated that the funding rate for the State will not exceed 37% of total project costs, leaving 63% of the project costs to be split among other Colorado River Basin water users and other interested parties. Funding partners in support of continued weather modification activities in the Wind River Mountains during the winter of 2021-2022 included the Southern Nevada Water Authority, the Central Arizona Water Conservation District, the Colorado River Board of California - Six Agency Committee, Genesis Alkali, TATA Chemicals, Rocky Mountain Power, and the Green River/Rock Springs/Sweetwater County Joint Powers Water Board.

Ten ground-based ice nucleus generators (ground generators) were employed, eight of which were deployed for the seven previous operational seasons. Nine generators were sited on the west, southwest, and southern flanks of the range. The tenth was sited on the southeastern flank, southwest of Lander.

The 2021-2022 season became operational on 15 November 2021 and concluded after 15 April 2022. The first seeding event occurred on 24 November 2021.



Figure 1. WMI Technicians finish up work on the ground-based cloud seeding generator at Big Sandy (WR01) as the sun begins to set. The crew was able to access the site this day via UTV. Photo by WMI Technician Michael Paul.

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The 2021-2022 weather pattern produced considerably-reduced storm frequencies compared to the previous season, primarily due to the persistence of a long-wave ridge that resulted in an unfavorable storm track. One seeding event occurred in November 2021, ten in December 2021, three in January 2022, two in February 2022, three in March 2022, and six in April 2022, bringing the seasonal total to 25 events. Seasonal snowpack (snow water equivalents, or SWE) at project end (April 15) varied from 68% of the median annual value to 95%, with the five-site SNOTEL mean at just 81% of the long-term median value. The Hobbs Park site finished with the greatest percentage of seasonal snowpack, at 95%.

The twenty-five storm events accrued 239 hours and 29 minutes during which one or more generators were seeding during the winter. The fewest number of generators that operated during any one storm was one (during twelve easterly upslope events), and the most, nine.

Similar to last season, the 2021-2022 season featured mostly shorter-interval storms compared to previous seasons. Of the 25 seeding events, only seven lasted for more than ten hours and only two for over twenty. These shorter-interval storms produced good seeding conditions, but these conditions were brief. Additional and more detailed information is provided in the pages that follow, and the attached appendices.

The total number of “generator hours”, defined as the sum of times each generator was operated during a storm, was 1372 hours and 13 minutes. For seeding to have been conducted, the wind direction had to be such that seeding agent released from each specific generator would carry seeding aerosol particles (silver iodide, AgI) upslope into cold but yet-unfrozen clouds at speeds sufficient to ensure that transport would occur. The seeding rate is approximately 25 grams of silver iodide per generator, per hour. The results discussed in this report show a variance in the number of generators used from seeding event to seeding event. This variance is due to situations when the wind direction favored the activation of specific generators. The three other requisite conditions needed to initiate seeding was: the presence of liquid water clouds, suitable cloud temperatures, and the absence of a stable layer which would inhibit the transport of the seeding agent up and over the range. The temperature of the clouds aloft had to be cold enough (-6°C or colder) to ensure that the seeding agent would nucleate ice, thus starting precipitation development. This is discussed in greater detail later in this report.

In the 2021-2022 season, WMI obtained high-resolution weather model information from the National Center for Environmental Prediction (NCEP) and created its own numerical weather prediction (NWP) information from custom-designed Weather Research and Forecasting (WRF) model domains. This information was retrieved and created as quickly as possible leveraging resources from the Amazon Elastic Compute Cloud, providing unique meteorological guidance designed specifically to aid project meteorologists make efficient and successful operational cloud seeding decisions. Hybrid Single-Particle Lagrangian Integrated Trajectory, or HYSPLIT, modeling was also run in real-time from WRF and other publicly available numerical weather prediction models. More about these models are presented in the body of this report.



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As accuracy of numerical models as increased, the need to verify requisite temperature and wind criteria by atmospheric soundings has decreased. For the 2021-2022 season, atmospheric soundings were not conducted. The presence of liquid water clouds over the range was established by the WWDO radiometer sited at the East Fork site, or confidence in model forecasts, coupled with the presence of clouds on satellite and webcams. New satellite products from the GOES-R suite, including day cloud phase and nighttime microphysics, are also used to help assess cloud coverage and composition.



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ACKNOWLEDGMENTS

The 2021-2022 project had multiple partners whom WMI here acknowledges. In addition, the project ran smoothly, effectively, and safely because of the diligence of many people, and we appreciate all of them.

The State of Wyoming, through the Wyoming Water Development Commission (WWDC), contributed 37% of the program costs. Much of the remaining funding was provided by the Colorado River Board of California – Six Agency Committee, the Central Arizona Water Conservation District, and the Southern Nevada Water Authority. Contributions toward project operations were received from Genesis Alkali, TATA Chemicals, Rocky Mountain Power, and the Green River/Rock Springs/Sweetwater County Joint Powers Water Board. We appreciate the active participation of these stakeholders very much.

Project guidance and direction on behalf of the State of Wyoming was provided by Program Manager Julie Gondzar and Barry Lawrence of the Wyoming Water Development Office. The WMI ground-based generator crew was comprised of Lead Technician, Michael Paul assisted by Ryan Hudson, and Pat Trujillo. Meteorological services, which included forecasting, weather monitoring (for seeding conditions), and direction of operations were provided primarily by Jason Goehring and Adam Brainard. Numerical weather prediction services and a meteorological web interface for the project was provided by Brainard. Additional meteorological support including forecasting services was provided by Sarah-Ellen Calise, Corey Clay, Jeff Ceratto, and Dan Gilbert. Bruce Boe, Vice President of Meteorology, provided scientific program oversight.

From the Fargo corporate office, logistical and technical support for the ground-based seeding equipment was provided by Dennis Afseth, Jake Van Ornum and Erin Fischer (Client Services), provided administrative and recordkeeping support, with the assistance of Ramona Adams and Cindy Dobbs.



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1 BACKGROUND AND OVERVIEW

1.1 Background

Atmospheric water transformed to precipitation is one of the primary sources of fresh water in the world. However, a large amount of water present in clouds never is converted into precipitation at the surface. This has prompted scientists and engineers to develop the means to augment water supplies through cloud seeding.

From 2006 through the spring of 2014, cloud seeding operations in the Wind River Range were conducted within the context of the Wyoming Weather Modification Pilot Project (WWMPP; Breed et al. 2014, Rasmussen et al. 2018). Eight of the ten ground-based cloud seeding generators used in that project were funded by the Wyoming State Legislature through the Wyoming Water Development Commission (WWDC). The two additional generators were funded by the Lower Colorado River Basin States.

Though the WWMPP concluded in the spring of 2014, local and regional interest in continuing operations remained. In recognizing this interest, the WWDC obtained legislative support and the funding for a 2014-2015 operational cloud seeding program in the Wind River Range. This interest continues, and operations have continued through this mechanism during subsequent winters. Funding sources are discussed further in Section 1.4.

1.2 Scientific Basis

Clouds in the lower troposphere form when, in cooling air, water vapor condenses upon cloud condensation nuclei (CCN), forming cloud droplets. The size of the droplets produced depends on the amount of water vapor present, and the character of the CCN. When the CCN are large or have properties that attract water (such as salt), the resulting droplets will be larger. The formation of cloud droplets happens on a very small scale, as illustrated in Figure 2. About one million (10^6) typical cloud droplets are required to produce a single, one-millimeter (mm) raindrop.

Precipitation forms in two ways. The simpler process involves the collision and coalescence of cloud droplets until the droplet becomes large enough to fall as precipitation. Thus, the initially-tiny cloud droplets grow, becoming drizzle, and with continued growth, rain. This process is known as the *collision-coalescence* or *warm rain* process.

The alternative path to precipitation development is through the formation of ice instead of raindrops, and it is this process that plays a significant role in winter clouds in Wyoming. For ice to exist, the cloud must be colder than 32°F (0°C). However, ice does not form spontaneously at temperatures colder than 32°F (0°C). In the absence of ice nuclei, water can become “supercooled”, meaning the water in the cloud remains in liquid form at temperatures well below zero Celsius. To most persons this is surprising, as we are accustomed to seeing water (at the surface) freeze whenever temperatures fall “below freezing.” Freezing happens at the surface because there are lots of substrates (substances or materials) present that encourage nucleation of the ice phase (freezing), and these substrates are largely absent in the free atmosphere.



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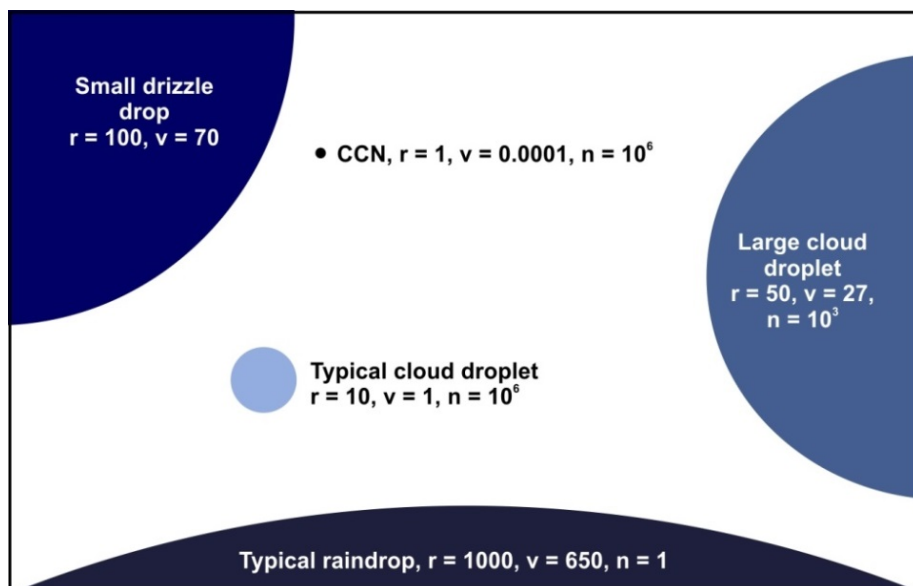


Figure 2. Relative characteristics of particles involved in cloud processes. For each, the radius (r , microns), fall velocity (v , cm per second), and number concentration (n , per liter) are given (after Wallace and Hobbs 1977). The raindrop shown (radius = 1000) is a 2 mm diameter raindrop.

Nature's solution to the lack of substrates available to encourage the freezing process in clouds comes in the form of tiny particles called *ice nuclei*. Ice nuclei provide microscopic, crystalline "templates" for supercooled liquid water (SLW) to follow and transform to the solid form known as ice. The shape of an ice nucleus plays an important role in determining which atmospheric conditions will be better suited for the formation of ice crystals in clouds.

Once ice forms in a cloud, the crystals grow quickly. Initially, growth occurs through water vapor deposition directly on the nascent ice particle, producing six-sided crystals. Within five minutes, these tiny ice crystals grow large enough to begin to fall. As they fall, growth by deposition continues, but because the ice crystals are heavier than the nearby SLW droplets they collect them as they fall. Upon contact with the ice crystals, the SLW droplets freeze. As they grow ever larger, the ice crystals may encounter each other and become tangled, forming aggregates known as snowflakes.

When clouds grow colder than about 23°F (-5°C) but do not immediately form ice crystals (very common), they can be treated with silver iodide-based ice nuclei which immediately initiate ice crystal formation, thus starting the ice-phase precipitation process. Ground-based seeding is commonly used in orographic applications, especially when the prevailing wind flow is roughly perpendicular to the mountain range, so that seeding agent is lofted immediately upward into the targeted clouds. This orographic seeding technique was the prime strategy used to seed winter clouds throughout the WWMPP and continued to be the main approach utilized in the Wind River Range during the operational seeding seasons in the winters since.



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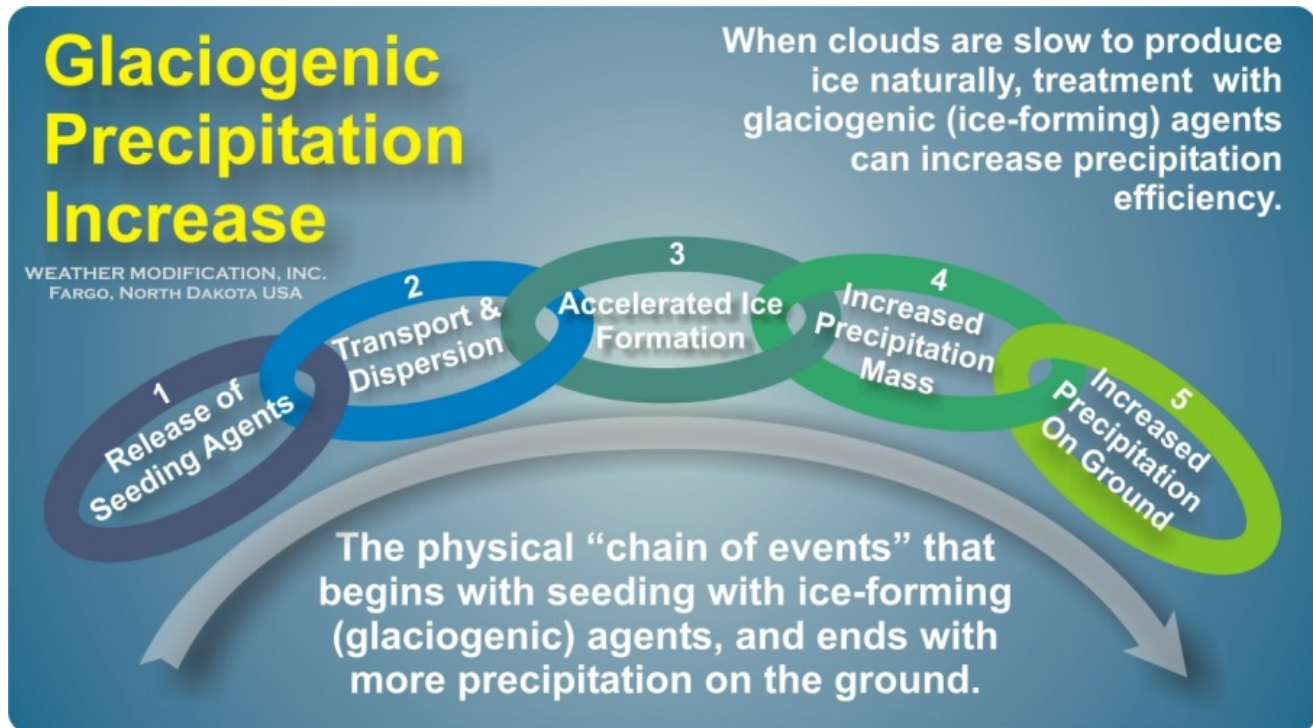


Figure 3. The physical chain-of-events that begins with release of ice-forming seeding agents and culminates with increased precipitation.

Given the chain-of-events illustrated in Figure 3, effectiveness of seeding operations depends upon three things:

- The clouds of interest must contain liquid water.
- The cloud temperature at the level where liquid water is present, typically 10,000 feet MSL, must be colder than +23°F (-5°C). Natural ice nuclei, such as crystalline soil particles, do not act to form ice crystals until the cloud is much colder, +5°F (-15°C) at the warmest. The AgI seeding agent, by virtue of its crystalline shape being very close to that of ice, begins to form ice crystals much sooner, at about +23°F (-5°C). As a result, precipitation formation within the cloud starts significantly sooner, allowing more time for the ice crystals to grow and transform into snow.
- The wind direction and speed must be such that the seeding agent released from the ground-based generators will be transported up the mountain slope and into the target clouds.

1.3 Operations

The three criteria above were the same as those used in the WWMPP research, except the temperature criterion for seeding during the WWMPP was slightly colder (+17.6°F or -8°C) during the pilot project. The colder temperature threshold was used in the research to ensure that more of the seeding agent would activate in the cloud and produce a stronger seeding signature.



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In operational seeding, the temperature criterion can be met in warmer conditions as long as some of the ice nuclei still produce ice crystals. It must be noted that the magnitude of the seeding effectiveness will diminish as temperatures warm. Seeding should not occur when temperatures aloft are warmer than +23°F (-5°C). This widening of the temperature window for seeding increases the number of seeding opportunities. Most operational (vs. research) seeding programs use this warmer temperature criterion.

1.4 2021-2022 Program Funding

In addition to the 37% of funding costs provided by the State of Wyoming, funding for the 2021-2022 operations was also provided by the following organizations/agencies.

Southern Nevada Water Authority. The Southern Nevada Water Authority (SNWA) is a cooperative agency formed in 1991 to address Southern Nevada's unique water needs on a regional basis. SNWA officials are charged with managing the region's water resources and providing for Las Vegas Valley residents' and businesses' present and future water needs. With Colorado River water currently representing 90% of SNWA's water supply, the SNWA partners with other Colorado River Basin states to optimize and enhance Colorado River water supplies.

Central Arizona Water Conservation District. The Central Arizona Project (CAP) delivers Colorado River water via a 335-mile aqueduct system to customers in Maricopa, Pinal, and Pima Counties in Arizona, home to 80% of Arizona's population. The CAP diverts more than 1.6 million acre-feet annually, providing water to cities, towns, irrigation districts, Native American communities, and stores water underground for future use during times of drought or shortage. The Central Arizona Water Conservation District manages its Colorado River resources for current and future residents in central Arizona, and continuously seeks collaborative approaches with partners in the Colorado River Basin to protect and augment the water supplies in the Colorado River System.

Colorado River Board of California - Six Agency Committee. The Six Agency Committee was created in 1950 through an agreement among Palo Verde Irrigation District, Coachella Valley Water District, San Diego County Water Authority, Imperial Irrigation District, the Metropolitan Water District of Southern California and the City of Los Angeles Department of Water and Power. The Six Agency Committee provides funding to support actions to safeguard the members' rights and interests in the Colorado River system and for the Colorado River Board of California.

For the 2021-2022 winter season, five other project sponsors continued their support, each having an interest in the water resources within the Green River Basin. Their contributions were modest but meaningful, and very much appreciated. These supporters were: Genesis Alkali, TATA Chemicals, Rocky Mountain Power, and the Green River/Rock Spring/Sweetwater County Joint Powers Water Board. Each of these contributed \$3,000, except for Rocky Mountain Power and the Green River/Rock Springs/Sweetwater County Joint Powers Water Board, which each contributed \$5,000.



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2 PROJECT PERSONNEL AND FACILITIES

2.1 Personnel

WMI provided an experienced ground-based cloud seeding crew for the 2021-2022 winter season. It consisted of project forecasters who monitored the weather and made the decisions regarding which ground-based generators should be used, and when each should be turned on and off, and the project technicians, who maintained and operated the field units.

2.1.1 Meteorology Team

The meteorology team was led by an experienced team of four, with occasional assistance by two others. Adam Brainard was located on-site in Pinedale, WY for the early part of the project, after which Corey Clay was primary. Brainard operated WMI's numerical weather prediction models and coordinated data collection during the season. Jason Goehring led the forecasting team and was the primary operations meteorologist. Goehring was assisted by Clay and Sarah-Ellen Calise. Jeff Ceratto participated in forecasting and operations in November and early December.

This was Goehring's seventeenth season of Wyoming seeding operations and forecasting. Brainard has been involved with the Wyoming seeding programs since 2016, providing numerical weather prediction services and web-based information support. Ceratto has four seasons of winter experience on the Central Mountain & Upper Snake River Weather Modification Program (sponsored by Idaho Power Company) as a WMI contract meteorologist.

Goehring, Brainard, Ceratto, Clay, and Gilbert are all Modification Association Certified Operators. Bruce Boe, WMI Vice President of Meteorology, provided overall management of the meteorology team and is a Weather Modification Association Certified Manager.

2.1.2 Technician Team

Three technicians participated in the 2021-2022 operations. On-site technical work was conducted by Mr. Michael Paul, assisted by Mr. Ryan Hudson and Mr. Pat Trujillo.

Since maintenance and servicing of generator sites could only occur when storms were not expected, field days were often long, as technicians tried to get to as many sites as possible. Safety guidelines require that no fewer than two technicians travel into the field together, largely in the event of equipment failure (i.e., a snowmobile breaking down or getting badly stuck), but also because two persons are required to complete tasks such as adding seeding solution to a generator. Safety is always of paramount importance, but even more so during heavy-snow winters (such as the 2016-2017 season) when sleds sink more deeply into the always-fresh snow, and avalanche risk may be heightened.



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Additional support from WMI headquarters in Fargo, ND was provided by Dennis Afseth, WMI Director of Electronics, and technicians Ryan Richter and Jeremy Bilben. Richter has been providing support for the field program since its inception in 2006. Overall project recordkeeping and reporting was done by Jake Van Ornum and Erin Fischer, Director of Client Services.

WMI WINTER 2021-2022 METEOROLOGY TEAM



DANIEL GILBERT
Chief Meteorologist



JASON GOEHRING
Field Meteorologist



ADAM BRAINARD
Field Meteorologist/
Numerical Modeler



JEFF CERATTO
Field Meteorologist



CORY CLAY
Field Meteorologist



SARAH-ELLEN CALISE
Field Meteorologist

Figure 4. The 2021-2022 WMI Meteorology Team.

2.1.3 Pre-Project Ground School

A pre-project ground school was held remotely via GoToMeeting with the flight crew, meteorology team, client, and key WMI staff on 25 October 2021. Attendance was mandatory for WMI project employees. The meeting topics included forecasting, modeling, media protocol, overview of the project, reporting pre- and post-flight, aerial cloud seeding operations, and safety. WMI administrators – Bruce Boe, Vice President of Meteorology; Jody Fischer, Director of Flight Operations; and Erin Fischer, Director of Client Services, and Jake Van Ornum, Client Services Assistant, also attended the kickoff meeting. The meeting allowed both groups to share information which improved communication, program efficiency, and contributed to the overall success of the program.

2.2 Siting of Seeding Equipment

Ground-based units were placed at ten physical locations within the project target area. Eight of the ten sites remain unchanged from those utilized in the WWMPP and the previous operational seeding seasons in the Wind River



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Range. Prior to the project start, Anderson Ridge and Sweetwater dismantled and relocated to two new sites (Willow Lake and Highland) that were studied for feasibility in 2019-2020 and 2020-2021, see Figure 5.

The generator placement was such that individual generators could be activated according to wind direction, and as storms passed and conditions changed. As shown, nine of the ten generator sites wrapped around the western to southwestern side of the mountain range, beginning with the Green River site on the west and ending with the Anderson Ridge site at the extreme southern end. These locations allowed targeting of the range when wind directions were within the southwestern quadrant. The tenth site, Enterprise, allowed targeting when winds were easterly. All sites were on state-owned or private lands. Permissions were established through the Wyoming Office of State Lands and Investments or private memoranda of understanding, accordingly.

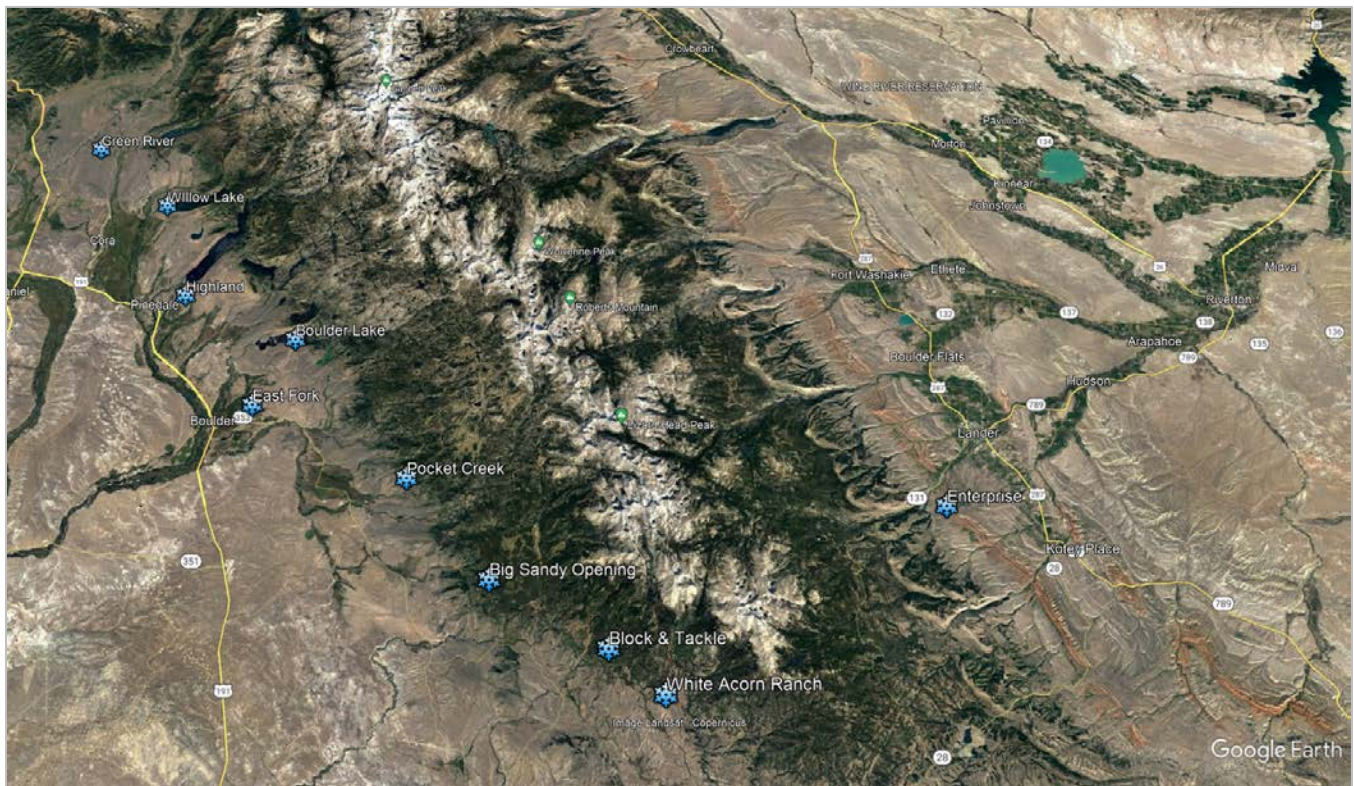


Figure 5. The locations of the ground-based ice nucleus generators are indicated by the snow crystal symbols.

2.3 Ice Nucleus Generators

The ice nucleus generators were designed, fabricated, deployed, operated, and serviced by WMI. The primary components are shown in Figure 6.



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The Wind River Range generators are entirely independent, controlled via satellite, and powered by batteries charged by solar power. This allows siting of generators at higher elevations, significantly improving delivery of seeding agent to the clouds. Remotely-controlled generators can be activated and deactivated as weather conditions warrant. This allows seeding agent to be dispersed only when it will be effective. All generator lines and fittings are made of corrosion-resistant stainless steel, to accommodate the high-performance seeding solution.

The generators are robust; designed to function in extreme temperatures, winds, and precipitation.

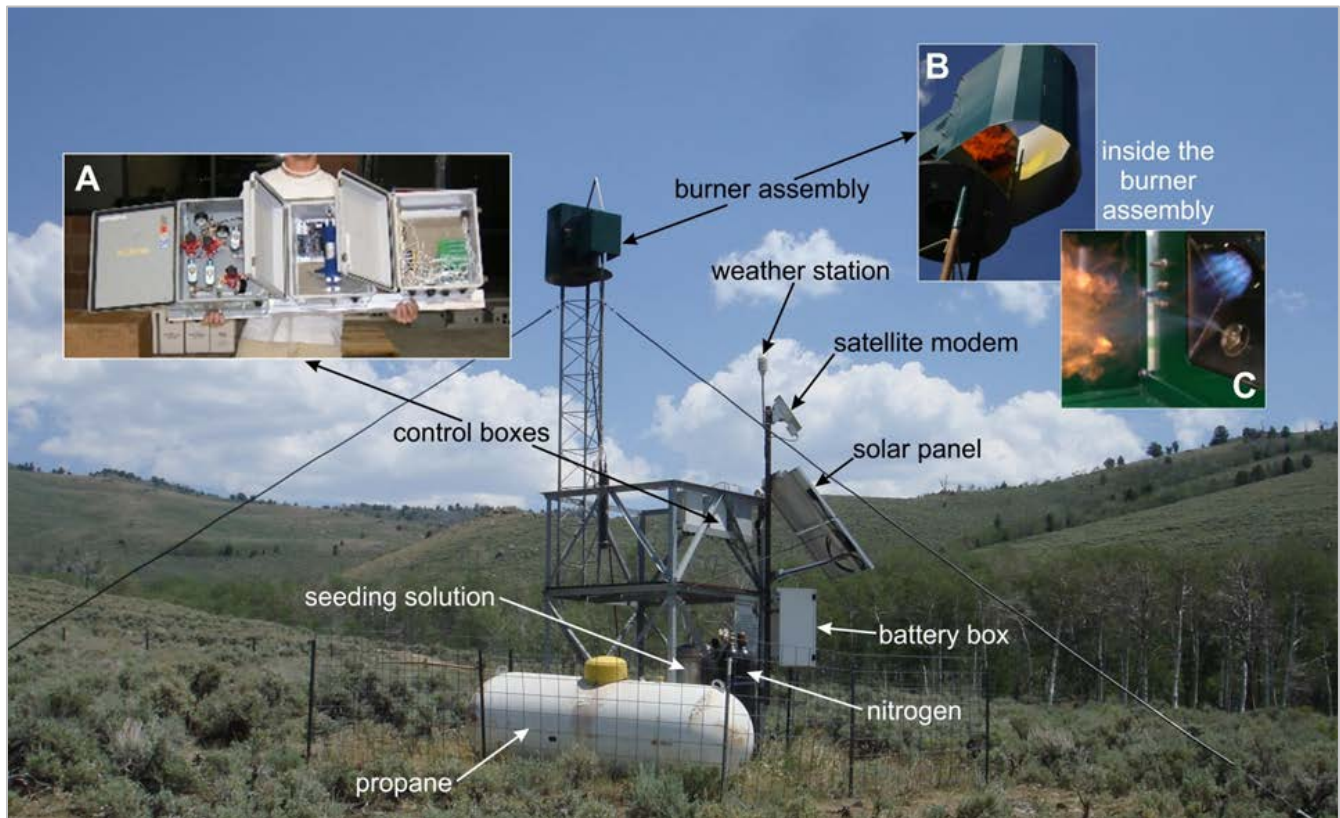


Figure 6. The primary components of the WMI remotely-controlled ground-based ice nucleus generator is illustrated. Inset A, shows the contents of the control boxes. From left to right, these are: solenoids (electronic valves) to turn flows on and off, seeding solution flow rate regulation and measurement, and computer interface with the satellite modem. Inset B, provides a view up and into an ignited generator, and Inset C, shows how the seeding solution is atomized through a nozzle (silver disk, lower right) and into the burning propane (blue flame) and ignited (bright orange flame).

The computer interface used to control the generators is shown in Figure 7. The status of the entire generator system (voltage, pressure, relay (valve) status, and flame temperature) is available for inspection by the technician immediately upon connection to the satellite.



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Clicking the Start Seeding button (lower left on the interface, Figures 7 and 8) automatically sequences the generator start-up. At the generator, a valve will open to allow propane to flow. Ignition of the propane is confirmed on the interface by a rapid increase in indicated flame temperature. When the generator is not burning, the “flame temperature” is that of the ambient air. Once the generator is burning, the seeding solution is atomized by the nozzle and sprayed as an aerosol into the propane flame (Figure 6, Inset C). As the solution burns, particles of silver iodide are transported by the wind into the clouds over the mountains. Several of these steps, such as the flow rate of the seeding agent, can be confirmed by the technician utilizing the WMI remote-controlled ice nucleus generator interface.

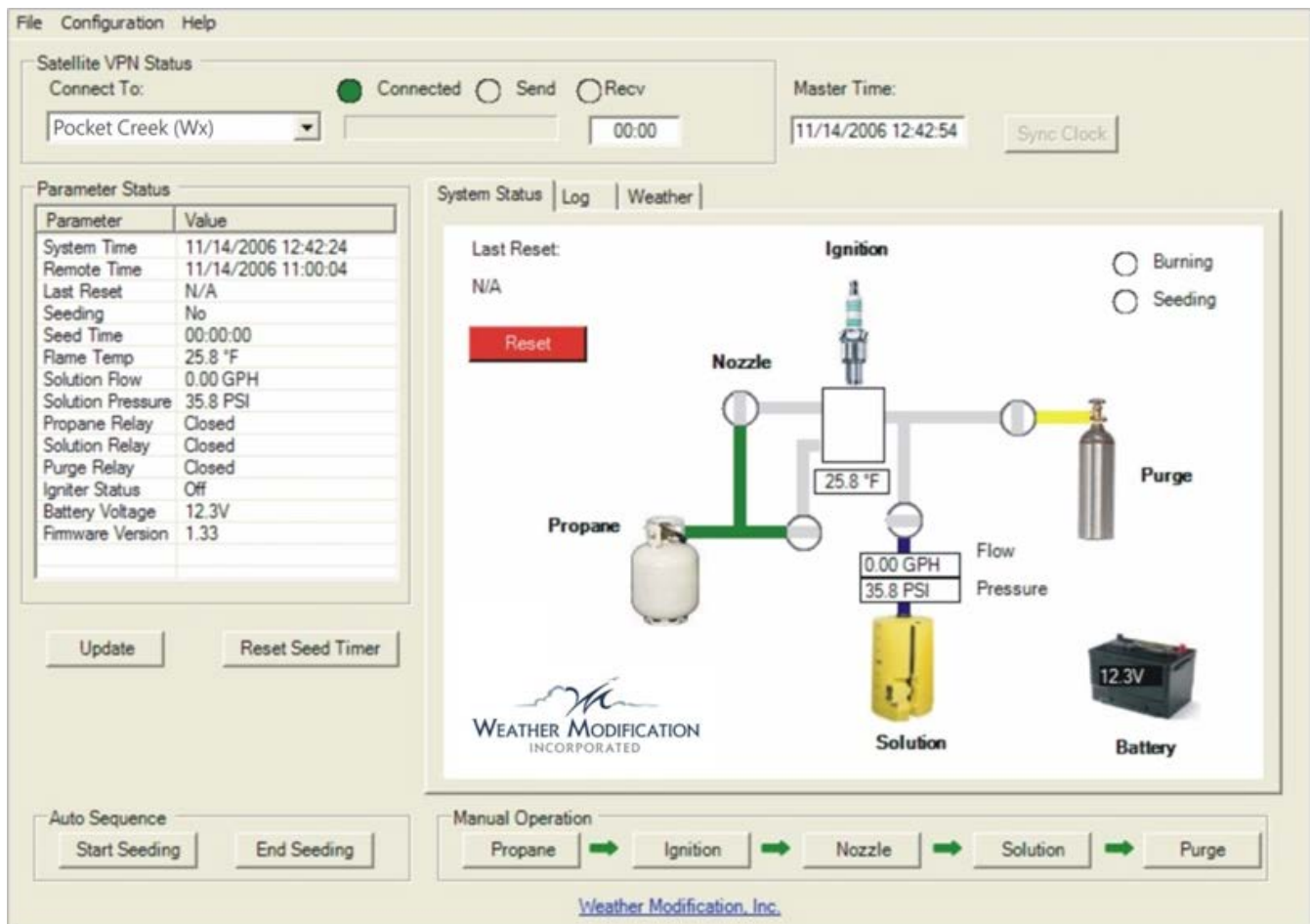


Figure 7. The control interface for the WMI remotely-controlled ground-based ice nucleus generator is shown, after connection is established via satellite, but before the generator is turned on. All flow valves are off, seeding solution flow is zero, but system status is reported.



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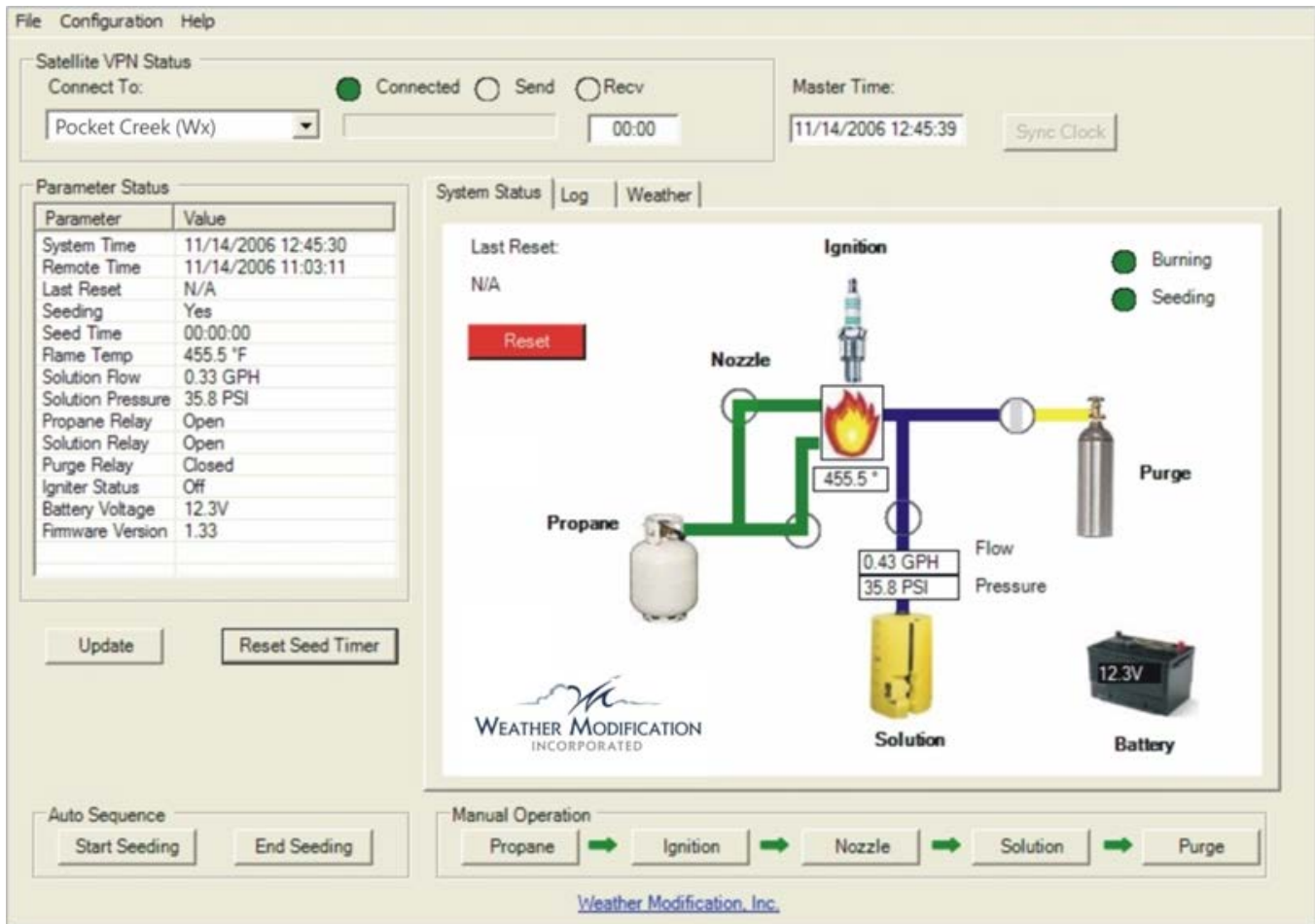


Figure 8. The WMI remote-controlled ice nucleus generator interface is shown, as it appears during seeding operations. Valves are open, the flame is known to be burning, and the seeding solution flow rate is also known. Seeding is certain.

2.4 Seeding Solution

The high-performance seeding solution used on this program was tested at the Colorado State University Cloud Simulation and Aerosol Laboratory by DeMott (1997). These tests determined that colder cloud temperatures produce a bigger yield of active ice nuclei per gram of AgI burned. As shown in Figure 9, the yield increases markedly from -6°C (+21.2°F) to -8°C (+17.6°F), and even more at -10°C (+14°F). At a cloud temperature of -6°C, 3×10^{11} nuclei are active per gram of AgI burned. In more conventional notation, this is 300,000,000,000, or 300 billion.

Most operational seeding programs in the western United States commonly commence seeding operations at -5 or -6°C. As in the previous five seasons, the 2021-2022 Wind River operations used a temperature criterion of -21°F (-6°C) at 700 hPa, which is about 10,000 feet above sea level, the average elevation of the crestline of the Wind River Range.



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It was previously mentioned that this seeding solution is “high-performance”. This means that unlike simpler solutions that produce a simple AgI nucleus, this high-performance solution produces nuclei that contain salt, which enables them to function by the condensation-freezing mechanism. The non-salty, simple AgI nucleus functions by the contact-freezing mechanism. The differences between the two are as follows:

Contact-freezing. For this freezing process to occur, the ice nucleus must contact a supercooled cloud droplet ($\leq -5^{\circ}\text{C}$). The speed at which this type of nucleation occurs depends upon the density of the water droplets in the cloud. Clouds with a lesser liquid water content contain fewer droplets, so it takes much longer for the chance collisions between the AgI nuclei and water droplets to occur, resulting in slower nucleation of the cloud. In clouds with greater liquid water content cloud droplets are plentiful, so nucleation occurs more quickly. After the ice nucleus and supercooled water droplets make contact, the droplets freeze and can continue to grow by other ice-phase growth processes: deposition, accretion, and aggregation.

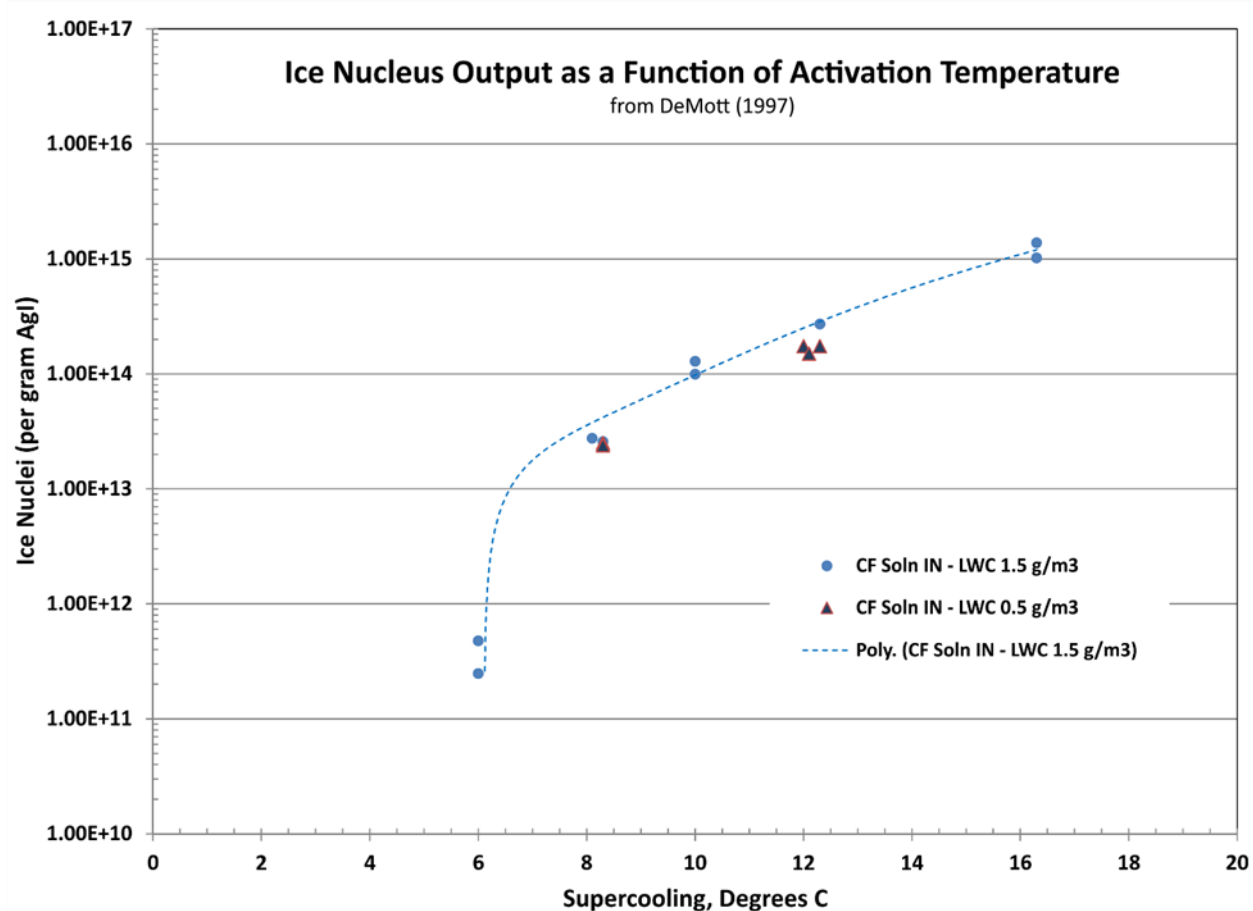


Figure 9. Yield as measured by the number of active ice nuclei per gram of silver iodide (AgI) burned, is shown as a function of temperature (DeMott 1997). These nuclei are comprised of silver iodide, silver chloride, and salt (NaCl).



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Condensation-freezing. Nuclei of this type attract water vapor and immediately form water droplets, eliminating the requirement for collisions between ice nuclei and cloud droplets. Freezing results as soon as the droplets containing these nuclei cool to at least -5°C. Unlike the contact-freezing process, the speed at which this type of nucleation occurs does not depend upon the density of the water in the cloud. As soon as freezing occurs, the new ice particle can grow by other ice-phase growth processes.

The nucleation advantage of the more complex solution used in the Wind River operations is considerable, especially in clouds having lesser liquid water. The sole disadvantage of the complex seeding solution is that, containing salt, it is more corrosive than the simpler solution. Using the more complex seeding solution requires generators designed to burn it. The generators must be equipped with corrosion-resistant stainless-steel tanks, lines, and fittings to avoid operational failure, and require more frequent maintenance.

2.5 Shop and Site Servicing

Throughout the season, WMI maintained a shop in Pinedale that provided storage and served as a staging area for generator service. The shop housed WMI's 4x4 truck, UTV, snowmobiles, trailer, spare generator parts, trouble-shooting equipment, and replacement nitrogen tanks.



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Figure 10. The WMI technician crew preform a maintenance check of generator WR01 (Big Sandy) on a clear day. Photo by WMI technician Michael Paul.



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3 FORECASTING AND OPERATIONAL DECISION-MAKING

3.1 Meteorological Data Sources

The bulk of the weather information used for forecasting and weather monitoring was obtained from the Internet. Among these sites were those of RAP Real-Time Weather, the National Center for Environmental Prediction (NCEP), the College of DuPage, Pivotal Weather, and the University of Wyoming. While many of the web-based weather products (i.e., National Weather Service (NWS) products) were publicly available, some data sources were project-specific. WMI also implemented an operational numerical model for the project; this is discussed in detail later in this section.

3.1.1 Radiometer

The WWDO radiometer was deployed at the East Fork generator site for the 2021-2022 season. The unit was operated at a 10° elevation angle over the Wind River Range, where the measurements indicated if liquid water was present.

3.2 Numerical Modeling

3.2.1 WRF Modeling

For the 2021-2022 season, WMI operated a variable nested limited area domain of the Weather Research and Forecasting (WRF) model. During quiet weather periods, an inner high-resolution nest covering both this ground-based generator program and the Wyoming-Aerial project was used. When weather was more active, and operations were either possible or ongoing (aka IOP mode), individual nests for the two programs were implemented. The high-resolution inner nest(s), whose boundaries are shown with a thick black border(s) on the plots below, was initialized from the High Resolution Rapid Refresh (HRRR) model, and was given the North American Model (NAM) forecast for boundary conditions at 3-hour intervals. The outer domain grid spacing was 7.5 km and the inner higher-resolution nest grid spacing was 2.5 km during quiet periods, 7.5km and 1.5km in IOP mode. The model was routinely run twice per day, with a 60-hour forecast duration for the 12 UTC model cycle and a 72-hour forecast duration for the 00 UTC model cycle. When IOP mode was activated, shorter model integrations from 06 and 18 UTC initial condition datasets were also executed. Information provided by these customized WRF runs provided very specific tools that greatly improved targeting and effectiveness of seeding, such as the explicit forecasting of supercooled water content over the flight tracks, and winds/temps aloft at a high spatiotemporal resolution.

Many graphical outputs were developed specifically to aid cloud seeding decision-making. A few examples of the more unique or meteorologist-favorite products are shown in the following figures. Figure 11 shows forecast integrated cloud water colder than -5°C over the Wind River Range.



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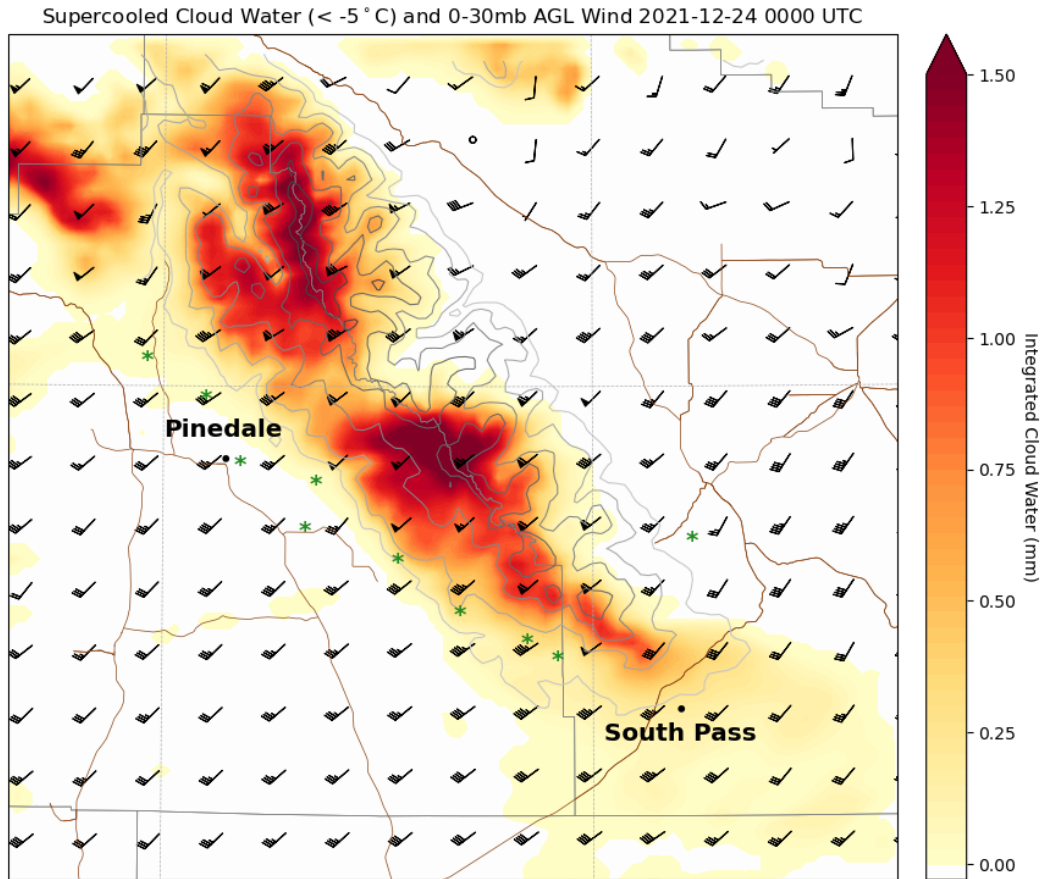


Figure 11. Near surface wind barbs are shown with integrated cloud water on this panel from the WMI WRF model, valid on 24 December 2021, at 00:00 UTC. Since the water shown is only that occurring at -5°C and colder, it is supercooled sufficiently for seeding. The WMI WRF was initialized and run as often as every six hours; plots such as this were produced every hour. Contours show model terrain elevation at 1,000 ft intervals beginning at 8,000 ft. Small green asterisk symbols denote the location of a project ground generator.

Though knowing the SLW distribution shown in Figure 11 is very helpful in determining which of the 10 ground-based generators should be activated, it is also very helpful to know the vertical distribution of SLW and cloud ice, as well as the height of the -10°C isotherm. This information was available to the project meteorologists in the form of vertical cross-sections (Figure 12).



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The meteorologist could examine the evolution of SLW and cloud ice along four different cross sections. One was along the southwest side of the Continental Divide, northwest to southeast. Another was from the Green River generator site, approximately perpendicular to the orientation of the Wind River Mountains. A third was from the Pocket Creek generator site, perpendicular to the range, and the fourth was west-to-east through the central portion of the range.

Southwest Slope Cross Section 2021-12-24 0300 UTC

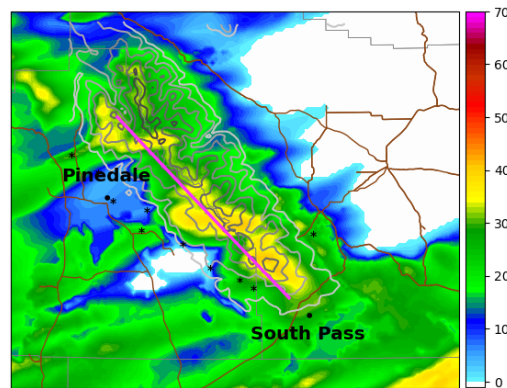
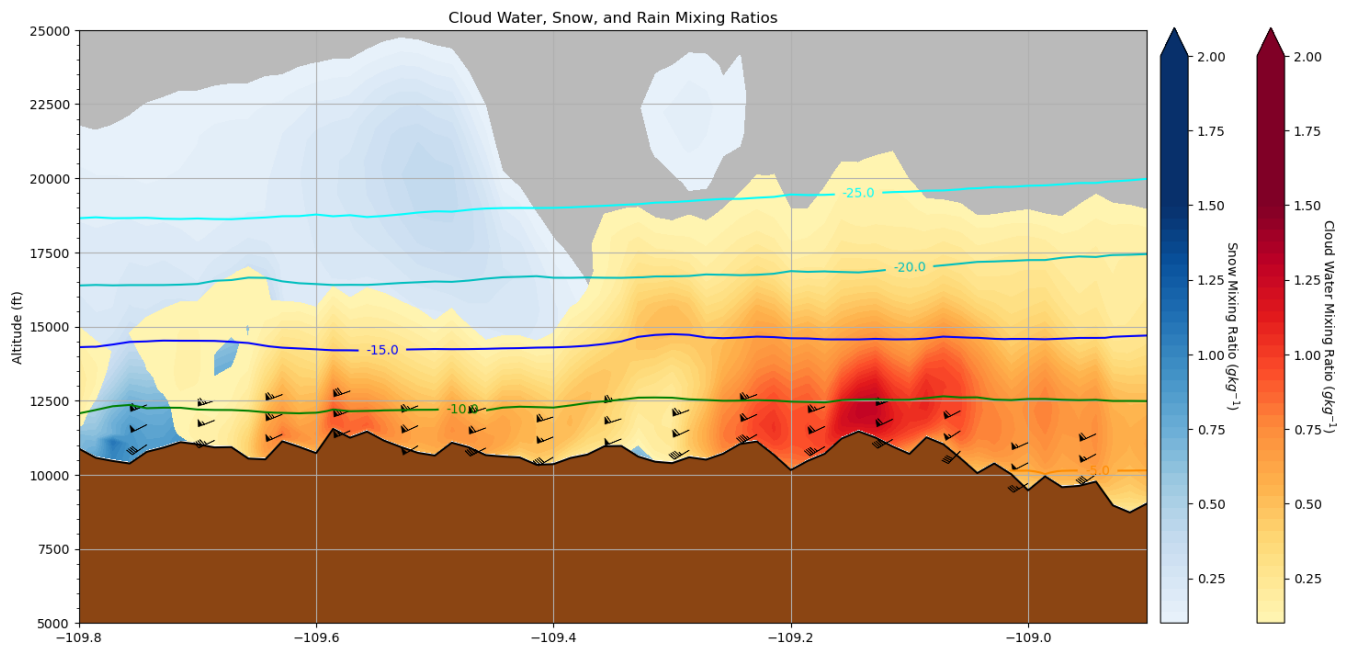


Figure 12. Vertical cross section from northwest to southeast near and west of the continental divide. Cross section line shown in pink in the forecast composite reflectivity plot on the top half of the image. The plot represents 03:00 UTC on 24 December 2021. See text for interpretation and discussion.



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The example shown in Figure 12 for 24 December 2021 is the cross section southwest of the continental divide. In the lower panel, a substantial region of cloud water is predicted. Note that the region lies entirely above the -5°C isotherm, so the liquid water is supercooled—perfect for seeding. The position is also very favorable, being to the left (upwind) of the range. This allowed the seeding agent to initiate the development of ice—and thus precipitation—in time for it to fall on the target. Plot priority is given to cloud water over snow, so some areas of predicted snow are not visible. Spatial maps and cross sections were animated in 1-hour time steps, providing a crucial understanding of expected storm evolution.

Thermodynamic stability throughout the Wind River domain was made part of the suite of products created during the WMI WRF model runs. The meteorologists also considered Froude Number to determine if the plume(s) would go over the range or be blocked by it, as well as the model vertical velocity field at the lowest vertical level (Figure 15).

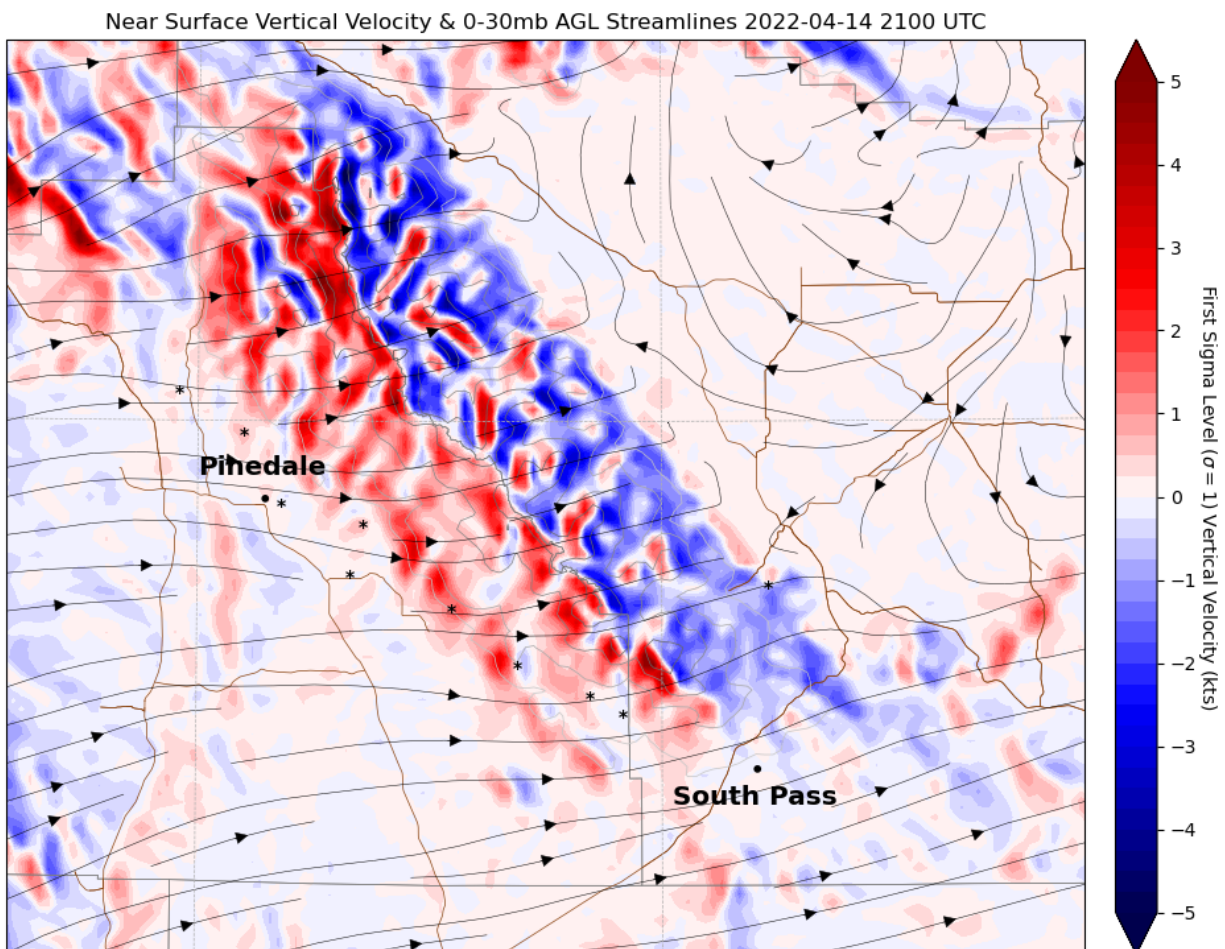


Figure 13. This product, also designed specifically for winter orographic seeding, shows the near surface vertical velocity along with streamlines of the near surface (average 0-30 mb AGL) wind. Here, ascending air is shown in red, with descending air in blue. This plot helps illuminate when sufficient upslope winds exist to transport seeding materials from ground generators up into the target area. This plot shows favorable seeding conditions for the Enterprise generator (north of South Pass on the east side of the range) during the second to last seeding event of the 2021-2022 season.



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Finally, meteograms show a snapshot of upcoming weather conditions at a fixed point in space. Several different types of meteograms are produced for a number of locations in the target area, but a particularly useful one is the Mid Atmosphere Conditions plot shown below (Figure 14). This plot illustrates the progression of 500 hPa and 700 hPa temperature through the 60-hour forecast duration, along with 700 hPa relative humidity, precipitable water, and 700 hPa wind. In this example, modest warming is predicted to occur the evening and night of April 14, with near-saturated conditions at 700 hPa and potentially favorable west winds. Seeding occurred from late morning into the overnight hours when winds became too northerly and orographic cloud coverage diminished.

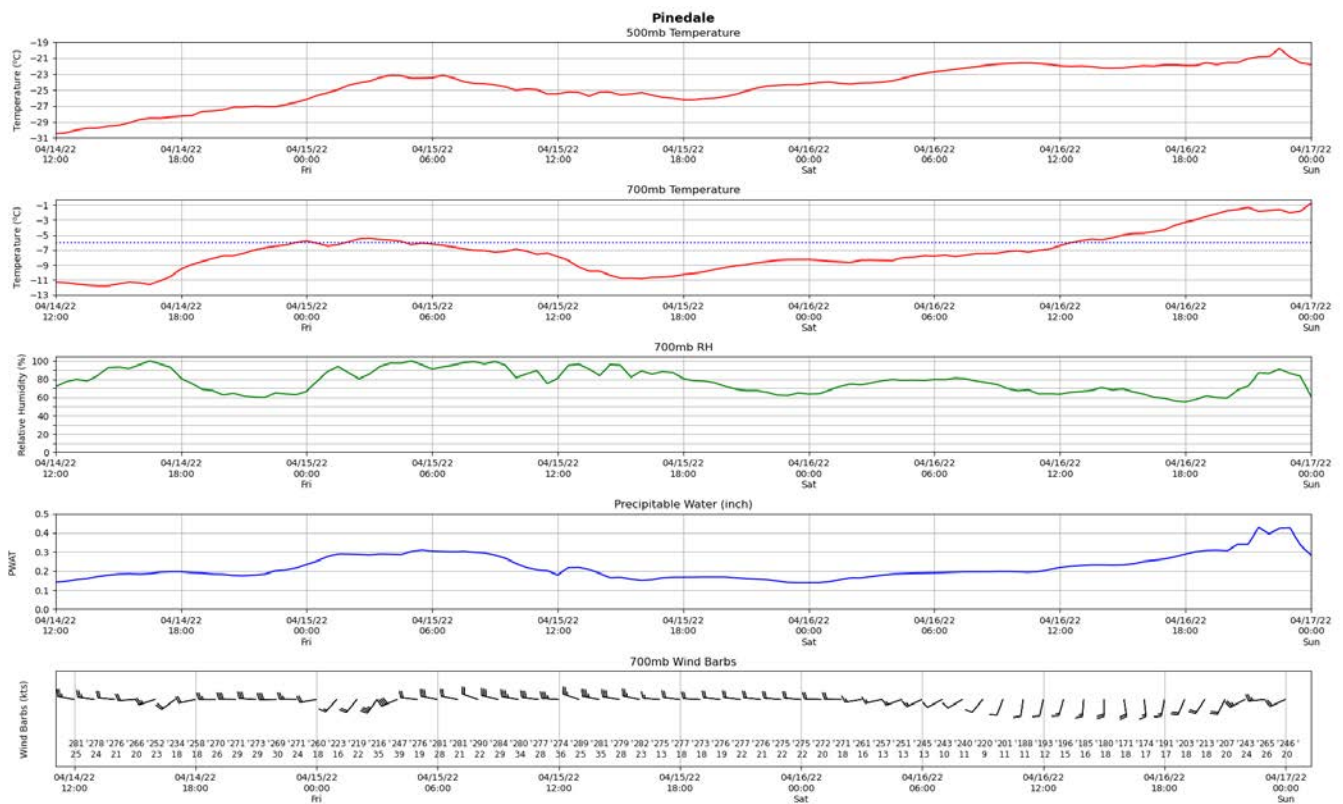


Figure 14. A meteogram illustrating the progression of key atmospheric variables (mid and low-level temperature, moisture, and low-level wind) in Pinedale. In this example, from the 12 UTC run on April 14, cooling temperatures, increasing moisture, and potentially conducive wind gave forecasters and ground technicians early warning a favorable period for seeding operations may develop. Additional information and commentary are provided in the text above.



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3.2.2 HYSPLIT Modeling

During the 2021-2022 season, WMI ran the Hybrid Single-Point Lagrangian Integrated Trajectory (HYSPLIT) plume dispersion model to establish a better idea of seeding agent plume behavior. The process was automated, performed with each update of the WRF, providing a complete record of predicted plume trajectories for the season. These HYSPLIT plots were output in one-hour increments, with each plot showing forecast locations of plume centerline (the most-dense portions of the plumes) for four hours. A series of such plots is provided as Figure 15, for the 14 April 2021 seeding event. In the plots, each hour is shown by a “dot” on the plume centerline.



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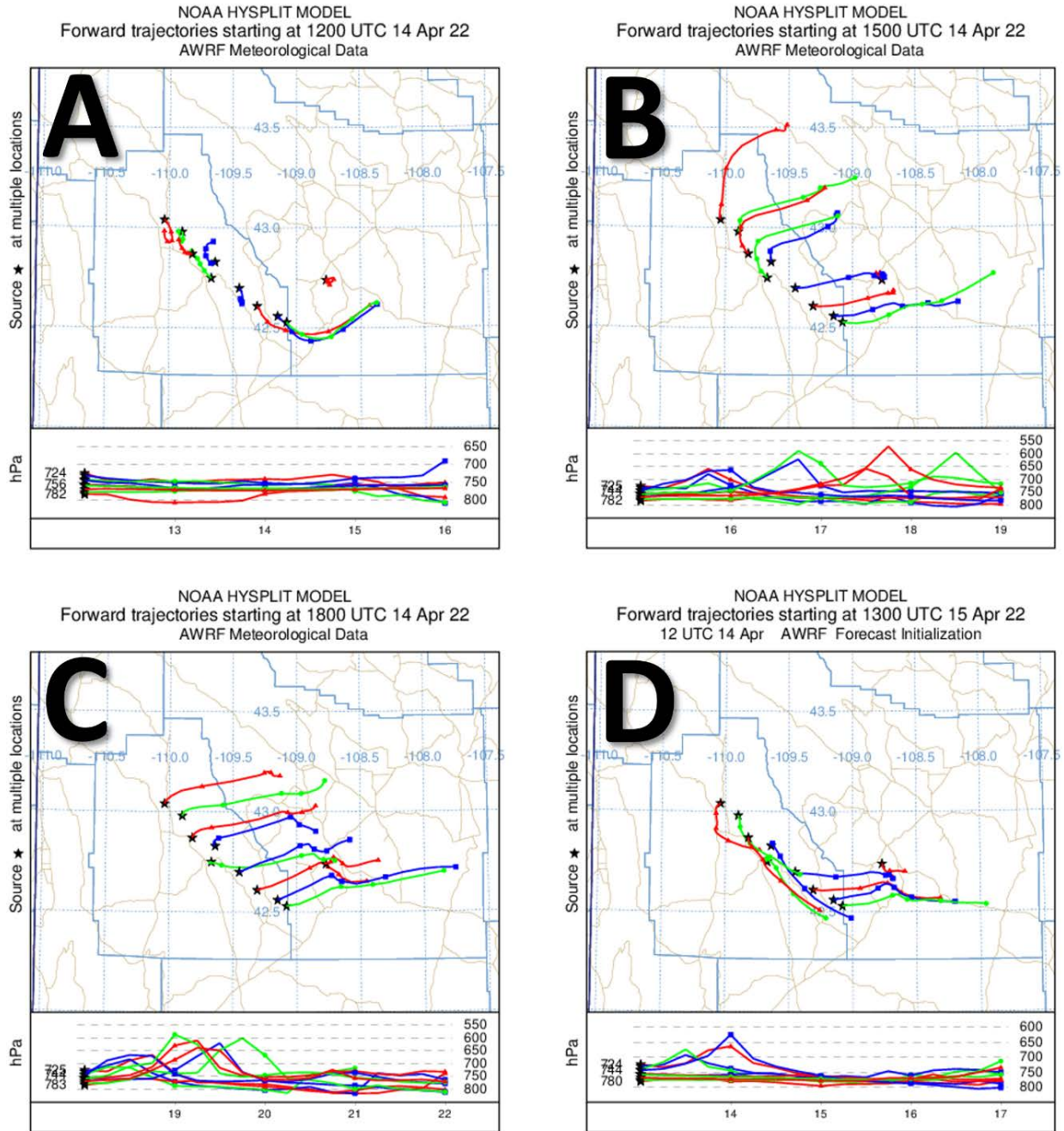


Figure 15. The evolution of the centers of plume trajectories is shown for the seeding event on 14 April 2021. Times (UTC) are as follows: (A) 12:00 April 14th, (B) 15:00 April 14th, (C) 18:00 April 14th, and (D) 13:00 April 15th. Before the seeding began (A), most plumes were projected to remain beneath a stable layer of air, with only a couple ground generators forecast to flow indirectly over the Wind River Mountains after a period of a couple hours. In (B) instability has increased and winds have strengthened such that trajectories from several ground generators all travel directly over the crest, however lower elevation sites such as Green River and East Fork continue to indicate initial movement of a seeding plume would not lift over the range. By 18:00 UTC (C), flow and instability have improved enough that all western ground generators indicate favorable lifting over the target range. By (D) at 13:00 UTC (April 15th), a cold front has shifted low



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level winds to the northwest, and all seeding opportunities ceased. Cloud conditions had deteriorated prior to this time, and seeding was no longer in progress.



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3.3 Timetables and Routines

If seeding was not underway at dawn, the following daily routine ensued.

WMI furnished a daily “first glance” update that provided an outlook into the probability of seeding operations taking place that day. This very simple form, sent to all project personnel, provided an early look at the weather expected each day. Four time periods were specified, from issuance until noon, from noon until sunset, from sunset until midnight, and from midnight until dawn the next day. The probability of seeding operations occurring in each of these time periods was rated by the forecaster as no chance, unlikely, possible, or probable. Technicians used this outlook to help inform equipment operation and maintenance decisions. In instances when seeding operations were already active in the morning, the “first glance” outlook would still be issued, reflecting the status of current operations.

The “first glance” update was followed by a much more detailed forecast and weather briefing, typically disseminated to the WWDO and all funding partners by late morning via email. These daily briefings included a summary of the preceding day’s weather and seeding activities, a summary of the current synoptic-scale weather pattern, and conditions likely to exist for the next 24 hours in the Wind River Range. Oftentimes weather conditions would vary sufficiently during the day that evening forecast updates were warranted and provided. The Orographic Day Category (ODC), shown in Table 1, numerically categorized the probability of seeding operations occurring.



PROBABILITY OF SEEDABLE CONDITIONS			
Until Noon	Noon to Sunset	Sunset to Midnight	Midnight to Dawn
☐ NO CHANCE	☐ NO CHANCE	☐ NO CHANCE	☐ NO CHANCE
☐ UNLIKELY	☒ UNLIKELY	☐ UNLIKELY	☐ UNLIKELY
☐ POSSIBLE	☐ POSSIBLE	☐ POSSIBLE	☐ POSSIBLE
☒ PROBABLE	☐ PROBABLE	☒ PROBABLE	☒ PROBABLE

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Figure 16. First glance outlook issued for 23 December 2021.



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	SYNOPSIS <p>A very strong, westerly upper level jet is over WY today with the core speeds at 160 to 175 kts. There is no one dominate mid level feature affecting the area, but there is a lot of scattered vorticity embedded within the quasi-zonal flow. This setup remains fairly stable through Saturday. This keeps a good flow of moisture into the area throughout that period. A trough will be coming through on Sunday, clearing out the vorticity and cutting off the that flow of moisture, but there will still be moisture coming into the area behind the trough, just not as much.</p>
---	---

FORECAST <p>Thick clouds will be over the range all day today, all tomorrow, and Saturday. SLW will be highest this afternoon, but decent SLW is expected that whole period. Snowfall will be continuous today, become a little lighter and somewhat broken at times tomorrow, then light and scattered on Christmas Day. The temperature has warmed a little this morning, which put an end to seeding operations from last night; it will continue warming through the late afternoon, then will be cooling this evening. After that it should not be a limiting factor the rest of this storm period. The wind develops a strong cross barrier flow this afternoon and looks to continue tonight, tomorrow and Saturday.</p> <p>The snowfall will become less on Sunday with the trough moving through, then stronger on Monday. Tuesday and Wednesday will be kind of a lull, but more next Thursday and Friday.</p>
--

ACTION: Seeding from last night has ended. Seeding will resume around 03Z, run all night and tomorrow. Christmas Day has been declared a down day by the WWDO, so no seeding will occur on Saturday.	Day 2 Outlook ODC: +2
---	------------------------------

WRF MODEL SOUNDING		YESTERDAY'S WEATHER
PNA	00Z, 24 December	Observed ODC: +1
0 °C level	7.7 kft	Pinedale: 37/1 Rock Springs: 41/19 Lander: 54/24
-5 °C level	10.3 kft	Thick mid level clouds were over the range with cloud bases above the peaks during the daytime and evening hours, with little to no snowfall during that time. The clouds were thickening by midnight with continuous snowfall and SLW forming. The wind flow was not favorable until the middle of the night and favorable seeding conditions continued into Thursday morning until warmer air pushed into the area. Snowfall map showed accumulation was 1 to 3 inches by Thursday morning.
-10 °C level	12.9 kft	Seeding with 4 GGEN began at 1014Z and ended at 1724Z.
-20 °C level	17.1 kft	
Precipitable Water	0.34 inches	
700 mb T	-3.0 °C	
700 mb wind	245 @ 55 kts	

Orographic Day Category (ODC)		
-3	No Seeding	Clear skies, or clear with isolated upper-level cloudiness.
-2	No Seeding	Occasionally clear, with cirrus, cirrostratus; or altostratus with bases above mountains.
-1	No Seeding	Limited coverage or short-lived orographic clouds, not enough temporal or spatial extent to warrant seeding activities.
0	Possible Seeding	Some orographic clouds/stratus over mountain tops. SLW/Winds/Temps marginal or uncertain. Operations possible, but not likely.
+1	Seeding Likely	Orographic clouds and/or stratus deck enshrouding mountain tops, Supercooled Liquid Water/Winds/Temps favorable for seeding.
+2	Extensive Seeding	Persistent orographic clouds and/or stratiform cloud deck enshrouding mountain tops, Supercooled Liquid Water/Winds/Temps favorable for extended seeding operations.

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Figure 17. WMI forecast sheet from 23 December 2021; all forecasts were submitted to the client and the client's distribution list via email daily.

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The seeding criteria were straightforward. First, 700 hPa temperature, meaning the temperature near the cloud elevation (about 10,000 feet), had to be equal to, or less than -6°C ($+21.2^{\circ}\text{F}$). Secondly, there had to be SLW present in the clouds. Finally, wind speeds needed to be strong enough to transport seeding agent from the generator upward into the mountains. Wind direction was also considered, as it helped inform which generators would be activated.

The first criterion, temperature, was determined by consulting the most recent prognostic numerical modeling runs.

The presence of SLW was informed by GOES-16 satellite products such as day cloud phase and nighttime microphysics, and by real-time data from the radiometer located near Pinedale, WY. The wind speed and direction were obtained from the numerical models.

When all three conditions were satisfied, seeding was initiated by the meteorologist and the generator technician. The meteorologist would communicate to the technician which generators should be activated, when, and for how long. The length of time a generator was activated depended upon how long weather conditions remained favorable. Once seeding was initiated, the meteorologist would begin tracking the real-time weather conditions that would impact seeding duration. If wind direction changed, some generators could be deactivated while others would be turned on. When favorable weather conditions ended, the technician would be directed to shut down all remaining active generators.

Orographic Day Category

ODC	Seeding	Meteorological Description
-3	No	Clear skies, or clear with isolated upper-level cloudiness.
-2	No	Occasionally clear, with cirrus, cirrostratus; or altostratus with bases above
-1	No	Limited coverage or short-lived orographic clouds, not enough temporal or spatial extent to warrant seeding activities.
0	Possible	Some orographic clouds/stratus over mountain tops. SLW/Winds/Temps marginal or uncertain. Operations possible, but not likely.
+1	Yes	Orographic clouds and/or stratus deck enshrouding mountain tops, Supercooled Liquid Water/Winds/Temps favorable for seeding.
+2	Yes	Persistent orographic clouds and/or stratiform cloud deck enshrouding mountain tops, Supercooled Liquid Water/Winds/Temps favorable for extended

Table 1. The Orographic Day Category.



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4 OPERATIONS

4.1 2021-2022 Season

Project operations began on 15 November 2021, with forecasts and full data collection activities. The first seeding opportunity occurred immediately on 24 November 2021 with six generators being operated. During the season, seeding opportunities were observed on twenty five occasions, as enumerated in Table 2.

November had one seeding event, December ten, January three, February two, March three, and April six. Table 3 summarizes operations by month and provides season totals. In total, 37.64 kg of seeding agent were released. Generators were operated for a total of 222:30 hours during the season, accruing a total of 1372:13 generator hours. [Generator hours are calculated by summing the number of hours each generator was operated. For example, six generators operated for five hours yields thirty generator hours.]

The twenty four seeding events that utilized more than one generator were all quality opportunities that used three to nine generators and were of 3 or more hours in duration. seven events were ten hours or longer, and two exceeded twenty hours.



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2021-2022 List of Seeding Events

Date	Number of Generators Utilized	Length of Seeding (hours)	Total Generator Hours	AgI Released this date (kg)	AgI Monthly Total (kg)	Generator Hours	Total Duration of Seeding
11/24/2021	6	4:24	18:32	0.504	0.504	18:32	4:24
12/5/2021	4	8:36	34:24	1.031	19.302	731:39	112:49
12/8/2021	9	12:39	75:13	2.034			
12/12/2021	5	7:33	37:30	0.872			
12/16/2021	9	22:00	152:13	3.652			
12/23/2021	4	7:10	28:40	0.864			
12/24/2021	9	24:24	219:31	5.980			
12/26/2021	8	5:04	40:29	1.106			
12/27/2021	8	13:13	100:54	2.637			
12/30/2021	4	4:30	18:00	0.485			
12/30/2021	4	7:40	24:45	0.641			
1/4/2022	9	13:30	92:39	2.527	4.419	159:28	25:18
1/8/2022	8	5:02	36:13	0.986			
1/31/2022	6	6:46	30:36	0.907			
2/16/2022	1	4:09	4:09	0.119	3.652	119:40	18:42
2/20/2022	9	14:33	115:31	3.533			
3/5/2022	7	5:49	25:19	0.715	3.178	103:25	17:17
3/8/2022	9	6:15	42:55	1.299			
3/13/2022	9	5:13	35:11	1.164			
4/7/2022	4	3:40	14:40	0.424			
4/10/2022	3	3:51	11:33	0.328			
4/11/2022	7	9:15	48:50	1.246			
4/13/2022	7	4:39	28:33	0.802			
4/14/2022	9	15:42	106:33	2.985			
4/15/2022	5	6:53	29:20	0.801			
SEASON	25 Events				31.055	1132:44	178:30

Table 2. 2021-2022 List of Seeding Events.



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The generator performance for the season was very good, at 95.4% functionality. This far surpassed last year's performance of 90.2%.

Table 3 shows the activity of each of the ten generators on a case-by-case basis. Each seeding event has two rows, the top indicates whether each generator was requested (REQ), and the bottom whether the generator ran (RAN). Ideally, every time a generator was requested it would run for the entire duration of the event. If a generator was requested to operate, a "Yes", "No", or "Partial" comment would be denoted in the appropriate (RAN) row.



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Ice Nucleus Generator Operations 2021-2022 Season

Wind River Range			WR01 Big Sandy	WR02 Block & Tackle	WR03 White Acorn	WR07 Enterprise	WR09 Boulder Lake	WR10 East Fork	WR12 Pocket Creek	WR13 Green River	WR14 Willow Lake	WR16 Highland	#Ggens Called	#Ggens Active
20211124	WRR0156	REQ	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	6	
		RAN	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES		6
20211205	WRR0157	REQ	NO	NO	NO	NO	YES	NO	NO	YES	YES	YES	4	
		RAN	NO	NO	NO	NO	YES	NO	NO	YES	YES	YES		4
20211208	WRR0158	REQ	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES		9
20211212	WRR0159	REQ	YES	YES	YES	NO	YES	NO	YES	NO	NO	NO	5	
		RAN	YES	YES	YES	NO	YES	NO	YES	NO	NO	NO		5
20211216	WRR0160	REQ	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES		9
20211223	WRR0161	REQ	YES	YES	YES	NO	NO	NO	YES	NO	NO	NO	4	
		RAN	YES	YES	YES	NO	NO	NO	YES	NO	NO	NO		4
20211224	WRR0162	REQ	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES		9
20211226	WRR0163	REQ	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	9	
		RAN	YES	NO	YES	NO	YES	YES	YES	YES	YES	YES		8
20211227	WRR0164	REQ	YES	NO	YES	NO	YES	YES	YES	YES	YES	YES	8	
		RAN	YES	NO	YES	NO	YES	YES	YES	YES	YES	YES		8
20211230	WRR0165	REQ	YES	YES	YES	NO	YES	NO	YES	NO	NO	NO	5	
		RAN	NO	YES	YES	NO	YES	NO	YES	NO	NO	NO		4
20211230	WRR0166	REQ	YES	YES	YES	NO	YES	NO	YES	NO	NO	NO	5	
		RAN	NO	YES	YES	NO	YES	NO	PARTIAL	NO	NO	NO		3.25
20220104	WRR0167	REQ	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES		9
20220108	WRR0168	REQ	YES	YES	YES	NO	YES	NO	YES	YES	YES	YES	8	
		RAN	YES	YES	YES	NO	YES	NO	YES	PARTIAL	YES	YES		7.75
20220131	WRR0169	REQ	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	6	
		RAN	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES		6
20220216	WRR0170	REQ	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO	1	
		RAN	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO		1
20220220	WRR0171	REQ	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES		9
20220305	WRR0172	REQ	YES	YES	YES	NO	YES	NO	YES	NO	YES	YES	7	
		RAN	YES	YES	YES	NO	YES	NO	YES	NO	YES	YES		7
20220308	WRR0173	REQ	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES		9



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20220313	WRR0174	REQ	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES		9
20220405	WRR0175	REQ	NO	NO	NO	NO	YES	NO	NO	YES	YES	YES	4	
		RAN	NO	NO	NO	NO	YES	NO	NO	YES	YES	YES		4
20220410	WRR0176	REQ	NO	NO	NO	NO	YES	NO	YES	NO	NO	YES	3	
		RAN	NO	NO	NO	NO	YES	NO	YES	NO	NO	YES		3
20220411	WRR0177	REQ	YES	NO	NO	NO	YES	YES	YES	YES	YES	YES	7	
		RAN	YES	NO	NO	NO	YES	YES	YES	YES	YES	YES		7
20220413	WRR0178	REQ	YES	YES	YES	NO	YES	YES	YES	NO	NO	YES	7	
		RAN	YES	YES	YES	NO	YES	NO	YES	NO	NO	YES		6
20220414	WRR0179	REQ	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	NO	YES	YES	YES	YES	YES	YES		9
20220415	WRR0180	REQ	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	6	
		RAN	NO	NO	NO	NO	YES	YES	NO	PARTIAL	YES	YES		4.25
ZULU DATES ONLY												TOTALS	167	160.25
PARTIAL = > 25% of Expected Runtime													RUN =	96.0%
													FAIL =	4.0%

Table 3. Ice nucleus generator operations are shown for each of the thirty-two seeding events during the 2021-2022 season.



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4.2 Comparisons with Previous Seasons

Comparisons of the five seasons of operational cloud seeding are provided in Tables 4 and 5. In Table 4, the lengths of seeding operations in each month are provided. Each season was different. In terms of actual number of hours with seeding operations, the 2015-2016 season tops the list. However, when one compares the total hours of seeding conducted each season (Table 5), the 2016-2017 season was far above the others, 400 hours more than the 2015-2016 season. Least active was the 2018-2019 season, in part due to budget constraints that precluded operations in November and April. The 2019-2020 season ended with below average snowpack values but near-normal total hours during which seeding occurred.

Hours of Seeding - 2014-2022 Winter Seasons

	<i>Nov</i>	<i>Dec</i>	<i>Jan</i>	<i>Feb</i>	<i>Mar</i>	<i>Apr</i>	<i>Season</i>
2014-2015	10:13	83:45	24:08	36:47	25:21	20:12	200:26
2015-2016	41:28	66:07	49:56	60:30	62:00	9:54	289:55
2016-2017	NA	120:22	63:12	58:53*	SUSP	NA	242:27
2017-2018	NA	49:37**	23:24	57:25	62:06	NA	192:54
2018-2019	NA	11:15	26:46	121:47	6:07	NA	165:55
2019-2020	22:10	40:03	77:59	29:07	56:23	18:57	244:29
2020-2021	19:31	39:18	27:37	85:37	48:13	17:51	262:07
2021-2022	4:24	112:49	25:18	18:42	17:17	44:00	222:30
Mean	19:53	65:24	39:47	58:36	39:38	22:11	227:36
<i>*Project was suspended on February 11th, 2017.</i>							
<i>**Project started on December 9th, 2017, not December 1st.</i>							

Table 4. Hour of seeding conducted over the Wind River Range the eight winter seasons.

The 2021-2022 season was significantly more active than the previous winter during which the storm track was largely blocked by a persistent ridge. Seeding operations were conducted 18 hours less, but the Enterprise generator was run only once, resulting in a 320-hour increase in total generator time, as most seeding periods involved multiple generators.

December was the most active month, logging 731:39 generator hours, raising the eight-season mean for that month to 369 hours. The least active month was November, during which 18:32 hours of generator time were logged. This is the lowest recorded in November of the five seasons in which the project was operated in that month. Overall, the total time seeding was five hours less than the eight-season mean, but seeding hours were 216 hours above the eight-season median!



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Hours of Ice Nucleus Generator Operation - 2014-2022 Winter Seasons

	<i>Nov</i>	<i>Dec</i>	<i>Jan</i>	<i>Feb</i>	<i>Mar</i>	<i>Apr</i>	<i>Season</i>
2014-2015	71:43	377:52	125:51	36:47	219:54	20:12	852:19
2015-2016	86:21	375:03	328:57	180:56	191:31	9:54	1172:42
2016-2017	NA	815:05	396:22	406:57*	SUSP	NA	1618:24
2017-2018	NA	304:53**	156:06	397:31	373:04	NA	1231:34
2018-2019	NA	39:49	159:48	745:21	6:07	NA	951:05
2019-2020	45:33	152:42	375:41	157:06	189:59	78:09	999:10
2020-2021	78:07	153:41	128:03	548:42	107:25	41:51	1057:49
2021-2022	18:32	731:39	159:28	119:40	103:25	239:29	1372:13
Mean	60:03	368:51	228:47	324:08	170:12	77:55	1156:54
<i>*Project was suspended on February 11th, 2017.</i> <i>**Project started on December 9th, 2017, not December 1st.</i>							

Table 5. Hours of ice nucleus generator operation over the Wind River Range the eight winter seasons.

Meteorological support of operational seeding in the Wind River Mountains continues to improve, specifically through continued development and refinement of numerical modeling products specifically tailored to assist winter orographic cloud seeding. With these tools, we are now more selective and accurate in our operational decision-making. We are also more responsive to shorter-term opportunities, and to changing conditions as storms pass.



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5 GENERATOR RELOCATION

In the course of the 2019-2020 project some alternative seeding generator sites were explored, with the intent of relocating the two lesser-used Anderson Ridge and Sweetwater generators to sites more amenable to frequent use. A small number of such locations were identified, but at a late date, too late to relocate either generator. Though relocation could not then occur, each of the prospective new sites was included in the WMI HYSPLIT modeling during the 2020-2021 season, to determine how the model predicted generators at these locations might perform and how often they might be used.

Several of the sites showed considerable promise, each having “virtual plumes” that would have contained seeding agent and successfully transported it to clouds upwind of the target. Two of these sites were selected for use in the 2021-2022 season. Thus, this report is the first in which the two new sites, Willow Lake and Highland, are reported. Sweetwater and Anderson Ridge have been deactivated and the sites reclaimed.



Figure 18. Looking SW at the Highland ground based generator site as it undergoes construction on 11 November 2021 Photo by WMI Technician Michael Paul.



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Figure 19. Installation of Willow Lake (equipment relocated from Sweetwater) was completed on 30 August 2021. Thank you to the landowner for grading the road and preparing the surface area, it was greatly appreciated! Photo by WMI Technician Michael Paul.

6 OUTREACH

Whenever possible, WMI likes to be receptive to requests to educate those showing an interest in our field efforts. In each recent season, WMI has done a “weather talk” to some local students and teachers, explained a little bit about the seeding project, and done a demonstration weather balloon launch. Unfortunately, no events took place this year. WMI appreciates being asked to take part in this type of educational outreach and will gladly participate in such events if requested. It is important to WMI to be receptive to requests to educate those showing an interest in our weather modification efforts. We look forward to future opportunities.



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7 SUMMARY

Operations were successfully conducted as planned for the entire 2021-2022 season. Twenty five seeding events occurred, twenty four of which involved multiple ice nucleus generators, activated in westerly or southwesterly flow. The other one occurred in easterly or northeasterly flow with the Enterprise generator, sited just south of Lander. The 2021-2022 season became operational on 15 November 2021 and concluded after 15 April 2022. The first seeding event occurred on 24 November 2021. The 2021-2022 weather pattern was significantly more active compared to the previous season, recording over 300 more hours' generator time.



Figure 20. The WMI technician team visits Willow Lake on 26 February 2022. This was the first season at this location. It proved to be beneficial move; 142 hours and 39 minutes of operational time were conducted by this unit making it the 5th (out of 10) most used location in 2021-2022. Photo by WMI technician Ryan Hudson.

One seeding event occurred in November 2021, ten in December 2021, five in January 2021, six in February 2021, seven in March 2021, and four in April 2021, bringing the seasonal total to 32 events. Seasonal snowpack (snow water equivalents, or SWE) at project end (April 15) varied from 68% of the median annual value to 95%, with the five-site SNOTEL mean at just 81% of the long-term median value. The Hobbs Park site finished with the greatest percentage of seasonal snowpack, at 95%.

The twenty-five seeded storm events lasted a total of 222:30 hours, during which one or more generators were seeding. The total number of “generator hours”, defined as the sum of the length each generator was operated during each storm, was 1372:13 hours. The seeding rate was approximately 25 grams of silver iodide per generator, per hour, throughout the season.



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As the accuracy of the WMI prognostic numerical modeling efforts has improved, the need to verify requisite temperate and wind criteria by atmospheric soundings has decreased. For the 2021-2022 season, atmospheric soundings were not conducted. The presence of liquid water clouds over the range in each case continued to be established by the WWDO radiometer sited at the East Fork site, or the numerical weather prediction (NWP), coupled with the presence of clouds on satellite and webcams.

The 2021-2022 season was significantly more active than the previous winter. There was an overall 320-hour increase in the total generator time from 2020-2021. This can be attributed to the fact that most operations involved multiple generators. This year there was only one instance of a single-generator event versus twelve single-generator events last year.

December was the most active month, logging 732 generator hours, raising the eight-season mean for that month to 369 hours. The least active month was November, during which 18.5 hours of generator time were logged. This is the lowest recorded in November of the five seasons in which the project has operated in that month. Overall, the total time seeding was five hours less than the eight-season mean, but seeding hours were 216 hours above the eight-season median!



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8 LIST OF TERMS AND ACRONYMS

Accretion	See <i>riming</i> .
Aerosol	A system in which particles, either solid or liquid, are dispersed in within a gas, usually air.
Ag	The chemical notation for silver.
Agl	See <i>silver iodide</i> .
Aggregation	The process of clumping together of snow crystals following collision as they fall, to form snowflakes.
AGL	Above ground level
ASCE	American Society of Civil Engineers
ATV	All-terrain vehicle
BTAC	Bridger-Teton Avalanche Center
CAP	Central Arizona Project, run by the Central Arizona Water Conservation District. The Central Arizona Project delivers Colorado River water via a 335-mile aqueduct system to customers in Maricopa, Pinal, and Pima Counties in Arizona, home to 80% of Arizona's population.
CCN	Cloud condensation nucleus
CSU	Colorado State University
GPS	Global Positioning System
Glaciogenic seeding	Cloud seeding with ice-forming aerosols
Ground generator	See <i>ice nucleus generator</i> .
hPa	Hectopascal, equivalent to one millibar (mb), the common unit used to measure atmospheric pressure. Pressure decreases as altitude increases; standard sea level pressure is 1,013.25 hPa, 850 hPa equates to approximately 5,000 feet (1,500 m) elevation, and 700 hPa, about 10,000 feet (3,000 m) above mean sea level.
HRRR	High-resolution, Rapid-Refresh numerical model. This model runs every three hours and produces predictions in one-hour increments, but only for the next 12 hours.
Ice nucleus	Any particle that serves as a nucleus leading to the formation of ice crystals, without regard to the particular physical processes involved in the nucleation.
Ice nucleus generator	The remotely-controlled machines that burn a silver iodide solution to produce the ice nuclei that “seed” clouds containing <i>supercooled liquid water</i> .
IN	See <i>ice nucleus</i> .
mb	Millibar, same as hectopascal (<i>hPa</i>)



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MOU	Memorandum of Understanding
MSL	Elevation above mean sea level
NaCl	The chemical notation for sodium chloride, common table salt
NAM	North American Model. A model run four times daily by the National Weather Service. This model produces output in 3-hour increments for the 72 hours following initialization (the start of each run). This model is not customized for the Wind River Range, and produces no graphics designed for cloud seeding operations, unlike the WMI WRF.
NCAR	National Center for Atmospheric Research, Boulder, CO
NCEP	National Centers for Environmental Prediction, a set of NOAA research centers.
NOAA	National Oceanic and Atmospheric Administration, U.S. Department of Commerce
NRCS	Natural Resource Conservation Service, an agency of the U.S. Department of Agriculture
NWP	Numerical weather prediction (forecasts generated by computer models)
NWS	National Weather Service, U.S. Department of Commerce
ODC	Orographic Day Category, used to summarize the expected chance of seeding on each day. For details, see Table 1.
OSLI	Office of State Lands and Investments
PNA	The airport and meteorological station identifier for Pinedale, Wyoming.
Precipitation efficiency	Expressed as a percentage, the ratio of the quantity of precipitation produced by a cloud to the total water condensate produced by the cloud.
Radiometer	A passive (non-transmitting) instrument that measures liquid water and water vapor in the atmosphere.
Rawinsonde	Commonly called a <i>weather balloon</i> , the rawinsonde is a small package of weather instruments carried aloft by balloon. Vertical profiles of temperature, humidity, and winds are obtained as a function of pressure.
Riming	The growth of an ice particle by the collision with <i>supercooled</i> cloud droplets that freeze wholly or partially upon contact.
RIW	The airport and meteorological station identifier for Riverton, Wyoming.
SCCD	Sublette County Conservation District, Pinedale, WY
Silver iodide	An inorganic chemical compound, AgI, that has a crystalline structure (symmetry, lattice spacing) similar to ice and a very low solubility in water and can be easily generated as an aerosol.
SLW	See <i>supercooled liquid water</i> .



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SNOTEL	Sites instrumented, operated, and maintained by the <i>NRCS</i> , to measure precipitation, <i>SWE</i> and other related parameters in the mountains.
SNWA	Southern Nevada Water Authority, a cooperative agency formed in 1991 to address Southern Nevada's unique water needs on a regional basis.
Supercooled liquid water	Liquid water at a temperature below the freezing point.
SWE	Snow water equivalent, the water content of snow, commonly expressed in depth (inches)
UTC	Universal Time Coordinates, the standard time used by aviation and meteorological reporting worldwide. UTC time is six hours ahead of Mountain Daylight Time, and seven hours ahead of Mountain Standard Time.
WMI	Weather Modification International, the business name of Weather Modification LLC, Fargo, North Dakota
WRDS	The Wyoming Water Resources Data System. This organization serves as a repository for all water-related information in the State of Wyoming and is located on the University of Wyoming campus in Laramie, WY.
WRF	Weather Research and Forecasting model, a means of numerical weather prediction.
WSEO	Wyoming State Engineer's Office, the regulatory agency for cloud seeding in the State of Wyoming. Cheyenne, WY.
WWDC	Wyoming Water Development Commission, Cheyenne, WY
WWDO	Wyoming Water Development Office, the administrative team serving under the direction of the Wyoming Water Development Commission. Cheyenne, WY.
WWMPP	Wyoming Weather Modification Pilot Program, conducted from 2005-2014 to evaluate the potential for cloud seeding in the Medicine Bow, Sierra Madre, and Wind River Ranges of Wyoming.



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9 REFERENCES

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Appendix A. Daily Operations Summaries

15 November 2021, Monday	
Broken to scattered high and a few broken mid level clouds were around throughout the daytime and evening hours. Low clouds formed over the range after midnight with very light snowfall and a high amount of radiometer detected SLW. The temperature was much too warm for seeding operations. By sunrise, the snowfall had amounted to less than one inch accumulation. Max/Min temperatures Pinedale: 52/21 Rock Springs: 62/39 Lander: 68/36 Observed ODC: 0	No ground-based seeding was conducted.
16 November 2021, Tuesday	
Thick low clouds were over the range during the morning, but the temperature was too warm for seeding operations until the late morning. By that time, the cloud was weakening but some thicker periods occurred into the early afternoon. Most of the cloud coverage had diminished by mid afternoon but some short-lived periods of thicker clouds occurred during the evening and night. Most of the range received less than 1 inch accumulation except 2-3 inches fell on the NW part. Max/Min temperatures Pinedale: 43/19 Rock Springs: 48/26 Lander: 60/24 Observed ODC: 0	No ground-based seeding was conducted.
17 November 2021, Wednesday	
Clear skies during the daytime and the evening hours. High clouds moved in from the west after midnight with mid level clouds beginning a little before sunrise. Max/Min temperatures Pinedale: 30/7 Rock Springs: 32/17 Lander: 36/14 Observed ODC: -2	No ground-based seeding was conducted.
18 November 2021, Thursday	
High and mid level clouds were around during the daytime, with increasing coverage through the afternoon. There were a	No ground-based seeding was conducted.



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<p>few, small low clouds during the evening, but the continuous low clouds over the range began around 10Z and persisted into Friday morning. The temperature and wind flow were not favorable for seeding operations. Snowfall was limited with total accumulation less than 0.5 inch on the top of the range except for an isolated spot with just over 1 inch.</p> <p>Max/Min temperatures Pinedale: 32/5 Rock Springs: 38/10 Lander: 37/12 Observed ODC: 0</p>	
<p>19 November 2021, Friday</p>	
<p>Widespread low cloud coverage over much of the region throughout the day. The snowfall was inconsistent and scattered in coverage. Most of the range received less than 1 inch accumulation with the NW part shown to have received near 2 inches. There was no time frame where both the temperature and wind flow were favorable for seeding operations at the same time.</p> <p>Max/Min temperatures Pinedale: 36/23 Rock Springs: 50/28 Lander: 56/23 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>20 November 2021, Saturday</p>	
<p>Low clouds over the mountains, with very light snow showers during the afternoon, transitioned more to high clouds overnight and into Sunday morning. Winds parallel to the range were not supportive of seeding operations.</p> <p>Max/Min temperatures Pinedale: 37/23 Rock Springs: 40/24 Lander: 49/25 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>21 November 2021, Sunday</p>	
<p>Scattered high clouds were seen across the project area with no precipitation taking place. Winds parallel to the range with little moisture.</p> <p>Max/Min temperatures Pinedale: 37/12 Rock Springs: 43/20 Lander: 49/21</p>	<p>No ground-based seeding was conducted.</p>



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Observed ODC: -2	
22 November 2021, Monday	
<p>Clear skies in the morning saw increasing mid level cloud coverage throughout the afternoon. Areas of mid level clouds continued through the evening before clearing. More mid level clouds moved in a little before sunrise from the west but then cleared Tuesday morning.</p> <p>Max/Min temperatures Pinedale: 50/12 Rock Springs: 52/25 Lander: 58/26 Observed ODC: -2</p>	No ground-based seeding was conducted.
23 November 2021, Tuesday	
<p>A few high and mid level clouds began moving into the area during the afternoon and low clouds began forming over the far NW part of the range right around sunset. The clouds slowly spread down the range over the next few hours, developing favorable seeding conditions with light snowfall. The wind shifted to NW in the late evening putting an end to seeding operations. The clouds slowly diminished during the night. Snowfall map showed accumulation amounted to less 1 inch on the range except for an isolated spot over 2 inches on the NW corner.</p> <p>Max/Min temperatures Pinedale: 45/9 Rock Springs: 50/17 Lander: 57/26 Observed ODC: +1</p>	<p>Seeding event WRR0156 began at 1822 MST on 11/23/2021.</p> <p>WRR0156 Summary: Generators: WR09, WR10, WR12, WR13, WR14, WR16. Time: 1822 (11/23) to 2246 (11/23) MST 0122 (11/24) to 0546 (11/24) UTC Duration: 4:24, 18:32 Total Time Seeding Material: 8.28 gallons (617.50 grams)</p>
24 November 2021, Wednesday	
<p>Scattered low clouds were around the range during the morning and afternoon. The wind flow was parallel to the range. Only a few areas of high and mid level clouds during the evening and night. Snowfall map showed a half to 1 inch accumulation, but most of that occurred in the early morning.</p> <p>Max/Min temperatures Pinedale: 32/16 Rock Springs: 37/18 Lander: 37/19 Observed ODC: -1</p>	No ground-based seeding was conducted.
25 November 2021, Thursday	



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<p>Periods of high and mid level clouds at times throughout the day.</p> <p>Max/Min temperatures Pinedale: 37/7 Rock Springs: 42/16 Lander: 55/13 Observed ODC: -2</p>	<p>No ground-based seeding was conducted.</p>
<p>26 November 2021, Friday</p>	
<p>Mid-level clouds during the morning into the early afternoon hours produced occasional snow showers over parts the mountains. Clouds thinned out by the late afternoon with more clouds arriving overnight. Additional light snow showers were observed over the mountains Saturday morning. Warm temperatures, little SLW, and unfavorable winds prevented seeding operations.</p> <p>Max/Min temperatures Pinedale: 45/34 Rock Springs: 49/35 Lander: 57/39 Observed ODC: 1</p>	<p>No ground-based seeding was conducted.</p>
<p>27 November 2021, Saturday</p>	
<p>Mid-level clouds in the morning into the early afternoon hours produced a few light snow showers over the northern mountain range. Clouds thinned out by the late afternoon with more clouds arriving overnight. Additional light snow showers were observed over the northern mountains Sunday morning. Little accumulation was reported. Warm temperatures, little SLW, and unfavorable winds prevented seeding operations.</p> <p>Max/Min temperatures Pinedale: 43/34 Rock Springs: 46/35 Lander: 49/38 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
<p>28 November 2021, Sunday</p>	
<p>Areas of high and mid level clouds were around throughout the period. Small, low clouds were sitting over the range during the daytime hours with bases above the peaks.</p> <p>Max/Min temperatures Pinedale: 50/16 Rock Springs: 54/31 Lander: 64/24</p>	<p>No ground-based seeding was conducted.</p>



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Observed ODC: -1	
29 November 2021, Monday	
<p>Clouds moved away in the morning and the sky was clear over the region the rest of the daytime until just before sunset. An area of clouds moved through from NW to SE during the evening. Low clouds developed over the NW part of the range with flurries but it was only a dusting of accumulation. The temperature and wind were not favorable for seeding operations. More mid level clouds moved in around sunrise.</p> <p>Max/Min temperatures Pinedale: 50/14 Rock Springs: 55/32 Lander: 59/34 Observed ODC: 0</p>	No ground-based seeding was conducted.
30 November 2021, Tuesday	
<p>Areas of high clouds during the daytime, becoming overcast a little before sunset. Mid level clouds moved in during the evening and continued through the night. No snowfall occurred.</p> <p>Max/Min temperatures Pinedale: 45/18 Rock Springs: 47/25 Lander: 53/26 Observed ODC: -2</p>	No ground-based seeding was conducted.
01 December 2021, Wednesday	
<p>Thick mid level clouds were around a portion of the area throughout the daytime hours. The cloud coverage shrunk in size during the evening but then increased again overnight. No snowfall occurred.</p> <p>Max/Min temperatures Pinedale: 52/19 Rock Springs: 53/37 Lander: 63/35 Observed ODC: -2</p>	No ground-based seeding was conducted.
02 December 2021, Thursday	
<p>Areas of mid level clouds around the region during the daytime and evening hours. The clouds diminished after midnight and the sky was clear.</p> <p>Max/Min temperatures Pinedale: 52/18</p>	No ground-based seeding was conducted.



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Rock Springs: 58/32 Lander: 65/34 Observed ODC: -2	
03 December 2021, Friday	
Clear skies during the daytime until late afternoon when some high and mid level clouds moved into the region. There were periods of high and mid level clouds throughout the evening and night. Max/Min temperatures Pinedale: 50/14 Rock Springs: 52/30 Lander: 57/27 Observed ODC: -2	No ground-based seeding was conducted.
04 December 2021, Saturday	
Scattered high clouds were seen until increasing clouds overnight. Light snow developed after midnight over the mountains and had continued into Sunday morning. Some light accumulations were observed. Favorable seeding conditions developed during the night. Max/Min temperatures Pinedale: 46/12 Rock Springs: 54/30 Lander: 62/30 Observed ODC: +1	Seeding event WRR0157 began at 0349 MST on 12/05/2021. WRR0157 Summary: Generators: WR09, WR13, WR14, WR16. Time: 0349 (12/05) to 1225 (12/05) MST 1049 (12/05) to 1925 (12/05) UTC Duration: 8:36, 34:24 Total Time Seeding Material: 16.94 gallons (860 grams)
05 December 2021, Sunday	
Light snow continued over the mountains through the evening hours, with the northern half of the range seeing anywhere between 1-3 inches of snowfall. The wind flow became unfavorable for proper plume transport a little after noon. As the snow came to an end, we were left with mid-level clouds across the area. Max/Min temperatures Pinedale: 41/21 Rock Springs: 46/29 Lander: 53/17 Observed ODC: +1	Seeding event WRR0157 continued until 1225 MST.
06 December 2021, Monday	
Low clouds started forming over the range in the early afternoon, but no SLW existed until after sunset. By that time, the wind was no longer favorable for seeding operations. Low clouds continued over the range through the night and then	No ground-based seeding was conducted.



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<p>diminished Tuesday morning. Total snowfall amounted to less than 1 inch.</p> <p>Max/Min temperatures Pinedale: 32/14 Rock Springs: 37/25 Lander: 32/10 Observed ODC: 0</p>	
<p>07 December 2021, Tuesday</p>	
<p>Shallow, low clouds were over the SW slopes of the range during the daytime hours. The clouds did not fully cover the range and no measurable snowfall occurred. Those clouds diminished after sunset with periods of mid and high clouds during the night.</p> <p>Max/Min temperatures Pinedale: 39/18 Rock Springs: 43/25 Lander: 51/21 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
<p>08 December 2021, Wednesday</p>	
<p>Shallow, small low clouds formed over the peaks of the range in the late morning. Thicker, larger low clouds developed in the later afternoon. Favorable seeding conditions began around sunset and continued for a few of the GGEN sites through most of the night. The wind became unfavorable after 12Z. Snowfall map showed 1 to 4 inches of accumulation.</p> <p>Max/Min temperatures Pinedale: 36/10 Rock Springs: 44/23 Lander: 52/22 Observed ODC: +2</p>	<p>Seeding event WRR0158 began at 1639 MST on 12/08/2021.</p> <p>WRR0158 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13, WR14, WR16. Time: 1643 (12/08) to 0522 (12/09) MST 2343 (12/08) to 1222 (12/09) UTC Duration: 12:39, 75:13 Total Time Seeding Material: 33.43 gallons (1880.25 grams)</p>
<p>09 December 2021, Thursday</p>	
<p>Thick, overcast conditions during the daytime and evening hours. Little to no SLW existed and snowfall was very light, amounting to less than 2 inches. The widespread clouds moved away by midnight leaving only a few, small low clouds over the range.</p> <p>Max/Min temperatures Pinedale: 30/10 Rock Springs: 33/21 Lander: 42/23 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>



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10 December 2021, Friday	
<p>Broken, low clouds developed over the range during the afternoon and diminished after sunset. Low clouds again developed during the night then weakened Saturday morning. The wind flow was not quite favorable for seeding operations. Snowfall accumulation was 0.5 to 1 inch over the top of the range.</p> <p>Max/Min temperatures Pinedale: 23/1 Rock Springs: 22/10 Lander: 32/13 Observed ODC: 0</p>	No ground-based seeding was conducted.
11 December 2021, Saturday	
<p>Low to mid-level clouds thinned out some by the afternoon with more clouds moving in by the evening. Some light snow was reported in the mountains with about 0.5 inch over the peaks. Wind flow was not supportive for operations.</p> <p>Max/Min temperatures Pinedale: 27/1 Rock Springs: 24/14 Lander: 37/12 Observed ODC: 0</p>	No ground-based seeding was conducted.
12 December 2021, Sunday	
<p>Low to mid-level clouds produced some light snow throughout the afternoon with 1-2 inches observed over the northern ranges. The clouds diminished through the evening with some clearing. More clouds then moved in overnight with a stratus deck left in place for Monday morning.</p> <p>Max/Min temperatures Pinedale: 34/18 Rock Springs: 35/8 Lander: 48/21 Observed ODC: +1</p>	<p>Seeding event WRR0159 began at 1055 MST on 12/12/2021.</p> <p>WRR0159 Summary: Generators: WR01, WR02, WR03, WR09, WR12. Time: 1040 (12/12) to 1813 (12/12) MST 1740 (12/12) to 0113 (12/13) UTC Duration: 7:33, 37:30 Total Time Seeding Material: 14.34 gallons (937.5 grams)</p>
13 December 2021, Monday	
<p>Widespread thick, low stratus over the range and the Upper Green River basin throughout the day and evening hours. The widespread clouds moved away by midnight but low clouds remained over the range during the night. Periods of light snowfall occurred throughout period, amounting to less than 2 inches. The wind and temperature were not right for seeding operations.</p>	No ground-based seeding was conducted.



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<p>Max/Min temperatures Pinedale: 34/23 Rock Springs: 40/22 Lander: 52/21 Observed ODC: 0</p>	
14 December 2021, Tuesday	
<p>Thick orographic cloud coverage over the range throughout the day with continuous snowfall. Snowfall was heaviest in the evening and night. The temperature was too warm for seeding operations until later in the night, when a cold front moved through, but the wind became unfavorable right away. The clouds thinned behind the front. Snowfall map showed a good portion of the range received over 5 inches with some spots over 10 inches of accumulation.</p> <p>Max/Min temperatures Pinedale: 43/21 Rock Springs: 45/33 Lander: N/A Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
15 December 2021, Wednesday	
<p>There were some thick, widespread clouds for a short time in the morning that moved away by noon. Shallow, low clouds lingered over the range in the afternoon with widespread clouds moving in again in the late afternoon and continued through the evening. There was light snowfall but little to no SLW existed. The sky was mostly clear overnight until clouds started forming again a little before sunrise. Snowfall map showed 0.5 to 1.5 inch accumulation except the southern end received 3 to 6 inches, which was from early morning.</p> <p>Max/Min temperatures Pinedale: 34/-2 Rock Springs: 40/8 Lander: 48/18 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
16 December 2021, Thursday	
<p>Orographic cloud formed over the range in the morning and cross barrier flow improved, allowing for seeding operations to begin before noon. These conditions remained mostly stable throughout the day. The wind began shifting to NW early Friday morning, putting an end to seeding operations. Snowfall map showed accumulation of 1 to 4 inches on most of the range.</p>	<p>Seeding event WRR0160 began at 1128 MST on 12/16/2021.</p> <p>WRR0160 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13, WR14, WR16. Time: 1128 (12/16) to 0928 (12/17) MST 1828 (12/16) to 1628 (12/17) UTC</p>



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<p>Max/Min temperatures Pinedale: 21/-6 Rock Springs: 25/7 Lander: 32/6 Observed ODC: +2</p>	<p>Duration: 22:00, 152:13 Total Time Seeding Material: 60.03 gallons (3805.25 grams)</p>
17 December 2021, Friday	
<p>Broken low clouds lingered over the region through the mid afternoon then began clearing away. Light snowfall was occurring, but the wind was parallel to the range. The sky was clear from early evening until a band of high clouds moved through Saturday morning. Snowfall map showed 1 to 3.5 inches accumulation on the top of the range, mostly from early in the morning.</p> <p>Max/Min temperatures Pinedale: 23/-2 Rock Springs: 26/12 Lander: 32/6 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
18 December 2021, Saturday	
<p>Mid to high level clouds were seen throughout the day with a more stratiform deck arriving overnight. No precipitation was reported with these. Clouds thinned out once sunrise approached and we were left with mostly sunny skies.</p> <p>Max/Min temperatures Pinedale: 25/-6 Rock Springs: 25/8 Lander: 27/4 Observed ODC: -2</p>	<p>No ground-based seeding was conducted.</p>
19 December 2021, Sunday	
<p>Scattered mid to high level clouds were seen throughout the day with a more stratiform deck arriving by the evening. These lasted through the morning with some clearing toward sunrise. No precipitation was reported, and no seeding occurred.</p> <p>Max/Min temperatures Pinedale: 30/-4 Rock Springs: 34/13 Lander: 41/22 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
20 December 2021, Monday	
<p>There was a short period of thick low clouds over parts of the range in the early afternoon, but coverage was not sufficient</p>	<p>No ground-based seeding was conducted.</p>



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<p>for seeding operations. There was another short period of thick clouds during the night. No accumulating snowfall occurred.</p> <p>Max/Min temperatures Pinedale: 41/5 Rock Springs: 39/16 Lander: 50/23 Observed ODC: -1</p>	
<p>21 December 2021, Tuesday</p>	
<p>Not much cloud coverage during the daytime. Areas of high and mid level clouds during the evening and night. Thick mid level clouds developed Wednesday morning, with areas of virga.</p> <p>Max/Min temperatures Pinedale: 37/9 Rock Springs: 38/26 Lander: 50/27 Observed ODC: -2</p>	<p>No ground-based seeding was conducted.</p>
<p>22 December 2021, Wednesday</p>	
<p>Thick mid level clouds were over the range with cloud bases above the peaks during the daytime and evening hours, with little to no snowfall during that time. The clouds were thickening by midnight with continuous snowfall and SLW forming. The wind flow was not favorable until the middle of the night and favorable seeding conditions continued into Thursday morning until warmer air pushed into the area. Snowfall map showed accumulation was 1 to 3 inches by Thursday morning.</p> <p>Max/Min temperatures Pinedale: 37/1 Rock Springs: 41/19 Lander: 54/24 Observed ODC: +1</p>	<p>Seeding event WRR0161 began at 0314 MST on 12/22/2021.</p> <p>WRR0161 Summary: Generators: WR01, WR02, WR03, WR12. Time: 0314 (12/22) to 1024 (12/22) MST 1014 (12/22) to 1724 (12/22) UTC Duration: 7:10, 28:40 Total Time Seeding Material: 14.20 gallons (717 grams)</p>
<p>23 December 2021, Thursday</p>	
<p>Thick clouds with continuous snowfall and radiometer detected LW existed throughout the whole period. The temperature was too warm for seeding operations during the afternoon but cooled during the evening. Snowfall map showed 10+ inches on most of the range with spots over 20 inches.</p> <p>Max/Min temperatures Pinedale: 39/16</p>	<p>Seeding event WRR0162 began at 2104 MST on 12/23/2021.</p> <p>WRR0162 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13, WR14, WR16. Time: 2104 (12/23) to 2128 (12/24) MST 0404 (12/24) to 0428 (12/25) UTC Duration: 24:24, 219:31 Total Time</p>



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Rock Springs: 43/23 Lander: 49/35 Observed ODC: +2	Seeding Material: 98.29 gallons (5487.50 grams)
24 December 2021, Friday	
Continued thick orographic clouds during the morning and afternoon, with a good amount of radiometer detected LW and strong cross barrier flow. The clouds weakened during the evening, putting an end to seeding operations. The clouds redeveloped after midnight. Snowfall map showed 6 to 12 inches on the top of the range. Max/Min temperatures Pinedale: 34/19 Rock Springs: 37/26 Lander: 46/30 Observed ODC: +2	Seeding event WRR0162 continued until 2128 MST on 12/24/2021.
25 December 2021, Saturday	
Thick orographic clouds with nearly continuous snowfall. SLW existed but was not quite continuous and very little occurred overnight. Snowfall map showed only 0.5 to 1 inch on most of the range except the NW part was over 10 inches. No seeding due to declared down day by WWDO. Max/Min temperatures Pinedale: 28/12 Rock Springs: 33/21 Lander: 39/24 Observed ODC: +2	No ground-based seeding was conducted.
26 December 2021, Sunday	
Widespread cloud coverage during the daytime over western WY, however the clouds thinned and bases lifted in the early afternoon. Thin clouds with minimal snowfall and little to no SLW remained over the range through the evening and early nighttime. By the middle of the night, the clouds thickened with continuous stronger snowfall into Monday. Snowfall map showed 4 to 10 inches of accumulation on most of the range. Max/Min temperatures Pinedale: 25/-2 Rock Springs: 34/9 Lander: 37/18 Observed ODC: +2	Seeding event WRR0163 began at 0821 MST on 12/26/2021. WRR0163 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13, WR14, WR16. Time: 0818 (12/26) to 1322 (12/26) MST 1518 (12/26) to 2022 (12/26) UTC Duration: 5:04, 40:29 Total Time Seeding Material: 18.18 gallons (1012.75 grams) Seeding event WRR0164 began at 0428 MST on 12/27/2021. WRR0164 Summary:



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		Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13, WR14, WR16. Time: 0428 (12/27) to 1738 (12/27) MST 1128 (12/27) to 0038 (12/28) UTC Duration: 13:13, 100:54 Total Time Seeding Material: 43.35 gallons (2523 grams)
27 December 2021, Monday		
Continued thick clouds over the range. Despite cold temperatures some LW existed and favorable conditions persisted until around sunset, when a cold front moved through. The clouds diminished throughout the evening, but shallow, thin low clouds lingered over the range during the night into Tuesday morning. Snowfall map showed 6 to 10 inches on most of the range. Seven day total snowfall map showed 24 to 48 inches on a good portion of the range, with a max of 64 inches. Max/Min temperatures Pinedale: 23/0 Rock Springs: 30/10 Lander: 34/18 Observed ODC: +2		Seeding event WRR0164 continued until 1738 MST on 12/27/2021.
28 December 2021, Tuesday		
Shallow, small low clouds existed during most of the daytime hours. A period of mid level clouds was present during the night. Shallow low clouds developed again Wednesday morning. Only a dusting of snowfall occurred. Max/Min temperatures Pinedale: 12/-9 Rock Springs: 14/3 Lander: 21/5 Observed ODC: -1		No ground-based seeding was conducted.
29 December 2021, Wednesday		
Thin, low clouds were over the range until thickening and becoming widespread over the region in the late afternoon. SLW began developing after sunset with favorable seeding conditions during the evening. By midnight, the SLW had diminished and the snowfall tapered off overnight, even though low clouds remained into Thursday morning. Snowfall map showed 1 to 4 inches of accumulation. Max/Min temperatures Pinedale: 12/-17 Rock Springs: 20/2 Lander: 28/2		Seeding event WRR0165 began at 1850 MST on 12/29/2021. WRR0165 Summary: Generators: WR02, WR03, WR09, WR12. Time: 1850 (12/29) to 2320 (12/29) MST 0150 (12/30) to 0620 (12/30) UTC Duration: 4:30, 18:00 Total Time Seeding Material: 7.97 gallons (450 grams)



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Observed ODC: +1	
30 December 2021, Thursday	
<p>Thin and shallow low clouds over the range in the morning strengthened after noon, with favorable seeding conditions during the afternoon into the early evening. SLW decreased and became more sporadic in the evening, which put an end to seeding operations. The clouds weakened during the night, but still existed Friday morning. Snowfall map showed 1 to 2 inches accumulation with up to 5 inches on the SE part of the range.</p> <p>Max/Min temperatures Pinedale: 19/3 Rock Springs: 30/15 Lander: 36/16 Observed ODC: +2</p>	<p>Seeding event WRR0166 began at 1258 MST on 12/30/2021.</p> <p>WRR0166 Summary: Generators: WR02, WR03, WR09, WR12. Time: 2104 (12/23) to 2128 (12/24) MST 0404 (12/24) to 0428 (12/25) UTC Duration: 7:40, 24:45 Total Time Seeding Material: 10.53 gallons (619 grams)</p>
31 December 2021, Friday	
<p>Mid-level clouds were present throughout the day with a lower deck over the mountains. SLW was minimal and inconsistent. Skies cleared overnight and snow exited the area. 1-3 inches of snow was seen over the range.</p> <p>Max/Min temperatures Pinedale: 21/-15 Rock Springs: 22/7 Lander: 31/4 Observed ODC: 0</p>	No ground-based seeding was conducted.
01 January 2022, Saturday	
<p>Clear skies were seen throughout the day with a few mid-level clouds over the range towards sunset. More mid-level clouds moved in overnight and into Sunday morning. No precipitation occurred.</p> <p>Max/Min temperatures Pinedale: 10/-18 Rock Springs: 11/-6 Lander: 22/0 Observed ODC: -2</p>	No ground-based seeding was conducted.
02 January 2022, Sunday	
<p>Areas of high and mid level clouds throughout the day. No precipitation.</p> <p>Max/Min temperatures Pinedale: 19/-2</p>	No ground-based seeding was conducted.



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<p>Rock Springs: 24/4 Lander: 30/9 Observed ODC: -2</p>	
<p>03 January 2022, Monday</p>	
<p>Areas of thin upper level clouds during the day until becoming overcast by mid afternoon. The widespread clouds moved away before midnight, then low clouds started forming over the range during the night. Favorable seeding conditions developed by the middle of the night and continued into Tuesday morning.</p> <p>Max/Min temperatures Pinedale: 23/-8 Rock Springs: 23/-1 Lander: 39/7 Observed ODC: +1</p>	<p>Seeding event WRR0167 began at 0328 MST on 01/04/2022.</p> <p>WRR0167 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12 Time: 0327 (01/04) to 1657 (01/04) MST 1027 (01/04) to 2357 (01/04) UTC</p> <p>WR13, WR14, WR16 1000 (01/04) to 1657 (12/26) MST 1700 (01/04) to 2357 (12/26) UTC Duration: 13:30, 92:39 Total Time Seeding Material: 41.53 gallons (2316.25 grams)</p>
<p>04 January 2022, Tuesday</p>	
<p>Continued thick cloud coverage over the region with favorable seeding conditions through the morning and afternoon. The seeding ended when the wind flow became unfavorable for proper plume transport. Moderate to heavy snowfall developed overnight but no SLW existed. Snowfall map showed 5 to 10 inches on most of the range, with a location over 14 inches.</p> <p>Max/Min temperatures Pinedale: 27/3 Rock Springs: 32/6 Lander: 40/21 Observed ODC: +2</p>	<p>Seeding event WRR0167 continued until 1649 MST on 01/04/2022.</p>
<p>05 January 2022, Wednesday</p>	
<p>Widespread thick cloud coverage over a good portion of the state throughout most of the day. Snowfall was light but mostly continuous over the range. Only a few short-lived hints of LW were detected by the radiometer and the wind flow was not favorable for seeding operations after noon. Snowfall map showed 5 to 12 inches of accumulation on the range.</p> <p>Max/Min temperatures Pinedale: 27/14 Rock Springs: 33/14 Lander: 28/1 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>

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06 January 2022, Thursday	
<p>Consistent snowfall during the daytime diminished during the evening and mostly ended over the range by midnight. The radiometer showed no LW except for one short period in the late morning and the wind flow was not right for seeding operations. The clouds diminished over the range during the night, but fog developed in the low lands on the south side of the range. Snowfall map showed mainly 2 to 6 inches of accumulation.</p> <p>Max/Min temperatures Pinedale: 27/19 Rock Springs: 38/14 Lander: 28/1 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
07 January 2022, Friday	
<p>Broken to scattered cloud coverage in the morning and early afternoon. Low clouds started forming over the range in the early afternoon, covering the range fully by late afternoon. The temperature was too warm for seeding operations until after sunset. Favorable seeding conditions existed during the evening until the wind became unfavorable by midnight. The clouds lingered through most of the night, diminishing early Saturday morning. Snowfall map showed less than an inch accumulation on most of the range, except the NW part received up to 6 inches.</p> <p>Max/Min temperatures Pinedale: 28/1 Rock Springs: 49/28 Lander: 50/0 Observed ODC: +1</p>	<p>Seeding event WRR0168 began at 1857 MST on 01/07/2022.</p> <p>WRR0168 Summary: Generators: WR01, WR02, WR03, WR09, WR12, WR13, WR14, WR16. Time: 1851 (01/07) to 2353 (01/07) MST 0151 (01/08) to 0653 (01/08) UTC Duration: 5:02, 36:13 Total Time Seeding Material: 16.20 gallon (905.25 grams)</p>
08 January 2022, Saturday	
<p>Small, shallow low clouds over the range slowly faded away throughout the daytime hours. Some high clouds existed during the night. Snowfall map showed a dusting of snow in some places on the range.</p> <p>Max/Min temperatures Pinedale: 23/0 Rock Springs: 31/16 Lander: 40/18 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
09 January 2022, Sunday	



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<p>Mostly clear skies except periods of high clouds at times.</p> <p>Max/Min temperatures Pinedale: 25/-8 Rock Springs: 30/13 Lander: 37/9 Observed ODC: -3</p>	<p>No ground-based seeding was conducted.</p>
10 January 2022, Monday	
<p>Clear skies were observed during the day. High clouds formed over the terrain after sunset and persisted into the early morning hours before clearing again. No precipitation was observed across the range.</p> <p>Max/Min temperatures Pinedale: 21/-15 Rock Springs: 32/13 Lander: 34/17 Observed ODC: -3</p>	<p>No ground-based seeding was conducted.</p>
11 January 2022, Tuesday	
<p>High clouds were around for most of the day. Low clouds developed over the range during the night with a light dusting of snowfall on the NW part of the range and some LW detected by the radiometer. The wind flow was not right for seeding operations.</p> <p>Max/Min temperatures Pinedale: 23/-15 Rock Springs: 35/12 Lander: 39/15 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
12 January 2022, Wednesday	
<p>A steady stream of broken mid/high clouds was observed during the day, increasing in coverage after sunset. Some marginally thicker clouds formed over the range after midnight, with cloud bases above the peaks. Isolated mid/high cloud cover observed Thursday morning. Winds remained out of the NW/N for the majority of the forecast period.</p> <p>Max/Min temperatures Pinedale: 28/3 Rock Springs: 45/21 Lander: 54/28 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
13 January 2022, Thursday	



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<p>Broken high and mid level cloud coverage during the daytime, clearing to the east during the evening hours. More clouds moved in after midnight with low clouds developing on the northern slopes a few hours before sunrise. The snowfall increased after sunrise. The wind was northerly but not quite right for seeding. Snowfall map showed less than 2 inches accumulation on most of the range.</p> <p>Max/Min temperatures Pinedale: 23/3 Rock Springs: 45/21 Lander: 39/24 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>14 January 2022, Friday</p>	
<p>Orographic clouds continued tapering over the south half of the range from morning to afternoon, clearing out by sunset. Scattered mid/high clouds were observed throughout the night into Saturday morning. Hoar frost / freezing fog was also observed in the lower elevations early Saturday due to strong radiative cooling overnight. The south half of the range saw nearly all of the snowfall over the last 24 hours, with anywhere from 1-4 in. observed. Most of this had fallen by noon.</p> <p>Max/Min temperatures Pinedale: 28/-8 Rock Springs: 30/16 Lander: 34/12 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>15 January 2022, Saturday</p>	
<p>Broken high clouds in the morning, with thick mid level clouds developing during the afternoon. The mid level clouds moved away during the evening and only areas of high clouds existed overnight.</p> <p>Max/Min temperatures Pinedale: 18/-8 Rock Springs: 40/14 Lander: 35/11 Observed ODC: -2</p>	<p>No ground-based seeding was conducted.</p>
<p>16 January 2022, Sunday</p>	
<p>A steady stream of high cirrus was observed throughout the day, with occasional mid-level clouds interspersed. Altostratus/lenticular clouds formed over the range overnight and had persisted into Monday morning. Bases had been much above the peaks. No precipitation observed across the range.</p>	<p>No ground-based seeding was conducted.</p>



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<p>Max/Min temperatures Pinedale: 27/1 Rock Springs: 43/25 Lander: 45/27 Observed ODC: -2</p>	
17 January 2022, Monday	
<p>Broken high and mid level cloud coverage throughout the day. The clouds cleared away around sunrise Tuesday morning. No snowfall occurred.</p> <p>Max/Min temperatures Pinedale: 32/1 Rock Springs: 44/22 Lander: 44/25 Observed ODC: -2</p>	No ground-based seeding was conducted.
18 January 2022, Tuesday	
<p>Consistent periods of patchy stratocumulus and high cirrus from morning to sunset with brief periods of clear skies interspersed. High clouds increased in coverage, becoming altostratus, after sunset through sunrise. Periods of intermittent orographic clouds were observed over the range throughout the period and were responsible for some snow flurries through this morning. Light snow accumulations (< 0.5 in) were observed, particularly in the N half of the range.</p> <p>Max/Min temperatures Pinedale: 30/-2 Rock Springs: 39/21 Lander: 52/18 Observed ODC: -1</p>	No ground-based seeding was conducted.
19 January 2022, Wednesday	
<p>Transient high clouds and occasional altocumulus observed throughout the day. Some small-scale orographic clouds and snow showers persisted over the range in the afternoon. Little accumulation to show for this, with < 1 in. on the N and S peripheries of the range and little to none elsewhere. Clear skies observed during the overnight hours.</p> <p>Max/Min temperatures Pinedale: 28/-2 Rock Springs: 34/16 Lander: 21/12 Observed ODC: -1</p>	No ground-based seeding was conducted.

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20 January 2022, Thursday	
<p>A thick layer of mid/high clouds was present throughout the day as the trough approached. Cloud bases were occasionally below peaks during this period. Orographic clouds formed along the W slope of the range after sunset and snowfall was observed through the early morning hours. Winds then shifted from NW to N/NNE and the large cloud shield gradually cleared out, making way for orographic cloud formation on the E slope. These orographic clouds had persisted through Friday morning. The range saw ~0.5 to 2.0 in. of snow accumulation with this system, with the ranges to our W and NW receiving a much larger stake of the riches. No seeding was conducted given the suboptimal flow regime.</p> <p>Max/Min temperatures Pinedale: 25/-2 Rock Springs: 32/16 Lander: 34/12 Observed ODC: 0</p>	No ground-based seeding was conducted.
21 January 2022, Friday	
<p>The wind flow had switched to northerly which brought more development to the northern slopes. There were only waves of thick cloud coverage during the daytime and no consistent coverage for an extended period of time. The wind was not quite favorable for seeding. The clouds diminished shortly after sunset and only high clouds existed overnight. Most of the range received a dusting of snowfall but 1 to 2 inches occurred on the SE and then NW part of the range.</p> <p>Max/Min temperatures Pinedale: 30/0 Rock Springs: 35/19 Lander: 37/20 Observed ODC: -1</p>	No ground-based seeding was conducted.
22 January 2022, Saturday	
<p>Brief periods of high clouds were observed throughout the day. Coverage increased a bit overnight. Mostly clear skies this morning, with occasional passing high clouds. No precipitation was observed across the range.</p> <p>Max/Min temperatures Pinedale: 23/-6 Rock Springs: 31/10 Lander: 43/14 Observed ODC: -3</p>	No ground-based seeding was conducted.

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23 January 2022, Sunday	
Waves of high and mid level clouds passed over the area throughout the period. Max/Min temperatures Pinedale: 32/-6 Rock Springs: 39/13 Lander: 47/18 Observed ODC: -2	No ground-based seeding was conducted.
24 January 2022, Monday	
High clouds observed during the morning, before a brief lull in coverage during the early afternoon. Mid clouds began to fill in from N around 23Z, transitioning to overcast conditions after sunset. Low orographic clouds formed over the terrain in the late evening and persisted into the early morning hours. Clouds had cleared on the W side of the range, while orographic clouds are persisting on the E slope Tuesday morning. The NW part of the range received ~2-5 in. of accumulation. The SE part was the big winner (as expected), receiving 4-8 in. The wind was not quite favorable enough for seeding with the Enterprise GGEN. Max/Min temperatures Pinedale: 30/-9 Rock Springs: 35/20 Lander: 45/22 Observed ODC: 0	No ground-based seeding was conducted.
25 January 2022, Tuesday	
Shallow, thin low clouds, mainly over the NE slopes, slowly diminished throughout the daytime hours. The wind flow was not favorable for seeding and no SLW existed. The sky was clear during the night until high and mid level clouds moved in just before sunrise. Snowfall map showed a dusting on the range except the NE corner of the range received 1 to 3 inches. Max/Min temperatures Pinedale: 27/-9 Rock Springs: 28/11 Lander: 32/13 Observed ODC: 0	No ground-based seeding was conducted.
26 January 2022, Wednesday	
Transient high clouds observed throughout the day. These cleared after sunset. Mid/low orographic clouds formed over the range after midnight, favoring the S half of the range. These have persisted into Thursday morning. The majority of	No ground-based seeding was conducted.



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<p>the range received at least a dusting, with the SE part receiving 2-3 in. of accumulation.</p> <p>Max/Min temperatures Pinedale: 28/-11 Rock Springs: 28/10 Lander: 33/10 Observed ODC: 0</p>	
<p>27 January 2022, Thursday</p>	
<p>A few, small low clouds existed over the NE part of the range until just after noon. The sky was clear the rest of the period except for a very few high clouds during the night. Snowfall map showed 0.5 to 2 inches on the NE side of the range, but that all occurred in the early morning.</p> <p>Max/Min temperatures Pinedale: 28/-6 Rock Springs: 28/10 Lander: 29/10 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
<p>28 January 2022, Friday</p>	
<p>Clear skies observed for most of the daylight hours. Some high clouds filtered in around sunset and a steady stream of isolated high clouds was observed over the range through sunrise. Mostly clear skies observed after sunrise Saturday morning.</p> <p>Max/Min temperatures Pinedale: 27/-4 Rock Springs: 36/9 Lander: 36/11 Observed ODC: -3</p>	<p>No ground-based seeding was conducted.</p>
<p>29 January 2022, Saturday</p>	
<p>Clear skies during the daytime except for a very few high clouds. A band of thicker clouds moved through from north to south during the evening, then clear skies the rest of the night.</p> <p>Max/Min temperatures Pinedale: 30/-8 Rock Springs: 38/13 Lander: 45/10 Observed ODC: -2</p>	<p>No ground-based seeding was conducted.</p>
<p>30 January 2022, Sunday</p>	



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<p>Persistent scattered coverage of high clouds throughout the daylight hours. These persisted through the night into the early morning hours. Mid/low clouds have increased in coverage since before sunrise Monday morning. Orographic clouds became more widespread over the range after sunrise. No precipitation observed over the last 24 hours (ending 12Z Monday morning).</p> <p>Max/Min temperatures Pinedale: 32/-11 Rock Springs: 41/9 Lander: 45/15 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
<p>31 January 2022, Monday</p>	
<p>Favorable seeding conditions developed in the later morning. By mid afternoon the cloud was diminishing but a small area over the NW part of the range remained until just after sunset. Only areas of high and mid level clouds existed overnight. Snowfall map showed an inch accumulation except the NW had 2 to 3 inches.</p> <p>Max/Min temperatures Pinedale: 28/-6 Rock Springs: 39/13 Lander: 43/15 Observed ODC: +1</p>	<p>Seeding event WRR0169 began at 0947 MST on 01/31/2022.</p> <p>WRR0169 Summary: Generators: WR09, WR10, WR12, WR13, WR14, WR16. Time: 0947 (01/31) to 1633 (01/31) MST 1647 (01/31) to 2333 (01/31) UTC Duration: 6:46, 30:36 Total Time Seeding Material: 14.91 gallons (765.50 grams)</p>
<p>01 February 2022, Tuesday</p>	
<p>Low clouds and snow flurries were observed over the N half of the range from ~19Z through sunset. Nearly clear skies through Wednesday morning, save for periodic low clouds over the range. Some low clouds existed over the S half of the range, with the occasional flurry observed as well. Less than an inch of snow accumulation was observed across the range.</p> <p>Max/Min temperatures Pinedale: 18/-13 Rock Springs: 24/6 Lander: 27/8 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
<p>02 February 2022, Wednesday</p>	
<p>Small, low clouds existed over the range for a few hours during the afternoon but did not fully cover the range and no SLW was detected by the radiometer. The snowfall amounted to less than 1 inch. Only periods of high clouds existed the rest of the day.</p>	<p>No ground-based seeding was conducted.</p>



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<p>Max/Min temperatures Pinedale: 14/-20 Rock Springs: 17/-2 Lander: 13/-7 Observed ODC: -1</p>	
03 February 2022, Thursday	
<p>Mostly clear skies observed during the daylight hours, aside from a few transient patches of high clouds. A few low clouds over the range here and there as well. Clear skies observed overnight and into the morning. A slight dusting observed over the N periphery of the range.</p> <p>Max/Min temperatures Pinedale: 19/-6 Rock Springs: 25/1 Lander: 23/-7 Observed ODC: -1</p>	No ground-based seeding was conducted.
04 February 2022, Friday	
<p>Clear skies until mid level clouds spread across the region in the later afternoon and lasted into the mid evening hours. Low clouds developed over the range around midnight continuing into Saturday. The wind was NW so orographic forcing was limited, and snowfall was basically non existent. Snowfall map showed no accumulation.</p> <p>Max/Min temperatures Pinedale: 28/9 Rock Springs: 35/9 Lander: 43/6 Observed ODC: 0</p>	No ground-based seeding was conducted.
05 February 2022, Saturday	
<p>Persistent periods of passing mid/high clouds observed through sunset with some lingering low clouds and sporadic flurries over the range. Mid/high cloud cover increased after sunset but cleared out by midnight. Some passing clouds over the N half of the range through sunrise. Winds shifted N/NNE after midnight, allowing for orographic cloud formation and reasonable snowfall on the E slope through sunrise. Most of the range saw at least a dusting over the last 24 hours, while the S half (particularly the SE corner) of the range saw ~1-5 in. of fresh snow.</p> <p>Max/Min temperatures Pinedale: 30/0 Rock Springs: 36/19 Lander: 44/18</p>	No ground-based seeding was conducted.



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Observed ODC: -1	
06 February 2022, Sunday	
<p>Clear skies during the daytime until mid level clouds spread across during the later afternoon but moved away shortly after sunset. Only a few high clouds during the evening and night.</p> <p>Max/Min temperatures Pinedale: 30/-6 Rock Springs: 35/12 Lander: 41/13 Observed ODC: -2</p>	No ground-based seeding was conducted.
07 February 2022, Monday	
<p>Clear skies observed during the morning hours, with isolated mid/high clouds filtering in after noon. This trend persisted into the overnight hours, with the majority of cloud cover confined to the range. No low clouds observed, however. Clouds cleared during the early morning hours, yielding clear skies once again.</p> <p>Max/Min temperatures Pinedale: 36/0 Rock Springs: 46/19 Lander: 53/15 Observed ODC: -2</p>	No ground-based seeding was conducted.
08 February 2022, Tuesday	
<p>Areas of high clouds during the daytime until some mid level clouds moved in just before sunset and continued through the evening. Shallow low clouds developed over the far NW corner of the range during the night and persisted into Wednesday morning, but no snowfall occurred.</p> <p>Max/Min temperatures Pinedale: 34/5 Rock Springs: 43/23 Lander: 50/24 Observed ODC: -1</p>	No ground-based seeding was conducted.
09 February 2022, Wednesday	
<p>Widespread mid/high clouds observed during the morning hours with thin orographic clouds over the N periphery of the range. The mid/high clouds cleared after noon, leaving mostly clear skies outside of the range. The orographic clouds deepened but remained confined to the N periphery of the range during the afternoon. These eventually cleared out by midnight, yielding clear skies with periodic high cloud cover</p>	No ground-based seeding was conducted.



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<p>overnight. Some flurries observed throughout the period, with perhaps ~0.25 in. of accumulation over the last 24 hours.</p> <p>Max/Min temperatures Pinedale: 36/23 Rock Springs: 42/27 Lander: 52/27 Observed ODC: -1</p>	
<p>10 February 2022, Thursday</p>	
<p>A steady stream of high and mid level clouds during the daytime and evening hours. A stratus layer developed over the Wind River basin late in the night with northerly flow and banked against the northern slopes during the morning. No snowfall occurred.</p> <p>Max/Min temperatures Pinedale: 37/28 Rock Springs: 42/25 Lander: 62/25 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>11 February 2022, Friday</p>	
<p>A low stratus layer was over the Wind River basin and against the northern slopes during the morning with snowfall north of the range. The clouds thickened over the range during the afternoon with very light snowfall. The wind was northerly but not quite right for seeding with Enterprise. The clouds lingered until almost midnight, then only a few mid level clouds the rest of the night and Saturday morning. Snowfall map showed areas of 1 to 2 inches on the edges of the range with 3 to 6 inches north of the range.</p> <p>Max/Min temperatures Pinedale: 34/10 Rock Springs: 43/15 Lander: 43/19 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>12 February 2022, Saturday</p>	
<p>Clear skies observed during the daylight hours + overnight. Some very isolated high clouds filtered in Sunday morning, with some stationary lenticulars observed over the range as well. No precipitation observed across the range.</p> <p>Max/Min temperatures Pinedale: 34/-2 Rock Springs: 43/10 Lander: 38/9</p>	<p>No ground-based seeding was conducted.</p>



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Observed ODC: -3	
13 February 2022, Sunday	
<p>A few mid level clouds existed in the early afternoon. The sky was clear until high and mid level clouds moved in a little before sunrise.</p> <p>Max/Min temperatures Pinedale: 37/3 Rock Springs: 50/22 Lander: 55/17 Observed ODC: -2</p>	No ground-based seeding was conducted.
14 February 2022, Monday	
<p>Some mid to high level clouds were around all day with increasing clouds in the overnight hours which allowed light snow to fall over the mountain range.</p> <p>Max/Min temperatures Pinedale: 41/0 Rock Springs: 49/25 Lander: 54/23 Observed ODC: -1</p>	No ground-based seeding was conducted.
15 February 2022, Tuesday	
<p>Plenty of high and mid level clouds around during the daytime with low clouds over the range and very light snowfall. No SLW was detected during this time and the temperature was a little too warm for seeding operations. The wind became more northerly in the evening with more consistent snowfall on the northern slopes, but the wind was not quite right for seeding with Enterprise. Widespread light snowfall continued through the night with the wind more NW. Snowfall map showed most of the range received 1 to 3 inches.</p> <p>Max/Min temperatures Pinedale: 37/16 Rock Springs: 49/25 Lander: 45/26 Observed ODC: 0</p>	No ground-based seeding was conducted.
16 February 2022, Wednesday	
<p>There were plenty of mid and high-level clouds throughout the day with some breaks in the clouds showing blue skies. By late afternoon, conditions became favorable for seeding with a northerly system that moved in and Enterprise seeded until the traj looked to no longer be favorable for seeding. Snowfall</p>	<p>Seeding event WRR0170 began at 1642 MST on 02/16/2022.</p> <p>WRR0170 Summary: Generators: WR07. Time: 1642 (02/16) to 2051 (02/16) MST</p>



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<p>map showed the middle to southern part of the range getting between 3-9.6 inches of snow.</p> <p>Max/Min temperatures Pinedale: 28/5 Rock Springs: 29/12 Lander: 28/14 Observed ODC: +1</p>	<p>2342 (02/16) to 0351 (02/17) UTC Duration: 4:09 Total Time Seeding Material: 1.95 gallons (103.75 grams)</p>
17 February 2022, Thursday	
<p>Small, shallow low clouds developed over the peaks of the range during the afternoon and continued into the evening, but never fully covered the range. A stratus cloud deck developed over the Upper Green River basin and the southern slopes of the range during the night, persisting into Friday morning. The wind was NW throughout the period. Snowfall map showed a dusting to 1 inch on the foothills of the range.</p> <p>Max/Min temperatures Pinedale: 28/-4 Rock Springs: 30/11 Lander: 28/-2 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
18 February 2022, Friday	
<p>Extensive cloud cover with some pockets of blue sky persisting through the morning and finally cleared up by the afternoon. Mid to high clouds were present throughout the day. Then clouds cleared out overnight leaving clear skies and some passing upper-level clouds.</p> <p>Max/Min temperatures Pinedale: 34/12 Rock Springs: 38/19 Lander: 45/20 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
19 February 2022, Saturday	
<p>Mostly clear skies with some clouds over the range persisting into the evening hours. Low clouds started to move in after midnight with complete cloud cover by the middle of the night, but wind flow was not favorable for seeding operations.</p> <p>Max/Min temperatures Pinedale: 34/3 Rock Springs: 44/23 Lander: 49/23 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>

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20 February 2022, Sunday	
<p>There were plenty of clouds throughout the day. Favorable seeding conditions developed during the morning and persisted into the evening hours. The wind started shifting to more NW during the evening and traj became unfavorable for all GGEN sites a little after midnight. Snowfall map showed the most snow sticking to the middle of the range with around 4 to 9.34 inches of snow. The rest of the range to the north and south got between 0.5 inches and 2 inches of accumulation.</p> <p>Max/Min temperatures Pinedale: 37/12 Rock Springs: 49/25 Lander: 49/29 Observed ODC: +1</p>	<p>Seeding event WRR0171 began at 1052 MST on 02/20/2022.</p> <p>WRR0171 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13, WR14, WR16. Time: 1052 (02/20) to 0125 (02/21) MST 1752 (02/20) to 0825 (02/21) UTC Duration: 14:33, 115:31 Total Time Seeding Material: 58.72 gallons (2888 grams)</p>
21 February 2022, Monday	
<p>Overcast skies persisted as the remnants of the Arctic cold front moved away from our area. There were some quick breaks in the clouds allowing blue sky to poke through but that didn't last very long. Light and short-lived snow showers stuck around during the day. These snow showers had less than an inch in accumulation.</p> <p>Max/Min temperatures Pinedale: 27/5 Rock Springs: 37/-3 Lander: 42/-1 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
22 February 2022, Tuesday	
<p>Overcast skies persisted throughout the morning and into the afternoon. Clouds were able to clear out by the afternoon leaving only some mid and high-level clouds near the mountains. However, clouds started moving back in during mid afternoon and stuck around for the rest of the night and Wednesday morning. Light and short-lived snow showers were around during the afternoon.</p> <p>Max/Min temperatures Pinedale: 7/-9 Rock Springs: 2/-8 Lander: 3/-8 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
23 February 2022, Wednesday	



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<p>Shallow, low clouds over the Upper Green River basin, but the range had inconsistent cloud coverage for most of the daytime. Widespread, thick clouds moved in just before sunset with light snowfall but no consistent SLW. Those clouds moved away by midnight with more high and mid level clouds moving in by morning. Snowfall amounted to less than 1 inch.</p> <p>Max/Min temperatures Pinedale: 14/-15 Rock Springs: 3/-9 Lander: 4/-9 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>24 February 2022, Thursday</p>	
<p>Mid level clouds spread across the region during the morning with low clouds gradually forming over the range. Thick low clouds existed from mid afternoon until after midnight with some areas of very light snowfall but no SLW was detected by the radiometer. The sky was clear by sunrise except for very small clouds over the range. Snowfall map showed accumulation was less than 1 inch and only on the foothills in the central part of the range.</p> <p>Max/Min temperatures Pinedale: 12/-15 Rock Springs: 18/-4 Lander: 17/-10 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>25 February 2022, Friday</p>	
<p>Low to mid-level clouds were seen over the mountains through most of the day with clearing taking place overnight. Some light snow accumulations were recorded with a trace to 2 inches over the range, with the southern part receiving the highest totals. No SLW was detected by the radiometer.</p> <p>Max/Min temperatures Pinedale: 16/-15 Rock Springs: 18/1 Lander: 22/4 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
<p>26 February 2022, Saturday</p>	
<p>Clear skies throughout the period except for one isolated streak of high clouds that moved through just before midnight.</p> <p>Max/Min temperatures Pinedale: 27/-8 Rock Springs: 23/0</p>	<p>No ground-based seeding was conducted.</p>

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Lander: 30/2 Observed ODC: -3	
27 February 2022, Sunday	
High and mid level cloud coverage increased in the afternoon. A band of thick clouds with virga passed through just before sunset. All clouds cleared to the east by midnight. Shallow low clouds had formed over the NW part of the range by Monday morning. No snowfall occurred. Max/Min temperatures Pinedale: 30/-9 Rock Springs: 37/8 Lander: 44/7 Observed ODC: -1	No ground-based seeding was conducted.
28 February 2022, Monday	
Most of the shallow low clouds over the NW part of the range diminished in the early afternoon but a small area remained through the afternoon. Low clouds developed over the SW slopes of the range in the late evening and continued into Tuesday morning, but the clouds did not fully cover the range. A dusting of snowfall occurred. Max/Min temperatures Pinedale: 43/1 Rock Springs: 46/19 Lander: 57/22 Observed ODC: -1	No ground-based seeding was conducted.
01 March 2022, Tuesday	
Shallow low clouds were over parts of the range throughout the daytime and early evening hours. Mid level clouds moved through during the late afternoon and evening. The 700 mb temperature was much warmer than the seeding threshold as well as very warm temperatures at the surface. Max/Min temperatures Pinedale: 45/16 Rock Springs: 55/31 Lander: 62/31 Observed ODC: -1	No ground-based seeding was conducted.
02 March 2022, Wednesday	
Mostly clear skies were present with some mid to high-level clouds throughout the day. Temperatures were quite warm with Rock Springs and Lander breaking the high temperature records and Pinedale tying the high temperature record.	No ground-based seeding was conducted.



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<p>These warm temperatures also continue up to the 700mb temperatures will the temperatures being much warmer than the seeding threshold.</p> <p>Max/Min temperatures Pinedale: 48/19 Rock Springs: 59/0 Lander: 65/32 Observed ODC: -2</p>	
<p>03 March 2022, Thursday</p>	
<p>Widespread high clouds over the region with a few mid level clouds at times throughout the day. Temperatures were quite warm with Rock Springs and Lander being close to tying their high temp records again.</p> <p>Max/Min temperatures Pinedale: 46/21 Rock Springs: 57/29 Lander: 61/0 Observed ODC: -2</p>	<p>No ground-based seeding was conducted.</p>
<p>04 March 2022, Friday</p>	
<p>A thick widespread storm moved over western WY in the early afternoon and continued through the rest of the day. The radiometer detected a high amount of LW during the afternoon and a continuous amount the rest of the period, but the temperature was too warm for seeding operations. Accumulation was mainly low with most of the range receiving less than 2 inches, but a few isolated spots had 3 to 6 inches.</p> <p>Max/Min temperatures Pinedale: 39/27 Rock Springs: 45/30 Lander: 51/30 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>05 March 2022, Saturday</p>	
<p>There were plenty of multi level clouds throughout the day. Favorable traj, temperature and good SLW started in the late morning for the four southern generators, but two of the generators were turned off in the mid afternoon. During this time, three of the northern generators were turned on, with seeding ending a little before sunset. Snowfall map showed the most snow around Lander with just over 8 inches of snow. The range didn't get much with the northern part getting around 4-5 inches. The rest of the range received 1-3 inches.</p> <p>Max/Min temperatures</p>	<p>Seeding event WRR0172 began at 1055 MST on 03/05/2022.</p> <p>WRR0172 Summary: Generators: WR01, WR02, WR03, WR09, WR12, WR14, WR16. Time: 1055 (03/05) to 1644 (03/05) MST 1755 (03/05) to 2344 (03/05) UTC Duration: 5:49, 25:19 Total Time Seeding Material: 11.75 gallons (633 grams)</p>



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<p>Pinedale: 32/21 Rock Springs: 31/19 Lander: 30/21 Observed ODC: +1</p>	
<p>06 March 2022, Sunday</p>	
<p>Widespread light snowfall around western WY through the day until the middle of the night. The wind flow was too NW to produce a full cross barrier flow. The heaviest accumulation occurred on the southern slopes with 4 to 8 inches. The clouds moved away during the night with clear skies by Monday morning.</p> <p>Max/Min temperatures Pinedale: 23/10 Rock Springs: 19/7 Lander: 24/15 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>07 March 2022, Monday</p>	
<p>Cloudy skies started off early in the morning. Blue skies with scattered mid to high level clouds were around throughout the rest of the day and into the overnight hours. Completely cloudy skies didn't move back in until Tuesday morning with some light snow flurries.</p> <p>Max/Min temperatures Pinedale: 23/-8 Rock Springs: 20/-2 Lander: 28/2 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
<p>08 March 2022, Tuesday</p>	
<p>Light snowfall over the range during the morning and afternoon with no SLW detected by the radiometer until the later afternoon. The radiometer continued to detect LW through the evening hours with favorable wind flow. The wind shifted a little before midnight and LW disappeared. Widespread light snowfall around the region continued through the night into Wednesday morning, but no LW was detected and the wind remained unfavorable. The range received 2 to 6 inches of accumulation.</p> <p>Max/Min temperatures Pinedale: 32/0 Rock Springs: 30/9 Lander: 27/6</p>	<p>Seeding event WRR0173 began at 1703 MST on 03/08/2022.</p> <p>WRR0173 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13, WR14, WR16 Time: 1703 (03/07) to 2318 (03/07) MST 0003 (03/08) to 0618 (03/08) UTC Duration: 6:15, 42:55 Total Time Seeding Material: 21.35 gallons (1072.50 grams)</p>



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Observed ODC: +1	
09 March 2022, Wednesday	
<p>Snow flurries continued on and off throughout the day with some periods of blue sky and sun peaking through. Clouds continued to stay around throughout the night before clearing out very early Thursday morning which helped temperatures cooldown to -20°F in Pinedale.</p> <p>Max/Min temperatures Pinedale: 16/1 Rock Springs: 23/-4 Lander: 11/-5 Observed ODC: 0</p>	No ground-based seeding was conducted.
10 March 2022, Thursday	
<p>A very cold start to the day under clear skies. Scattered high and mid level clouds moved in from the west during the afternoon. Shallow low clouds developed over the far NW part of the range during the evening and lasted into Friday morning</p> <p>Max/Min temperatures Pinedale: 18/-20 Rock Springs: 15/-9 Lander: 16/-15 Observed ODC: -1</p>	No ground-based seeding was conducted.
11 March 2022, Friday	
<p>Clear blue skies with some scattered clouds were around throughout the day. Shallow, orographic clouds over the mountains persisted through the day. Clouds started to increase during late afternoon and into the overnight hours, continuing into the Saturday morning.</p> <p>Max/Min temperatures Pinedale: 28/-8 Rock Springs: 25/2 Lander: 24/0 Observed ODC: -1</p>	No ground-based seeding was conducted.
12 March 2022, Saturday	
<p>Orographic clouds over the mountains weakened in the late morning before the wind became favorable for seeding operations. But shallow low clouds remained over the range through the afternoon and then diminished in the evening. Clouds started to increase Sunday morning with some snow showers.</p>	No ground-based seeding was conducted.



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<p>Max/Min temperatures Pinedale: 41/12 Rock Springs: 40/23 Lander: 48/12 Observed ODC: 0</p>	
13 March 2022, Sunday	
<p>Light snowfall and radiometer detected LW developed in the morning and persisted through the afternoon, but the wind flow was not favorable for seeding until mid-day. The wind started shifting to NW during the afternoon and seeding ended before sunset. The clouds gradually cleared during the evening and overnight. Snowfall map showed 1 to 3 inches accumulation on the range.</p> <p>Max/Min temperatures Pinedale: 36/9 Rock Springs: 38/24 Lander: 47/27 Observed ODC: +1</p>	<p>Seeding event WRR0174 began at 1222 MDT on 03/13/2022.</p> <p>WRR0174 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13, WR14, WR16 Time: 1222 (03/13) to 1735 (03/13) MDT 1822 (03/13) to 2335 (03/13) UTC Duration: 5:13, 35:11 Total Time Seeding Material: 19.13 gallons (879.75 grams)</p>
14 March 2022, Monday	
<p>Clear blue skies with some scattered high-level clouds were around throughout the day. Some mid-level clouds started to mix in with the high-level clouds during the early evening and continued to increase during the overnight hours. Clouds started to clear out again during the early morning hours with just some high-level clouds lingering.</p> <p>Max/Min temperatures Pinedale: 34/12 Rock Springs: 39/21 Lander: 46/24 Observed ODC: -2</p>	<p>No ground-based seeding was conducted.</p>
15 March 2022, Tuesday	
<p>Mid level cloud coverage increased throughout the afternoon with low clouds forming over the range beginning around sunset. Light snowfall occurred during the evening for a few hours then mostly ended after midnight. The temperature was too warm for seeding until just before midnight, but the wind was no longer favorable by that time. The low clouds diminished during the night with only shallow clouds left by morning.</p> <p>Max/Min temperatures Pinedale: 43/12 Rock Springs: 52/25 Lander: 57/29</p>	<p>No ground-based seeding was conducted.</p>



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Observed ODC: 0	
16 March 2022, Wednesday	
<p>Broken orographic clouds were present over the mountain range throughout the day. Snow shows persisted during the afternoon hours on and off with limited SLW. Most of the range got between 0.5-1 inch of snow with just south of the range getting over 7 inches of accumulation.</p> <p>Max/Min temperatures Pinedale: 36/21 Rock Springs: 42/27 Lander: 49/28 Observed ODC: 0</p>	No ground-based seeding was conducted.
17 March 2022, Thursday	
<p>Clear skies during the daytime and evening hours. Widespread high clouds moved in from the west after midnight with a few mid level clouds by the morning.</p> <p>Max/Min temperatures Pinedale: 34/10 Rock Springs: 39/20 Lander: 40/16 Observed ODC: -2</p>	No ground-based seeding was conducted.
18 March 2022, Friday	
<p>Small and broken orographic clouds were over the range during the afternoon with very light snowfall. SLW was sparse and inconsistent. A shallow stratus layer developed in the late evening lasting through the night and then diminished Saturday morning, but the clouds did not fully cover the range and the wind was not right for seeding operations. Snowfall map showed about a half inch accumulation on the peaks.</p> <p>Max/Min temperatures Pinedale: 36/12 Rock Springs: 45/23 Lander: 50/22 Observed ODC: 0</p>	No ground-based seeding was conducted.
19 March 2022, Saturday	
<p>Scattered high-level clouds were around during the day with increasing coverage throughout the afternoon. Low clouds slowly formed over the range during the night, with light snowfall beginning around sunrise. The temperature was too warm for seeding operations.</p>	No ground-based seeding was conducted.



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<p>Max/Min temperatures Pinedale: 43/16 Rock Springs: 50/27 Lander: 56/29 Observed ODC: 0</p>	
20 March 2022, Sunday	
<p>Thick orographic cloud over the range formed in the morning and lasted through the afternoon. Continuous, moderate snowfall occurred but the temperature was too warm for seeding operations. By the time the temperature cooled, the wind shifted to NW and was no longer favorable for seeding. The clouds became broken in coverage during the evening and then diminished overnight, but just small low clouds were left by morning. Snowfall map 5 to 8 inches on the range with isolated areas up to 11 inches.</p> <p>Max/Min temperatures Pinedale: 43/25 Rock Springs: 50/26 Lander: 58/26 Observed ODC: 0</p>	No ground-based seeding was conducted.
21 March 2022, Monday	
<p>Clear blue skies with some scattered high-level clouds were around throughout the day. Temperatures were slightly below average after a cold front moved through with very gusty winds throughout the day.</p> <p>Max/Min temperatures Pinedale: 34/18 Rock Springs: 42/17 Lander: 38/19 Observed ODC: -2</p>	No ground-based seeding was conducted.
22 March 2022, Tuesday	
<p>Scattered cumulus clouds over the range and the region during the afternoon producing snow showers. No continuous coverage but some areas did receive 0.5 to 1 inch accumulation. Clear skies overnight.</p> <p>Max/Min temperatures Pinedale: 39/19 Rock Springs: 41/21 Lander: 46/22 Observed ODC: -1</p>	No ground-based seeding was conducted.
23 March 2022, Wednesday	



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<p>Mostly clear skies except for a few periods of high and mid level clouds at times, mainly from the late afternoon to the middle of the night.</p> <p>Max/Min temperatures Pinedale: 46/25 Rock Springs: 54/22 Lander: 60/24 Observed ODC: -2</p>	<p>No ground-based seeding was conducted.</p>
24 March 2022, Thursday	
<p>Mid-level orographic clouds over the mountains throughout the day. Clouds cleared out by the night and clear skies stuck around into Friday morning.</p> <p>Max/Min temperatures Pinedale: 50/28 Rock Springs: 59/33 Lander: 66/34 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
25 March 2022, Friday	
<p>Clear blue skies with periods of high-level clouds with scattered orographic clouds over the mountains throughout the day. Clouds cleared during the night.</p> <p>Max/Min temperatures Pinedale: 54/23 Rock Springs: 64/34 Lander: 62/31 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
26 March 2022, Saturday	
<p>Record high temperature for LND and RKS. A few high clouds moved in during the afternoon with areas of mid level clouds developing around the region by late afternoon. Mid level clouds along with a few shallow low clouds existed through the evening then diminished gradually throughout the night. No precipitation occurred.</p> <p>Max/Min temperatures Pinedale: 59/27 Rock Springs: 68/36 Lander: 72/38 Observed ODC: -1</p>	<p>No ground-based seeding was conducted.</p>
27 March 2022, Sunday	



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<p>RKS set another daily high temperature while LND was 1 degree short. Upper level cloud coverage increased throughout the afternoon, with mid level clouds beginning in the evening. High and mid level clouds were around throughout the night, then thinning Monday morning.</p> <p>Max/Min temperatures Pinedale: 63/28 Rock Springs: 70/35 Lander: 73/36 Observed ODC: -2</p>	<p>No ground-based seeding was conducted.</p>
<p>28 March 2022, Monday</p>	
<p>Mid level clouds increased in coverage during the afternoon and covered all of western WY by sunset. Light snowfall began in the late evening, mostly over the highest terrain. Overnight, the wind changed to northerly with very light snowfall developing on the northern slopes by sunrise. The temperature was too warm for seeding operations. Snowfall amounted to less than 1 inch.</p> <p>Max/Min temperatures Pinedale: 55/32 Rock Springs: 64/39 Lander: 72/40 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>29 March 2022, Tuesday</p>	
<p>Low clouds and snowfall increased in the early afternoon due to northerly orographic forcing and convection. By the time the temperature cooled enough for seeding operations just before sunset, the wind was no longer favorable for seeding with Enterprise. The snowfall mainly ended by midnight while shallow low clouds lingered until sunrise and then diminished Wednesday morning. Snowfall map showed the northerly slopes received 4 to 7 inches of accumulation.</p> <p>Max/Min temperatures Pinedale: 52/30 Rock Springs: 51/29 Lander: 53/30 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>30 March 2022, Wednesday</p>	
<p>Clear blue skies with periods of high-level clouds with scattered orographic clouds over the mountains throughout the daytime. Clouds cleared out by the night and the northern lights were visible for about 20 minutes.</p>	<p>No ground-based seeding was conducted.</p>



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<p>Max/Min temperatures Pinedale: 52/19 Rock Springs: 50/22 Lander: 56/26 Observed ODC: -1</p>	
31 March 2022, Thursday	
<p>Low clouds increased in the late morning with areas of snowfall around the region during the afternoon. Conditions were not consistent enough for seeding operations and the temperature was a tad too warm during this time as well. The low clouds and snowfall had moved to the east by sunset. A small band of snowfall moved through during the night. Snowfall map showed most of the range received less than 1 inch, but one area had 3 to 5 inches of accumulation.</p> <p>Max/Min temperatures Pinedale: 41/27 Rock Springs: 47/29 Lander: 53/29 Observed ODC: 0</p>	No ground-based seeding was conducted.
01 April 2022, Friday	
<p>Scattered fair weather cumulus over the southern slopes of the range in the late morning and early afternoon hours. After those diminished, only areas of high and mid level clouds around the rest of the period.</p> <p>Max/Min temperatures Pinedale: 43/19 Rock Springs: 51/23 Lander: 52/27 Observed ODC: -1</p>	No ground-based seeding was conducted.
02 April 2022, Saturday	
<p>Mostly sunny skies with periods of mid and high-level clouds along with scattered orographic clouds over the mountains throughout the daytime. Scattered high-level clouds continued throughout the night with clouds finally clearing out early Sunday morning.</p> <p>Max/Min temperatures Pinedale: 54/19 Rock Springs: 59/28 Lander: 62/28 Observed ODC: -1</p>	No ground-based seeding was conducted.
03 April 2022, Sunday	



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<p>Clear skies around the region during the daytime. High and mid level clouds moved through during the evening and night, but the sky was clear again by sunrise.</p> <p>Max/Min temperatures Pinedale: 48/21 Rock Springs: 53/26 Lander: 57/29 Observed ODC: -2</p>	<p>No ground-based seeding was conducted.</p>
04 April 2022, Monday	
<p>A strong orographic cloud developed over the range in the early afternoon, with a high amount of radiometer detected LW and continuous heavy snowfall. These conditions continued through the evening with warm temperatures. The temperature cooled enough after midnight and the wind remained favorable for a few hours during the night before it became more NW and the cloud and snowfall slowly faded. By sunrise the cloud was becoming shallow, LW was dropping and the snowfall was broken and light. Snowfall map showed the range received 8 to 20 inches.</p> <p>Max/Min temperatures Pinedale: 45/18 Rock Springs: 53/26 Lander: 57/26 Observed ODC: +1</p>	<p>Seeding event WRR0175 began at 0059 MDT on 04/05/2022.</p> <p>WRR0175 Summary: Generators: WR09, WR13, WR14, WR16 Time: 0059 (04/05) to 0439 (04/05) MDT 0659 (04/05) to 1039 (04/05) UTC Duration: 3:40, 14:50 Total Time Seeding Material: 6.97 gallons (367 grams)</p>
05 April 2022, Tuesday	
<p>Cloudy skies during the day with periods of whiteout conditions as the strong wind was blowing snow all around. Wind gusts reached almost 50 mph. The wind flow was not favorable for seeding operations. Clouds started to clear out during the afternoon with the clouds completely clearing out by the overnight hours. The range only got between 1- 3 inches of snow.</p> <p>Max/Min temperatures Pinedale: 34/18 Rock Springs: 43/22 Lander: 44/29 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
06 April 2022, Wednesday	
<p>Clear skies throughout the period except for a few fair weather cumulus during the afternoon. No significant coverage and no snowfall occurred.</p> <p>Max/Min temperatures</p>	<p>No ground-based seeding was conducted.</p>



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<p>Pinedale: 34/10 Rock Springs: 41/18 Lander: 46/25 Observed ODC: -1</p>	
<p>07 April 2022, Thursday</p>	
<p>Clear skies except for a few isolated high clouds shortly after midnight.</p> <p>Max/Min temperatures Pinedale: 50/18 Rock Springs: 56/20 Lander: 55/22 Observed ODC: -3</p>	<p>No ground-based seeding was conducted.</p>
<p>08 April 2022, Friday</p>	
<p>Clear skies during the day with periods of mid to high-level clouds. Some low clouds existed over the range during the night. Warm temperatures throughout the period but started to cool down after a cold front has moved through Saturday morning.</p> <p>Max/Min temperatures Pinedale: 61/27 Rock Springs: 66/30 Lander: 72/25 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>09 April 2022, Saturday</p>	
<p>Low clouds formed over the range in the late morning and continued through the afternoon. There were areas of light snowfall and SLW, but the temperature was too warm for seeding at this time. The clouds had moved away by sunset. Another period of low clouds formed after midnight, with cooler temperatures, a small amount of LW and light snowfall during the night. Before sunrise the wind shifted, and the clouds thinned but remained into Sunday morning. Snowfall map showed less than 1 inch accumulation.</p> <p>Max/Min temperatures Pinedale: 46/21 Rock Springs: 58/28 Lander: 62/32 Observed ODC: +1</p>	<p>Seeding event WRR0176 began at 0121 MDT on 04/10/2022.</p> <p>WRR0176 Summary: Generators: WR09, WR12, WR16 Time: 0121 (04/10) to 0512 (04/10) MDT 0721 (04/10) to 1112 (04/10) UTC Duration: 3:51, 11:33 Total Time Seeding Material: 5.39 gallons (288.75 grams)</p>
<p>10 April 2022, Sunday</p>	
<p>Orographic clouds over the mountains were persistent throughout the entire day, but conditions were inconsistent</p>	<p>Seeding event WRR0177 began at 1904 MDT on 04/10/2022.</p>



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<p>until close to sunset. Favorable seeding conditions existed through the evening into the middle the night when the wind shifted, and the cloud thinned. Snowfall analysis shows the northern part of the range getting the most snow between 2-6 inches.</p> <p>Max/Min temperatures Pinedale: 32/18 Rock Springs: 38/21 Lander: 41/23 Observed ODC: +1</p>	<p>WRR0177 Summary: Generators: WR01, WR09, WR10, WR12, WR13, WR14, WR16 Time: 1904 (04/10) to 0419 (04/11) MDT 0104 (04/11) to 1019 (04/11) UTC Duration: 9:15, 48:50 Total Time Seeding Material: 20.48 gallons (1221 grams)</p>
<p>11 April 2022, Monday</p>	
<p>Thick clouds re-developed over the range during the morning hours. Continuous snowfall and radiometer detected LW existed, and the temperature remained just cool enough for seeding a few hours before it warmed some more. By the time the temperature cooled in the evening, the wind shifted to NW and the clouds thinned. Shallow, thin low clouds lingered over the range throughout the night into Tuesday morning.</p> <p>Max/Min temperatures Pinedale: 34/18 Rock Springs: 50/26 Lander: 51/23 Observed ODC: +1</p>	<p>Seeding event WRR0178 began at 1101 MDT on 04/11/2022.</p> <p>WRR0178 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR16 Time: 1101 (04/11) to 1540 (04/11) MDT 1701 (04/11) to 2140 (04/11) UTC Duration: 4:39, 28:33 Total Time Seeding Material: 13.18 gallons (713.75 grams)</p>
<p>12 April 2022, Tuesday</p>	
<p>Snow squalls moved through the area during the late morning and afternoon. Coverage was not consistent. There was a short-lived continuous period of snowfall in the evening, but SLW was sparse. Shallow, thin low clouds lingered over the range during the night into Wednesday morning. Snowfall map showed 1 to 4 inches of accumulation on the range.</p> <p>Max/Min temperatures Pinedale: 28/9 Rock Springs: 29/16 Lander: 32/13 Observed ODC: 0</p>	<p>No ground-based seeding was conducted.</p>
<p>13 April 2022, Wednesday</p>	
<p>The day started with patchy clouds and blue skies, but more clouds moved in throughout the day. As these clouds moved in, so did scattered snow showers. This continued throughout the daytime and into the overnight hours.</p> <p>Max/Min temperatures Pinedale: 27/9</p>	<p>No ground-based seeding was conducted.</p>



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<p>Rock Springs: 26/14 Lander: 26/11 Observed ODC: 0</p>	
<p>14 April 2022, Thursday</p>	
<p>Thick clouds developed over the range in the late morning with favorable seeding conditions. This persisted through the afternoon and evening hours. After midnight, the wind flow starting to shift and put an end to seeding when the traj became unfavorable. The clouds diminished during the rest of the night becoming shallow and broken by sunrise. Snowfall map showed most of the range received 4 to 8 inches.</p> <p>Max/Min temperatures Pinedale: 37/12 Rock Springs: 45/15 Lander: 47/11 Observed ODC: +2</p>	<p>Seeding event WRR0179 began at 1104 MDT on 04/14/2022.</p> <p>WRR0179 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13, WR14, WR16 Time: 1101 (04/14) to 0243 (04/15) MDT 1701 (04/14) to 0843 (04/15) UTC Duration: 15:42, 106:33 Total Time Seeding Material: 49.06 gallons (2663.75 grams)</p>
<p>15 April 2022, Friday</p>	
<p>Thick clouds redeveloped over the range during the morning with continuous but light snowfall and favorable seeding conditions in the late morning and most of the afternoon. By the late afternoon the moisture was waning, and the cloud diminished, putting an end to seeding operations. The low clouds disappeared during the evening, with only mid level clouds during the night. Snowfall map showed 1 to 3 inches of accumulation on the range.</p> <p>Max/Min temperatures Pinedale: 37/21 Rock Springs: 46/29 Lander: 49/22 Observed ODC: +1</p>	<p>Seeding event WRR0180 began at 1005 MDT on 04/15/2022.</p> <p>WRR0180 Summary: Generators: WR09, WR10, WR12, WR13, WR14, WR16 Time: 1005 (04/15) to 1658 (04/15) MDT 1605 (04/15) to 2258 (04/15) UTC Duration: 6:53, 36:13 Total Time Seeding Material: 15.91 gallons (905 grams)</p>

WYOMING WEATHER MODIFICATION PROGRAM
Wind River Mountain Range

Appendix B. National Oceanic and Atmospheric Administration Final Operations Report

Silver iodide seeding agent amounts are stated in grams.

MONTH		(a) NUMBER OF MODIFICATION DAYS	(b) NUMBER OF MODIFICATION DAYS PER MAJOR PURPOSE				(c) HOURS OF APPARATUS OPERATION BY TYPE		(d) TYPE AND AMOUNT OF AGENT USED					
			INCREASE PRECIPITA- TION	ALLEVIATE		OTHER	AIRBORNE	GROUND	SILVER IODIDE	CARBON DIOXIDE	UREA	SODIUM CHLORIDE	OTHER	
				HAIL	FOG									
JANUARY		3	3					159.47	4,419					
FEBRUARY		2	2					119.67	3,652					
MARCH		3	3					103.42	3,178					
APRIL		6	6					239.48	6,585					
MAY														
JUNE														
JULY														
AUGUST														
SEPTEMBER														
OCTOBER														
NOVEMBER		1	1					18.53	504					
DECEMBER		9	9					731.65	19,302					
TOTAL		0	0	0	0	0	0	0	0	0	0	0	0	
TOTALS FOR FINAL REPORT		24	24					1372.22	37,640					
DATE ON WHICH FINAL WEATHER MODIFICATION ACTIVITY OCCURRED (For Final Report only.) 04/15/2022														
CERTIFICATION: I certify that all statements in this report on this weather modification project are complete and correct to the best of my knowledge and are made in good faith.									NAME OF REPORTING PERSON Jake Van Ornum					
AFFILIATION Weather Modification LLC									SIGNATURE 					
STREET ADDRESS 3802 20th Street North									OFFICIAL TITLE Client Services Assistant					
CITY Fargo						STATE ND	ZIP CODE 58102	DATE 06/08/2022						



WINTER GROUND OPERATIONS 2021-2022
WYOMING WEATHER MODIFICATION PROGRAM
 Wind River Mountain Range



Appendix C. Ice Nucleus Generator Operations Summary – 2021-2022

2021-2022 Generator Operations Summary - WIND RIVER RANGE

LAST UPDATED

20220517

GRAND TOTAL OPERATIONAL "SEED" HOURS=	1372:13
Total Seeding Solution (Gallons)=	618.67

Monthly Totals	156:40	139:15	150:52	4:09	186:50	128:29	180:03	136:17	142:39	146:59	1372:13	1372:22		
November sub-total	0:00	0:00	0:00	0:00	2:26	2:26	2:26	4:24	4:24	2:26	18:32	18:53		
December sub-total	84:05	78:01	91:57	0:00	95:54	60:37	92:23	76:22	76:08	76:12	731:39	731.65		
January sub-total	16:54	16:54	14:36	0:00	19:04	17:46	22:16	17:24	18:45	15:49	159:28	159.47		
February sub-total	14:33	14:33	14:33	4:09	14:33	14:33	14:33	9:51	8:31	9:51	119:40	119.67		
March sub-total	14:58	12:52	12:52	0:00	10:53	6:29	14:58	8:48	10:53	10:42	103:25	103.42		
April sub-total	26:10	16:55	16:54	0:00	44:00	26:38	33:27	19:28	23:58	31:59	239:29	239.48		
UTC DATE	WR01 Big Sandy	WR02 Block & Tackle	WR03 White Acorn	WR07 Enterprise	WR09 Boulder Lake	WR10 East Fork	WR12 Pocket Creek	WR13 Green River	WR14 Willow Lake	WR16 Highland	DAILY TOTAL		Operation #	Solution Used (gallons)
11/24/2021					2:26	2:26	2:26	4:24	4:24	2:26	18:32	18.53	WRR0156	8.28
12/5/2021					8:36			8:36	8:36	8:36	34:24	34.40	WRR0157	16.94
12/8/2021	4:44	4:44	4:44		12:04	5:30	5:30	12:39	12:39	12:39	75:13	75.22	WRR0158	33.43
12/12/2021	7:33	7:33	7:33		7:18		7:33				37:30	37.50	WRR0159	14.34
12/16/2021	22:00	22:00	22:00		14:23	12:30	22:00	12:30	12:30	12:20	152:13	152.22	WRR0160	60.03
12/23/2021	7:10	7:10	7:10				7:10				28:40	28.67	WRR0161	14.20
12/24/2021	24:24	24:24	24:24		24:24	24:23	24:23	24:23	24:23	24:23	219:31	219.52	WRR0162	98.29
12/26/2021	5:04		5:01		5:04	5:04	5:04	5:04	5:04	5:04	40:29	40.48	WRR0163	18.18
12/27/2021	13:10		8:55		13:10	13:10	13:13	13:10	12:56	13:10	100:54	100.90	WRR0164	43.35
12/30/2021		4:30	4:30		4:30		4:30				18:00	18.00	WRR0165	7.97
12/30/2021		7:40	7:40		6:25		3:00				24:45	24.75	WRR0166	10.53
1/4/2022	12:18	12:18	10:00		10:12	13:30	13:30	6:57	6:57	6:57	92:39	92.65	WRR0167	41.53
1/8/2022	4:36	4:36	4:36		4:36		4:30	3:41	5:02	4:36	36:13	36.22	WRR0168	16.20
1/31/2022					4:16	4:16	4:16	6:46	6:46	4:16	30:36	30.60	WRR0169	14.91
2/16/2022				4:09							4:09	4.15	WRR0170	1.95
2/20/2022	14:33	14:33	14:33		14:33	14:33	14:33	9:51	8:31	9:51	115:31	115.52	WRR0171	58.07
3/5/2022	5:49	3:43	3:43		2:05		5:49		2:05	2:05	25:19	25.32	WRR0172	11.75
3/8/2022	6:15	6:15	6:15		3:35	3:35	6:15	3:35	3:35	3:35	42:55	42.92	WRR0173	21.35
3/13/2022	2:54	2:54	2:54		5:13	2:54	2:54	5:13	5:13	5:02	35:11	35.18	WRR0174	19.13
4/5/2022					3:40			3:40	3:40	3:40	14:40	14.67	WRR0175	6.97
4/10/2022					3:51		3:51			3:51	11:33	11.55	WRR0176	5.39
4/11/2022	9:15				9:15	9:15	9:15	4:07	4:07	3:36	48:50	48.83	WRR0177	20.48
4/13/2022	4:39	4:39	4:39		4:39	0:54	4:39			4:24	28:33	28.55	WRR0178	13.18
4/14/2022	12:16	12:16	12:15		15:42	9:36	15:42	9:36	9:35	9:35	106:33	106.55	WRR0179	49.06
4/15/2022					6:53	6:53		2:05	6:36	6:53	29:20	29.33	WRR0180	13.16
END OF PROJECT														