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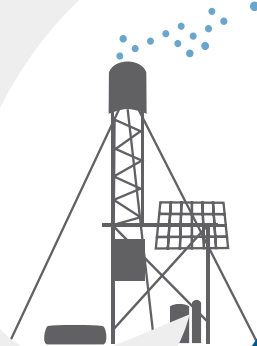
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FINAL SUMMARY

WINTER GROUND OPERATIONS 2020-2021

WYOMING WEATHER MODIFICATION
WIND RIVER MOUNTAINS



Ground-Based Cloud Seeding Operations 2020-2021 Winter Operations Report

For the

Wind River Mountain Range, Wyoming

Prepared By



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Submitted To



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EXECUTIVE SUMMARY

Funding for cloud seeding operations in the Wind River Range for the winter of 2020-2021 was provided in part by the 2020 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 2020-2021 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.

The same ten ground-based ice nucleus generators (ground generators) that were employed during the preceding season were deployed for the six 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 2020-2021 season became operational on 15 November 2020 and concluded after 15 April 2021. The first seeding event occurred on 15 November 2020.



Figure 1. A snow-covered New Fork Lakes on 17 November 2020; two days after the first seeding event of the 2020-2021 season. Photo by WMI Meteorologist Jeff Ceratto.



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The 2020-2021 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. Three seeding events occurred in November 2020, seven in December 2020, 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 72% of the median annual value to 102%, with the five-site SNOTEL mean at just 82% of the long-term median value. Only the Townsend Creek site ended above seasonal norm, whereas the rest varied between 72% and 81% of the 30-year median annual value.

The thirty-two storm events accrued 262 hours and 7 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. The Enterprise generator, sited on the eastern slope of the range near Lander, was used frequently during the 2020-2021 season, which with twelve operations broke the project record for its seasonal total operations. The previous record was ten operations in the 2015-2016 season.

The 2020-2021 season featured mostly shorter-interval storms compared to previous seasons. Of the 32 seeding events, only six lasted for more than ten hours and only three 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 1057 hours and 49 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 2020-2021 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 temperate and wind criteria by atmospheric soundings has decreased. For the 2020-2021 season, atmospheric soundings were only performed at times when the temperature and/or wind was questionable. One or more weather balloons were released during 7 seeding events, and no soundings were needed for 25 seeding events. In three instances the 700 hPa temperatures observed by weather balloon were not cold enough for seeding, and another sounding was done an hour or more later which indicated temperatures had cooled below the seeding threshold. 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.



ACKNOWLEDGMENTS

The 2020-2021 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, Pat Trujillo, and Brandon King. 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 Charles Sassaman, 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 that makes it to the ground. 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.

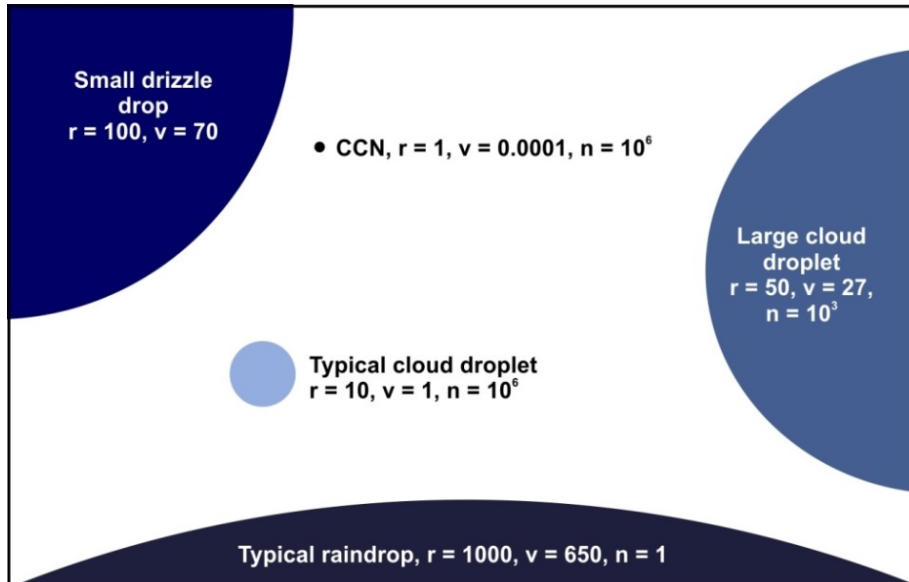


Figure 2. Relative characteristics of particles involved in cloud processes. For each, the radius (r , microns), fall velocity (v , cm per second), and number concentration (n , per liter) are given (after Wallace and Hobbs 1977). The raindrop shown (radius = 1000) is a 2 mm diameter raindrop.

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.

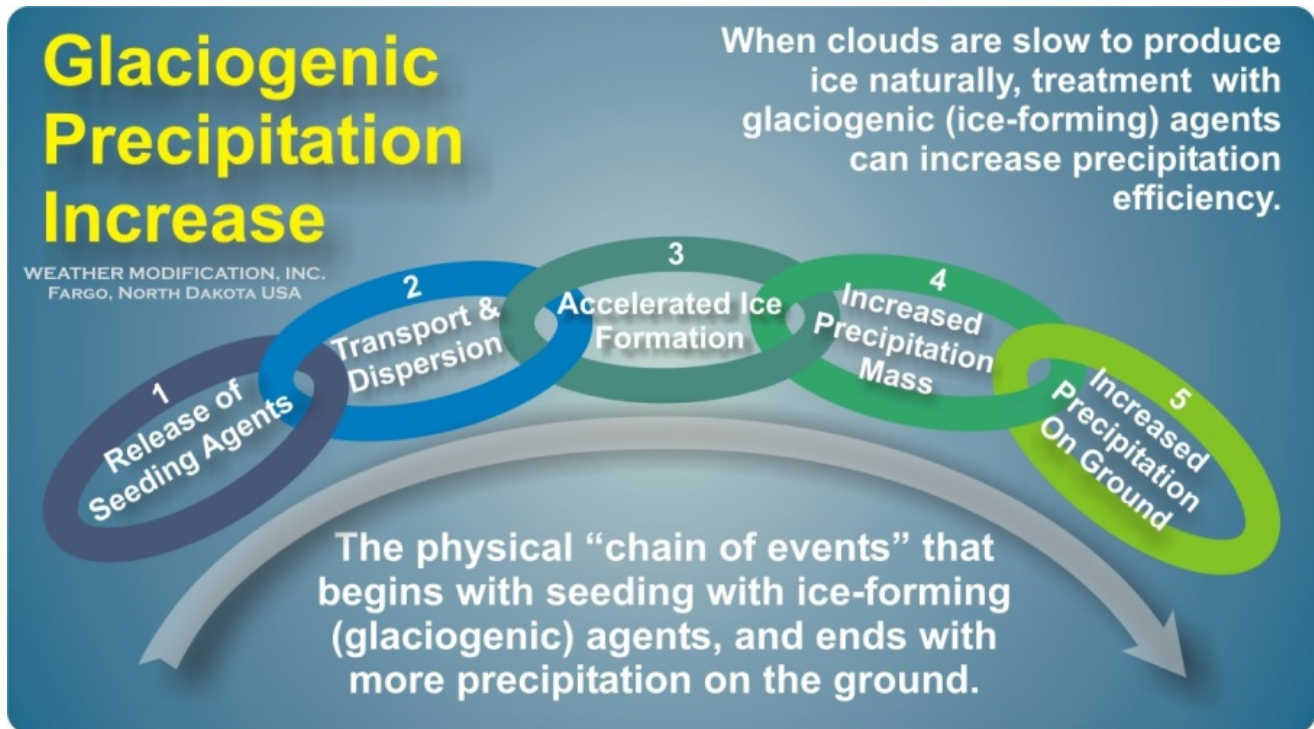


Figure 3. The physical chain-of-events that begins with release of ice-forming seeding agents and culminates with increased precipitation.

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 in the neighborhood of 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). A 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.



In operational seeding, the temperature criterion can be met in warmer conditions as long as some of the ice nuclei still produce ice crystals. This being said, 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 2020-2021 Program Funding

In addition to the 37% of funding costs provided by the State of Wyoming, funding for the 2020-2021 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 2020-2021 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.



2 PROJECT PERSONNEL AND FACILITIES

2.1 Personnel

WMI provided an experienced ground-based cloud seeding crew for the 2020-2021 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. Adam Brainard was located on-site in Pinedale, WY through most of the project. Brainard operated WMI's numerical weather prediction models and coordinated data collection during the season. He and meteorologist Charles Sassaman operated the upper air sounding system (weather balloons). Sassaman replaced Brainard when Brainard was off-site. Jason Goehring led the forecasting team and was the primary operations meteorologist. Goehring was assisted by Sassaman. A few early season forecasts were completed by Jeff Ceratto.

This was Goehring's sixteenth 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, 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 2020-2021 operations. On-site technical work was conducted by Mr. Michael Paul, assisted by Mr. Ryan Hudson and Mr. Pat Trujillo. An on-call tech, Brandon King, was available during the project, and made three trips to help with generator maintenance.

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 2020-2021 METEOROLOGY TEAM



DANIEL GILBERT
Chief Meteorologist



JASON GOEHRING
Field Meteorologist



ADAM BRAINARD
Field Meteorologist/
Numerical Modeler



JEFF CERATTO
Field Meteorologist



CHARLES SASSAMAN
Field Meteorologist

Figure 4. The 2020-2021 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 27 October 2020. 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. These sites remain unchanged from those utilized in the WWMPP and the previous operational seeding seasons in the Wind River Range, 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.

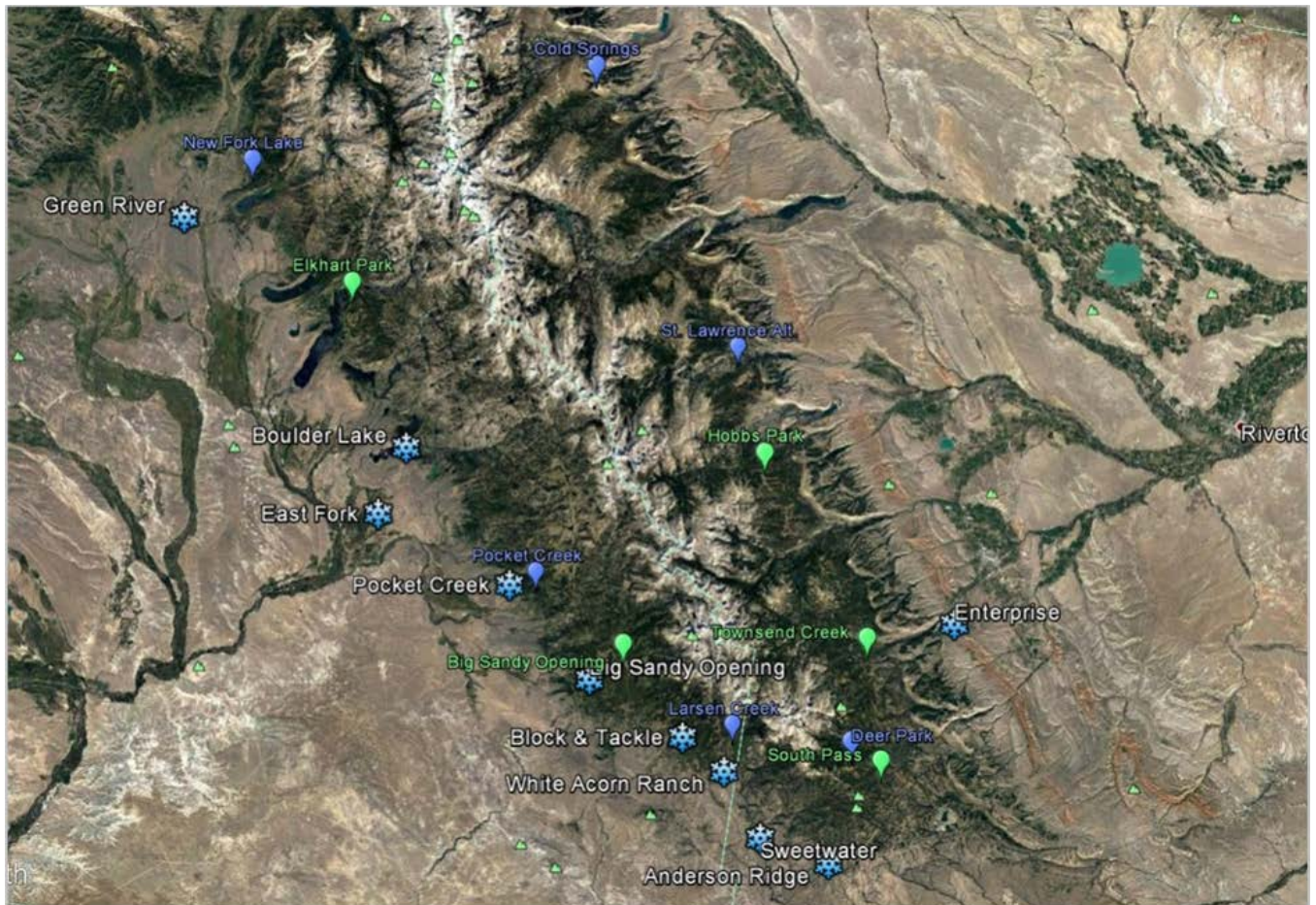


Figure 5. The locations of the ground-based ice nucleus generators are indicated by the snow crystal symbols. The green “balloons” indicate the locations of Natural Resources and Conservation Service (NRCS) snow telemetry (SNOTEL) sites used in monitoring snowpack during the 2020-2021 season. The blue balloons show the locations of additional SNOTELs that were not used because of proximity to sites that were used, or a short period of record (they were relatively new sites).



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.

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.

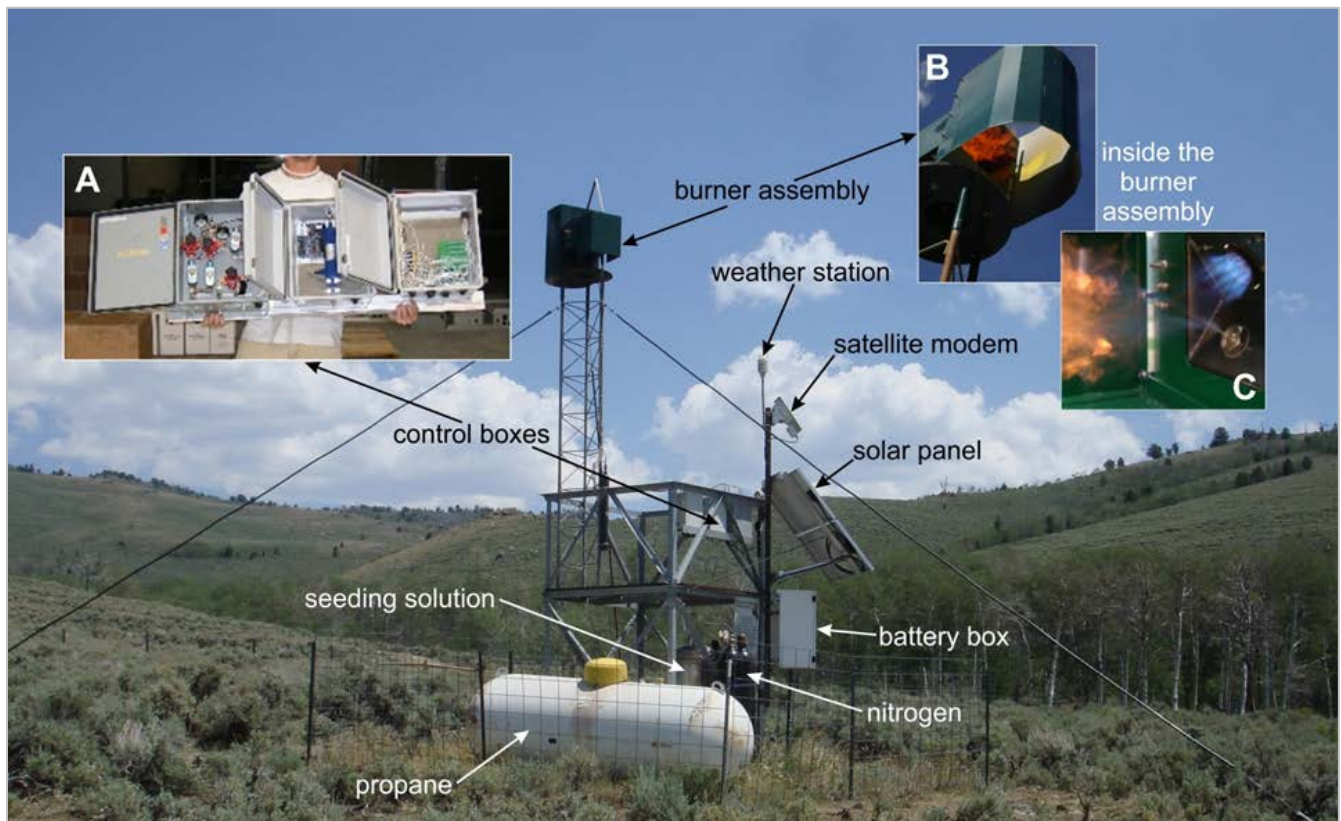


Figure 6. The primary components of the WMI remotely-controlled ground-based ice nucleus generator are illustrated. Inset A, shows the contents of the control boxes. From left to right, these are: solenoids (electronic valves) to turn flows on and off, seeding solution flow rate regulation and measurement, 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.

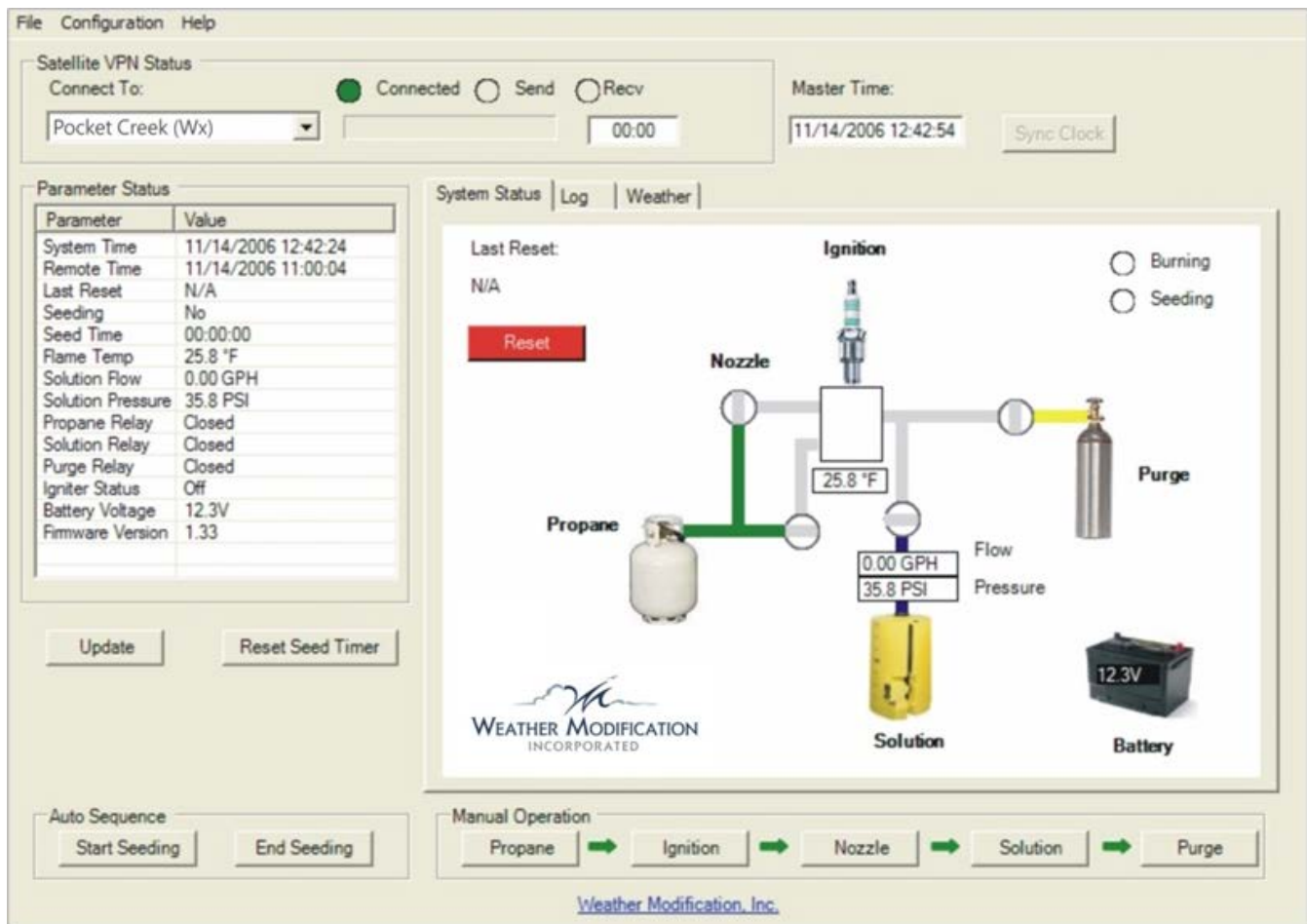


Figure 7. The control interface for the WMI remotely-controlled ground-based ice nucleus generator is shown, after connection is established via satellite, but before the generator is turned on. All flow valves are off, seeding solution flow is zero, but system status is reported.

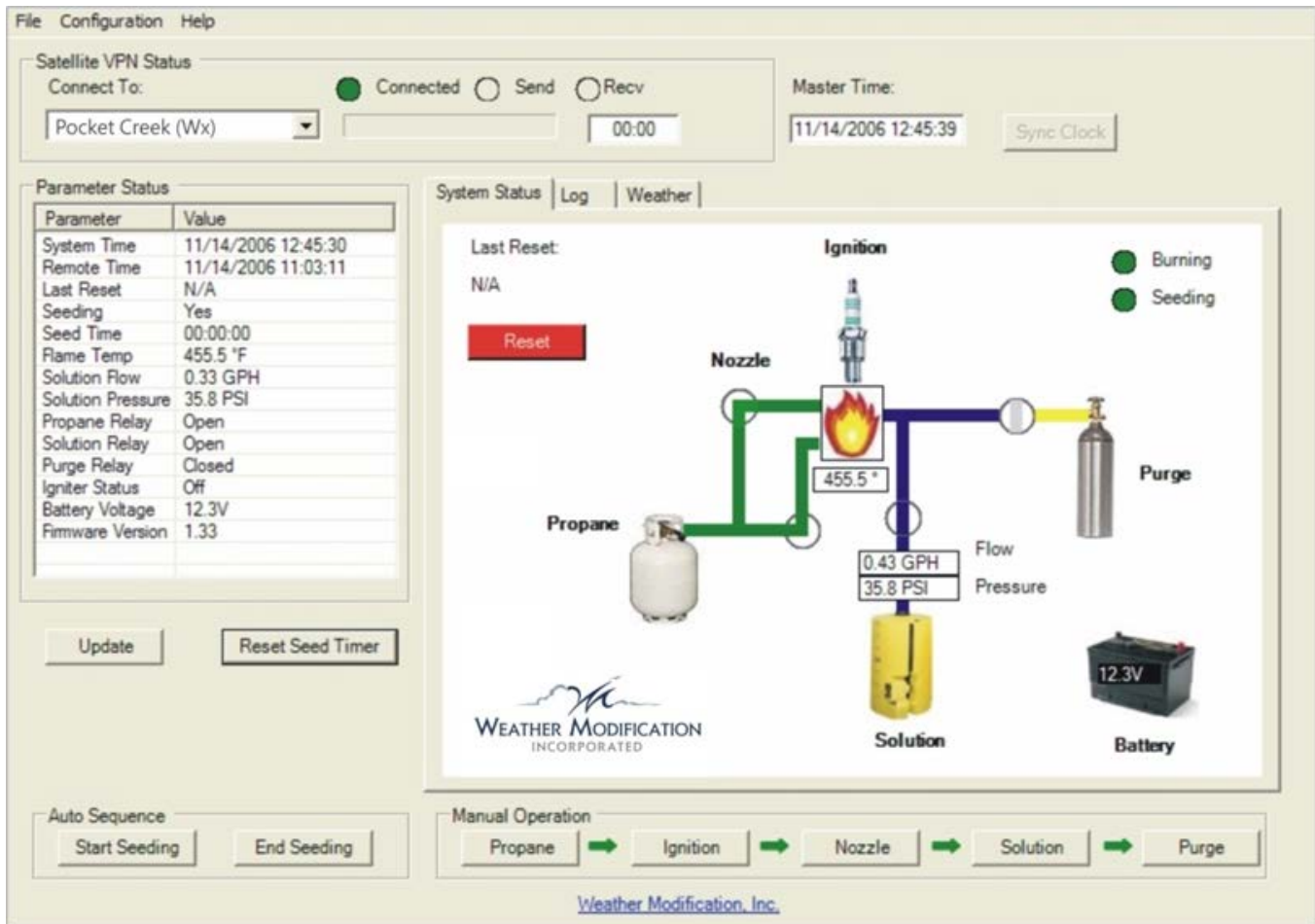


Figure 8. The WMI remote-controlled ice nucleus generator interface is shown, as it appears during seeding operations. Valves are open, the flame is known to be burning, and the seeding solution flow rate is also known. Seeding is certain.

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 2020-2021 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.



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.

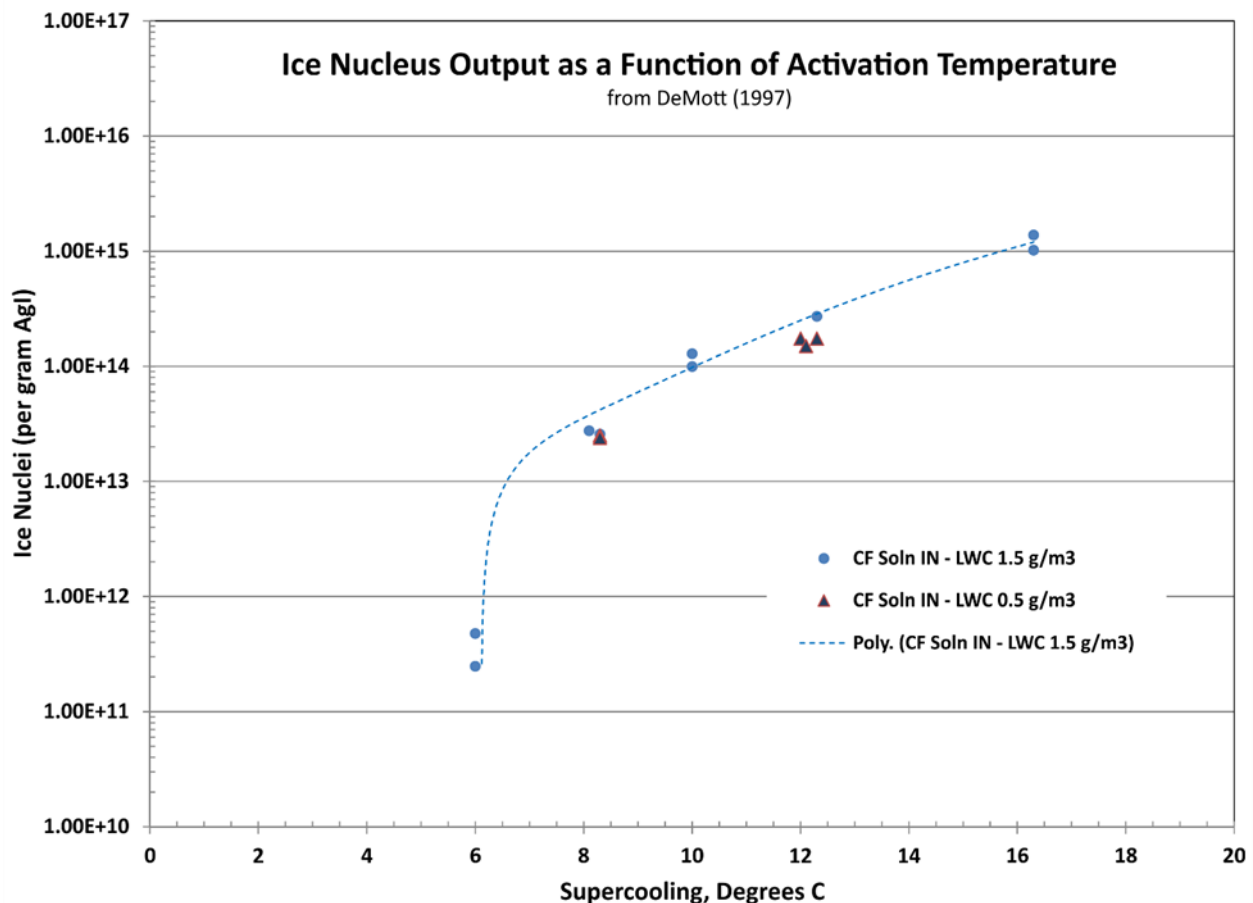


Figure 9. Yield as measured by the number of active ice nuclei per gram of silver iodide (AgI) burned, is shown as a function of temperature (DeMott 1997). These nuclei are comprised of silver iodide, silver chloride, and salt (NaCl).



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 Atmospheric Soundings (Weather Balloons/Rawinsondes)

Weather balloons were released from the WMI shop in Pinedale, WY to help determine whether the weather conditions were suitable for seeding, see Figure 13. Each balloon carried a miniaturized weather probe that measured temperature, humidity, and pressure. In addition, the GPS position of the balloon was also recorded, allowing the measurement of winds. The atmospheric sounding data were recorded and compared to the operating criteria to verify that observed weather conditions were sufficient to initiate cloud seeding procedures.

Each sounding required approximately one hour to travel from the surface to the 100 hPa level (an altitude of about 53,000 feet). Upon completion, the sounding data were immediately shared via e-mail with the National Weather Service Offices in Riverton and Cheyenne, and the State of Wyoming's Water Resources Data System (WRDS). All soundings were archived and are available for any post-analysis efforts that might be undertaken.



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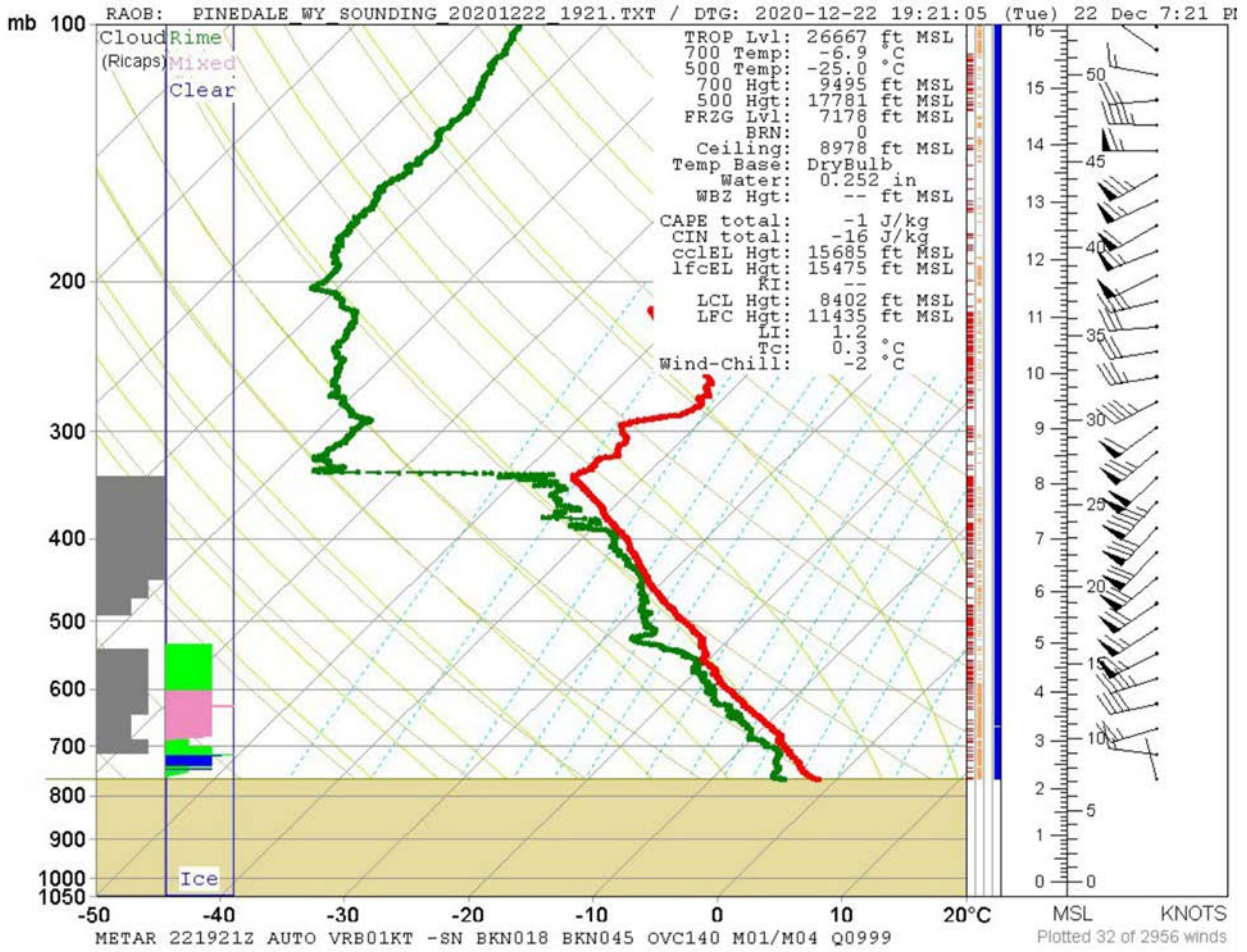


Figure 10. A plot of the upper-air sounding obtained from the weather balloon released from Pinedale, WY at 19:21 UTC on 22 December 2020. The temperature at 700 hPa level (approximately 10,000 feet) was -6°C (+21°F), and the wind speed was from 250° (westerly) at about 25 knots (~29 miles per hour). The temperature was just cold enough for seeding to begin.



2.6 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 and the preparation and release of weather balloons. The shop housed WMI's 4x4 truck, ATV, snowmobiles, trailer, spare generator parts, trouble-shooting equipment, and replacement nitrogen tanks. The Vaisala MW41 rawinsonde system used for the calibration and tracking of the weather balloons was also at the shop, as well as all the upper air consumables: helium, balloons, and rawinsondes. Internet service was available, allowing immediate sharing of upper air data with other interested parties (NWS, WRDS).



Figure 11. The WMI technician crew preform a maintenance check of generator WR03 (White Acorn Ranch) on 02 December 2020. Replacing the burner nozzle is Patrick Trujillo. Photo by WMI technician Michael Paul.



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 2020-2021 season. The unit was operated at a 10° elevation angle over the Wind River Range, where the measurements indicated if liquid water was present.



Figure 12. The radiometer is shown here, at the East Fork generator site near Boulder, WY. The instrument observes in the direction perpendicular to its axis, so as aligned here, it is configured to take measurements over the Wind River Range in the distance. The East Fork ice nucleus generator can be seen in the background, left. Photo by WMI Meteorologist Adam Brainard on 28 November 2020.



3.1.2 Atmospheric Soundings

Weather balloons were released from WMI's Pinedale shop whenever there was ambiguity about the suitability of the atmosphere for effective seeding. The data provided from these weather balloon releases help answer questions such as if the low-level wind direction's suitability to effectively transport seeding material transport to the target areas, or if the 700 hPa temperature was cold enough for seeding to be effective. The atmospheric soundings (weather balloons/rawinsondes) are discussed in Section 2.5. Data from the soundings were immediately shared with the NWS and WRDS.

Figure 13. The weather balloon is filled, and its sonde prepared at the WMI Pinedale shop in anticipation of seedable conditions. Photo by WMI Meteorologist Jeff Ceratto on 22 December 2020.



3.2 Numerical Modeling

3.2.1 WRF Modeling

WMI continued to operate a nested limited-area domain of the Weather Research and Forecasting (WRF) model in the 2020-2021 season. This model was specifically tailored to the Wind River and Wyoming Airborne seeding programs. A regional outer nest, with a 7.5 km grid spacing, was initialized from the High-Resolution Rapid Refresh (HRRR) model and used the North American Model (NAM) for boundary conditions at 3-hour intervals. The domain was operated to a 72-hour duration on the 0 UTC cycle and a 60-hour duration on the 12 UTC cycle. Optional runs from the 6 UTC and 18 UTC cycles were enabled when potentially seedable conditions were more imminent. The outer domain provided boundary conditions to an inner high-resolution nest, with a grid spacing of 2.5 km, that operated on the same frequency and duration as the outer domain.

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 14 shows forecast integrated cloud water colder than -5°C over the Wind River Range.

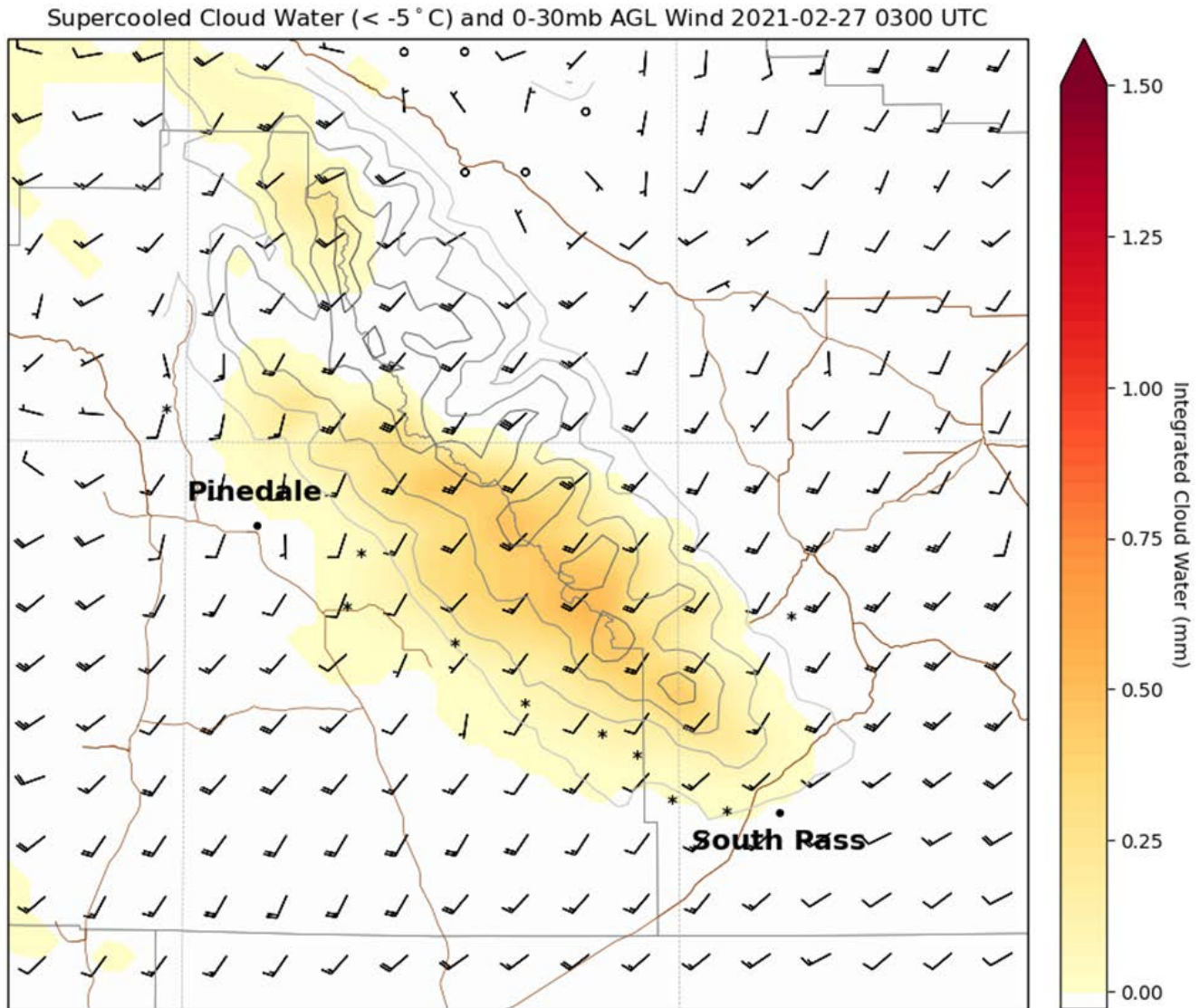


Figure 14. Near surface wind barbs are shown with integrated cloud water on this panel from the WMI WRF model, valid on 27 February 2021, at 03:00 UTC. Since the water shown is only that occurring at -5°C and colder, it is supercooled sufficiently for seeding. The WMI WRF was initialized and run as often 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 asterisk symbols denote the location of a project ground generator.

Though knowing the SLW distribution shown in Figure 14 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 also available to the project meteorologists in the form of vertical cross-sections (Figure 15).



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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 2021-02-27 0300 UTC

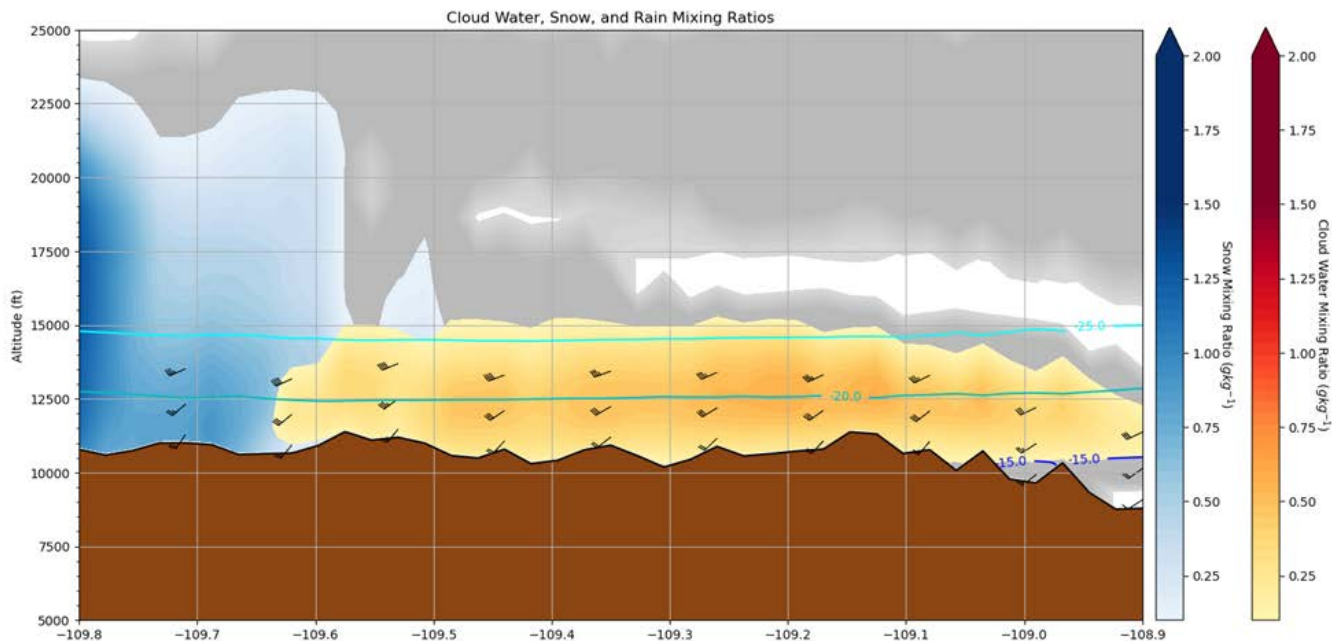
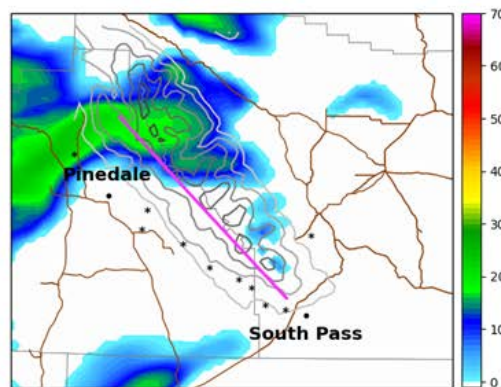


Figure 15. Vertical cross section from northwest to southeast near and west of the continental divide. Cross section line shown in pink on the forecast composite reflectivity plot on the top half of the image. The plot represents 03:00 UTC on 27 February 2021. See text for interpretation and discussion.



The example shown in Figure 15 for 27 February 2021 is the cross section southwest of the continental divide. In the lower panel, a nice region of cloud water is shown. Note that the region lies entirely above the -15°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 indicated 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 16).

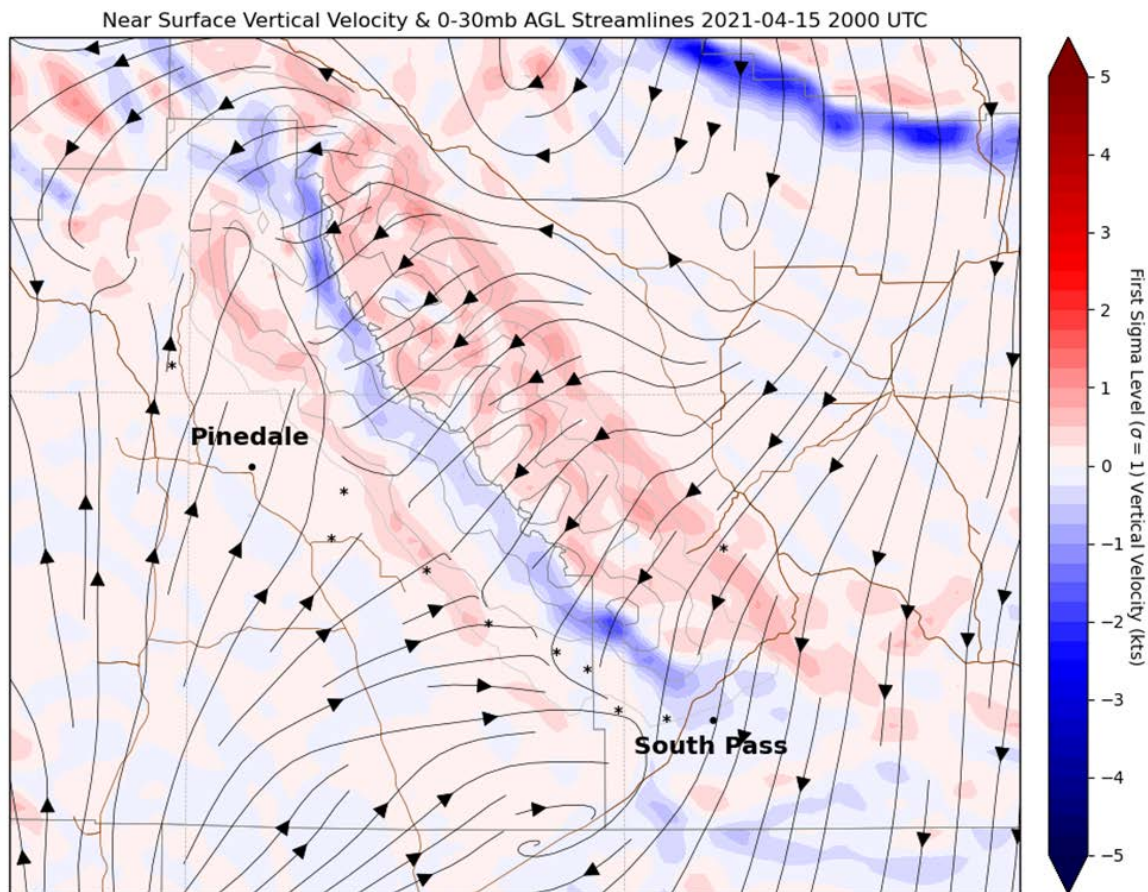


Figure 16. This product, also designed specifically for winter orographic seeding, shows the near surface vertical velocity along with streamlines of the near surface (average 0-30 mb AGL) wind. Here, ascending air is shown in red, with descending air in blue. This plot helps illuminate when sufficient 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 last seeding event of the 2020-2021 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 17). 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, significant cooling is predicted to occur the following day, December 26, along with increasing 700 hPa moisture and potentially favorable west-northwest winds. Seeding ultimately occurred throughout the afternoon of the 26th into the early evening.

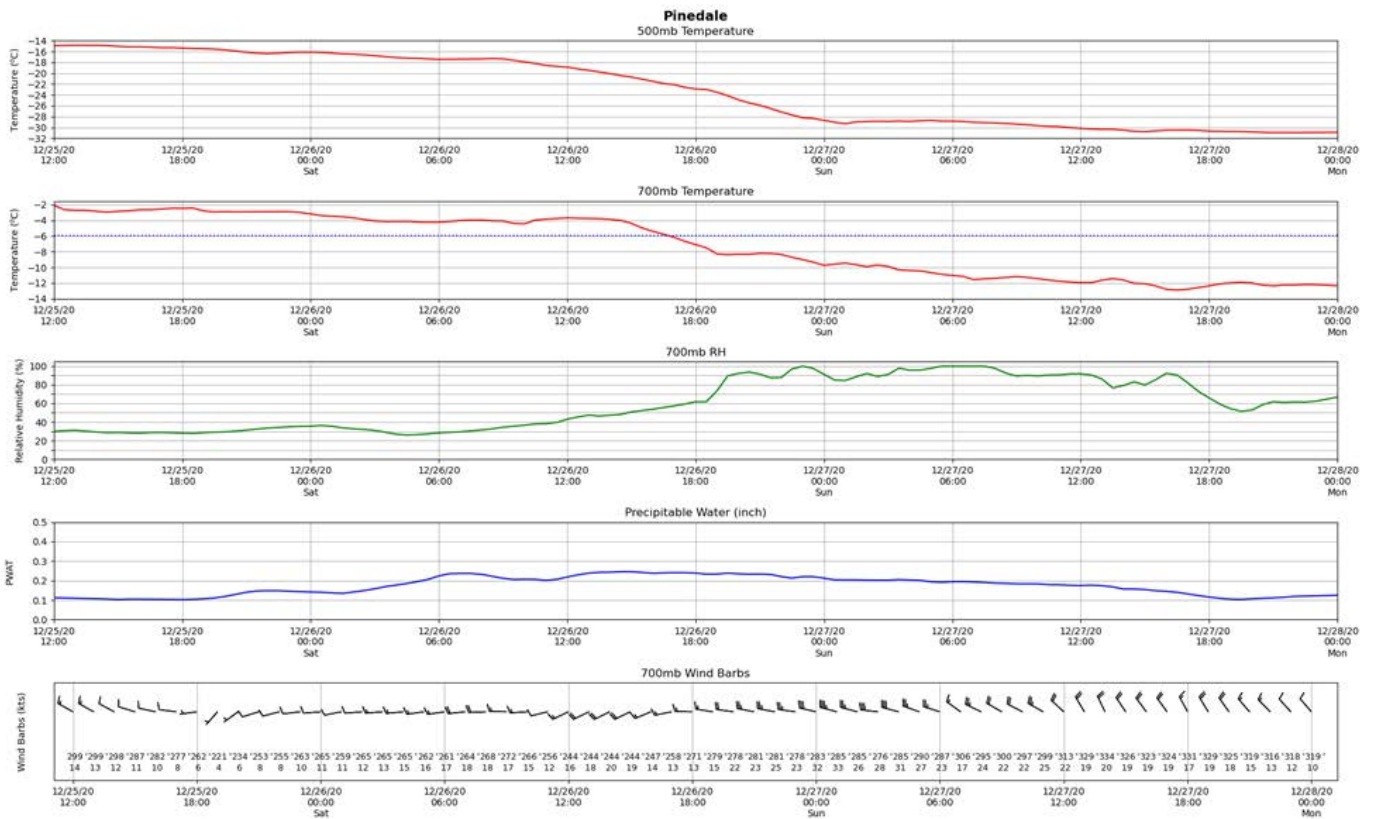


Figure 17. A meteogram illustrating the progression of key atmospheric variables (mid and low-level temperature, moisture, and low-level wind) in Pinedale. In this example, from the 12 UTC run on Christmas Day, cooling temperatures, increasing moisture, and potentially conducive wind gave forecasters and ground technicians early warning a favorable period for seeding operations may develop the following afternoon December 26. Additional information and commentary is provided in the text above.



3.2.2 HYSPLIT Modeling

During the 2020-2021 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 18, for the 8 February 2020 seeding event. In the plots, each hour is shown by a “dot” on the plume centerline.



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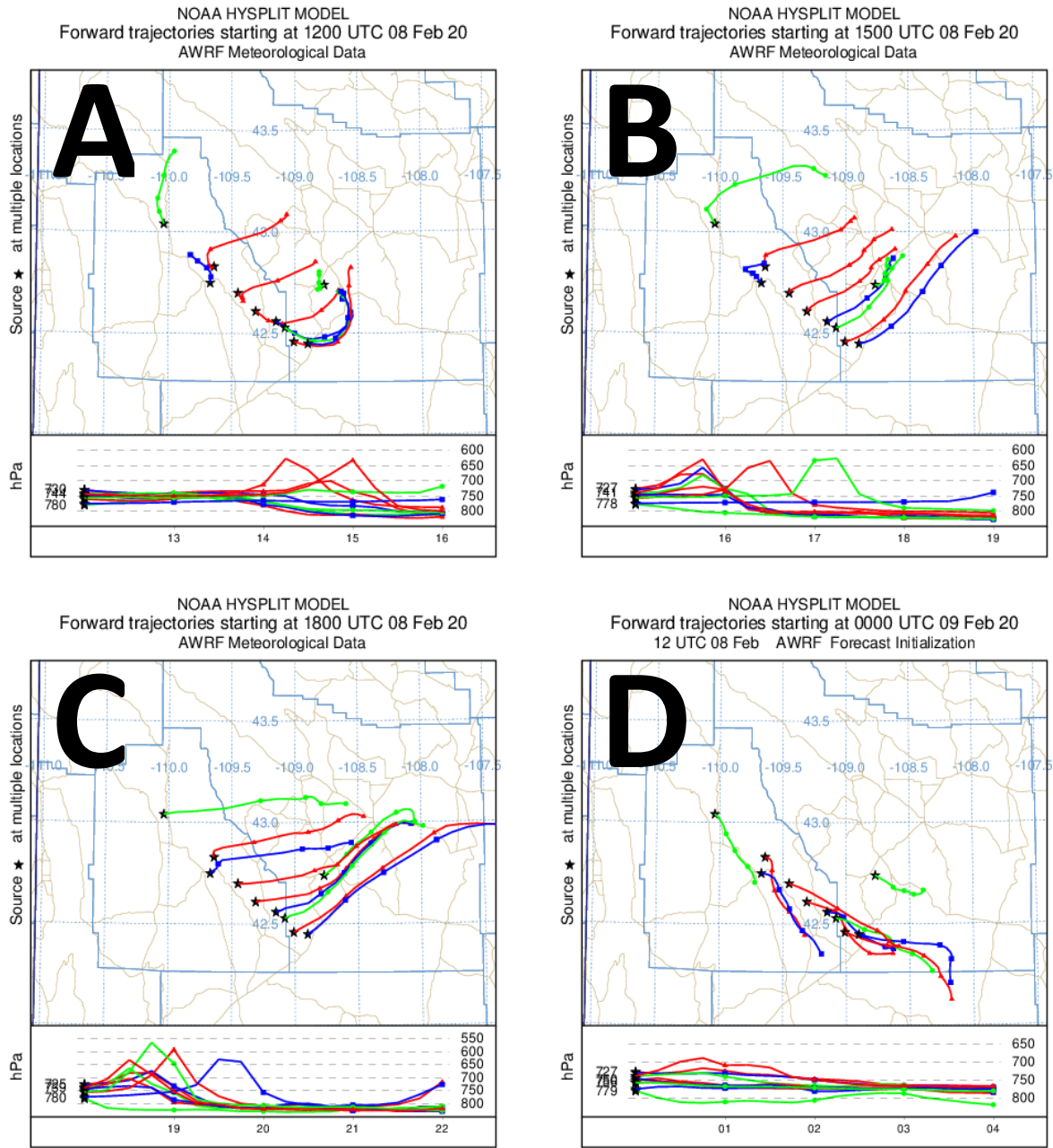


Figure 18. The evolution of the centers of plume trajectories is shown for the seeding event on 8 February 2020. Times (UTC) are as follows: (A) 12:00 February 8th, (B) 15:00 February 8th, (C) 18:00 February 8th, and (D) 0:00 February 9th. Before the seeding began (A), most plumes were projected to remain 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 0:00 UTC (February 9th), a cold front has shifted low 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.



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 |
| <input type="checkbox"/> NO CHANCE | <input type="checkbox"/> NO CHANCE | <input checked="" type="checkbox"/> NO CHANCE | <input checked="" type="checkbox"/> NO CHANCE |
| <input type="checkbox"/> UNLIKELY | <input type="checkbox"/> UNLIKELY | <input type="checkbox"/> UNLIKELY | <input type="checkbox"/> UNLIKELY |
| <input checked="" type="checkbox"/> POSSIBLE | <input type="checkbox"/> POSSIBLE | <input type="checkbox"/> POSSIBLE | <input type="checkbox"/> POSSIBLE |
| <input type="checkbox"/> PROBABLE | <input checked="" type="checkbox"/> PROBABLE | <input type="checkbox"/> PROBABLE | <input type="checkbox"/> PROBABLE |

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Figure 19. First glance outlook issued for 11 December 2020.



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WYOMING WEATHER MODIFICATION PROJECT
DAILY FORECAST
Wind River Mountain Range

WEATHER MODIFICATION INTERNATIONAL

FORECASTER: Jason Goehring

VALID 9 AM December 11, 2020 THROUGH 9 AM December 12, 2020

| | |
|--|--|
| | SYNOPSIS <p>A large broad trough region extends from the PACNW through the Rockies to the Great Plains. The jet stream is south of WY leaving weak flow across the state. A broad low will be coming into the area from the NW tonight and passing through by tomorrow evening. There is a lot of low level moisture around WY today but the flow into the project area will be dropping off this evening. The low coming tonight and tomorrow will be bringing more moisture but it looks like it will not be affecting the project area much except for a little bit of wrap around from the north during the afternoon.</p> |
|--|--|

FORECAST

There are thick clouds over the lowlands around the range with light snowfall at PNA and LND, but the range has had thin cloud coverage. Thicker clouds have started to form over the southern slopes of the range in the past half hour and will continue expanding as the wind develops a better cross barrier flow. Thick orographic clouds with light snowfall and SLW will persist through the afternoon. The wind begins shifting to NW in the later afternoon and looks to become fully parallel to the range in the early evening. This will put an end to the snowfall. Thick mid level clouds will continue through the night, but no snowfall will occur in the project area. Widespread, continuous light snowfall will move into SW WY from the low, but it is not expected to get to the WR range. Light snowfall develops on the northern slopes tomorrow late morning and into the afternoon for a few hours with northerly flow. It looks like the wind will not be quite right for seeding but close. A small ridge comes across Saturday evening through Sunday afternoon, with another system expected Sunday evening.

ACTION: Watching for a little more development before starting seeding, expected to start in the next hr. Seeding should end by 02Z. **Day 2 Outlook ODC: 0**

| WRF MODEL SOUNDING | |
|--------------------|------------------|
| PNA | 00Z, 12 December |
| 0 °C level | N/A |
| -5 °C level | N/A |
| -10 °C level | 8.6 kft |
| -20 °C level | 13.4 kft |
| Precipitable Water | 0.17 inches |
| 700 mb T | -12.6 °C |
| 700 mb wind | 285 @ 15 kts |

| YESTERDAY'S WEATHER | Observed ODC: +1 |
|---|------------------|
| Pinedale: 34/10 Rock Springs: 34/13 Lander: 33/25 South Pass: 32/21 | |
| A shallow but thick stratus cloud deck developed over the Wind River Valley and the northern slopes during the morning and continued through the afternoon. There was no snowfall during the afternoon. Snowfall began after sunset with favorable wind flow existing during the evening. Widespread light snowfall around the region formed after midnight continuing into Friday morning. Snowfall map showed little to no snowfall over the peaks of the range but 1 to 3 inches in some areas around the edges. Seeding with Enterprise GGEN from 0230Z to 0751Z. | |

| 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 20. WMI forecast sheet from 11 December 2020; all forecasts were submitted to the client and the client's distribution list via email daily.



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°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 first determined by consulting the most recent prognostic numerical modeling runs. When such consultation yielded uncertain results, that is, temperatures at 700 hPa were not clearly -6°C or colder, a weather balloon was released from Pinedale, WY (Figure 13), to obtain vertical temperature, humidity, and wind profiles.

The presence of SLW was confirmed by the real-time data from the radiometer (Figure 12) located near Pinedale, WY. The wind speed and direction were obtained from the numerical models, except when atmospheric soundings were done.

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.



4 OPERATIONS

4.1 2020-2021 Season

Project operations began on 15 November 2020, with forecasts and full data collection activities. The first seeding opportunity occurred immediately on 15 November 2020 with four generators being operated. During the season, seeding opportunities were observed on thirty-two occasions, as enumerated in Table 2.

November and had three seeding events, December seven, January five, February six, March seven, and April four. Table 3 summarizes operations by month and provides season totals. In total, 27.914 kg of seeding agent were released. Generators were operated for a total of 262:07 hours during the season, accruing a total of 1057:49 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 seeding events that utilized more than one generator were all quality opportunities that used four to nine generators and were of 3 or more hours in duration. six events were ten hours or longer, and two exceeded twenty hours.



2020-2021 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 |
|------------|-------------------------------|---------------------------|-----------------------|-----------------------------|------------------------|-----------------|---------------------------|
| 11/15/2020 | 4 | 11:10 | 44:35 | 1.146 | 1.971 | 78:07 | 19:31 |
| 11/19/2020 | 5 | 3:22 | 16:22 | 0.430 | | | |
| 11/25/2020 | 4 | 4:59 | 17:10 | 0.395 | | | |
| 12/1/2020 | 1 | 4:53 | 4:53 | 0.113 | 4.052 | 153:41 | 39:18 |
| 12/11/2020 | 1 | 5:24 | 5:24 | 0.134 | | | |
| 12/11/2020 | 8 | 5:46 | 38:55 | 1.050 | | | |
| 12/17/2020 | 4 | 7:42 | 30:48 | 0.834 | | | |
| 12/19/2020 | 5 | 2:19 | 11:11 | 0.254 | | | |
| 12/22/2020 | 6 | 4:11 | 20:32 | 0.509 | | | |
| 12/26/2020 | 5 | 9:03 | 41:58 | 1.157 | | | |
| 1/14/2021 | 7 | 4:00 | 24:08 | 0.695 | 3.649 | 128:03 | 27:37 |
| 1/19/2021 | 1 | 5:07 | 5:07 | 0.112 | | | |
| 1/23/2021 | 6 | 6:13 | 35:07 | 1.019 | | | |
| 1/28/2021 | 5 | 6:58 | 32:54 | 0.950 | | | |
| 1/29/2021 | 8 | 5:19 | 30:47 | 0.873 | | | |
| 2/3/2021 | 7 | 4:40 | 26:31 | 0.695 | 13.991 | 548:42 | 85:37 |
| 2/6/2021 | 7 | 27:03 | 189:14 | 4.704 | | | |
| 2/12/2021 | 9 | 9:19 | 63:15 | 1.594 | | | |
| 2/20/2021 | 4 | 4:25 | 17:36 | 0.472 | | | |
| 2/23/2021 | 6 | 10:59 | 65:54 | 1.710 | | | |
| 2/26/2021 | 7 | 29:11 | 186:12 | 4.815 | | | |
| 3/10/2021 | 1 | 3:17 | 3:17 | 0.096 | 2.912 | 107:25 | 48:13 |
| 3/14/2021 | 1 | 7:57 | 7:57 | 0.208 | | | |
| 3/16/2021 | 1 | 7:06 | 7:06 | 0.173 | | | |
| 3/23/2021 | 1 | 11:26 | 11:26 | 0.223 | | | |
| 3/25/2021 | 6 | 6:20 | 34:22 | 1.020 | | | |
| 3/26/2021 | 1 | 5:39 | 5:39 | 0.127 | | | |
| 3/29/2021 | 6 | 6:28 | 37:38 | 1.065 | | | |

Table 2 continued following page.



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| | | | | | | | |
|---------------|------------------|-------|-------|-------|---------------|----------------|---------------|
| 4/12/2021 | 1 | 4:05 | 4:05 | 0.094 | 1.340 | 41:51 | 41:51 |
| 4/13/2021 | 1 | 4:26 | 4:26 | 0.151 | | | |
| 4/14/2021 | 1 | 8:38 | 8:38 | 0.268 | | | |
| 4/15/2021 | 1 | 24:42 | 24:42 | 0.827 | | | |
| Season | 32 Events | | | | 27.914 | 1057:49 | 262:07 |

Table 2. 2020-2021 List of Seeding Events.



2020-2021 Summary of Seeding Events

| Month | Events () denotes easterly flow | Event Averages | | Seeding Agent (kg) | |
|--|--|-------------------------|---------------------|----------------------------------|-------------------|
| | | Number of Generators | Generator Hours* | Average Released per Event | Total Released |
| November | 3 | 4.3 | 26:02 | 0.657 | 1.971 |
| December | 5 (2) | 4.3 | 21:57 | 0.579 | 4.052 |
| January | 4 (1) | 5.4 | 25:36 | 0.730 | 3.649 |
| February | 6 | 6.7 | 91:27 | 2.332 | 13.991 |
| March | 2 (5) | 2.4 | 15:20 | 0.416 | 2.912 |
| April | 0 (4) | 1.0 | 10:27 | 0.335 | 1.340 |
| Totals/Averages | 20 (12) | 4.1 | 33:03 | 0.872 | 27.914 |
| <i>*Generator Hours = sum of the hours each generator was run for each event, e.g., 4 generators each operated for 3.5 hours = 14 generator hours.</i> | | | | | |

Table 3. Summary of seeding events conducted during the 2020-2021 winter season.

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

Table 4 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.

As Table 4 shows, the problems were scattered among the generators. Four of them, Green River, Big Sandy, Sweetwater, and Anderson Ridge, ran flawlessly the whole season. White Acorn and Boulder Lake each experienced problems (less than a complete run) on more than one occasion. The Block and Tackle, Pocket Creek, Enterprise, and East Fork generators each experienced a single failure.



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Ice Nucleus Generator Operations 2020-2021 Season

| Wind River Range | | WR01 Big Sandy | WR02 Block & Tackle | WR03 White Acorn | WR04 Sweetwater | WR05 Anderson | WR07 Enterprise | WR09 Boulder Lake | WR10 East Fork | WR12 Pocket Creek | WR13 Green River | #Ggens Called | #Ggens Active | |
|------------------|---------|-------------------|------------------------|---------------------|--------------------|------------------|--------------------|----------------------|-------------------|----------------------|---------------------|------------------|------------------|------|
| 20201115 | WRR0124 | REQ | YES | YES | YES | NO | NO | NO | NO | NO | YES | NO | 4 | |
| | | RAN | YES | YES | YES | NO | NO | NO | NO | NO | YES | NO | | 4 |
| 20201119 | WRR0125 | REQ | YES | YES | YES | NO | NO | NO | YES | NO | YES | YES | 6 | |
| | | RAN | YES | YES | NO | NO | NO | NO | YES | NO | YES | YES | | 5 |
| 20201125 | WRR0126 | REQ | YES | NO | NO | NO | NO | NO | YES | YES | YES | NO | 4 | |
| | | RAN | YES | NO | NO | NO | NO | NO | YES | YES | YES | NO | | 4 |
| 20201201 | WRR0127 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | | 1 |
| 20201211 | WRR0128 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | | 1 |
| 20201211 | WRR0129 | REQ | YES | YES | YES | YES | YES | NO | YES | YES | YES | YES | 9 | |
| | | RAN | YES | YES | NO | YES | YES | NO | YES | YES | YES | YES | | 8 |
| 20201217 | WRR0130 | REQ | YES | YES | YES | NO | NO | NO | NO | NO | YES | NO | 4 | |
| | | RAN | YES | YES | YES | NO | NO | NO | NO | NO | YES | NO | | 4 |
| 20201219 | WRR0131 | REQ | YES | YES | YES | NO | NO | NO | YES | NO | YES | NO | 5 | |
| | | RAN | YES | YES | YES | NO | NO | NO | PARTIAL | NO | YES | NO | | 4.75 |
| 20201222 | WRR0132 | REQ | YES | YES | YES | NO | NO | NO | YES | YES | YES | YES | 7 | |
| | | RAN | YES | NO | YES | NO | NO | NO | PARTIAL | YES | PARTIAL | YES | | 5 |
| 20201226 | WRR0133 | REQ | YES | YES | YES | NO | NO | NO | YES | NO | YES | NO | 5 | |
| | | RAN | YES | YES | YES | NO | NO | NO | PARTIAL | NO | YES | NO | | 4.75 |
| 20210114 | WRR0134 | REQ | YES | YES | YES | NO | NO | NO | YES | YES | YES | YES | 7 | |
| | | RAN | YES | YES | YES | NO | NO | NO | YES | YES | YES | YES | | 7 |
| 20210119 | WRR0135 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | | 1 |
| 20210123 | WRR0136 | REQ | YES | YES | YES | NO | NO | NO | YES | YES | YES | NO | 6 | |
| | | RAN | YES | YES | YES | NO | NO | NO | YES | YES | YES | NO | | 6 |
| 20210128 | WRR0137 | REQ | YES | YES | YES | NO | NO | NO | YES | NO | YES | NO | 5 | |
| | | RAN | YES | YES | YES | NO | NO | NO | YES | NO | YES | NO | | 5 |
| 20210129 | WRR0138 | REQ | YES | YES | YES | YES | YES | NO | YES | YES | YES | NO | 8 | |
| | | RAN | YES | YES | YES | YES | YES | NO | YES | YES | YES | NO | | 8 |
| 20210203 | WRR0139 | REQ | YES | YES | YES | NO | NO | NO | YES | YES | YES | YES | 7 | |
| | | RAN | YES | YES | YES | NO | NO | NO | YES | YES | YES | YES | | 7 |
| 20210206 | WRR0140 | REQ | YES | YES | YES | NO | NO | NO | YES | YES | YES | YES | 7 | |
| | | RAN | YES | YES | YES | NO | NO | NO | YES | YES | YES | YES | | 7 |
| 20210212 | WRR0141 | REQ | YES | YES | YES | YES | YES | NO | YES | YES | YES | YES | 9 | |
| | | RAN | YES | YES | YES | YES | YES | NO | YES | YES | YES | YES | | 9 |
| 20210220 | WRR0142 | REQ | YES | NO | NO | NO | NO | NO | YES | NO | YES | YES | 4 | |
| | | RAN | YES | NO | NO | NO | NO | NO | YES | NO | YES | YES | | 4 |
| 20210223 | WRR0143 | REQ | YES | YES | YES | NO | NO | NO | YES | NO | YES | YES | 6 | |
| | | RAN | YES | YES | YES | NO | NO | NO | YES | NO | YES | YES | | 6 |



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| | | | | | | | | | | | | | | |
|-------------------------------------|---------|-----|-----|-----|-----|----|----|---------|-----|-----|-----|--------|--------|--------|
| 20210226 | WRR0144 | REQ | YES | YES | YES | NO | NO | NO | YES | YES | YES | YES | 7 | |
| | | RAN | YES | YES | YES | NO | NO | NO | YES | YES | YES | YES | | 7 |
| 20210310 | WRR0145 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | | 1 |
| 20210314 | WRR0146 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | | 1 |
| 20210316 | WRR0147 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | | 1 |
| 20210323 | WRR0148 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | | 1 |
| 20210325 | WRR0149 | REQ | YES | YES | YES | NO | NO | NO | YES | YES | YES | NO | 6 | |
| | | RAN | YES | YES | YES | NO | NO | NO | YES | YES | YES | NO | | 6 |
| 20210326 | WRR0150 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | | 1 |
| 20210329 | WRR0151 | REQ | YES | YES | YES | NO | NO | NO | YES | YES | YES | YES | 7 | |
| | | RAN | YES | YES | YES | NO | NO | NO | YES | NO | YES | YES | | 6 |
| 20210412 | WRR0152 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | PARTIAL | NO | NO | NO | NO | | 0.25 |
| 20210413 | WRR0153 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | | 1 |
| 20210414 | WRR0154 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | | 1 |
| 20210415 | WRR0155 | REQ | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | 1 | |
| | | RAN | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO | | 1 |
| ZULU DATES ONLY | | | | | | | | | | | | TOTALS | 135 | 128.75 |
| PARTIAL = > 25% of Expected Runtime | | | | | | | | | | | | | RUN = | 95.4% |
| | | | | | | | | | | | | | FAIL = | 4.6% |

Table 4. Ice nucleus generator operations are shown for each of the thirty-two seeding events during the 2020-2021 season.



4.2 Comparisons with Previous Seasons

Comparisons of the five seasons of operational cloud seeding are provided in Tables 5 and 6. In Table 5, 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 6), 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 - 2014-2021 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 |
| Mean | 23:20 | 60:08 | 41:51 | 65:12 | 43:21 | 22:43 | 228:19 |
| *Project was suspended on February 11 th , 2017. | | | | | | | |
| **Project started on December 9 th , 2017, not December 1 st . | | | | | | | |

Table 5. Hour of seeding conducted over the Wind River Range the last six winter seasons.

The 2020-2021 season was unfavorable in terms of the generalized upper-air patterns, largely because of a dominant ridge that remained over the Western U.S. throughout much of the winter. In spite of that, there were some good opportunities, and the total number of seeding hours and generator hours (262:07 and 1057:49, respectively), were both not far from the median values.



Hours of Ice Nucleus Generator Operation - 2014-2021 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 |
| Mean | 70:26 | 319:02 | 238:41 | 344:23 | 181:20 | 37:31 | 1126:09 |
| <i>*Project was suspended on February 11th, 2017.</i> | | | | | | | |
| <i>**Project started on December 9th, 2017, not December 1st.</i> | | | | | | | |

Table 6. Hours of ice nucleus generator operation over the Wind River Range the last six winter seasons.

Since the inception of operational seeding in the Wind River Mountains in the winter of 2014-2015, WMI has significantly improved the guidance available to its meteorological team, especially through numerical modeling products specifically tailored to assist winter orographic cloud seeding. With these tools, we believe we are now more selective in our operational decision-making. We are also more responsive to shorter-term opportunities, and to changing conditions as storms pass. This was again evident for the 2020-2021 season, where a less-favorable storm track resulted in many shorter-duration snowfalls that were seeded, and the operation of the east-slope Enterprise generator a record twelve times.



5 GENERATOR SITE OPTIMIZATION STUDY

In the course of the 2019-2020 project some alternative seeding generator sites were explored, with the intent of relocating the two seldom 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 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 have been selected for use in the 2021-2022 season. Thus, this report is the last that will report any activity from the Anderson Ridge and Sweetwater sites.

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. This season the COVID-19 pandemic was still in progress, so such plans remained shelved for the 2020-2021 season. WMI appreciates being asked to take part in this type of educational outreach and will gladly participate in such events after the pandemic subsides. It is important to WMI to be receptive to requests to educate those showing an interest in our weather modification efforts. WMI looks forward to resuming these activities when it is again safe to do them.



7 SUMMARY

Operations were successfully conducted as planned for the entire 2020-2021 season, despite the ongoing pandemic. Thirty-two seeding events occurred, twenty of which involved multiple ice nucleus generators, activated in westerly or southwesterly flow. The other twelve occurred in easterly or northeasterly flow with the Enterprise generator, sited just south of Lander. The 2020-2021 season became operational on 15 November 2020 and concluded after 15 April 2021. The first seeding event occurred on 15 November 2020. The 2020-2021 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.

Three seeding events occurred in November 2020, seven in December 2020, 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 72% of the median annual value to 102%, with the five-site SNOTEL mean at just 82% of the long-term median value. Only the Townsend Creek site ended above seasonal norm, whereas the rest varied between 72% and 81% of the 30-year median annual value.



Figure 21. A snow shower passes over the range on 01 December 2020. Photo by WMI Meteorologist Jeff Ceratto.

The thirty-two seeded storm events lasted a total of 262:07 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 1057:49 hours. The seeding rate was approximately 25 grams of silver iodide per generator, per hour, throughout the season.

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 2020-2021 season, atmospheric soundings were only performed at times when the temperature and/or wind was questionable. One or more weather balloons were released during only 7 of the 32 seeding events. (No soundings were needed for 25 seeding events.) 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.



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In spite of the generally unfavorable weather patterns, the number of hours during which seeding was conducted and the cumulative number of hours seeded by all generators were both close to the eight-season project median values.

The 2020-2021 winter was the final season for the Sweetwater and Anderson Ridge generators. These two generators were relocated to new sites, farther north, in the fall of 2021, and will be operated under new names, Willow Lake and Highland, for the 2021-2022 season.



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. |



9 REFERENCES

- Breed, D., R. Rasmussen, C. Weeks, B. Boe, and T. Deshler, 2014: Evaluating winter orographic cloud seeding: Design of the Wyoming Weather Modification Pilot Project (WWMPP), *J. Appl. Meteor. Climatol.*, **53**, 282-299.
- DeMott, P.J., 1997: Report to the North Dakota Atmospheric Resource Board and Weather Modification Incorporated on Tests of the Ice Nucleating Ability of Aerosols Produced by the Lohse Airborne Generator, 1997: Cloud Simulation and Aerosol Laboratory, Colorado State University, Fort Collins, CO, USA. 14 p.
- Rasmussen, R.M., S.A. Tessendorf, L. Xue, C. Weeks, K. Ikeda, S. Landolt, D. Breed, T. Deshler, and B. Lawrence, 2018: Evaluation of the Wyoming Weather Modification Pilot Project (WWMPP) Using Two Approaches: Traditional Statistics and Ensemble Modeling. *J. Appl. Meteor. Climatol.*, **57**, 2639-2660.



Appendix A. Daily Operations Summaries

| Wyoming Weather Modification Program - Wind River Mountains 2020-2021 Season – WMI Daily Project Summary Week 1: 15 November, 2020 – 15 April, 2021 | |
|---|---|
| 15 November 2020, Sunday | |
| <p>Thin clouds over the range in the morning thickened after noon. Favorable seeding conditions persisted through the afternoon and evening, as the temperature did not warm as expected. The heaviest snowfall occurred in the late afternoon and evening. The clouds thinned overnight. Most of the range received 2 to 4 inches snowfall, with the highest elevations receiving 6 to 8 inches.</p> <p>Max/Min temperatures Pinedale: 30/12 Rock Springs: 38/20 Lander: 54/15 South Pass: 30/10 Observed ODC: +2</p> | <p>Seeding event WRR0124 was called at 1230 MST on 11/15/2020 and began at 1240 MST.</p> <p>WRR0124 Summary: Generators: WR01, WR02, WR03, WR12. Time: 1240 (11/15) to 2350 (11/15) MST 1940 (11/15) to 0650 (11/16) UTC Duration: 44:35 Total Time Seeding Material: 18.84 gallons (1114.75 grams)</p> |
| 16 November 2020, Monday | |
| <p>Thick clouds with scattered snow showers existed over the range from mid morning to mid afternoon. The temperature was too warm for seeding operations. By sunset, the clouds were very shallow with minimal coverage of the range. Some mid level clouds existed overnight. Most of the snowfall was on the SW slopes, amounting to 0.5 to 2 inches.</p> <p>Max/Min temperatures Pinedale: 43/21 Rock Springs: 51/31 Lander: 53/26 South Pass: 39/28 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| 17 November 2020, Tuesday | |
| <p>Clear skies until the mid afternoon when some high clouds moved into the area and an arch cloud formed on the NE side of the range. High clouds continued to pass through the area with mid level clouds coming during the night. Low clouds had begun forming over the range early Wednesday morning.</p> <p>Max/Min temperatures Pinedale: 48/12 Rock Springs: 56/24</p> | <p>No ground-based seeding was conducted.</p> |



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| Lander: 62/29 South Pass: 46/30 Observed ODC: -1 | |
| <p>18 November 2020, Wednesday</p> | |
| <p>Snowfall over the range became more widespread and continuous in the early afternoon and continued the rest of the period. The temperature was much too warm for seeding operations. Snowfall map showed most of the range received 1 to 3 inches, with some areas over 6 inches. The temperature did finally cool enough to allow for seeding operations by 14Z Thursday morning.</p> <p>Max/Min temperatures Pinedale: 45/27 Rock Springs: 56/35 Lander: 66/40 South Pass: 45/32 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>19 November 2020, Thursday</p> | |
| <p>Continued orographic cloud coverage over the range from Wednesday. Favorable seeding conditions existed during the morning hours, but by late morning the cloud was broken in coverage. Shallow, broken orographic cloud and areas of light snowfall persisted over the range through the afternoon, but it wasn't consistent enough to warrant seeding operations. The clouds slowly diminished throughout the evening hours, with clear skies overnight. Most of the snowfall fell on the NE slopes, amounting to 1 to 2 inches with an area on the NW part of the range receiving over 5 inches.</p> <p>Max/Min temperatures Pinedale: 34/19 Rock Springs: 41/25 Lander: 48/24 South Pass: 32/25 Observed ODC: +1</p> | <p>Seeding event WRR0125 was called at 0708 MST on 11/19/2020 and began at 0735 MST.</p> <p>WRR0125 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13. Time: 0735 (11/19) to 1057 (11/19) MST 1435 (11/19) to 1757 (11/19) UTC Duration: 16:22 Total Time Seeding Material: 7.07 gallons (395.75 grams)</p> |
| <p>20 November 2020, Friday</p> | |
| <p>Skies were clear across the Wind River Range. Modest NW winds were recorded at PNA ranging from 5 to 10 mph. A trace amount of snow was observed in the NW region of the range, but likely accumulated before the issuance of yesterday's forecast when skies became clear. Otherwise, no precipitation occurred.</p> <p>Max/Min temperatures</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>Pinedale: 32/5 Rock Springs: 38/21 Lander: 43/19 South Pass: 30/19 Observed ODC: -3</p> | |
| <p>21 November 2020, Saturday</p> | |
| <p>Clear skies prevailed throughout the forecast period. Winds at PNA were out of the NW between 5 and 10 mph with a breezy period in the afternoon where winds were between 10 and 15 mph. No clouds were observed in the project area.</p> <p>Max/Min temperatures Pinedale: 34/1 Rock Springs: 39/12 Lander: 46/12 South Pass: 34/21 Observed ODC: -3</p> | <p>No ground-based seeding was conducted.</p> |
| <p>22 November 2020, Sunday</p> | |
| <p>Clear skies were present during the morning, becoming partly cloudy during the afternoon as upper-level clouds moved over the area. Overnight, skies partially cleared with occasional patches of high cloud passing and lenticular clouds observed above the peaks. Winds at PNA were generally out of the NW at 5-10 kts with a period of light and variable winds during midday.</p> <p>Max/Min temperatures Pinedale: 37/-2 Rock Springs: 37/9 Lander: 37/13 South Pass 34/7 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>23 November 2020, Monday</p> | |
| <p>Partly cloudy skies mid-day become mostly cloudy during the late afternoon with periods of mountain obscuration, but for the most part cloud bases remained above the peaks. Cloud cover began to break up during the evening and skies cleared by 1AM. Pinedale saw winds out of the WNW at 5-10kts in the morning, with calm winds for much of the afternoon, then a return of WNW winds near 10kts through the evening and overnight.</p> <p>Max/Min temperatures Pinedale: 36/3 Rock Springs: 34/15</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>Lander: 43/16 South Pass: 34/19 Observed ODC: -1</p> | |
| <p>24 November 2020, Tuesday</p> | |
| <p>Clear skies under a high pressure ridge. Wind flow during the afternoon was a little strong and gusty.</p> <p>Max/Min temperatures Pinedale: 32/12 Rock Springs: 34/17 Lander: 43/19 South Pass: 30/19 Observed ODC: -3</p> | <p>No ground-based seeding was conducted.</p> |
| <p>25 November 2020, Wednesday</p> | |
| <p>Orographic cloud began developing over the NW part of the range around noon. The cloud spread down the range during the afternoon and thickened by the mid afternoon. Favorable seeding conditions existed for a few hours until the wind shifted to the NW in the early evening and the cloud weakened. There were short periods of low clouds during the night with clear skies by Thursday morning. Snowfall map showed 1 to 2 inches of snow fell on the range.</p> <p>Max/Min temperatures Pinedale: 32/3 Rock Springs: 41/18 Lander: 44/15 South Pass: 32/18 Observed ODC: +1</p> | <p>Seeding event WRR0126 was called at 1523 MST on 11/25/2020 and began at 1534 MST.</p> <p>WRR0126 Summary: Generators: WR01, WR09, WR10, WR12. Time: 1534 (11/25) to 2033 (11/25) MST 2234 (11/25) to 0333 (11/26) UTC Duration: 17:10 Total Time Seeding Material: 6.49 gallons (429 grams)</p> |
| <p>26 November 2020, Thursday</p> | |
| <p>The sky was clear for the majority of the area, but small, low clouds existed over the far NW corner of the range during the afternoon. Some flurries occurred but no significant accumulation. A very few high clouds started coming into the area during the night.</p> <p>Max/Min temperatures Pinedale: 28/5 Rock Springs: 32/15 Lander: 39/16 South Pass: 28/14 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>27 November 2020, Friday</p> | |



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| <p>Mostly clear skies apart from thin high cirrus out of the north-northeast. No low clouds or precipitation were observed. KPNA largely saw calm winds, with occasional 'gusts' out of the NW at 7mph, especially overnight</p> <p>Max/Min temperatures Pinedale: 34/1 Rock Springs: 33/13 Lander: 40/11 South Pass: 28/7 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>28 November 2020, Saturday</p> | |
| <p>A cold start to the day in PNA but temperatures warmed into the low 40s. There were a few areas of high and mid level clouds around during the daytime. More consistent mid level clouds moved through with a cold front during the late evening and early nighttime hours. The sky was clear by Sunday morning.</p> <p>Max/Min temperatures Pinedale: 43/0 Rock Springs: 41/16 Lander: 42/12 South Pass: 46/28 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>29 November 2020, Sunday</p> | |
| <p>Another cold morning in PNA and high temperatures around the region were a few degrees cooler than previous days. Clear skies throughout the period.</p> <p>Max/Min temperatures Pinedale: 34/1 Rock Springs: 37/17 Lander: 41/18 South Pass: 32/19 Observed ODC: -3</p> | <p>No ground-based seeding was conducted.</p> |
| <p>30 November 2020, Monday</p> | |
| <p>There were a few mid level clouds around in the late morning, then clear skies for a few hours and more mid level clouds in the late afternoon. Low clouds with light snowfall began forming over the NW part of the range a few hours after sunset and expanded down the range through the evening. The clouds moved away a little after midnight. The wind was not favorable for seeding operations. Snowfall map showed 1 to 2 inches fell on most of the range.</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>Max/Min temperatures Pinedale: 34/-2 Rock Springs: 40/8 Lander: 43/9 South Pass: 36/23 Observed ODC: 0</p> | |
| <p>01 December 2020, Tuesday</p> | |
| <p>A stratus cloud deck first developed over the Wind River Valley and northern slopes during the morning, but this diminishing in the early afternoon. A few hours later, the cloud deck redeveloped and became thicker. Snowfall began a little before sunset as the wind became more favorable for orographic forcing over the range. Snowfall continued during the evening and most of the night, but the wind was only favorable for seeding for a few hours in the evening. The clouds quickly diminished early Wednesday morning. Snowfall map showed a good portion of the northern slopes received 6 to 10 inches</p> <p>Max/Min temperatures Pinedale: 32/5 Rock Springs: 31/16 Lander: 39/21 South Pass: 27/16 Observed ODC: +1</p> | <p>Seeding event WRR0127 was called at 1637 MST on 12/01/2020 and began at 1640 MST.</p> <p>WRR0127 Summary: Generators: WR07. Time: 1640 (12/01) to 2133 (12/01) MST 2340 (12/01) to 0433 (12/02) UTC Duration: 4:53 Total Time Seeding Material: 1.85 gallons (122 grams)</p> |
| <p>02 December 2020, Wednesday</p> | |
| <p>A very few low clouds were over the peaks of the range and the southern slopes during the morning, diminishing a little after noon. Clear skies the rest of the day.</p> <p>Max/Min temperatures Pinedale: 27/0 Rock Springs: 25/8 Lander: 29/10 South Pass: 32/12 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>03 December 2020, Thursday</p> | |
| <p>Clear skies. The wind was generally less than 7 mph.</p> <p>Max/Min temperatures Pinedale: 34/-6 Rock Springs: 32/5 Lander: 29/3 South Pass: 41/27</p> | <p>No ground-based seeding was conducted.</p> |



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| Observed ODC: -3 | |
| 04 December 2020, Friday | |
| <p>Clear skies with winds generally light and northwesterly.</p> <p>Max/Min temperatures Pinedale: 43/0 Rock Springs: 40/9 Lander: 34/8 South Pass: 45/30 Observed ODC: -3</p> | No ground-based seeding was conducted. |
| 05 December 2020, Saturday | |
| <p>Clear skies during the day with NW winds around 5 to 10 mph at PNA. A thin cloud layer developed above the range overnight but withered by midnight. No precipitation was observed across the project area.</p> <p>Max/Min temperatures Pinedale: 45/3 Rock Springs: 42/8 Lander: 36/11 South Pass: 43/32 Observed ODC: -3</p> | No ground-based seeding was conducted. |
| 06 December 2020, Sunday | |
| <p>Continued clear skies and wind less than 10 mph.</p> <p>Max/Min temperatures Pinedale: 43/3 Rock Springs: 44/10 Lander: 38/11 South Pass: 46/34 Observed ODC: -3</p> | No ground-based seeding was conducted. |
| 07 December 2020, Monday | |
| <p>Clear skies except for a few isolated high clouds in the late evening and overnight.</p> <p>Max/Min temperatures Pinedale: 43/1 Rock Springs: 41/5 Lander: 37/6 South Pass: 46/34 Observed ODC: -3</p> | No ground-based seeding was conducted. |
| 08 December 2020, Tuesday | |



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| <p>Clear skies over the range during the daylight, though there were high clouds close to the area. An area of mid level clouds formed over the range just before midnight and existed for a short time before moving off to the NE.</p> <p>Max/Min temperatures Pinedale: 48/7 Rock Springs: 46/16 Lander: 41/11 South Pass: 50/41 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>09 December 2020, Wednesday</p> | |
| <p>A few mid level clouds were around in the morning, then the sky was clear for a few hours. High clouds began moving in from the SW during the afternoon. High and a few mid level clouds continued to flow through during the night. The wind was generally less than 10 mph, except at South Pass when it switched to north and increased during the night.</p> <p>Max/Min temperatures Pinedale: 45/7 Rock Springs: 48/16 Lander: 45/19 South Pass: 46/32 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>10 December 2020, Thursday</p> | |
| <p>A shallow but thick stratus cloud deck developed over the Wind River Valley and the northern slopes during the morning and continued through the afternoon. There was no snowfall during the afternoon. Snowfall began after sunset with favorable wind flow existing during the evening. Widespread light snowfall around the region formed after midnight continuing into Friday morning. Snowfall map showed little to no snowfall over the peaks of the range but 1 to 3 inches in some areas around the edges.</p> <p>Max/Min temperatures Pinedale: 34/10 Rock Springs: 34/13 Lander: 33/25 South Pass: 32/21 Observed ODC: +1</p> | <p>Seeding event WRR0128 was called at 1922 MST on 12/10/2020 and began at 1927 MST.</p> <p>WRR0128 Summary: Generators: WR07. Time: 1927 (12/10) to 0051 (12/11) MST 0227 (12/11) to 0751 (12/11) UTC Duration: 5:24 Total Time Seeding Material: 2.21 gallons (135 grams)</p> |
| <p>11 December 2020, Friday</p> | |
| <p>Orographic clouds began forming over the southern slopes of the range in the late morning and expanded enough to</p> | <p>Seeding event WRR0129 was called at 1235 MST on 12/11/2020 and began at 1241 MST.</p> |



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| <p>allow for seeding conditions after noon. Favorable seeding conditions continued through the afternoon with the wind gradually changing to NW. The low clouds diminished once the wind switched after sunset. An area of mid level clouds moved into SW WY overnight. Snowfall map showed most of the range received about 1 inch with a small area of 2 to 3 inches</p> <p>Max/Min temperatures Pinedale: 27/-4 Rock Springs: 28/13 Lander: 26/8 South Pass: 21/12 Observed ODC: +1</p> | <p>WRR0129 Summary: Generators: WR01, WR02, WR03, WR04, WR05, WR09, WR10, WR12, WR13. Time: 1241 (12/11) to 1827 (12/11) MST 1941 (12/11) to 0127 (12/12) UTC Duration: 5:46, 38:52 Total Time Seeding Material: 17.26 gallons (973.5 grams)</p> |
| <p><i>12 December 2020, Saturday</i></p> | |
| <p>Skies over the valley were mostly clear yesterday with orographic clouds covering the mountains during the day. The orographic clouds dissipated overnight revealing clear skies throughout the project area. Upper-level clouds returned by daybreak. Winds at PNA were generally out of the NW at around 5 to 10 mph with a short-lived breezy period around sunset when winds were around 20 mph. Only a trace amount of snow fell in the mountains with observed LW unresponsive of seeding.</p> <p>Max/Min temperatures Pinedale: 21/-11 Rock Springs: 23/4 Lander: 22/4 South Pass: 16/9 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p><i>13 December 2020, Sunday</i></p> | |
| <p>Scattered mid and upper level clouds around the area during the daylight hours. Low clouds started forming over the southern slopes around sunset, then widespread light snowfall beginning during the evening and continuing through the night into Monday morning. SLW was spotty and the wind flow was not favorable for proper plume transport over the range, so no seeding occurred. Snowfall map showed 0.5 to 2 inches, with a small area up to 5 inches.</p> <p>Max/Min temperatures Pinedale: 21/-13 Rock Springs: 23/3 Lander: 18/2 South Pass: 25/9</p> | <p>No ground-based seeding was conducted.</p> |



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| Observed ODC: 0 | |
| 14 December 2020, Monday | |
| <p>Slightly broken, thick clouds were over the area from the morning through the early evening hours. Snowfall was scattered to broken in coverage and mainly occurred on the edges of the range as the wind did not have much cross barrier flow. Snowfall map showed 2 to 4 inches on the SW slopes and a small area of 4 to 6 inches on the NE corner of the range. Shallow clouds lingered over the PNA through the night while the rest of the cloud coverage cleared. No seeding occurred as the wind was not favorable for seeding operations.</p> <p>Max/Min temperatures Pinedale: 25/5 Rock Springs: 22/15 Lander: 25/7 South Pass: 23/18 Observed ODC: 0</p> | No ground-based seeding was conducted. |
| 15 December 2020, Tuesday | |
| <p>Broken mid level clouds moved into the area from the NW during the afternoon. Low clouds formed in the early evening hours and continued through the night. Scattered areas of very light snowfall existed, mainly over the southern slopes. By Wednesday morning, shallow low clouds were confined to the southern slopes. Snowfall map showed less than 1 inch accumulation.</p> <p>Max/Min temperatures Pinedale: 21/-6 Rock Springs: 23/9 Lander: 29/12 South Pass: 23/10 Observed ODC: 0</p> | No ground-based seeding was conducted. |
| 16 December 2020, Wednesday | |
| <p>Shallow low clouds were over the SW slopes of the range in the morning, and then the clouds slowly diminished throughout the afternoon. There were a few areas of light snowfall, but snowfall map showed accumulation was less than 1 inch. Widespread upper and mid level clouds moved in from the west after midnight. Thick low clouds with light snowfall and some SLW started forming over the range right around sunrise Thursday morning</p> <p>Max/Min temperatures</p> | No ground-based seeding was conducted. |



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| <p>Pinedale: 30/1 Rock Springs: 30/19 Lander: 40/12 South Pass: 28/16 Observed ODC: 0</p> | |
| <p>17 December 2020, Thursday</p> | |
| <p>Thick clouds with light snowfall had formed over the range a little before sunrise. The wind flow was not right for proper plume transport until mid day. Favorable seeding conditions with widespread moderate snowfall continued through the afternoon into the early evening. The wind shifted to NW in the evening and the conditions deteriorated. Most of the clouds left the area during the night except for some shallow clouds over the southern tip. Snowfall map showed most of the southern slopes received 3 to 5 inches with a small area over 6 inches.</p> <p>Max/Min temperatures Pinedale: 27/3 Rock Springs: 29/14 Lander: 29/15 South Pass: 30/12 Observed ODC: +2</p> | <p>Seeding event WRR0130 was called at 1130 MST on 12/17/2020 and began at 1135 MST.</p> <p>WRR0130 Summary: Generators: WR01, WR02, WR03, WR12 Time: 1135 (12/17) to 1917 (12/17) MST 1835 (12/17) to 0217 (12/18) UTC Duration: 7:42, 30:48 Total Time Seeding Material: 13.71 gallons (770 grams)</p> |
| <p>18 December 2020, Friday</p> | |
| <p>Shallow low clouds mainly on the southern edge of the range in the morning diminished shortly after noon. Scattered mid level clouds were around the rest of the afternoon and evening. A band of low and mid level clouds moved through during the night, but no snowfall occurred until around sunrise. The wind flow was not favorable for seeding during the night. Snowfall map showed a dusting of snowfall with a small area of 3 to 8 inches, but that occurred in the early morning. No seeding occurred.</p> <p>Max/Min temperatures Pinedale: 27/9 Rock Springs: 28/15 Lander: 36/17 South Pass: 27/18 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>19 December 2020, Saturday</p> | |
| <p>The Wind River Range was enshrouded with orographic clouds, though only receiving a trace amount of SWE accumulation. Light snow fell in the basin in the morning before stopping for the remainder of the day. Trajectories</p> | <p>Seeding event WRR0131 was called at 0830 MST on 12/19/2020 and began at 0834 MST.</p> <p>WRR0131 Summary:</p> |



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| <p>and SLW were favorable for a short period in the morning. After the snow cleared, skies over the basin were partly clear with mid-level clouds moving through intermittently. Winds at PNA were from the NW at 5 to 15 mph and became calm overnight as skies cleared. Orographic clouds persisted through the night.</p> <p>Max/Min temperatures Pinedale: 27/9 Rock Springs: 30/20 Lander: 40/15 South Pass: 28/12 Observed ODC: +1</p> | <p>Generators: WR09, WR12 Time: 0834 (12/19) to 1110 (12/19) MST 1534 (12/19) to 1810 (12/19) UTC</p> <p>WR01, WR02, WR03 Time: 0851 (12/19) to 1110 (12/19) MST 1551 (12/19) to 1810 (12/19) UTC Duration: 2:19, 11:11 Total Time Seeding Material: 4.18 gallons (280 grams)</p> |
| <p><i>20 December 2020, Sunday</i></p> | |
| <p>Thick but shallow clouds started forming over the southern slopes of the range in the early afternoon. These clouds continued the rest of the period into Monday. Overall snowfall was very low as the snowfall map showed less than 1 inch fell. The wind flow was not favorable for seeding operations throughout the whole period.</p> <p>Max/Min temperatures Pinedale: 34/9 Rock Springs: 37/23 Lander: 43/19 South Pass: 34/19 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p><i>21 December 2020, Monday</i></p> | |
| <p>Thick but shallow clouds were over the range from the morning through mid evening. Snowfall was very limited, as the snowfall map showed only a few areas received any and it was less than 1 inch. Warm temperature and generally unfavorable wind flow precluded any seeding operations. The clouds were mostly thin overnight but started to redevelop early Tuesday morning.</p> <p>Max/Min temperatures Pinedale: 37/18 Rock Springs: 47/28 Lander: 53/23 South Pass: 34/28 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p><i>22 December 2020, Tuesday</i></p> | |
| <p>Thick clouds developed over the range in the morning. Once the temperature cooled after noon, favorable seeding</p> | <p>Seeding event WRR0132 was called at 1225 MST on 12/22/2020 and began at 1233 MST.</p> |



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| <p>conditions existed during the afternoon. The wind became NW and parallel to the range just before sunset. Snowfall was generally light. The clouds thinned during the evening but small clouds continued through the night along with mid level clouds. Snowfall map showed most of the range received 1 to 3 inches with a small area over 6 inches on the SE edge.</p> <p>Max/Min temperatures Pinedale: 32/9 Rock Springs: 40/15 Lander: 52/20 South Pass: 34/10 Observed ODC: +1</p> | <p>WRR0132 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13. Time: 1233 (12/22) to 1644 (12/22) MST 1933 (12/22) to 2344 (12/22) UTC Duration: 4:11, 20:32 Total Time Seeding Material: 8.37 gallons, (513.25 grams)</p> |
| <p>23 December 2020, Wednesday</p> | |
| <p>There were shallow, thin low clouds around parts of the range during the morning. Those clouds had diminished by noon. There were periods of high clouds passing through the rest of the day. No snowfall occurred.</p> <p>Max/Min temperatures Pinedale: 19/3 Rock Springs: 21/8 Lander: 27/13 South Pass: 21/5 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>24 December 2020, Thursday</p> | |
| <p>Skies were clear during the daylight hours before some high clouds moved in overnight. Winds were from the SE at 5 to 10 mph before shifting to the NW after sunset. No snow fell throughout the day.</p> <p>Max/Min temperatures Pinedale: 27/0 Rock Springs: 34/12 Lander: 35/13 South Pass: 37/5 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>25 December 2020, Friday</p> | |
| <p>The project area saw mostly clear skies during the day with a few passing high clouds. Skies were mostly clear after sunset before occasional mid-level clouds began advecting into the area from the west around 10PM. Mid- and low-level cloud cover became more prominent by daybreak. No</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>snow fell. Winds were generally from the NW around 5 mph at PNA.</p> <p>Max/Min temperatures Pinedale: 30/-6 Rock Springs: 36/11 Lander: 32/11 South Pass: 41/25 Observed ODC: -1</p> | |
| <p>26 December 2020, Saturday</p> | |
| <p>Thick clouds had started developing over the range in the early morning. The wind flow and temperature were not right for seeding until mid day and the coverage was not continuous during the morning either. Thick clouds continued over the range for the afternoon and most of the evening with favorable seeding conditions. By late evening the wind had shifted to NW. Scattered to broken low clouds persisted through the night with areas of light snowfall. Snowfall map showed a good portion of the range received 2 to 5 inches.</p> <p>Max/Min temperatures Pinedale: 28/12 Rock Springs: 34/13 Lander: 44/15 South Pass: 32/21 Observed ODC: +2</p> | <p>Seeding event WRR0133 was called at 1155 MST on 12/26/2020 and began at 1203 MST.</p> <p>WRR0133 Summary: Generators: WR01, WR02, WR03, WR09, WR12. Time: 1203 (12/26) to 2106 (12/26) MST 1903 (12/26) to 0406 (12/27) UTC Duration: 19:03, 42:58 Total Time Seeding Material: 19.02 gallons (1074 grams)</p> |
| <p>27 December 2020, Sunday</p> | |
| <p>Almost all the clouds from Saturday had diminished in the morning. Scattered, small low clouds existed around the edges of the range during the afternoon with no consistent coverage. Those clouds diminished shortly after sunset, then high and mid level clouds moved in during the night. Snowfall map showed some areas received 0.5 to 2 inches, but most of that occurred in the early morning.</p> <p>Max/Min temperatures Pinedale: 28/-6 Rock Springs: 32/13 Lander: 36/17 South Pass: 27/18 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>28 December 2020, Monday</p> | |
| <p>A large storm system moved up into WY from the SW during the morning and afternoon, however it just skimmed the</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>area and only brought widespread high and mid level cloud coverage to the project area. No snowfall fell in the WR region from this system.</p> <p>Max/Min temperatures Pinedale: 19/-11 Rock Springs: 19/5 Lander: 23/10 South Pass: 19/12 Observed ODC: -2</p> | |
| <p>29 December 2020, Tuesday</p> | |
| <p>Clear skies during the daylight hours and the evening. A few areas of high and mid level clouds started coming through during the night and continued into Wednesday. At PNA after 1 pm, the wind shifted from light SE to WNW around 15 mph with gusts over 20.</p> <p>Max/Min temperatures Pinedale: 27/-13 Rock Springs: 22/6 Lander: 32/5 South Pass: 23/14 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>30 December 2020, Wednesday</p> | |
| <p>Scattered to broken mid level clouds were around for most of the day. Thin low clouds existed during the afternoon and evening hours, but no consistent coverage. Snowfall map showed no snowfall in the WR range but the mountains to the west received a small amount.</p> <p>Max/Min temperatures Pinedale: 27/-4 Rock Springs: 28/11 Lander: 32/7 South Pass: 25/18 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>31 December 2020, Thursday</p> | |
| <p>Areas of mid level clouds were around during the daylight hours then completely diminished by mid evening. Some small, low clouds existed during the morning with minimal coverage. The sky was clear overnight.</p> <p>Max/Min temperatures Pinedale: 30/0 Rock Springs: 29/16</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>Lander: 35/17 South Pass: 32/18 Observed ODC: -1</p> | |
| 01 January 2021, Friday | |
| <p>Clear skies during the morning and afternoon. A few upper level clouds passed through in the evening. Mid level cloud coverage increased throughout the night with shallow low clouds beginning to form a little before sunrise. No snowfall occurred.</p> <p>Max/Min temperatures Pinedale: 27/-6 Rock Springs: 27/7 Lander: 33/11 South Pass: 32/18 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| 02 January 2021, Saturday | |
| <p>Partly cloudy skies with a low stratus cloud covered the peaks from morning through evening. Some snow fell in the project area, but little accumulation occurred. Clouds mostly cleared overnight until 3AM when a low stratus deck covered the region again. Winds were generally light from the WNW at PNA. There was some LW on the radiometer until just after 1PM when it became flat. LW returned by 3AM and was spiking by Monday morning, but trajectories never became favorable.</p> <p>Max/Min temperatures Pinedale: 27/-6 Rock Springs: 32/11 Lander: 41/9 South Pass: 31/18 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| 03 January 2021, Sunday | |
| <p>Orographic clouds blanketed the range during the day as with intermittent light snow in the valley. Skies were mostly cloudy south of the Wind River Range with little snow accumulation. Winds at PNA were generally from the NW at 5 to 15 mph. LW was detected at the radiometer until 3Z, but trajectories were never favorable for seeding. Cloud bases lifted overnight with high clouds lingering by morning. The Big Sandy Opening and Elkhart Park SNOTEL sites saw about a 0.1" increase of SWE.</p> <p>Max/Min temperatures</p> | <p>No ground-based seeding was conducted.</p> |



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| Pinedale: 30/3 Rock Springs: 32/11 Lander: 42/15 South Pass: 30/16 Observed ODC: 0 | |
| <p>04 January 2021, Monday</p> | |
| <p>Increasing cloud coverage during the daylight hours. Low clouds began forming in the mid afternoon with snowfall beginning shortly before sunset. Thick low clouds with SLW and continuous snowfall persisted the rest of the period. The temperature was slightly too warm for seeding during the evening and a shallow stable layer prevented proper seeding plume transport over the range during the night. No seeding occurred. Snowfall map showed most of the range received 3 to 5 inches.</p> <p>Max/Min temperatures Pinedale: 27/0 Rock Springs: 35/18 Lander: 39/17 South Pass: 30/14 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>05 January 2021, Tuesday</p> | |
| <p>Thick low clouds were covering a good portion of the range in the morning, but by mid day coverage was decreasing. A small area of clouds remained over the SE part of the range for most of the afternoon. The sky was clear the rest of the period except for a few high clouds. The wind was not favorable for seeding at any point. Snowfall map showed most of the range received less than 2 inches.</p> <p>Max/Min temperatures Pinedale: 30/1 Rock Springs: 30/16 Lander: 37/21 South Pass: 30/18 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>06 January 2021, Wednesday</p> | |
| <p>High clouds with a few mid level clouds during the daylight and evening hours. A few waves of low clouds passed through the region during the night. Snowfall map showed no accumulation.</p> <p>Max/Min temperatures Pinedale: 28/1</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>Rock Springs: 31/11 Lander: 34/14 South Pass: 41/19 Observed ODC: -1</p> | |
| <p>07 January 2021, Thursday</p> | |
| <p>Shallow, broken low clouds moved into the area shortly after sunrise. Thicker clouds moved through during the afternoon bringing a short period of moderate snowfall. The wind was not favorable for seeding operations and the radiometer only showed LW during the morning. The clouds cleared during the evening. Snowfall map showed only 0.5 to 2 inches accumulation.</p> <p>Max/Min temperatures Pinedale: 30/3 Rock Springs: 34/11 Lander: 37/17 South Pass: 34/18 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>08 January 2021, Friday</p> | |
| <p>Clear sky during the daylight hours, except for a few small low clouds over the southern tip in the early afternoon. High clouds moved into the area from the SW around sunset and continued through the night. A stratus cloud deck moved towards the range from the NE a little before sunrise.</p> <p>Max/Min temperatures Pinedale: 27/-9 Rock Springs: 30/8 Lander: 36/15 South Pass: 25/16 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>09 January 2021, Saturday</p> | |
| <p>Skies were clear during the day to the SW of the Winds, but a mid-level cloud layer persisted through the day on the east side in Lander. As skies cleared after sunset in the east, thin low clouds moved over PNA before clearing by daybreak. Areas of fog developed close to sunrise as well in the basin but quickly lifted. LW was never recorded on the radiometer and trajectories were never favorable from any GGEN.</p> <p>Max/Min temperatures Pinedale: 25/-9 Rock Springs: 24/10</p> | <p>No ground-based seeding was conducted.</p> |



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| Lander: 30/12 South Pass: 23/14 Observed ODC: -1 | |
| 10 January 2021, Sunday | |
| The project area saw clear skies during the day with NW winds around 5 mph at PNA. A layer of isolated high clouds briefly passed over the Winds after midnight but mostly cleared by morning with lingering clouds near South Pass. No LW was measured on the radiometer and no precipitation fell in the range or in the basin. Max/Min temperatures Pinedale: 25/-13 Rock Springs: 26/7 Lander: 26/8 South Pass: 30/19 Observed ODC: -3 | No ground-based seeding was conducted. |
| 11 January 2021, Monday | |
| Strong inversion around the area as evidenced by the temperature difference from South Pass to Pinedale. Only a few high clouds were around during the daylight hours. Bands of mid and high clouds passed through during the evening and night, becoming overcast by sunrise. Max/Min temperatures Pinedale: 21/-15 Rock Springs: 28/0 Lander: 28/3 South Pass: 36/23 Observed ODC: -2 | No ground-based seeding was conducted. |
| 12 January 2021, Tuesday | |
| Scattered to broken high and mid level cloud coverage during the daylight hours. Small, low clouds began forming over the peaks of the range just before sunset. Areas of high and mid level clouds continued through the night while the low clouds expanded after midnight. However, there was no snowfall until just before sunrise Wednesday morning, when flurries began on the NW part of the range. Max/Min temperatures Pinedale: 34/-4 Rock Springs: 40/14 Lander: 36/9 South Pass: 36/21 Observed ODC: 0 | No ground-based seeding was conducted. |



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| 13 January 2021, Wednesday | |
| <p>Thick low clouds expanded over the range in the early morning hours, with radiometer detected LW and continuous snowfall. The clouds had convective cells. The temperature was too warm for seeding operations. These conditions continued until the late afternoon when cooler air arrived. Favorable seeding conditions persisted until the mid evening, at which point the clouds diminished. Only high clouds existed overnight. Snowfall map showed most of the range received 2 to 4 inches, with a few areas up to 6 inches.</p> <p>Max/Min temperatures Pinedale: 36/9 Rock Springs: 45/24 Lander: 57/24 South Pass: 32/19 Observed ODC: +1</p> | <p>Seeding event WRR0134 was called at 1655 MST on 01/13/2021 and began at 1705 MST.</p> <p>WRR0134 Summary: Generators: WR09, WR10, WR13. Time: 1700 (01/13) to 1946 (01/13) MST 0000 (01/14) to 0246 (01/14) UTC</p> <p>WR01, WR02, WR03, WR12 Time: 1700 (01/13) to 2100 (01/13) MST 0000 (01/14) to 0400 (01/14) UTC Duration: 4:00, 24:08 Total Time Seeding Material: 11.42 gallons (603.50 grams)</p> |
| 14 January 2021, Thursday | |
| <p>The only clouds around were high clouds at times throughout the day. No precipitation occurred.</p> <p>Max/Min temperatures Pinedale: 27/-6 Rock Springs: 31/16 Lander: 35/14 South Pass: 25/10 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| 15 January 2021, Friday | |
| <p>A few high and mid level clouds for most of the daylight hours. By late afternoon, more and thicker clouds began moving into the region from the NW. Waves of thick clouds passed through during the evening and early nighttime hours. The clouds had left the area by 3 am. Most of the snowfall from this system occurred in the mountains to the west except the far NW part of the WR, which received a dusting.</p> <p>Max/Min temperatures Pinedale: 37/21 Rock Springs: 43/21 Lander: 38/11 South Pass: 39/12 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>16 January 2021, Saturday</p> | |
| <p>The project area saw mostly clear skies in the mid to lower levels with occasional clearing in the upper levels. A few, low-level clouds developed by morning, but bases were still above the peaks. Winds were breezy out of the NW at 15 to 25 mph and a peak gust of 32 mph at PNA. No precipitation fell in the range.</p> <p>Max/Min temperatures Pinedale: 32/19 Rock Springs: 36/23 Lander: 45/20 South Pass: 34/21 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>17 January 2021, Sunday</p> | |
| <p>Skies were partly cloudy over the upper Green River Basin with prevalent cloud cover along the range through the day. Thicker clouds enshrouded the range after sunset with snow showers in higher elevations. A trace amount of snow fell around the Winds with around 2" falling in the NW region of the range. Skies over the basin cleared after midnight with low clouds blanketing the mountains through sunrise. LW was measured by the radiometer through the day and until 04Z, but trajectories were never good for seeding.</p> <p>Max/Min temperatures Pinedale: 36/18 Rock Springs: 41/25 Lander: 51/18 South Pass: 37/19 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>18 January 2021, Monday</p> | |
| <p>Low clouds started forming over the range during the afternoon with moist, northerly flow. Conditions became favorable for seeding around sunset. By midnight, the wind had shifted just enough that the plume traj was just outside the favorable range. Light snowfall and thick clouds continued over the northern slopes through the night, diminishing quickly around sunrise. Snowfall map showed 2 to 5 inches, mainly on the eastern half of the northern slopes.</p> <p>Max/Min temperatures Pinedale: 28/3 Rock Springs: 32/16 Lander: 38/21 South Pass: 27/12</p> | <p>Seeding event WRR0135 was called at 1725 MST on 01/18/2021 and began at 1727 MST.</p> <p>WRR0135 Summary: Generators: WR07. Time: 1727 (01/18) to 2234 (01/18) MST 0027 (01/19) to 0534 (01/19) UTC Duration: 5:07 Total Time Seeding Material: 1.84 gallons (128 grams)</p> |



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| Observed ODC: +1 | |
| 19 January 2021, Tuesday | |
| <p>Clear skies during the day. High clouds moved in during the evening and continued coming from the NW throughout the night. Mid level clouds formed over the range by Wednesday morning.</p> <p>Max/Min temperatures Pinedale: 27/-8 Rock Springs: 30/13 Lander: 35/16 South Pass: 28/14 Observed ODC: -2</p> | No ground-based seeding was conducted. |
| 20 January 2021, Wednesday | |
| <p>Cloud coverage increased during the afternoon, becoming quite thick with some LW detected by the radiometer. However, the cloud bases were above the peaks and no snowfall occurred. The clouds thinned during the evening but persisted throughout the night.</p> <p>Max/Min temperatures Pinedale: 28/-9 Rock Springs: 41/13 Lander: 45/14 South Pass: 32/18 Observed ODC: -1</p> | No ground-based seeding was conducted. |
| 21 January 2021, Thursday | |
| <p>Broken low cloud coverage in the morning increased in coverage and thickness after noon with very light snowfall. There was a short period with favorable wind flow, but the LW had decreased by then and had become inconsistent. Periods of very light snowfall continued throughout the night with NW wind flow. Snowfall map showed accumulation was less than 1 inch.</p> <p>Max/Min temperatures Pinedale: 32/9 Rock Springs: 38/21 Lander: 39/20 South Pass: 30/14 Observed ODC: 0</p> | No ground-based seeding was conducted. |
| 22 January 2021, Friday | |
| <p>Thick clouds with very light snowfall areas were over the southern slopes in the morning and early afternoon. By the</p> | No ground-based seeding was conducted. |



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| <p>time the wind flow developed a better cross barrier flow, the LW had diminished. Continuous light snowfall began a little after midnight and continued through the night. The radiometer detected LW but the wind flow was not favorable for seeding operations. Snowfall map showed only 0.5 to 2 inches accumulation on the range.</p> <p>Max/Min temperatures Pinedale: 30/10 Rock Springs: 40/26 Lander: 29/12 South Pass: 30/19 Observed ODC: 0</p> | |
| <p>23 January 2021, Saturday</p> | |
| <p>An appreciable amount of snow fell in the project area with good LW on the radiometer and favorable trajectories during the afternoon. Clouds covered the range all day, with partial clearing in the valley during the afternoon. Further clearing occurred after midnight before fog developed by Monday morning. Up to 5" of snow accumulated in parts of the range, but mostly between 2 and 4 inches fell around the project area.</p> <p>Max/Min temperatures Pinedale: 30/19 Rock Springs: 30/18 Lander: 27/13 South Pass: 25/14 Observed ODC: +1</p> | <p>Seeding event WRR0136 was called at 1037 MST on 01/23/2021 and began at 1042 MST.</p> <p>WRR0136 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12. Time: 1042 (01/23) to 1655 (01/23) MST 1742 (01/23) to 2355 (01/23) UTC Duration: 6:13, 35:07 Total Time Seeding Material: 16.75 gallons (878.25 grams)</p> |
| <p>24 January 2021, Sunday</p> | |
| <p>A thin stratus cloud deck was on the south side of the range and the southern slopes during the morning, slowly diminishing throughout the afternoon. But some small, low clouds remained and persisted through the night. The range was never fully covered. Snowfall map showed a trace amount of accumulation.</p> <p>Max/Min temperatures Pinedale: 28/0 Rock Springs: 30/12 Lander: 25/7 South Pass: 25/10 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>25 January 2021, Monday</p> | |



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| <p>Light southerly moist flow gave thin stratus cloud layers around the region throughout the period. Most of the clouds remained around the range and not over the top. There were areas of flurries and the snowfall map showed a dusting on the southern slopes.</p> <p>Max/Min temperatures Pinedale: 19/-15 Rock Springs: 25/6 Lander: 24/4 South Pass: 19/10 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>26 January 2021, Tuesday</p> | |
| <p>Areas of stratus clouds were around the region throughout the period. There were periods of very light snowfall but amounted to less than 0.5 inch accumulation. Most of the clouds were around the range and not over the top. The radiometer showed only small bits of LW.</p> <p>Max/Min temperatures Pinedale: 23/-6 Rock Springs: 19/9 Lander: 24/7 South Pass: 18/7 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>27 January 2021, Wednesday</p> | |
| <p>Broken clouds in the morning turned to overcast skies in the afternoon with clouds covering the range through the day. Snow fell in the evening, and just after sunset west of the divide. More snow fell after midnight. Clouds descended below the peaks in the afternoon and remained there for the remainder of the forecast period. There was no LW on the radiometer until the afternoon when trajectories were no longer favorable. There was a lull in LW from late afternoon until after midnight, with a small spike at 3Z. Snowfall analysis showed up to 3" of snow fell in the range.</p> <p>Max/Min temperatures Pinedale: 21/-9 Rock Springs: 29/3 Lander: 31/2 South Pass: 23/5 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>28 January 2021, Thursday</p> | |



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| <p>The wind flow developed a better cross barrier flow in the early morning, creating thick orographic clouds over the range with a high amount of radiometer detected LW and continuous snowfall. These conditions continued into the mid afternoon, when the wind became less favorable and the clouds weakened. Cloud coverage continued through the evening and night, but it was thin with very little snowfall. Snowfall map showed most of the range received 2 to 6 inches, with a small area up to 10 inches.</p> <p>Max/Min temperatures Pinedale: 32/9 Rock Springs: 37/20 Lander: 47/12 South Pass: 30/18 Observed ODC: +1</p> | <p>Seeding event WRR0137 was called at 0745 MST on 01/28/2021 and began at 0748 MST.</p> <p>WRR0137 Summary: Generators: WR01, WR02, WR03, WR09, WR12. Time: 0748 (01/28) to 1446 (01/28) MST 1448 (01/28) to 2146 (01/28) UTC Duration: 6:58, 32:54 Total Time Seeding Material: 15.61 gallons (822.75 grams)</p> |
| <p>29 January 2021, Friday</p> | |
| <p>SW flow allowed for orographic clouds to form along the range through the day with LW present on the radiometer for a few hours in the afternoon. Clouds covered the project area until the evening when skies became partly clear. Patchy fog developed in the basin overnight with a few flurries around midnight. Trajectories and temperatures were suitable for seeding in the late morning and early afternoon.</p> <p>Max/Min temperatures Pinedale: 34/14 Rock Springs: 43/28 Lander: 51/24 South Pass: 32/25 Observed ODC: +1</p> | <p>Seeding event WRR0138 was called at 1041 MST on 01/29/2021 and began at 1042 MST.</p> <p>WRR0138 Summary: Generators: WR01, WR02, WR03, WR04, WR05, WR09, WR10, WR12. Time: 1042 (01/29) to 1605 (01/29) MST 1742 (01/29) to 2305 (01/29) UTC Duration: 5:19, 30:47 Total Time Seeding Material: 14.35 gallons (769.75 grams)</p> |
| <p>30 January 2021, Saturday</p> | |
| <p>Low stratus and a few orographic clouds covered the mountains in the morning and into the afternoon. Skies over the basins were mostly cloudy in the morning before becoming partly cloudy in the afternoon. Clouds diminished across the project area overnight revealing clear skies by midnight. Winds were never good for seeding. Light snow fell in the range, but accumulation was likely less than half an inch – just a trace of SWE.</p> <p>Max/Min temperatures Pinedale: 30/1 Rock Springs: 32/17 Lander: 46/24 South Pass: 30/18</p> | <p>No ground-based seeding was conducted.</p> |



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| Observed ODC: 0 | |
| 31 January 2021, Sunday | |
| <p>Clear skies in the morning then a few mid and upper level clouds came through during the afternoon. These clouds continued the rest of the period. No snowfall occurred.</p> <p>Max/Min temperatures Pinedale: 27/-13 Rock Springs: 35/12 Lander: 40/16 South Pass: 36/19 Observed ODC: -2</p> | No ground-based seeding was conducted. |
| 01 February 2021, Monday | |
| <p>Arch clouds existed on the NE side of the range during the morning. The afternoon saw broken, thin high and mid level clouds moving through from west to east. There was less cloud coverage during the night, but small low clouds formed over the range and continued into Tuesday morning.</p> <p>Max/Min temperatures Pinedale: 32/-8 Rock Springs: 36/10 Lander: 46/18 South Pass: 41/27 Observed ODC: -1</p> | No ground-based seeding was conducted. |
| 02 February 2021, Tuesday | |
| <p>Scattered to broken cloud coverage around the region during the daylight hours. A few small low clouds existed in the morning and early afternoon, then became more continuous over the peaks by mid afternoon. The low clouds expanded in the evening with increased moisture flow. Continuous snowfall began in the later evening with good LW detected by the radiometer. This continued through the night, but the temperature was too warm for seeding operations. Snowfall map showed 2 to 5 inches on the range.</p> <p>Max/Min temperatures Pinedale: 36/5 Rock Springs: 45/16 Lander: 48/19 South Pass: 37/28 Observed ODC: 0</p> | No ground-based seeding was conducted. |
| 03 February 2021, Wednesday | |



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| <p>Thick widespread clouds from a cold front covered the region in the morning but had moved to the east by late morning. Orographic cloud coverage remained over the range, but slowly degraded during the afternoon. Favorable seeding conditions existed for a few hours, until the wind became unsuitable for plume transport. There were a few waves of very light snowfall during the evening and night, but the wind was not right for seeding. Snowfall map showed mostly 3 to 5 inches accumulation on the range, with an area over 6 on the NW part of the range.</p> <p>Max/Min temperatures Pinedale: 30/0 Rock Springs: 37/12 Lander: 47/18 South Pass: 32/14 Observed ODC: +1</p> | <p>Seeding event WRR0139 was called at 1010 MST on 02/03/2021 and began at 1031 MST.</p> <p>WRR0139 Summary: Generators: WR09, WR10, WR12, WR13. Time: 1011 (02/03) to 1451 (02/03) MST 1711 (01/03) to 2151 (02/03) UTC Duration: 4:40, 26:31 Total Time Seeding Material: 11.43 gallons (663 grams)</p> |
| <p>04 February 2021, Thursday</p> | |
| <p>Small shallow low clouds around during the daytime with very minimal coverage. Widespread high and mid level clouds moved in from the NW by late afternoon. The clouds became thicker in the evening with areas of light snowfall becoming more widespread a few hours before sunrise. The wind was not favorable for seeding and no LW existed. Snowfall map showed less than 1 inch accumulation.</p> <p>Max/Min temperatures Pinedale: 23/-11 Rock Springs: 26/12 Lander: 38/13 South Pass: 25/12 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>05 February 2021, Friday</p> | |
| <p>Thick cloud coverage with light snowfall over the range and Green River basin during the morning. In the afternoon, the clouds over the basin diminished but the clouds continued over the range the rest of the period. Little to no SLW was detected by the radiometer. Snowfall became very light during the night. Snowfall map showed a good portion of the range received 3 to 6 inches of accumulation, with a small area up to 8 inches.</p> <p>Max/Min temperatures Pinedale: 27/0 Rock Springs: 30/17 Lander: 43/17 South Pass: 27/9</p> | <p>No ground-based seeding was conducted.</p> |



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| Observed ODC: 0 | |
| 06 February 2021, Saturday | |
| <p>Low clouds covered the Winds and the basin west of the divide through the daylight hours with persistent snow until 2PM in the basin and again from the evening to 10PM. Snow fell in the Winds throughout the day and night with a snowfall analysis suggesting up to 18" accumulating in the highest elevations. Trajectories became favorable in the afternoon with LW showing up on the radiometer after 22UTC and favorable seeding conditions continued through the night into Sunday.</p> <p>Max/Min temperatures Pinedale: 28/14 Rock Springs: 34/19 Lander: 39/15 South Pass: 23/18 Observed ODC: +2</p> | <p>Seeding event WRR0140 was called at 1615 MST on 02/06/2021 and began at 1623 MST.</p> <p>WRR0140 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13. Time: 1623 (02/06) to 1926 (02/07) MST 2323 (02/06) to 0226 (02/08) UTC Duration: 27:03, 189:14 Total Time Seeding Material: 77.32 gallons (4730.75 grams)</p> |
| 07 February 2021, Sunday | |
| <p>Skies were partly cloudy over the basin west of the divide with gusty winds in the morning and early afternoon (peak of 31 mph at PNA). Clouds covered the range through the forecast period with ongoing operations finally ending at 2:26UTC when trajectories were no longer favorable. The radiometer did not detect LW long after noon, though models suggested SLW closer to the mountains. Mid-level clouds moved over the basin overnight but cleared before sunrise. Snowfall analysis shows up to 10" of snow fell in the Winds.</p> <p>Max/Min temperatures Pinedale: 27/9 Rock Springs: 38/23 Lander: 37/5 South Pass: 23/18 Observed ODC: +2</p> | <p>Seeding event WRR0140 continued until 1926 MST on 02/07/2021.</p> |
| 08 February 2021, Monday | |
| <p>Thick low clouds covered the NW half of the range during the morning, while the SE half had only a few small low clouds. The clouds slowly diminished throughout the afternoon. Scattered high and mid level clouds moved through during the nighttime. Small low clouds forming over the range by Tuesday morning but bases were above the peaks. Snowfall map showed a dusting of accumulation from the early clouds.</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>Max/Min temperatures Pinedale: 27/-13 Rock Springs: 37/23 Lander: 30/-1 South Pass: 23/18 Observed ODC: 0</p> | |
| <p>09 February 2021, Tuesday</p> | |
| <p>Mid level clouds and low clouds with bases above the peaks existed in the morning. The clouds thickened by mid day with some radiometer detected LW and then persisted longer than expected with a slight cross barrier flow during the afternoon. Light snowfall existed during the afternoon and evening. Only small, shallow low clouds lingered overnight. Snowfall map showed less than 2 inches on the range. No seeding occurred.</p> <p>Max/Min temperatures Pinedale: 32/-8 Rock Springs: 37/21 Lander: 39/-1 South Pass: 28/21 Observed ODC: +1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>10 February 2021, Wednesday</p> | |
| <p>Low clouds over the NW part of the range during the morning, then a small area of clouds formed over the southern slopes during the afternoon. These clouds never fully covered the range and continued through the evening. The clouds expanded during the night. There was radiometer detected LW but snowfall was very limited as the snowfall map showed only a small area with a dusting over the peaks.</p> <p>Max/Min temperatures Pinedale: 32/-2 Rock Springs: 40/24 Lander: 27/-3 South Pass: 28/21 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>11 February 2021, Thursday</p> | |
| <p>Low clouds existed over the range during the morning and afternoon but didn't quite fully cover the range and little to no LW was detected by the radiometer. The cloud coverage was improving by sunset but the wind became unfavorable for seeding. Widespread clouds and snowfall moved in</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>during the evening hours and continued through the night. The radiometer showed little to no LW during this time as well. Snowfall map showed 2 to 6 inches of accumulation on the range. No seeding occurred. With frigid air to the north and east, big temperature difference between LND and RKS.</p> <p>Max/Min temperatures Pinedale: 30/7 Rock Springs: 41/25 Lander: 8/-8 South Pass: 28/19 Observed ODC: 0</p> | |
| <p>12 February 2021, Friday</p> | |
| <p>The persistent low clouds over the range thinned right away in the morning, but then began redeveloping by late morning. Conditions became favorable for seeding in the early afternoon and continued until close to midnight. Light snowfall continued over the range during the night, but the wind was not favorable for seeding operations. Snowfall map showed a good portion of the range received 4 to 8 inches. Continued cold air damming by the WR range with frigid air to the north and east.</p> <p>Max/Min temperatures Pinedale: 30/19 Rock Springs: 31/2 Lander: 6/-9 South Pass: 23/-8 Observed ODC: +2</p> | <p>Seeding event WRR0141 was called at 1335 MST on 02/12/2021 and began at 1406 MST.</p> <p>WRR0141 Summary: Generators: WR01, WR02, WR03, WR04, WR05, WR09, WR10, WR12, WR13. Time: 1346 (02/12) to 2305 (02/12) MST 2046 (02/12) to 0605 (02/13) UTC Duration: 9:19, 63:15 Total Time Seeding Material: 26.20 gallons (1581.25 grams)</p> |
| <p>13 February 2021, Saturday</p> | |
| <p>Skies were mostly cloudy with a few brief periods of broken clouds. There was light snowfall in the project area through most of the day except for lower elevations late in the afternoon/evening. Despite near continuous snowfall in the range, accumulation was light with only trace SWE in the mountains. The radiometer was quiet except for some LW near the end of the forecast period. At that time, trajectories were not favorable. There was more clearing overnight before skies became overcast again by morning.</p> <p>Max/Min temperatures Pinedale: 23/5 Rock Springs: 5/-5 Lander: 1/-11 South Pass: 10/-9 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>14 February 2021, Sunday</p> | |
| <p>Skies in the range and to the west were cloudy in the morning with a few flurries in the basin. To the east of the divide, skies were partly cloudy. Clouds gradually cleared in the evening becoming mostly clear overnight, resulting in frigid low temperatures. LW on the radiometer was flat through the period and trajectories were never conducive of cross-barrier plume transport. A snowfall analysis map depicts up to 0.1" snow accumulation in the NW section the range.</p> <p>Max/Min temperatures Pinedale: 12/-13 Rock Springs: 7/-10 Lander: 8/-13 South Pass: 12/-9 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>15 February 2021, Monday</p> | |
| <p>Shallow low clouds with light snowfall were around the region the majority of the period. The clouds were mainly over the Green River basin and the southern slopes with only scattered coverage over the peaks of the range. The snowfall map showed no accumulation on the peaks and up to 2 inches on the southern slopes and northern basin. No seeding occurred.</p> <p>Max/Min temperatures Pinedale: 19/-18 Rock Springs: 28/-1 Lander: 21/-7 South Pass: 21/9 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>16 February 2021, Tuesday</p> | |
| <p>Low clouds were over the NW part of the range in the morning, then spread down the range by late morning. Low clouds continued over the range through the afternoon and evening hours. The wind flow was not right for seeding operations. The low clouds diminished after midnight while mid level clouds moved through. Snowfall map showed 1 to 3 inches mainly on the NW 2/3rds of the range.</p> <p>Max/Min temperatures Pinedale: 30/-9 Rock Springs: 31/17 Lander: 41/2 South Pass: 28/16 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>17 February 2021, Wednesday</p> | |
| <p>Low clouds started forming over the range in the late morning and expanded to covering most of the range in the early afternoon. The wind was not favorable for seeding operations. These clouds diminished a few hours after sunset. Shallow stratus clouds formed over the northern Green River basin and southern slopes of the range a few hours before sunrise and continued into Thursday morning. Snowfall map showed the range received less than 2 inches of accumulation, but 3 to 5 inches fell in a small area on the north side of the range.</p> <p>Max/Min temperatures Pinedale: 23/-4 Rock Springs: 27/10 Lander: 32/13 South Pass: 21/9 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>18 February 2021, Thursday</p> | |
| <p>Stratus clouds over the northern Green River basin diminished during the morning, while shallow low clouds over the southern slopes slowly disappeared throughout the afternoon. Little to no snowfall occurred. High clouds first moved in around sunset followed by mid level clouds a few hours later. Widespread light snowfall developed after midnight over the region, but the wind was unfavorable for seeding operations. The snowfall was diminishing by sunrise</p> <p>Max/Min temperatures Pinedale: 21/-11 Rock Springs: 24/5 Lander: 29/1 South Pass: 21/9 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>19 February 2021, Friday</p> | |
| <p>Thick cloud coverage over the region in the morning had thinned by mid day. Shallow low clouds lingered over the southern slopes of the range through the afternoon but never fully covered the range. The clouds started increasing by mid evening, with continuous snowfall and radiometer detected LW throughout the night into Saturday morning. The wind flow was not favorable for seeding plume transport. Snowfall map showed most of the range received 2 to 5 inches</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>Max/Min temperatures Pinedale: 28/7 Rock Springs: 24/14 Lander: 44/13 South Pass: 27/5 Observed ODC: 0</p> | |
| <p>20 February 2021, Saturday</p> | |
| <p>Conditions in the basin west of the divide were foggy in the early morning with snow in the mountains as LW was evident on the radiometer, and trajectories were favorable for seeding. Operations lasted until LW diminished, and trajectories no longer supported plume transport over the range with NW flow. Skies became partly cloudy in the afternoon, with thinning coverage lingering in the Winds through the period. Skies cleared further after sunset becoming mostly clear overnight. The NOHRSC 24h snowfall analysis suggests up to 5" of snow fell in the Winds, mostly in the NW region of the range. 1" accumulated in the rest of the range.</p> <p>Max/Min temperatures Pinedale: 27/1 Rock Springs: 30/14 Lander: 43/18 South Pass: 27/12 Observed ODC: +1</p> | <p>Seeding event WRR0142 was called at 0741 MST on 02/20/2021 and began at 0751 MST.</p> <p>WRR0142 Summary: Generators: WR01, WR09, WR12, WR13. Time: 0747 (02/20) to 1212 (02/20) MST 1447 (02/20) to 1912 (02/20) UTC Duration: 4:25, 17:36 Total Time Seeding Material: 7.75 gallons (440.25 gallons)</p> |
| <p>21 February 2021, Sunday</p> | |
| <p>Skies were mostly clear over the basin with clouds covering the range through the period. Clouds over the basin increased overnight to become mostly cloudy. Only a few flurries were seen in the basin west of the divide closest to the range with just a tenth on inch of snow accumulation in the Winds according to a snowfall analysis. Despite LW detected on the radiometer after sunset, trajectories were never good enough to seed through the period. Winds were strong out of the NW with peak gusts at PNA of 36 mph before becoming calm overnight</p> <p>Max/Min temperatures Pinedale: 27/-4 Rock Springs: 25/12 Lander: 44/10 South Pass: 30/10 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>22 February 2021, Monday</p> | |



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| <p>Thin low clouds were over the southern slopes of the range during the morning and early afternoon. The clouds thickened by late afternoon but limited to no snowfall occurred. The clouds slowly diminished through the evening and the hours after midnight. Thick clouds began developing over the range after 10Z, with favorable seeding conditions developing shortly after, continuing into Tuesday morning. Snowfall map showed less than 1 inch accumulation.</p> <p>Max/Min temperatures Pinedale: 36/18 Rock Springs: 34/20 Lander: 55/22 South Pass: 28/18 Observed ODC: +1</p> | <p>Seeding event WRR0143 was called at 0350 MST on 02/23/2021 and began at 0356 MST.</p> <p>WRR0143 Summary: Generators: WR01, WR02, WR03, WR09, WR12, WR13. Time: 0356 (02/23) to 1455 (02/23) MST 1056 (02/23) to 2155 (02/23) UTC Duration: 10:59, 65:54 Total Time Seeding Material: 28.11 gallons (1647 grams)</p> |
| <p>23 February 2021, Tuesday</p> | |
| <p>Continued thick orographic cloud coverage over the range during the morning with favorable seeding conditions. The cloud weakened in the afternoon so that it was no longer conducive for seeding operations, however the cloud continued into the evening. There was a short period around midnight with near favorable seeding conditions again, but no seeding occurred. The cloud diminished over night and the range was clear by sunrise. Snowfall map showed mainly 2 to 4 inches of accumulation on the range.</p> <p>Max/Min temperatures Pinedale: 30/0 Rock Springs: 35/16 Lander: 46/19 South Pass: 28/14 Observed ODC: +1</p> | <p>Seeding event WRR0143 continued until 1455 MST on 02/23/2021.</p> |
| <p>24 February 2021, Wednesday</p> | |
| <p>Clear skies in the morning, then low clouds starting developing over the range a little before noon. The clouds fully covered the range by mid afternoon. The wind flow was favorable for seeding with the Enterprise GGEN, but not enough SLW was expected to warrant seeding operations. The clouds diminished in the evening with clear skies overnight. Snowfall map showed a few areas of 1 to 3 inches over the top of the range.</p> <p>Max/Min temperatures Pinedale: 27/-8 Rock Springs: 24/10 Lander: 34/13 South Pass: 21/9</p> | <p>No ground-based seeding was conducted.</p> |



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| Observed ODC: 0 | |
| 25 February 2021, Thursday | |
| <p>Clear skies in the morning saw increasing high and mid level clouds during the afternoon, becoming overcast by sunset. Low clouds started forming over the range after sunset, but no LW was detected by the radiometer until the higher clouds moved away. The wind became favorable for seeding in the late evening and continued overnight. The clouds had thinned around sunrise, but thicker clouds moved back in shortly after so seeding continued. Snowfall map showed 1 to 5 inches of accumulation on most of the range, with the higher amounts on the NW.</p> <p>Max/Min temperatures Pinedale: 23/-17 Rock Springs: 26/2 Lander: 42/7 South Pass: 23/9 Observed ODC: +2</p> | <p>Seeding event WRR0144 was called at 2205 MST on 02/25/2021 and began at 2209 MST.</p> <p>WRR0144 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13. Time: 2209 (02/25) to 0320 (02/27) MST 0509 (02/26) to 1020 (02/27) UTC Duration: 29:11, 186:12 Total Time Seeding Material: 79.15 gallons (4655 grams)</p> |
| 26 February 2021, Friday | |
| <p>Continued strong cross barrier flow for most of the day, until the wind flow became parallel to the range during the night. There was a lull in SLW during the morning but with better conditions expected, seeding operations continued through that period. Very good conditions existed during the afternoon and evening, then deteriorated after midnight. By sunrise, the clouds over the range were shallow and scattered in coverage. Snowfall map showed a good portion of the range received 2 to 4 inches with 6 to 8 on the NW part of the range.</p> <p>Max/Min temperatures Pinedale: 27/9 Rock Springs: 26/15 Lander: 39/20 South Pass: 19/10 Observed ODC: +2</p> | <p>Seeding event WRR0144 continued until 0320 MST on 02/27/2021.</p> |
| 27 February 2021, Saturday | |
| <p>Skies over the project area were mostly cloudy with orographic clouds covering the Winds during the day. Snowfall was recorded at PNA in the morning and was seen in Lander in the afternoon. Cloud cover reduced sharply west of the divide around sunset while clouds lingered to the east and south of the range until just before midnight with areas of snow until then. With a light northerly wind,</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>trajectories were never quite favorable and LW was too inconsistent for seeding operations. Snowfall analysis shows up to 5" near South Pass, with up to 2" elsewhere in the range.</p> <p>Max/Min temperatures Pinedale: 21/-2 Rock Springs: 25/9 Lander: 33/15 South Pass: 18/5 Observed ODC: 0</p> | |
| <p>28 February 2021, Sunday</p> | |
| <p>Skies were mostly clear over the Upper Green River and Wind River basins with scattered low-level cloudiness along the Winds west of the divide. Skies became clear across most of the project area after sunset with only a few isolated upper-level clouds passing through. There was also an area of thicker clouds that brushed the far northwestern side of the range, dropping a few flurries, but accumulation was negligible. Conditions were never good for seeding.</p> <p>Max/Min temperatures Pinedale: 23/-13 Rock Springs: 26/4 Lander: 40/8 South Pass: 21/5 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>01 March 2021, Monday</p> | |
| <p>Clear skies throughout the period, except for very thin high clouds around sunrise.</p> <p>Max/Min temperatures Pinedale: 30/-6 Rock Springs: 37/11 Lander: 45/12 South Pass: 25/10 Observed ODC: -3</p> | <p>No ground-based seeding was conducted.</p> |
| <p>02 March 2021, Tuesday</p> | |
| <p>Clear skies until high and mid level clouds came in and formed a little before sunset. Arch clouds formed on the north side of the range during the evening and continued until sunrise. The clouds mostly cleared early Wednesday morning.</p> <p>Max/Min temperatures</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>Pinedale: 36/-4 Rock Springs: 43/15 Lander: 58/14 South Pass: 32/21 Observed ODC: -2</p> | |
| <p>03 March 2021, Wednesday</p> | |
| <p>A very few, thin high clouds were around during the daytime and evening. There were more high clouds overnight and then widespread mid level clouds moved in from the south around sunrise as a low was coming into CO.</p> <p>Max/Min temperatures Pinedale: 41/-4 Rock Springs: 50/19 Lander: 57/28 South Pass: 37/30 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>04 March 2021, Thursday</p> | |
| <p>Areas of mid level clouds around the region during the morning and most of the afternoon as a low moved through CO. No low clouds existed. A few high clouds moved through during the night.</p> <p>Max/Min temperatures Pinedale: 41/3 Rock Springs: 46/27 Lander: 54/24 South Pass: 41/30 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>05 March 2021, Friday</p> | |
| <p>Mostly clear skies in the morning, then consistent upper-level clouds by the afternoon. Thicker development occurred east of the divide after midnight, and west of the divide by sunrise. Still nothing below the peaks. No precipitation occurred.</p> <p>Max/Min temperatures Pinedale: 41/5 Rock Springs: 49/25 Lander: 59/25 South Pass: 41/32 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>06 March 2021, Saturday</p> | |



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| <p>Scattered mid-level clouds in the morning and afternoon with a cloud deck just above the range. The cloud deck lowered below the peaks as snow fell in the mountains in the evening, mostly on the lee side of the Winds. A snowfall analysis suggests snow accumulation of a little more than an inch on the south, east, and far north sides of the range. Clouds diminished after midnight, revealing clear skies by sunrise. Temperatures were not cool enough for seeding.</p> <p>Max/Min temperatures Pinedale: 43/3 Rock Springs: 52/28 Lander: 64/23 South Pass: 41/30 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>07 March 2021, Sunday</p> | |
| <p>Only a few high clouds were around during the daytime and evening hours. Thick mid level clouds moved in from the SW during the night. Cloud bases were above the peaks, but the radar showed weak echoes. This was from virga as the precipitation did not reach the ground.</p> <p>Max/Min temperatures Pinedale: 45/10 Rock Springs: 51/27 Lander: 59/27 South Pass: 39/28 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>08 March 2021, Monday</p> | |
| <p>Mid level cloud coverage in the morning thinned by mid day. Thicker clouds developed by mid afternoon over the range, then widespread cloud coverage during the evening. There was some very light snowfall and radiometer detected LW, but the temperature was much too warm for seeding operations. A cold front moved through overnight and the clouds slowly diminished behind the front as the wind switched to NW. Snowfall map showed a dusting of accumulation on the peaks of the range.</p> <p>Max/Min temperatures Pinedale: 48/14 Rock Springs: 57/35 Lander: 64/25 South Pass: 46/32 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>09 March 2021, Tuesday</p> | |
| <p>Mid level clouds were over the range with bases just above the peaks during the morning and early afternoon. The radiometer detected LW but the wind was not favorable for seeding, and snowfall was very weak. Widespread clouds started moving into WY a little before sunset and snowfall increased across much of the state throughout the evening. The wind flow became favorable for seeding with Enterprise during the night and just enough SLW was forecast to make seeding worthwhile. The wind became less favorable for seeding around sunrise, though continuous snowfall remained. Snowfall map showed 1 to 3 inches over the range, with 5 to 9 inches on the northern slopes and the LND area.</p> <p>Max/Min temperatures Pinedale: 32/21 Rock Springs: 45/27 Lander: 54/30 South Pass: 35/25 Observed ODC: +1</p> | <p>Seeding event WRR0145 was called at 0223 MST on 03/10/2021 and began at 0347 MST.</p> <p>WRR0145 Summary: Generators: WR07. Time: 0347 (03/10) to 0704 (03/10) MST 1047 (03/10) to 1404 (03/11) UTC Duration: 3:17 Total Time Seeding Material: 1.57 gallons (82 grams)</p> |
| <p>10 March 2021, Wednesday</p> | |
| <p>Widespread snowfall in the morning but was diminishing by mid day. Despite cross barrier flow from late morning through the afternoon, no SLW was detected by the radiometer except for a short time in the mid afternoon when the clouds became more convective and broken. Snowfall over the range ended shortly after sunset and the clouds cleared. High and then mid level clouds moved in from the south during the night. No seeding occurred. Snowfall map showed mostly 2 to 5 inches, with some areas up to 8 inches.</p> <p>Max/Min temperatures Pinedale: 32/5 Rock Springs: 29/15 Lander: 30/18 South Pass: 23/14 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>11 March 2021, Thursday</p> | |
| <p>Mid level clouds were over the region in the morning and afternoon. There were a few low clouds over the peaks of the range during the afternoon as well. All the clouds diminished over the WR region in the early evening hours and the sky was clear overnight into Friday morning. Snowfall map showed 0.5 to 2 inches of accumulation in a few spots over the peaks.</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>Max/Min temperatures Pinedale: 32/1 Rock Springs: 30/14 Lander: 30/12 South Pass: 23/14 Observed ODC: -1</p> | |
| <p>12 March 2021, Friday</p> | |
| <p>A few small, low clouds formed over the peaks around noon and existed for most of the afternoon. Otherwise, the sky was clear during the daytime and evening. A shallow stratus deck developed on the north side of the range and moved against the northern slopes during the night. Light snowfall began around sunrise, but the wind was not favorable for seeding. Snowfall map showed the only accumulation by 12Z was from those small, low clouds in the afternoon, which produced less than 2 inches in a small area.</p> <p>Max/Min temperatures Pinedale: 36/-6 Rock Springs: 36/19 Lander: 32/8 South Pass: 28/14 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>13 March 2021, Saturday</p> | |
| <p>Consistent heavy to moderate snowfall in the WR range started in the morning from a large storm system centered over CO. Skies were partly cloudy west of the divide, while snowfall was consistent to the east. 24 hour snowfall analysis showed most of range saw at least a foot of snow, while nearly 28" of snow fell in the SE region. Negligible totals were observed near PNA. Trajectories were never good enough for seeding despite consistent NE flow aloft.</p> <p>Max/Min temperatures Pinedale: 41/9 Rock Springs: 35/25 Lander: 32/8 South Pass: 27/21 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>14 March 2021, Sunday</p> | |
| <p>Continued widespread heavy to moderate snowfall over much of WY from the strong low to the south. The northeasterly wind flow became favorable for seeding during the morning. Favorable seeding conditions existed</p> | <p>Seeding event WRR0146 was called at 0955 MDT on 03/14/2021 and began at 1011 MDT.</p> <p>WRR0146 Summary:</p> |



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| <p>through the afternoon though the snowfall was weakening throughout the afternoon and then ended in the project area during the early evening. A shallow stratus cloud deck developed on the south side of the range during the night. Snowfall map showed 4 to 12 inches on the range.</p> <p>Max/Min temperatures Pinedale: 45/25 Rock Springs: 32/25 Lander: 38/22 South Pass: 25/10 Observed ODC: +2</p> | <p>Generators: WR07. Time: 1011 (03/14) to 1808 (03/14) MDT 1611 (03/14) to 0008 (03/15) UTC Duration: 7:57 Total Time Seeding Material: 3.42 gallons (198.75 grams)</p> |
| <p>15 March 2021, Monday</p> | |
| <p>There were areas of mid level clouds around most of the day. A few low clouds were around during the afternoon, increasing in coverage by the late afternoon with light snowfall on the NE side of the range. The snowfall increased in coverage before midnight, including the lowlands on both sides of the range and continued into Tuesday morning. The northerly wind flow was not quite right for seeding with Enterprise. Snowfall map showed most of the northern slopes of the range received 3 to 6 inches.</p> <p>Max/Min temperatures Pinedale: 43/28 Rock Springs: 44/19 Lander: 43/19 South Pass: 37/21 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>16 March 2021, Tuesday</p> | |
| <p>Continued light snowfall around the region in the morning. The hysplit traj from Enterprise improved during the morning and seeding begun. The snowfall over the lowlands ended in the early afternoon but continued over the range until just after sunset. The wind became less favorable for seeding before the snowfall ended. A shallow stratus layer developed on the south side of the range during the evening and continued through the night, while clouds cleared over the range. Snowfall map showed most of the range received 1 to 3 inches.</p> <p>Max/Min temperatures Pinedale: 41/28 Rock Springs: 38/28 Lander: 37/31 South Pass: 30/25 Observed ODC: +1</p> | <p>Seeding event WRR0147 was called at 0954 MDT on 03/16/2021 and began at 0958 MDT.</p> <p>WRR0147 Summary: Generators: WR07. Time: 0958 (03/16) to 1704 (03/16) MDT 1558 (03/16) to 2304 (03/16) UTC Duration: 7:06 Total Time Seeding Material: 2.84 gallons (177.50 grams)</p> |



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| 17 March 2021, Wednesday | |
| <p>The shallow stratus clouds on the south side of the range diminished during the morning and became scattered in the afternoon. Low clouds developed over the range during the afternoon but did not fully cover the range. Shallow, small, low clouds persisted over the range through the evening and night. The temperature was too warm for seeding operations. Snowfall map showed a dusting of snowfall over the peaks of the range, with a small area over 2 inches.</p> <p>Max/Min temperatures Pinedale: 39/21 Rock Springs: 41/26 Lander: 41/22 South Pass: 32/19 Observed ODC: -1</p> | No ground-based seeding was conducted. |
| 18 March 2021, Thursday | |
| <p>Areas of mid level clouds were around for most of day. A few low clouds also existed over the range during the afternoon and early evening hours. No snowfall occurred.</p> <p>Max/Min temperatures Pinedale: 45/16 Rock Springs: 51/23 Lander: 44/23 South Pass: 37/28 Observed ODC: -1</p> | No ground-based seeding was conducted. |
| 19 March 2021, Friday | |
| <p>Increasing cloud coverage during the daytime, with low clouds beginning to develop just before sunset. Strong southerly cross barrier flow developed during the evening and a thick orographic cloud existed over the range through the night into Saturday morning, with a high amount of radiometer detected LW. However, snowfall was very limited as the snowfall map only showed a few isolated areas around the range up to 3 inches.</p> <p>Max/Min temperatures Pinedale: 54/19 Rock Springs: 57/31 Lander: 56/28 South Pass: 45/32 Observed ODC: 0</p> | No ground-based seeding was conducted. |
| 20 March 2021, Saturday | |



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| <p>A band of precipitation swept across the project area as the day was otherwise mostly cloudy and windy throughout the region. The cold front passed PNA in the late morning and Lander in the early afternoon. Much of the region saw snowfall with lower lying areas seeing rain mixed in. Not much snow accumulation in the basins, but up to 9" fell in the range according to the NOHRSC snowfall analysis. Temperatures were too warm for seeding prior to the front, and trajectories were not favorable after. The front allowed for clearing skies overnight as the Upper Green River Basin woke up to clear skies Sunday morning, but clouds lingered along the range east of the divide.</p> <p>Max/Min temperatures Pinedale: 46/27 Rock Springs: 55/27 Lander: 56/34 South Pass: 41/28 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>21 March 2021, Sunday</p> | |
| <p>Clear skies west of the divide and lingering snow showers to the east in the morning. Skies became partly cloudy in the Upper Green River Basin in the afternoon, mostly around the range with snowfall in the Winds. Skies remained partly sunny to the east before clearing across the project area after sunset. Skies were clear through the night and into the morning throughout the target region. 24-hour snowfall analysis suggests a little more than 4.5" of snow fell near Enterprise, with at least an inch falling everywhere else in the range. The highest values are most likely from moderate showers in the early morning. No LW was measured on the radiometer.</p> <p>Max/Min temperatures Pinedale: 36/21 Rock Springs: 25/22 Lander: 41/27 South Pass: 30/21 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>22 March 2021, Monday</p> | |
| <p>High and mid level clouds moved into the area from the west during the morning. Low clouds developed over the range during the afternoon but did not fully cover the range. Snowfall and SLW were not consistent. These clouds diminished during the night. The wind flow switched to northerly and continuous snowfall developed over the northern slopes and the Wind River Basin during the night.</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>The wind was not favorable for seeding with Enterprise. Snowfall map shows widespread snowfall around the region, but light accumulation, less than 2 inches.</p> <p>Max/Min temperatures Pinedale: 32/10 Rock Springs: 39/18 Lander: 42/20 South Pass: 30/18 Observed ODC: 0</p> | |
| <p>23 March 2021, Tuesday</p> | |
| <p>Continued snowfall over the northern slopes of the range with northerly flow through the evening hours. The traj from Enterprise was just favorable enough for seeding from the late morning until the late evening. Those clouds diminished after midnight, with a shallow stratus layer forming on the south side of the range during the night and lasting into Wednesday morning. Snowfall map shows a fairly large area of 6 to 14 inches of accumulation.</p> <p>Max/Min temperatures Pinedale: 37/19 Rock Springs: 35/20 Lander: 34/26 South Pass: 27/18 Observed ODC: +2</p> | <p>Seeding event WRR0148 was called at 1049 MDT on 03/23/2021 and began at 1051 MDT.</p> <p>WRR0148 Summary: Generators: WR07. Time: 1051 (03/23) to 2217 (03/23) MDT 1651 (03/23) to 0417 (03/24) UTC Duration: 11:26 Total Time Seeding Material: 3.66 gallons (285.75 grams)</p> |
| <p>24 March 2021, Wednesday</p> | |
| <p>The low clouds on the south side of the range in the morning diminished shortly after noon. High clouds began moving in from the west in the early afternoon with mid level clouds by sunset. Low clouds slowly formed during the night, but snowfall was very limited as the snowfall map showed only a dusting in small areas.</p> <p>Max/Min temperatures Pinedale: 34/18 Rock Springs: 39/17 Lander: 40/16 South Pass: 28/14 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>25 March 2021, Thursday</p> | |
| <p>Very light snowfall was occurring over the range during the morning. The clouds thickened by mid day with favorable seeding conditions throughout the afternoon. During the evening, the wind shifted to northerly and the snowfall</p> | <p>Seeding event WRR0149 was called at 1125 MDT on 03/25/2021 and began at 1130 MDT.</p> <p>WRR0149 Summary:</p> |



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| <p>shifted to the northern slopes. A small area of thick low cloud coverage existed through the night into Friday morning on the NE side of the range. The wind became favorable for seeding with the Enterprise GGEN a few hours before sunrise until the late morning. Snowfall map showed mainly 2 to 5 inches on the range.</p> <p>Max/Min temperatures Pinedale: 34/21 Rock Springs: 38/22 Lander: 42/24 South Pass: 30/19 Observed ODC: +2</p> | <p>Generators: WR01, WR02, WR03, WR09, WR10, WR12. Time: 1130 (03/25) to 1750 (03/25) MDT 1730 (03/25) to 2350 (03/25) UTC Duration: 6:20, 36:22 Total Time Seeding Material: 16.77 gallons (859.25 grams)</p> <p>Seeding event WRR0150 was called at 0435 MDT on 03/26/2021 and began at 0441 MDT.</p> <p>WRR0150 Summary: Generators: WR07. Time: 0441 (03/26) to 1020 (03/26) MDT 1041 (03/26) to 1620 (03/26) UTC Duration: 5:39 Total Time Seeding Material: 2.09 gallons (141.25 grams)</p> |
| 26 March 2021, Friday | |
| <p>Partly cloudy skies in the basins with scattered showers in the range. There was also some snowfall east of the divide, but mostly in the early morning and briefly in the afternoon. Skies remained partly cloudy overnight before becoming clear by sunrise. The 24h snowfall analysis map suggests between an inch and two fell in the mountains and west of the divide until 12Z this morning. No seeding through the forecast period.</p> <p>Max/Min temperatures Pinedale: 39/21 Rock Springs: 42/26 Lander: 42/28 South Pass: 34/23 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| 27 March 2021, Saturday | |
| <p>Mostly clear skies with mid to high clouds over the range. There were brief orographic clouds along the Winds, especially overnight. The 24h snowfall analysis map suggests a tenth of an inch of snow fell along the crest. Otherwise, there was no precipitation in the project area.</p> <p>Max/Min temperatures Pinedale: 41/21 Rock Springs: 48/25 Lander: 53/24 South Pass: 37/19 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| 28 March 2021, Sunday | |



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| <p>Warm day with only some mid level clouds during the daytime and evening hours. Low, orographic clouds started forming over the range just before sunrise. Favorable seeding conditions developed around sunrise and continued Monday morning. No snowfall had fell before 12Z so the snowfall map showed no accumulation.</p> <p>Max/Min temperatures Pinedale: 52/18 Rock Springs: 57/29 Lander: 62/31 South Pass: 43/28 Observed ODC: +1</p> | <p>Seeding event WRR0151 was called at 0649 MDT on 03/29/2021 and began at 0654 MDT.</p> <p>WRR0151 Summary: Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13. Time: 0654 (03/29) to 1322 (03/29) MDT 1254 (03/29) to 1922 (03/29) UTC Duration: 6:28, 37:38 Total Time Seeding Material: 17.51 gallons (940.75 gallons)</p> |
| <p>29 March 2021, Monday</p> | |
| <p>Continued thick orographic cloud over the range with favorable seeding conditions during the morning. By mid day the cloud coverage was diminishing. Low clouds redeveloped over the range a few hours later, but those never fully covered the range and snowfall was very light. These clouds along with some scattered snow showers existed through the evening, before clearing overnight. High temperatures around the region occurred in the morning hours, as a cold front moved through and the temperature gradually cooled in the afternoon. Snowfall map showed only a dusting of accumulation on the south end of the range but over 4 inches in the NW.</p> <p>Max/Min temperatures Pinedale: 43/16 Rock Springs: 50/22 Lander: 54/25 South Pass: 36/14 Observed ODC: +1</p> | <p>Seeding event WRR0151 continued until 1322 MDT on 03/29/2021.</p> |
| <p>30 March 2021, Tuesday</p> | |
| <p>Cumulus clouds started forming around the region in the late morning. Low clouds developed over the range during the afternoon and continued until the mid evening. There was some very light snowfall, but the clouds never fully covered the range. The sky was clear overnight. Snowfall map showed less than 1 inch accumulation and mostly on the southern slopes of the range.</p> <p>Max/Min temperatures Pinedale: 30/5 Rock Springs: 34/12 Lander: 39/16 South Pass: 25/7</p> | <p>No ground-based seeding was conducted.</p> |



WINTER GROUND OPERATIONS 2020-2021
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| Observed ODC: -1 | |
| 31 March 2021, Wednesday | |
| <p>Clear skies around the region, except for a small area of high clouds for a short time in the late afternoon and then a few high clouds overnight.</p> <p>Max/Min temperatures Pinedale: 41/9 Rock Springs: 48/17 Lander: 51/19 South Pass: 36/14 Observed ODC: -3</p> | No ground-based seeding was conducted. |
| 01 April 2021, Thursday | |
| <p>Clear skies around the region except for a very few high clouds early Friday morning.</p> <p>Max/Min temperatures Pinedale: 55/12 Rock Springs: 61/23 Lander: 67/26 South Pass: 46/30 Observed ODC: -3</p> | No ground-based seeding was conducted. |
| 02 April 2021, Friday | |
| <p>Mostly clear skies, but there were some mid level clouds over the range at times during the daytime. A larger area of high and mid level clouds developed during the evening, with most of the clouds moving away by sunrise. RKS and LND were a few degrees short of record high temperatures (could not find record for PNA and South Pass). Big Piney did set a record high though.</p> <p>Max/Min temperatures Pinedale: 59/18 Rock Springs: 66/30 Lander: 71/33 South Pass: 52/36 Observed ODC: -2</p> | No ground-based seeding was conducted. |
| 03 April 2021, Saturday | |
| <p>Mostly clear skies in the morning with a few upper-level clouds. High cloud cover increased later in the afternoon and winds picked up slightly. Skies cleared again after sunset, but another mid-level cloud layer moved overhead by sunrise. No precipitation was observed. Record high temperatures were set around western WY.</p> | No ground-based seeding was conducted. |



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| <p>Max/Min temperatures Pinedale: 64/19 Rock Springs: 71/33 Lander: 75/37 South Pass: 55/39 Observed ODC: -2</p> | |
| <p>04 April 2021, Sunday</p> | |
| <p>Another day of record high temperatures around the region. Scattered high and mid level clouds around the region most of the daylight hours. No precipitation occurred. The only clouds during the night were a small area of mid level clouds over the range.</p> <p>Max/Min temperatures Pinedale: 64/27 Rock Springs: 71/38 Lander: 76/39 South Pass: 55/43 Observed ODC: -2</p> | <p>No ground-based seeding was conducted.</p> |
| <p>05 April 2021, Monday</p> | |
| <p>High based convective clouds developed around the region in the early afternoon, with coverage becoming more continuous by sunset. Little to no precipitation reached the ground from these clouds. Widespread precipitation began in western WY a little before midnight and continued through the night. Lower elevations received rain at the beginning before changing to snowfall during the night. The temperature was too warm for seeding operations until sunrise and the wind was not favorable for seeding at any point. Snowfall map showed over 6 inches on both sides of the range, with less on the top and over a foot accumulation in an area on the south slopes.</p> <p>Max/Min temperatures Pinedale: 61/21 Rock Springs: 68/39 Lander: 73/37 South Pass: 52/32 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |
| <p>06 April 2021, Tuesday</p> | |
| <p>The widespread snowfall over western WY ended in the morning, but snowfall continued on the northern slopes of the range and the Wind River basin until the later afternoon. The wind flow was never favorable for seeding</p> | <p>No ground-based seeding was conducted.</p> |



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| <p>operations. Most of the snowfall had ended by sunset. The low clouds slowly shrunk away throughout the evening and night. Only a few low clouds were left by sunrise. Snowfall map showed most of the range received 2 to 5 inches with some areas over 6.</p> <p>Max/Min temperatures Pinedale: 41/28 Rock Springs: 41/25 Lander: 39/32 South Pass: 32/27 Observed ODC: 0</p> | |
| <p>07 April 2021, Wednesday</p> | |
| <p>There were very small low clouds around the range throughout most of the late morning and afternoon hours. No significant coverage occurred, and snowfall map showed a dusting of accumulation only over the peaks. Mid level clouds moved in during the night with a few lasting into Thursday morning.</p> <p>Max/Min temperatures Pinedale: 50/27 Rock Springs: 55/29 Lander: 56/34 South Pass: 43/28 Observed ODC: -1</p> | <p>No ground-based seeding was conducted.</p> |
| <p>08 April 2021, Thursday</p> | |
| <p>Orographic clouds started forming over the range in the later morning hours and increased in coverage during the afternoon. Snowfall was fairly limited and the temperature was too warm for seeding operations. Continuous snowfall began a little before midnight mainly on the northern slopes, lasting through the night ending a little before sunrise. The wind was not favorable for seeding operations during the night. Only small, scattered clouds were left Friday morning. Snowfall map showed 3 to 5 inches on the NE side of the range with a dusting on most of the rest of the range.</p> <p>Max/Min temperatures Pinedale: 52/19 Rock Springs: 57/25 Lander: 61/31 South Pass: 45/25 Observed ODC: 0</p> | <p>No ground-based seeding was conducted.</p> |



WINTER GROUND OPERATIONS 2020-2021
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| 09 April 2021, Friday | |
| <p>Small low clouds were around the southern portion of the range through the mid afternoon. The sky was clear the rest of the day. Snowfall map showed a dusting of accumulation on the southern portion of the range, but that was mainly from the early morning clouds.</p> <p>Max/Min temperatures Pinedale: 43/18 Rock Springs: 51/22 Lander: 49/26 South Pass: 37/19 Observed ODC: -1</p> | No ground-based seeding was conducted. |
| 10 April 2021, Saturday | |
| <p>Skies were clear in the project area in the morning and early afternoon before cumulus developed across the area. Low cloud cover developed east of the range overnight while skies to the west remained clear. There was snowfall around sunrise from South Pass to Lander, but this was not picked up by the 24h snowfall analysis map that ended at 12Z.</p> <p>Max/Min temperatures Pinedale: 55/16 Rock Springs: 61/24 Lander: 64/28 South Pass: 46/30 Observed ODC: 0</p> | No ground-based seeding was conducted. |
| 11 April 2021, Sunday | |
| <p>Mostly clear skies during the day with scattered cumulus across the project area. Skies remained clear west of the divide overnight, while snow began to fall in LND starting around midnight. Favorable seeding conditions developed during the night and persisted into Monday morning. Snowfall analysis over a 24 hour period ending at 12Z suggested a max accumulation of 6.27" of snow fell on the southeastern slopes.</p> <p>Max/Min temperatures Pinedale: 43/21 Rock Springs: 50/26 Lander: 30/23 South Pass: 37/19 Observed ODC: +1</p> | <p>Seeding event WRR0152 was called at 0331 MDT on 04/12/2021 and began at 0335 MDT.</p> <p>WRR0152 Summary: Generators: WR07. Time: 0335 (04/12) to 0840 (04/12) MDT 0935 (04/12) to 1340 (04/12) UTC Duration: 4:05 Total Time Seeding Material: 1.55 gallons (102 grams)</p> |
| 12 April 2021, Monday | |



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| <p>Low clouds continued over the northern slopes of the range during the morning but had thinned by mid day. Thick clouds developed over the range during the afternoon with a period of westerly flow. There was a short time with favorable traj during the afternoon, but it wasn't long enough for seeding operations. Those clouds diminished shortly after sunset and the wind went back to northerly. Thin clouds continued over the northern slopes through the night but the traj from Enterprise was not favorable. Snowfall map showed accumulation was 1 to 3 inches.</p> <p>Max/Min temperatures Pinedale: 37/12 Rock Springs: 42/18 Lander: 34/23 South Pass: 23/16 Observed ODC: +1</p> | <p>Seeding event WRR0152 ended at 0740 MDT on 04/12/2021 but would have continued until around 1200 MDT had the GGEN ran out of propane.</p> |
| <p>13 April 2021, Tuesday</p> | |
| <p>Low clouds with favorable seeding conditions developed in the early morning hours. The clouds deteriorated enough after noon that seeding ended. Thicker clouds with more snowfall moved in a little before sunset and the became widespread around the region during the evening. The wind and available SLW were not favorable for seeding again until closer to sunrise Wednesday morning. Snowfall map showed 1 to 4 inches on the northern slopes and a 0.5 to 1 inch on the rest of the range.</p> <p>Max/Min temperatures Pinedale: 41/14 Rock Springs: 39/17 Lander: 33/24 South Pass: 21/14 Observed ODC: +2</p> | <p>Seeding event WRR0153 was called at 0840 MDT on 04/13/2021 and began at 0844 MDT.</p> <p>WRR0153 Summary: Generators: WR07. Time: 0844 (04/13) to 1310 (04/13) MDT 1444 (04/13) to 1910 (04/13) UTC Duration: 4:26 Total Time Seeding Material: 2.48 gallons (110.75 gallons)</p> <p>Seeding event WRR0154 was called at 0540 MDT on 04/14/2021 and began at 0543 MDT.</p> <p>WRR0154 Summary: Generators: WR07. Time: 0543 (04/14) to 1421 (04/14) MDT 1143 (04/14) to 2021 (04/14) UTC Duration: 8:38 Total Time Seeding Material: 4.40 gallons (215.75 gallons)</p> |
| <p>14 April 2021, Wednesday</p> | |
| <p>Continued widespread snowfall over the region for most of the day, though it wasn't always continuous and consistent. The wind was favorable for seeding with Enterprise during the morning and early afternoon. Unfavorable wind flow and lack of SLW precluded seeding the rest of the period. Snowfall map showed over 2 inches accumulation on most of the range with over 6 on the NE corner.</p> <p>Max/Min temperatures</p> | <p>Seeding event WRR0154 continued until 1421 MDT on 04/14/2021.</p> |



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| <p>Pinedale: 32/23 Rock Springs: 28/19 Lander: 27/22 South Pass: 19/14 Observed ODC: +1</p> | |
| <p>15 April 2021, Thursday</p> | |
| <p>Widespread snowfall around the region though it wasn't continuous on the lowlands. Favorable seeding conditions existed throughout the entire day for Enterprise even though there were some thinner periods for a short time. The clouds were beginning to thin Friday morning. Snowfall map showed an area of 4 to 8 inches accumulation on the NE side of the range while most of the rest of the range received less than 1 inch.</p> <p>Max/Min temperatures Pinedale: 34/23 Rock Springs: 32/20 Lander: 32/23 South Pass: 25/16 Observed ODC: +2</p> | <p>Seeding event WRR0155 was called at 0810 MDT on 04/15/2021 and began at 0813 MDT.</p> <p>WRR0155 Summary: Generators: WR07. Time: 0813 (04/15) to 0855 (04/16) MDT 1413 (04/15) to 1455 (04/16) UTC Duration: 24:42 Total Time Seeding Material: 13.59 gallons (617.50 grams)</p> |



WINTER GROUND OPERATIONS 2020-2021
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Wind River Mountain Range



Appendix B. National Oceanic and Atmospheric Administration Final Operations Report

Silver iodide seeding agent amounts are stated in grams.

| NOAA FORM 17-4A (4-81) | | U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION | | | | Form Approved OMB No. 0648-0025 Expires 03/31/08 | | | | | | | | |
|---|------------------------------------|--|-----------|----------|----------------|---|--|--------------------------------------|----------------|------|--|-------|---------------|--|
| INTERIM ACTIVITY REPORTS AND FINAL REPORT | | | | | | | | | | | NOAA FILE NUMBER | | | |
| This report is required by Public Law 92-205; 85 Stat. 735; 145 U.S.C. 330b. Knowing and willful violation of any rule adopted under the authority of Section 2 of Public Law 92-205 shall subject the person violating such rule to a fine of not more than \$10,000, upon conviction thereof. | | | | | | | | | | | <input type="checkbox"/> INTERIM REPORT <input checked="" type="checkbox"/> FINAL REPORT | | | |
| Complete in accordance with instructions on reverse and forward one copy to: National Oceanic and Atmospheric Administration Office of Oceanic and Atmospheric Research 1315 East-West Highway SSMC-3 Room 11216 Silver Spring, MD 20910 | | | | | | | | | | | REPORTING PERIOD | | | |
| | | | | | | | | | | | FROM 11/15/2020 | | TO 04/15/2021 | |
| 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 PRECIPITATION | ALLEVIATE | | OTHER | AIRBORNE | GROUND | SILVER IODIDE | CARBON DIOXIDE | UREA | SODIUM CHLORIDE | OTHER | | |
| | | | HAIL | FOG | | | | | | | | | | |
| JANUARY | 5 | 5 | | | | | 128 | 3,649 | | | | | | |
| FEBRUARY | 6 | 6 | | | | | 549 | 13,991 | | | | | | |
| MARCH | 7 | 7 | | | | | 107 | 2,912 | | | | | | |
| APRIL | 4 | 4 | | | | | 42 | 1,340 | | | | | | |
| MAY | | | | | | | | | | | | | | |
| JUNE | | | | | | | | | | | | | | |
| JULY | | | | | | | | | | | | | | |
| AUGUST | | | | | | | | | | | | | | |
| SEPTEMBER | | | | | | | | | | | | | | |
| OCTOBER | | | | | | | | | | | | | | |
| NOVEMBER | 3 | 3 | | | | | 78 | 1,971 | | | | | | |
| DECEMBER | 6 | 6 | | | | | 154 | 4,052 | | | | | | |
| TOTAL | 31 | 31 | 0 | 0 | 0 | 0 | 1,058 | 27,915 | 0 | 0 | 0 | 0 | 0 | |
| TOTALS FOR FINAL REPORT | 31 | 31 | 0 | 0 | 0 | 0 | 1,058 | 27,915 | 0 | 0 | 0 | 0 | 0 | |
| DATE ON WHICH FINAL WEATHER MODIFICATION ACTIVITY OCCURRED (For Final Report only.) | | | | | | | | | | | 04/15/2021 | | | |
| 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 Erin Fischer | | | | | | | |
| AFFILIATION Weather Modification International | | | | | | | SIGNATURE | | | | | | | |
| STREET ADDRESS 3802 20th Street North | | | | | | | OFFICIAL TITLE Client Services | | | | | | | |
| CITY Fargo | | | | STATE ND | ZIP CODE 58102 | DATE 04/28/2021 | | | | | | | | |



WINTER GROUND OPERATIONS 2020-2021
 WYOMING WEATHER MODIFICATION PROGRAM
 Wind River Mountain Range



Appendix C. Ice Nucleus Generator Operations Summary – 2020-2021

2020-2021 Generator Operations Summary - WIND RIVER RANGE

LAST UPDATED 20210419

GRAND TOTAL OPERATIONAL "SEED" HOURS= 1057:49
 Total Seeding Solution (Gallons)= 458.81

| Monthly Totals | 167:25 | 149:27 | 145:34 | 14:24 | 14:25 | 92:40 | 133:35 | 83:15 | 167:19 | 89:45 | 1057:49 | 1057.82 | | |
|--------------------|-------------------|---------------------------|---------------------|--------------------|------------------|--------------------|----------------------|-------------------|----------------------|---------------------|-------------|-------------|----------------------------|-------|
| UTC DATE | WR01 Big Sandy | WR02 Black & Tackle | WR03 White Acorn | WR04 Sweetwater | WR05 Anderson | WR07 Enterprise | WR09 Boulder Lake | WR10 East Fork | WR12 Pocket Creek | WR13 Green River | DAILY TOTAL | Operation # | Solution Used (gallons) | |
| November sub-total | 19:26 | 14:32 | 11:10 | 0:00 | 0:00 | 0:00 | 7:53 | 2:13 | 19:31 | 3:22 | 78:07 | 78.12 | | |
| December sub-total | 29:01 | 24:50 | 23:07 | 5:46 | 5:46 | 10:17 | 13:38 | 6:47 | 27:44 | 6:45 | 153:41 | 153.68 | | |
| January sub-total | 22:30 | 21:16 | 22:28 | 3:10 | 3:11 | 5:07 | 16:25 | 9:00 | 22:10 | 2:46 | 128:03 | 128.05 | | |
| February sub-total | 83:40 | 76:01 | 76:01 | 5:28 | 5:28 | 0:00 | 85:15 | 60:44 | 85:06 | 70:59 | 548:42 | 548.70 | | |
| March sub-total | 12:48 | 12:48 | 12:48 | 0:00 | 0:00 | 35:25 | 10:24 | 4:31 | 12:48 | 5:53 | 107:25 | 107.42 | | |
| April sub-total | 0:00 | 0:00 | 0:00 | 0:00 | 0:00 | 41:51 | 0:00 | 0:00 | 0:00 | 0:00 | 41:51 | 41.85 | | |
| 11/15/2020 | 11:05 | 11:10 | 11:10 | | | | | | 11:10 | | 44:35 | 44.58 | WRR0124 | 18.84 |
| 11/19/2020 | 3:22 | 3:22 | | | | | 2:54 | | 3:22 | 3:22 | 16:22 | 16.37 | WRR0125 | 7.07 |
| 11/25/2020 | 4:59 | | | | | | 4:59 | 2:13 | 4:59 | | 17:10 | 17.17 | WRR0126 | 6.49 |
| 12/1/2020 | | | | | | 4:53 | | | | | 4:53 | 4.88 | WRR0127 | 1.85 |
| 12/11/2020 | | | | | | 5:24 | | | | | 5:24 | 5.40 | WRR0128 | 2.21 |
| 12/11/2020 | 5:46 | 5:46 | | 5:46 | 5:46 | | 4:39 | 2:43 | 5:46 | 2:43 | 38:55 | 38.92 | WRR0129 | 17.26 |
| 12/17/2020 | 7:42 | 7:42 | 7:42 | | | | | | 7:42 | | 30:48 | 30.80 | WRR0130 | 13.71 |
| 12/19/2020 | 2:19 | 2:19 | 2:19 | | | | 1:55 | | 2:19 | | 11:11 | 11.18 | WRR0131 | 4.18 |
| 12/22/2020 | 4:11 | | 4:07 | | | | 1:14 | 4:04 | 2:54 | 4:02 | 20:32 | 20.53 | WRR0132 | 8.37 |
| 12/26/2020 | 9:03 | 9:03 | 8:59 | | | | 5:50 | | 9:03 | | 41:58 | 41.97 | WRR0133 | 19.02 |
| 1/14/2021 | 4:00 | 3:56 | 4:00 | | | | 2:46 | 2:45 | 3:55 | 2:46 | 24:08 | 24.13 | WRR0134 | 11.42 |
| 1/19/2021 | | | | | | 5:07 | | | | | 5:07 | 5.12 | WRR0135 | 1.84 |
| 1/23/2021 | 6:13 | 5:52 | 6:13 | | | | 6:13 | 4:23 | 6:13 | | 35:07 | 35.12 | WRR0136 | 16.75 |
| 1/28/2021 | 6:58 | 6:27 | 6:58 | | | | 5:33 | 6:58 | 6:58 | | 32:54 | 32.90 | WRR0137 | 15.61 |
| 1/29/2021 | 5:19 | 5:01 | 5:17 | 3:10 | 3:11 | | 1:53 | 1:52 | 5:04 | | 30:47 | 30.78 | WRR0138 | 14.35 |
| 2/3/2021 | 2:43 | 2:43 | 2:43 | | | | 4:24 | 4:39 | 4:40 | 4:39 | 26:31 | 26.52 | WRR0139 | 11.43 |
| 2/6/2021 | 27:03 | 27:03 | 27:03 | | | | 27:03 | 27:03 | 26:56 | 27:03 | 189:14 | 189.23 | WRR0140 | 77.32 |
| 2/12/2021 | 9:19 | 9:19 | 9:19 | 5:28 | 5:28 | | 9:13 | 3:05 | 8:59 | 3:05 | 63:15 | 63.25 | WRR0141 | 26.20 |
| 2/20/2021 | 4:25 | | | | | | 4:25 | | 4:21 | 4:25 | 17:36 | 17.60 | WRR0142 | 7.75 |
| 2/23/2021 | 10:59 | 10:59 | 10:59 | | | | 10:59 | | 10:59 | 10:59 | 65:54 | 65.90 | WRR0143 | 28.11 |
| 2/26/2021 | 29:11 | 25:57 | 25:57 | | | | 29:11 | 25:57 | 29:11 | 20:48 | 186:12 | 186.20 | WRR0144 | 79.15 |
| 3/10/2021 | | | | | | 3:17 | | | | | 3:17 | 3.28 | WRR0145 | 1.57 |
| 3/14/2021 | | | | | | 7:57 | | | | | 7:57 | 7.95 | WRR0146 | 3.42 |
| 3/16/2021 | | | | | | 7:06 | | | | | 7:06 | 7.10 | WRR0147 | 2.84 |
| 3/23/2021 | | | | | | 11:26 | | | | | 11:26 | 11.43 | WRR0148 | 3.66 |
| 3/25/2021 | 6:20 | 6:20 | 6:20 | | | | 4:31 | 4:31 | 6:20 | | 34:22 | 34.37 | WRR0149 | 16.77 |
| 3/26/2021 | | | | | | 5:39 | | | | | 5:39 | 5.65 | WRR0150 | 2.09 |
| 3/29/2021 | 6:28 | 6:28 | 6:28 | | | | 5:53 | | 6:28 | 5:53 | 37:38 | 37.63 | WRR0151 | 17.51 |
| 4/12/2021 | | | | | | 4:05 | | | | | 4:05 | 4.08 | WRR0152 | 1.55 |
| 4/13/2021 | | | | | | 4:26 | | | | | 4:26 | 4.43 | WRR0153 | 2.48 |
| 4/14/2021 | | | | | | 8:38 | | | | | 8:38 | 8.63 | WRR0154 | 4.40 |
| 4/15/2021 | | | | | | 24:42 | | | | | 24:42 | 24.70 | WRR0155 | 13.59 |
| END OF PROJECT | | | | | | | | | | | | | | |