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GROUND-BASED OPERATIONS REPORT

FINAL SUMMARY

Wyoming Water Development Office

WYOMING WEATHER MODIFICATION

Wind River Mountain Range

WINTER OPERATIONS 2019-2020

weathermodification.com

Ground-Based Cloud Seeding Operations
2019-2020 Winter Operations Report

For the

Wind River Mountain Range, Wyoming

Prepared By

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EXECUTIVE SUMMARY

Funding for cloud seeding operations in the Wind River Range for the winter of 2019-2020 was provided in part by the 2019 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 interested parties. Funding partners in support of continued weather modification activities in the Wind River Mountains during the winter of 2019-2020 included the Southern Nevada Water Authority, the Central Arizona Water Conservation District, the Colorado River Board of California - Six Agency Committee, Genesis Alkali, Solvay Minerals, TATA Chemicals, Ciner Wyoming, 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 five previous operational seasons. The White Acorn Ranch generator is shown in Figure 1. 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 2019-2020 season became operational on 15 November 2019 and concluded after 15 April 2020. The first seeding event occurred on 20 November 2019.

Figure 1. The ice nucleus generator sited at White Acorn Ranch on the west flank of the Wind River Range (WMI photograph). For the locations of all the generators, see Figure 5.

The 2019-2020 weather pattern produced considerably higher storm frequencies compared to the previous season, both partly due to the expanded season and more active storm track. Three seeding events occurred in both November and December 2019, a busy ten in January 2020, four in February 2020, seven in March 2020, and four in April 2020, bringing the seasonal total to 31 events. Seasonal snowpack (snow water equivalents, or SWE) at project end (April 15) varied from 85.1% of the median annual value to 114.1%, with the five-site SNOTEL mean at 97.0%. The Hobbs Park and Townsend Creek sites ended above seasonal norms, whereas the rest varied between 85.1% and 91.2% of the median annual value.

The thirty-one storm events accrued 244 hours and 29 minutes during which one or more generators were seeding during the winter. The fewest number of generators that operated during any one storm was one (during three easterly upslope events), and the most, nine. The Enterprise generator, sited on the eastern slope of the range near Lander, was used both early and late during the 2019-2020 season, which is rather typical. Further seasonal extension into the months of November and April could increase the seedable opportunities for this generator.

The total number of "generator hours", defined as the sum of times each generator was operated during a storm, was 999 hours. 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 were: 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.

As accuracy of numerical models as increased, the need to verify requisite temperate and wind criteria by atmospheric soundings has decreased. For the 2019-2020 season, atmospheric soundings were only performed at times when the temperature and/or wind was questionable. One or more weather balloons were released during 12 seeding events and no soundings were needed for 19 seeding events. Seven other weather balloons were released at times when a seeding event didn't occur due to measured conditions being unfavorable. 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 forecast along with presence of clouds on satellite and webcams.

In the 2019-2020 season, WMI obtained high-resolution weather model information from the National Center for Environmental Prediction (NCEP) and created its own model, using a custom-designed nested domain of the Weather Research and Forecasting (WRF) model. 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 with WRF and the other publicly available numerical weather prediction models. More about these models are presented in the body of this report.

The 2019-2020 season featured more shorter-interval storms compared to previous seasons. Of the 31 seeding events, 6 lasted less than four and a half hours. 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.

ACKNOWLEDGMENTS

The 2019-2020 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. The majority 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. For the first time, contributions toward project operations were received from Genesis Alkali, Solvay Minerals, TATA Chemicals, Ciner Wyoming, Rocky Mountain Power, and the Green River/Rock Springs/Sweetwater County Joint Powers Water Board. We appreciate very much the active participation of these stakeholders.

Project guidance and direction on behalf of the State of Wyoming was provided by 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, Michael Willette, 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.

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). 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.

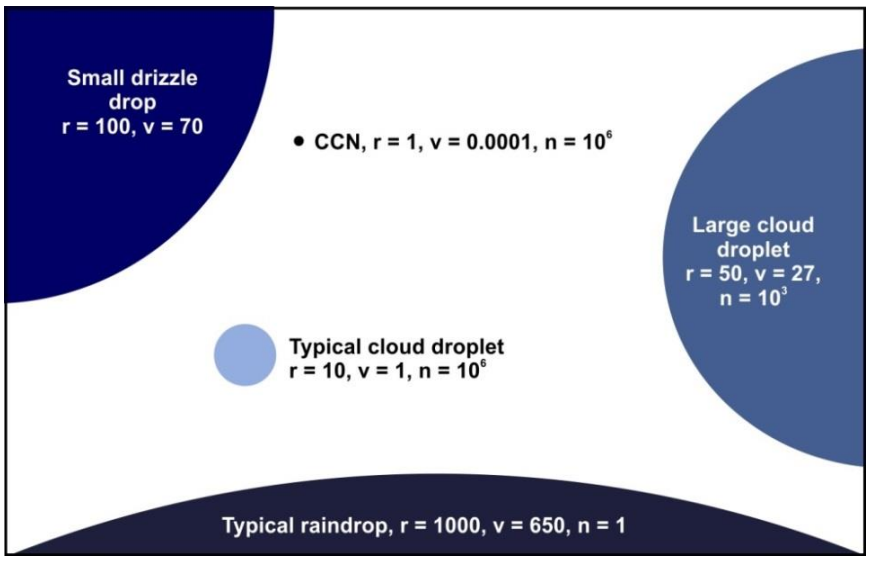

Figure 2. Relative characteristics of particles involved in cloud processes. For each, the radius (r, microns), fall velocity (v, cm per second), and number concentration (n, per liter) are given (after Wallace and Hobbs 1977). The raindrop shown (radius = 1000) is a 2 mm diameter raindrop.

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 -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.

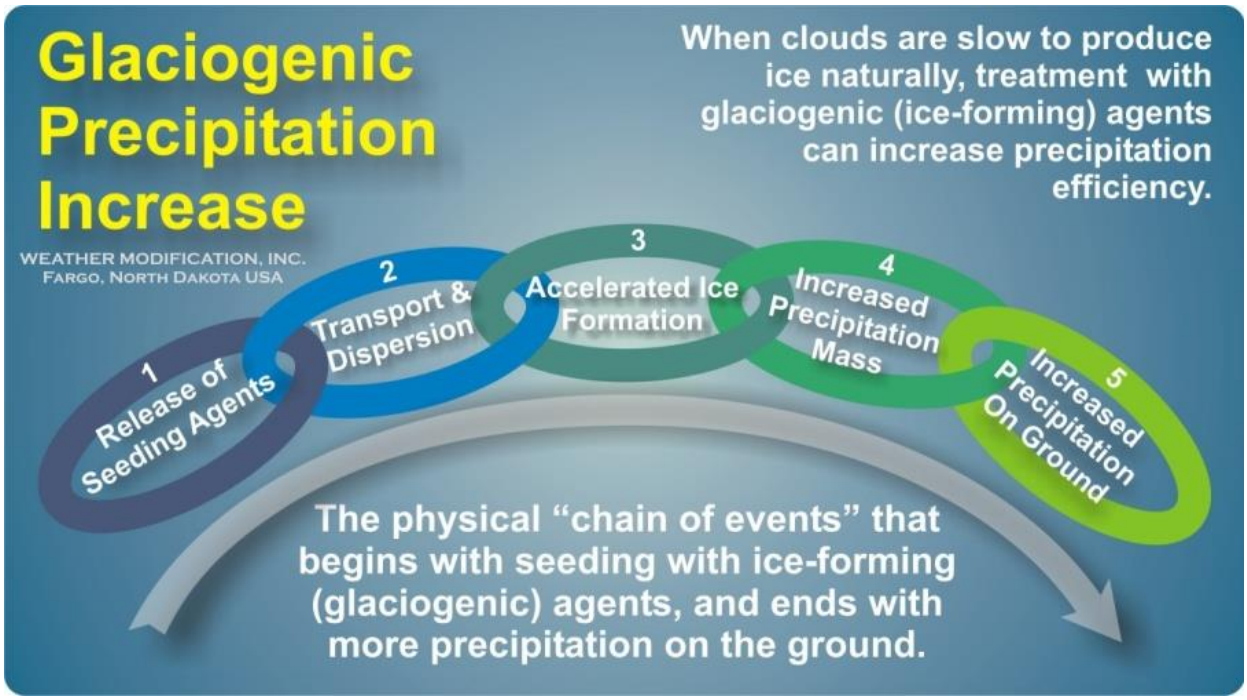

Figure 3. The physical chain-of-events that begins with release of ice-forming seeding agents and culminates with increased precipitation.

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 2019-2020 Program Funding

In addition to the 37% of funding costs provided by the State of Wyoming, funding for the 2019-2020 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-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 2019-2020 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, Solvay Minerals, TATA Chemicals, Ciner Wyoming, 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 2019-2020 winter season. It consisted of primarily 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 the project. Brainard operated WMI's numerical weather prediction model and coordinated data collection during the season. He and meteorologist Michael Willette operated the upper air sounding system (weather balloons). Willette replaced Brainard when Brainard was off-site, with further assistance from Charles Sassaman. Jason Goehring led the forecasting team and was the primary operations meteorologist. Goehring was assisted by Sassaman.

This was Goehring's fifteenth year 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. This was his and Willette's second year in the field in Pinedale, WY. Sassaman was hired by WMI in the late summer of 2019 and spent a month in India on the Maharashtra Cloud Seeding Program before joining the Forecast Team.

Goehring, Brainard, and Willette are all Weather Modification Association Certified Operators. Bruce Boe, WMI Vice President of Meteorology, provided overall management of the meteorology team and its day-to-day operations. He is a Weather Modification Assoication Certified Manager.

2.1.2 Technician Team

Three technicians participated in the 2019-2020 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, but he was not called to assist except for a short generator visit after ground school.

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.

Additional support from WMI headquarters in Fargo, ND was provided by Dennis Afseth, WMI Director of Electronics, and technician's Ryan Richter and Jeremy Bilben. Richter has been providing support for the field program since its inception in 2006.

Figure 4. The 2019-2020 WMI Meteorology Team.

2.1.3 Pre-Project Ground School

A pre-project ground school was held in Cheyenne, WY on Tuesday, 12 November 2019 for all Wyoming cloud seeding project personnel, both ground-based and aerial. Attendance was mandatory for WMI project employees. The meeting topics included forecasting, media protocol, overview of the project, reporting pre- and post-flight, conducting cloud seeding operations (aerial and ground-based), and winter 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.

Figure 5. Michael Paul, WMI Technician, explains safety around the ground-based cloud seeding generators as participants listen at the combined airborne and ground-based seeding pre-project meeting in Cheyenne, WY on 12 November 2019. Photo by Erin Fischer.

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).

Figure 6. The technician team services the Sweetwater generator site on a sunny day. Photo by WMI Lead Technician Michael Paul.

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.

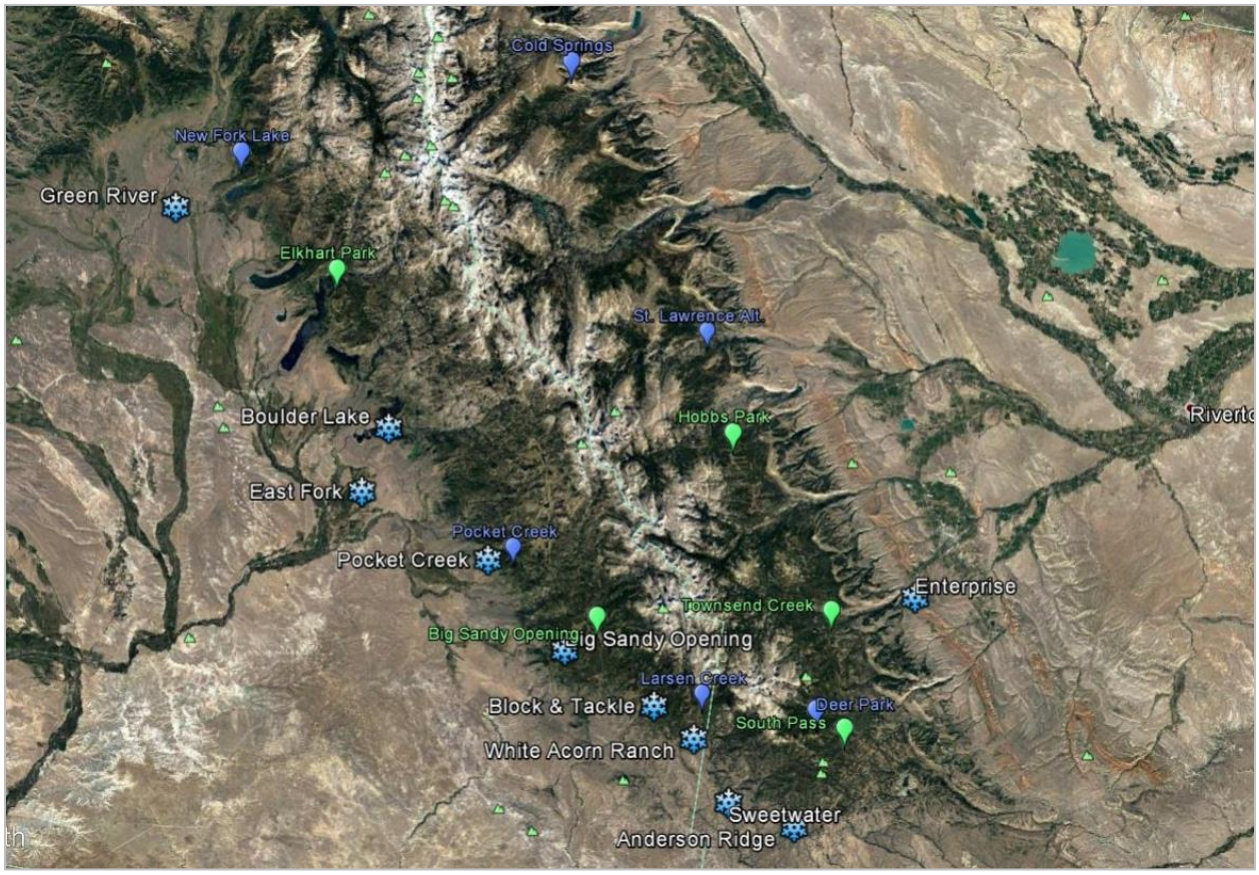

Figure 7. The locations of the ground-based ice nucleus generators are indicated by the snow crystal symbols. The green "balloons" indicate the locations of Natural Resources and Conservation Service (NRCS) snow telemetry (SNOTEL) sites used in monitoring snowpack during the 2019-2020 season. The blue 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 8.

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.

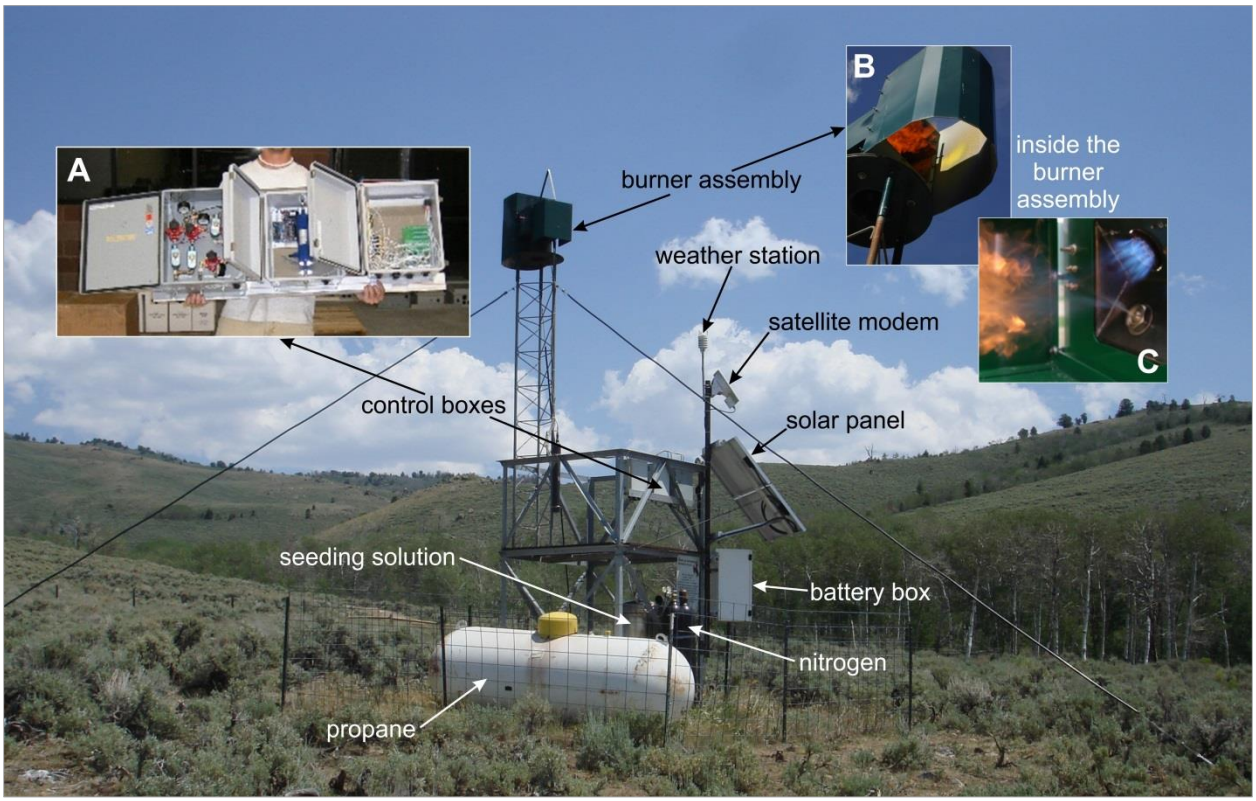

Figure 8. The primary components of the WMI remotely-controlled ground-based ice nucleus generator are illustrated. Inset A, shows the contents of the control boxes. From left to right, these are: solenoids (electronic valves) to turn flows on and off, seeding solution flow rate regulation and measurement, 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 9. 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.

Clicking the Start Seeding button (lower left on the interface, Figures 9 and 10) 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 8, 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, as shown in Figure 10.

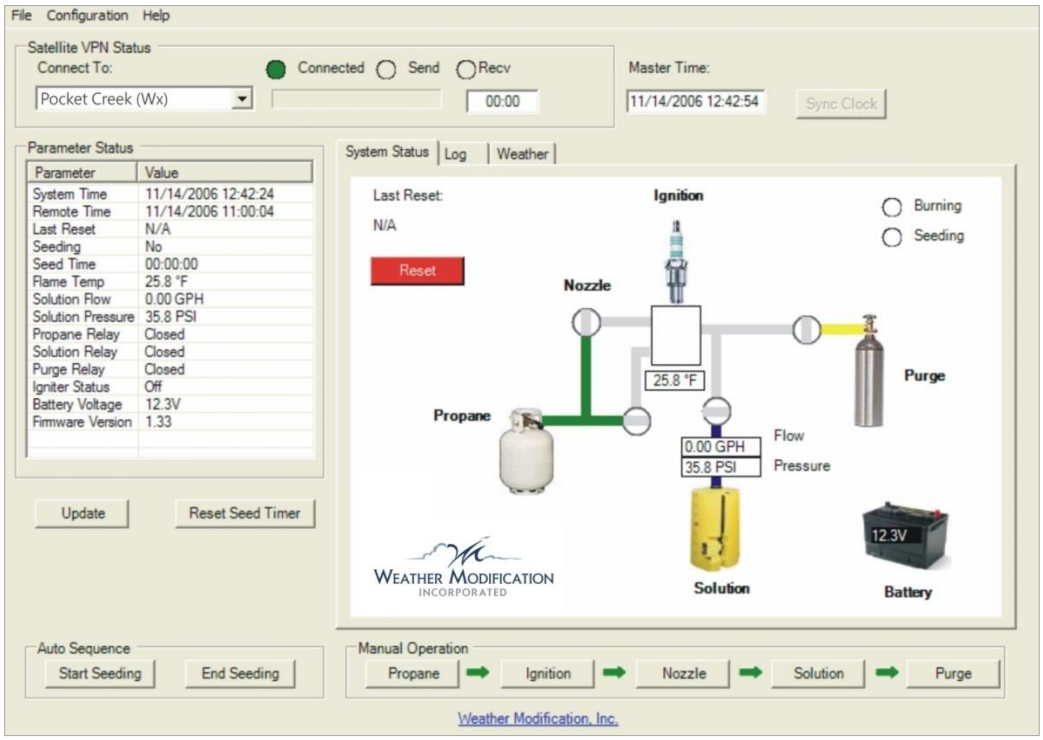

Figure 9. The control interface for the WMI remotely-controlled ground-based ice nucleus generator is shown, after connection is established via satellite, but before the generator is turned on. All flow valves are off, seeding solution flow is zero, but system status is reported.

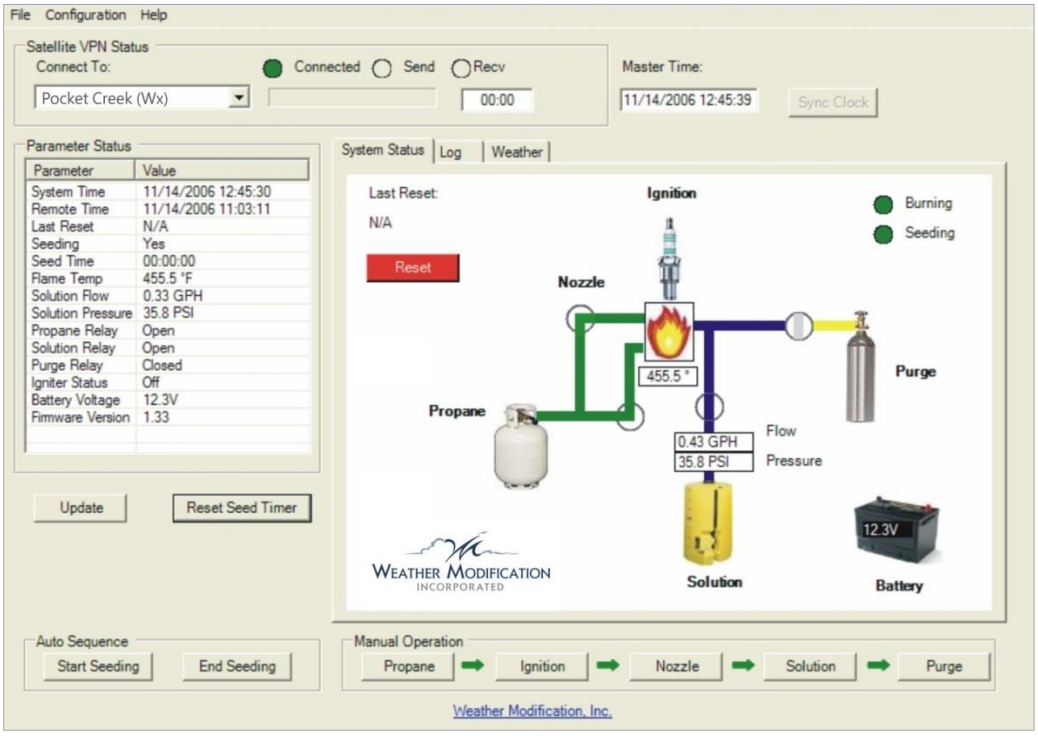

Figure 10. The WMI remote-controlled ice nucleus generator interface is shown, as it appears during seeding operations. Valves are open, the flame is known to be burning, and the seeding solution flow rate is also known. Seeding is certain.

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 11, 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 x 10^{11} nuclei are active per gram of AgI burned. In more convectional 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 2019-2020 Wind River operations used a temperature criterion of -6°C at 700 hPa, which is about 10,000 feet above sea level.

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 come into contact with a supercooled cloud droplet (≤ -5°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.

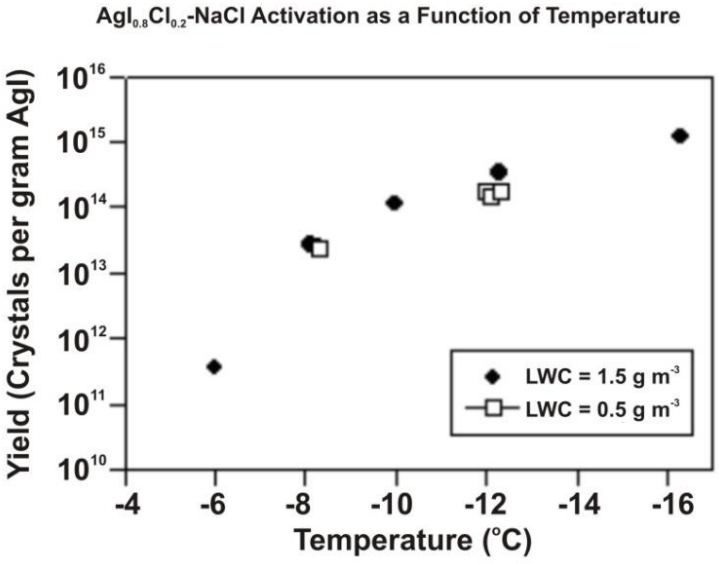

Figure 11. Yield as measured by the number of active ice nuclei per gram of silver iodide (AgI) burned, is shown as a function of temperature (DeMott 1997). These nuclei are comprised of silver iodide, silver chloride, and salt (NaCl).

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 12. 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 of the soundings were archived and are available for any post-analysis efforts that might be undertaken.

Figure 12. WMI Meteorologist Michael Willette launches a weather balloon in anticipation of a seedable weather during the 2019-2020 season from Pinedale, WY. Photo by WMI Meteorologist Adam Brainard.

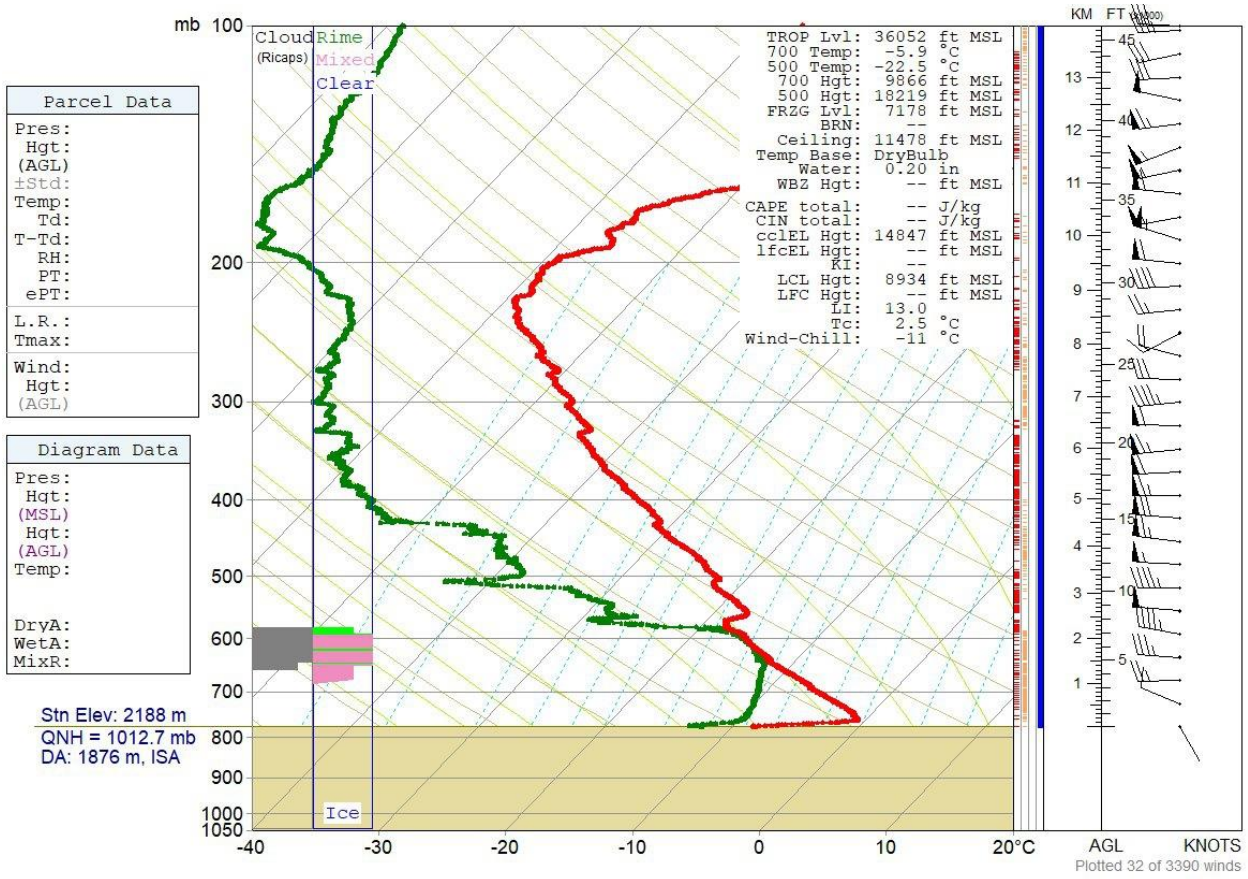

Figure 13. A plot of the upper-air sounding obtained from the weather balloon released from Pinedale, WY at 3:21 UTC on 24 February 2020. The temperature at 700 hPa level (approximately 10,000 feet) was -5°C (+23°F), and the wind speed was from 268° (westerly) at about 25 knots (~29 miles per hour). The temperature, though cool, was not quite cold enough. The atmosphere was cooling, however, so seeding was able to begin shortly thereafter.

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).

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, European Community satellite imagery, Northern Illinois University, and Unisys. While many of the web-based weather products (i.e., National Weather Service (NWS) products) were publicly available, some data sources were project-specific. This year, WMI also implemented a fully-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 2018-2019 project this radiometer had been deployed only in the vertically pointing (zenith) mode because the manufacturer of the unit (Radiometrics) advised WMI that this specific unit was calibrated only for that mode. The quote provided for a calibration at a 10° elevation angle so it could be used quantitatively, with confidence, over the Wind River Range, was well beyond that affordable by the project.

Comparisons of the 30 GHz channel of the instrument, that most sensitive to absorption by liquid water, to the liquid water observed in the (calibrated) zenith mode provided the confidence needed to use that channel as a surrogate for liquid water while operating at the 10° elevation angle. Thus, for the 2019-2020 season the unit was operated at this angle, over the Wind River Range, where the measurements were meaningful. For seeding operations, it is more important to know if liquid water is present; quantitative accuracy is secondary.

Figure 14. 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.

3.1.2 Atmospheric Soundings

Weather balloons were released from WMI's Pinedale shop whenever there was ambiguity about the suitability 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.

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 2019-2020 season. This model was specifically tailored to the Wind River and Wyoming Airborne seeding programs. A regional outer nest, with a 7.5km 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 72h duration on the 0 and 12 UTC cycles. This domain provided boundary conditions to an inner high-resolution nest, with a grid spacing of 2.5km, which was operated to a 48h forecast duration.

Many graphical outputs were developed specifically to aid cloud seeding decision-making. Examples of some of the most unique, the meteorologists' favorites, are shown in the following figures. Figure 15 shows forecast integrated cloud water colder than -5°C over the Wind River Range.

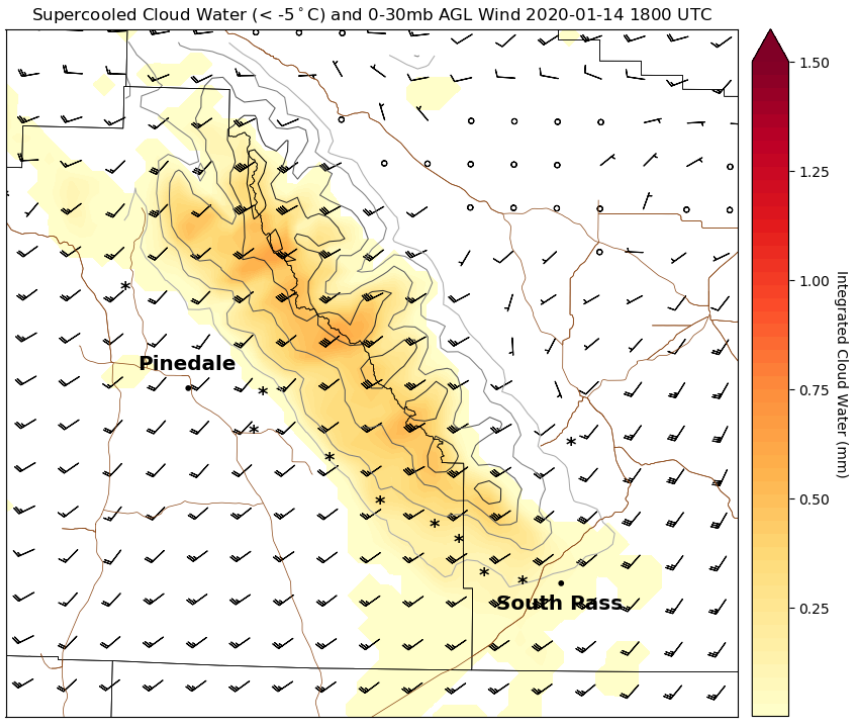

Figure 15. Near surface wind barbs are shown with integrated cloud water on this panel from the WMI WRF model, valid on 14 January 2020, at 18:00 UTC. Since the water shown is only that occurring at -5°C and colder, it is supercooled sufficiently for seeding. The WMI WRF was initialized and run as often as every six hours; plots such as this were created for hourly intervals. Contours show model terrain elevation at 1,000 ft intervals beginning at 8,000 ft.

Though knowing the SLW distribution shown in Figure 15 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 16).

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.

The example shown in Figure 16 for 8 February 2020 is for a west-to-east "zonal" cross section. In the lower panel, a very nice region of cloud water is shown. Note that the region lies entirely above the -5°C isotherm, so the SLW 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. With real-time web access to all imagery, spatial maps can be animated in 1-hour time steps, providing a crucial understanding of expected storm evolution.

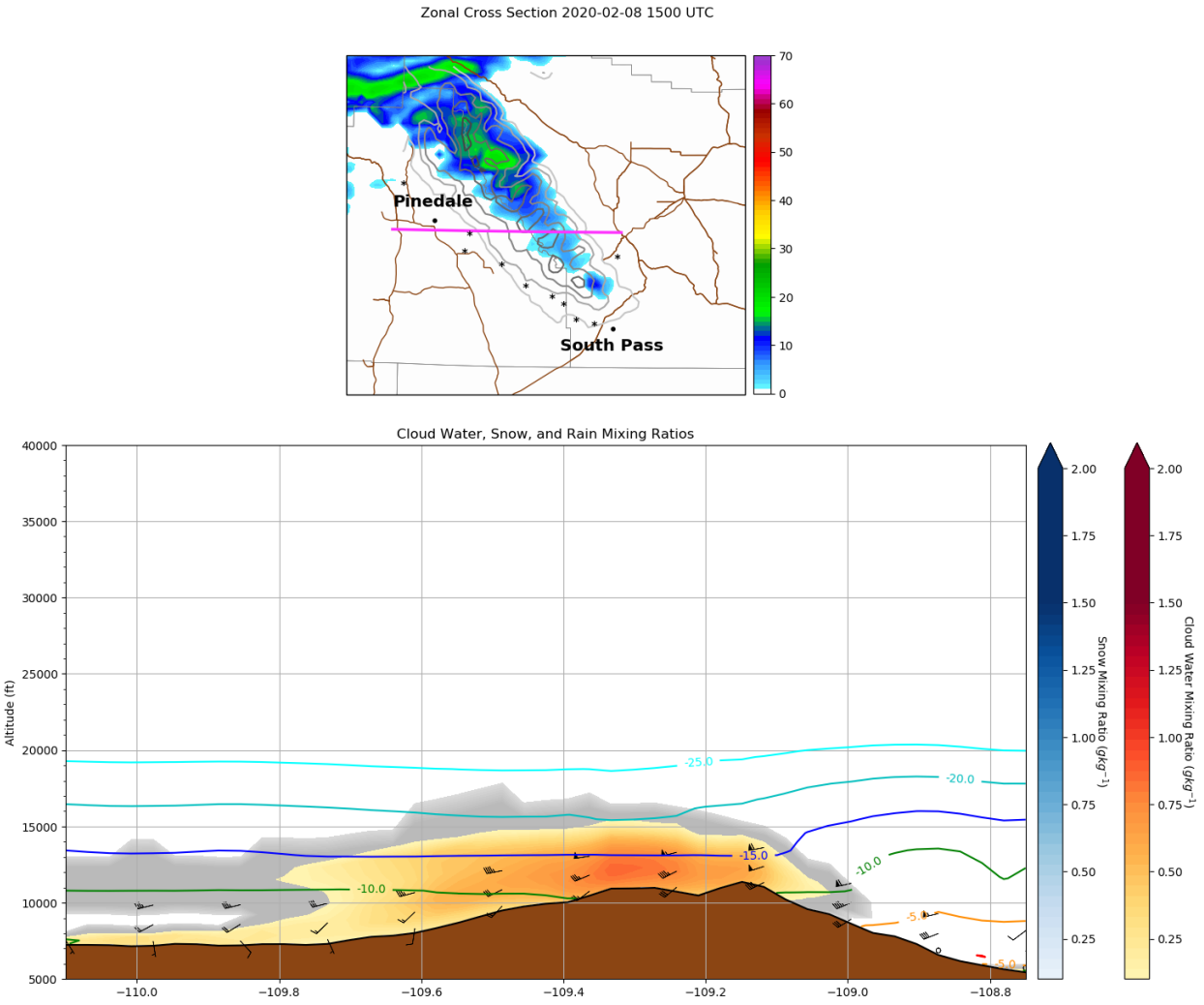

Figure 16. Zonal vertical cross section from near the Boulder Lake generator site to Lander. Cross section line shown in pink on the forecast composite reflectivity plot on the top half of the image. The plot represents 15:00 UTC on 8 February 2020, or 8 AM MST. See text for interpretation and discussion.

Stability throughout the Wind River domain was made part of the suite of products created during the WMI WRF model runs, as depicted in Figure 17. 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 18).

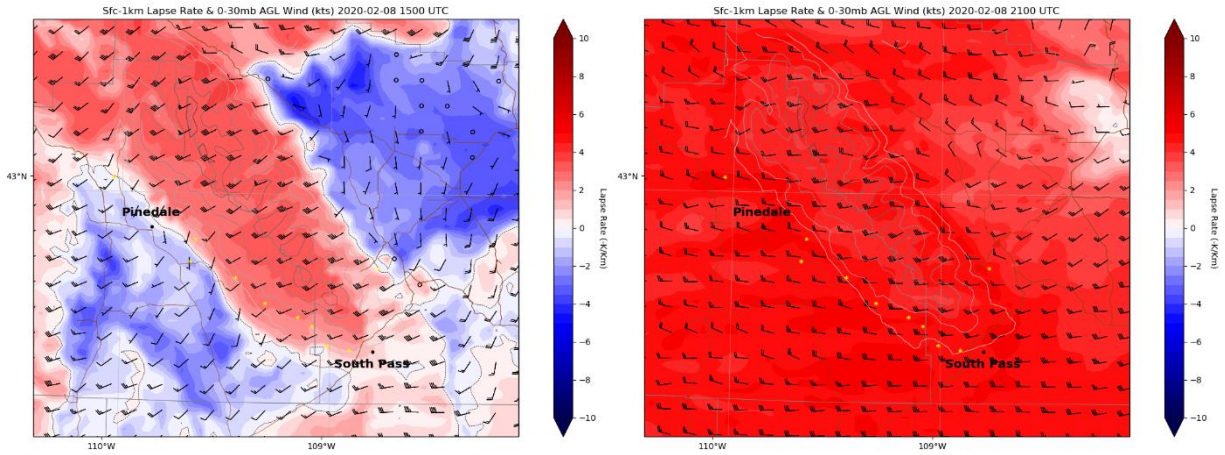

Figure 17. Another product developed specifically for winter orographic seeding is the vertical temperature lapse rate plot of the lowest 1 km (~3,000 feet), shown here. In these graphics, a negative change (blue) indicates increasing temperature with height (warming), while reds and pinks indicate cooling. Thus, the redder the area, the more easily air (seeding plumes) is mixed from below. The left panel shows lapse rates at 15:00 UTC, after seeding began from a number of higher elevation generators. Lower elevation generators can be seen residing in more stable air in the valleys. The right plot shows how conditions had become more favorable (less stable) by 21:00 UTC, when seeding was occuring with all nine western generators.

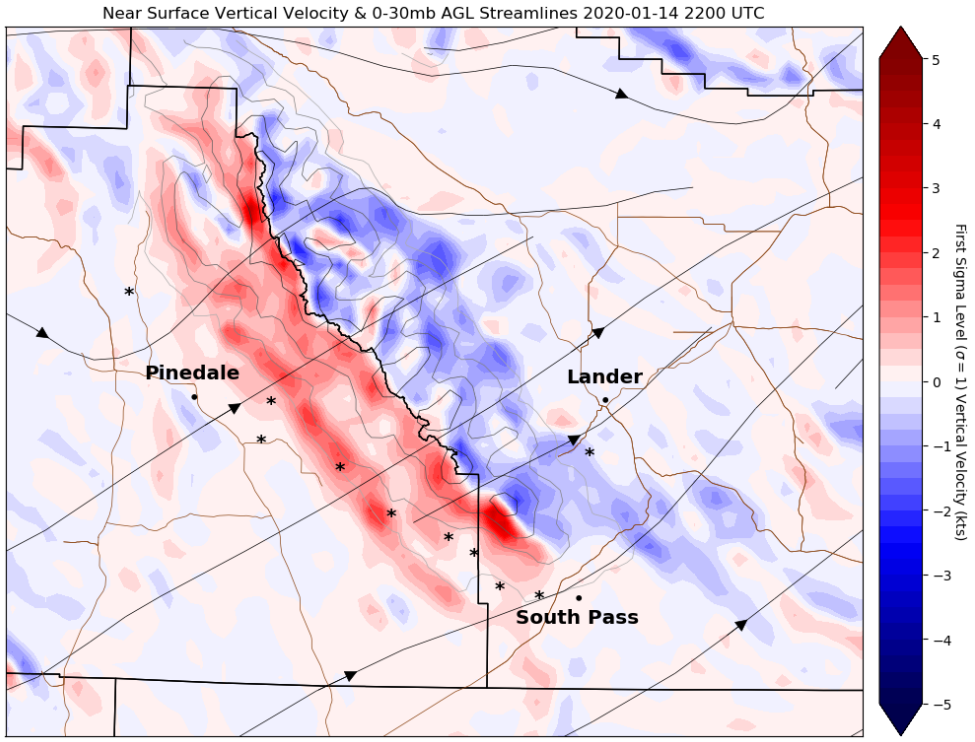

Figure 18. This product, also designed specifically for winter orographic seeding, shows the near surface vertical velocity along with streamlines of the near surface (average 0-30 mb AGL) wind. Here, ascending air is shown in red, with descending air in blue. This plot helps illuminate when sufficient upslope winds exist to transport seeding materials from ground generators up into the target area. This plot shows favorable seeding conditions during a seeding event in mid-January 2020.

3.2.2 HYSPLIT Modeling

During the 2019-2020 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 19, for the 8 February 2020 seeding event. In the plots, each hour is shown by a "dot" on the plume centerline.

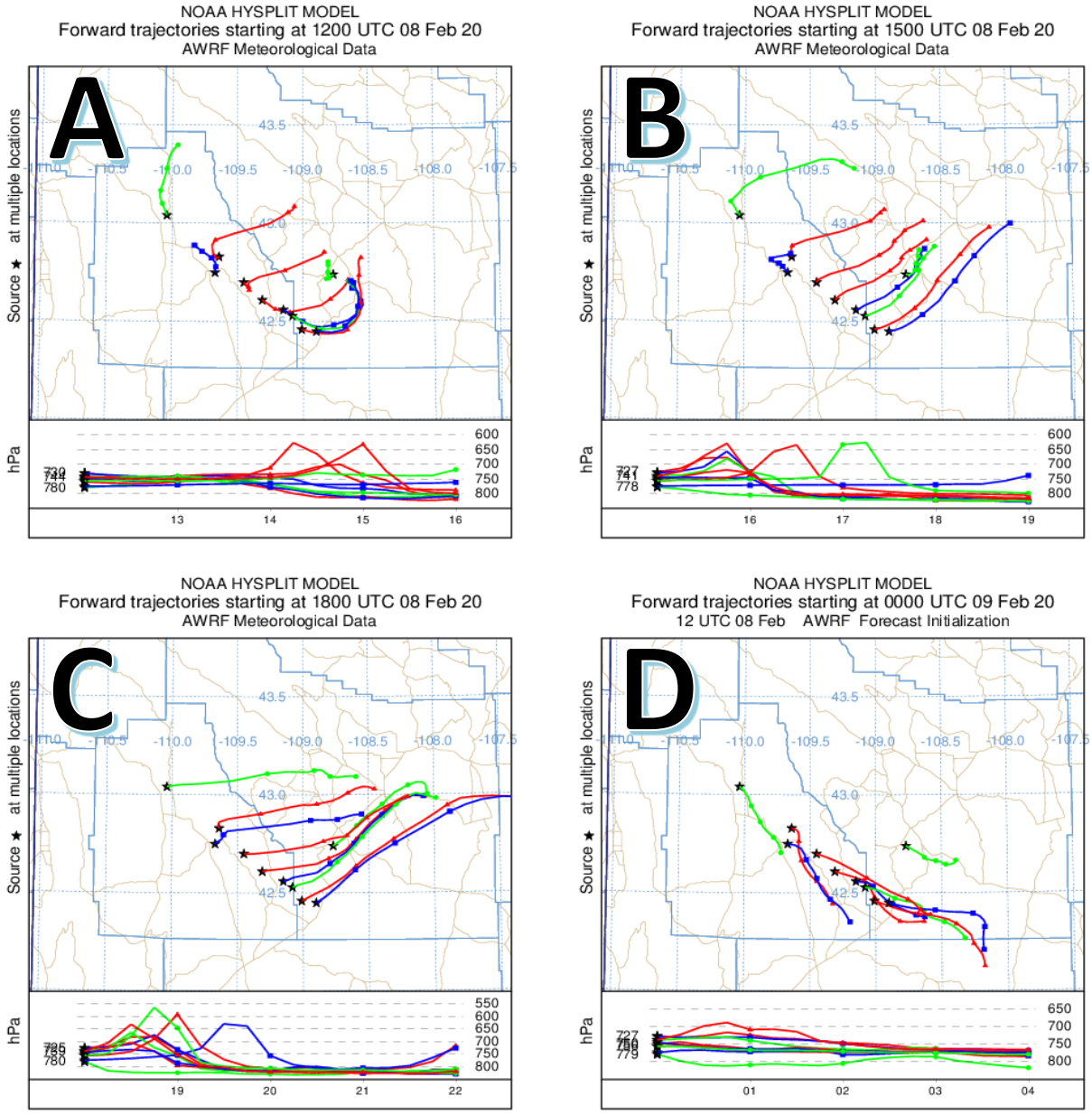

Figure 19. The evolution of the centers of plume trajectories is shown for the seeding event on 8 February 2020. Times (UTC) are as follows: (A) 12:00 February 8th, (B) 15:00 February 8th, (C) 18:00 February 8th, and (D) 0:00 February 9th. Before the seeding began (A), most plumes were projected to remain 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 a number of 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.

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 (Section 2.5, Figure 12), to obtain vertical temperature, humidity, and wind profiles.

The presence of SLW was confirmed by the real-time data from the radiometer (Section 3.1.1) 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 mountains.
-1	No	Limited coverage or short-lived orographic clouds, not enough temporal or spatial extent to warrant seeding activities.
0	Possible	Some orographic clouds or stratiform cloud deck(s) over mountain tops. SLW likely insufficient for seeding operations or winds clearly unfavorable.
+1	Yes	Orographic clouds and/or stratiform cloud deck(s) enshrouding mountain tops, winds favorable and SLW likely sufficient for seeding operations.
+2	Yes	Persistent orographic clouds and/or stratiform cloud deck(s) enshrouding mountain tops, SLW probable, winds favorable. Lengthy operations possible.

Table 1. The Orographic Day Category.

4 OPERATIONS

4.1 2019-2020 Season

Project operations began on 15 November 2019, with forecasts and full data collection activities. The first seeding opportunity occurred on 20 November 2019 as an eastern upslope event. During the season, seeding opportunities were observed on thirty-one occasions, as enumerated in Table 2.

November and December had three seeding events each, January ten, February four, March seven, and April four. Table 3 summarizes operations by month and provides season totals. In total, 25.314 kg of seeding agent were released. Generators were operated for a total of 244:29 hours during the season, accruing a total of 999 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-seven seeding events that utilized more than one generator were all quality opportunities that used four to nine generators and were of 3.5 or more hours in duration. Five events were ten hours or longer, and one exceeded twenty hours.

2019-2020 List of Seeding Events

Date	Number of Generators Utilized	Length of Seeding (hours)	Total Generator Hours	Agl Released this date (kg)	Agl Monthly Total (kg)	Generator Hours	Total Duration of Seeding
11/20/2019	1	9:37	9:37	0.275	1.187	45:33	22:00
11/25/2019	2	5:09	7:38	0.209			
11/28/2019	4	7:14	28:18	0.703			
12/8/2019	3	5:51	15:55	0.386	3.807	152:42	40:03
12/12/2019	4	29:09	116:36	2.891			
12/24/2019	4	5:03	20:11	0.531			
1/1/2020	3	5:52	17:36	0.475	9.265	375:41	77:59
1/2/2020	2	3:22	6:44	0.156			
1/4/2020	7	4:02	24:00	0.605			
1/7/2020	4	5:09	20:33	0.510			
1/8/2020	5	9:50	42:02	0.972			
1/12/2020	8	5:46	28:38	0.732			
1/13/2020	7	17:05	94:31	2.378			
1/14/2020	9	16:21	108:07	2.579			
1/15/2020	4	5:16	21:03	0.540			
1/17/2020	4	5:16	12:27	0.318			
2/8/2020	9	9:52	69:16	1.809	4.089	157:06	29:07
2/14/2020	5	7:29	32:01	0.860			
2/16/2020	7	7:27	46:42	1.173			
2/24/2020	3	4:19	9:07	0.247			
3/1/2020	1	6:04	6:04	0.170	4.956	189:59	56:23
3/9/2020	5	11:39	46:01	1.217			
3/18/2020	3	3:41	8:10	0.231			
3/19/2020	1	13:39	13:39	0.391			
3/22/2020	3	4:24	8:55	0.240			
3/24/2020	3	7:58	21:02	0.490			
3/25/2020	8	8:58	86:08	2.216			
4/1/2020	4	7:54	31:08	0.739	2.010	78:09	18:57
4/2/2020	4	4:15	17:00	0.445			
4/12/2020	5	6:48	30:01	0.826			
4/15/2020	1	0:00	0:00	0.000			
Season	31 Events				25.314	999:10	244:29

Table 2. 2019-2020 List of Seeding Events.

2019-2020 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	2 (1)	2.3	15.18	0.40	1.187
December	3	3.7	50.90	1.27	3.807
January	10	5.3	37.57	0.93	9.265
February	4	6	39.28	1.02	4.089
March	5 (2)	3.4	27.14	0.71	4.956
April	3 (1)	3.5	19.54	0.50	2.010
Totals/Averages	*27 (4)*	*4.3*	*32.23*	*0.80*	*25.314*

**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.*

Table 3. Summary of seeding events conducted during the 2019 - 2020 winter season.

The generator performance for the season was good, at 90.2% functionality.

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. Three of them, White Acorn, Sweetwater, and Anderson, ran flawlessly the whole season. Green River, Pocket Creek, and Boulder Lake each experienced problems (less than a complete run) on numerous occasions.

Ice Nucleus Generator Operations 2019-2020 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
20191120	WRR0093	REQ	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	1	
		RAN	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO		1
20191125	WRR0094	REQ	YES	NO	NO	NO	NO	NO	YES	NO	YES	YES	4	
		RAN	NO	NO	NO	NO	NO	NO	YES	NO	PARTIAL	NO		1.5
20191128	WRR0095	REQ	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO	4	
		RAN	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO		4
20191208	WRR0096	REQ	YES	NO	NO	NO	NO	NO	YES	YES	YES	YES	5	
		RAN	YES	NO	NO	NO	NO	NO	YES	NO	YES	NO		3
20191212	WRR0097	REQ	YES	YES	YES	NO	NO	NO	YES	NO	YES	NO	5	
		RAN	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO		4
20191224	WRR0098	REQ	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO	4	
		RAN	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO		4
20200101	WRR0099	REQ	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	3	
		RAN	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO		3
20200102	WRR0100	REQ	NO	NO	NO	NO	NO	NO	YES	NO	YES	NO	2	
		RAN	NO	NO	NO	NO	NO	NO	YES	NO	YES	NO		2
20200104	WRR0101	REQ	YES	YES	YES	NO	NO	NO	YES	YES	YES	YES	7	
		RAN	YES	YES	YES	NO	NO	NO	YES	YES	YES	YES		7
20200107	WRR0102	REQ	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO	4	
		RAN	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO		4
20200108	WRR0103	REQ	YES	YES	YES	NO	NO	NO	YES	NO	YES	NO	5	
		RAN	YES	YES	YES	NO	NO	NO	YES	NO	YES	NO		5
20200112	WRR0104	REQ	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	YES	YES	NO	YES	YES	YES	NO		8
20200113	WRR0105	REQ	YES	YES	YES	YES	YES	NO	YES	NO	YES	NO	7	
		RAN	YES	YES	YES	YES	YES	NO	YES	NO	YES	NO		7
20200114	WRR0106	REQ	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES		9
20200115	WRR0107	REQ	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO	4	
		RAN	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO		4
20200117	WRR0108	REQ	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO	4	
		RAN	YES	PARTIAL	YES	NO	NO	NO	NO	NO	PARTIAL	NO		2.75
20200208	WRR0109	REQ	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES		9
20200214	WRR0110	REQ	YES	YES	YES	NO	NO	NO	YES	NO	YES	NO	5	
		RAN	YES	YES	YES	NO	NO	NO	YES	NO	YES	NO		5
20200216	WRR0111	REQ	YES	YES	YES	NO	NO	NO	YES	YES	YES	YES	7	
		RAN	YES	YES	YES	NO	NO	NO	YES	YES	YES	YES		7
20200224	WRR0112	REQ	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO	4	
		RAN	YES	NO	YES	NO	NO	NO	NO	NO	NO	NO		2
20200301	WRR0113	REQ	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	1	
		RAN	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO		1

20200309	***WRR0114***	***REQ***	YES	YES	YES	NO	NO	NO	YES	NO	YES	NO	5	
		RAN	YES	YES	YES	NO	NO	NO	YES	NO	YES	NO		5
20200318	***WRR0115***	***REQ***	YES	NO	NO	NO	NO	NO	YES	NO	YES	NO	3	
		RAN	YES	NO	NO	NO	NO	NO	YES	NO	NO	NO		2
20200319	***WRR0116***	***REQ***	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	1	
		RAN	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO		1
20200322	***WRR0117***	***REQ***	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	3	
		RAN	NO	NO	NO	NO	NO	NO	NO	NO	YES	YES		2
20200324	***WRR0118***	***REQ***	YES	NO	NO	NO	NO	NO	NO	NO	YES	YES	3	
		RAN	YES	NO	NO	NO	NO	NO	NO	NO	YES	YES		3
20200325	***WRR0119***	***REQ***	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	9	
		RAN	YES	YES	YES	YES	YES	NO	NO	YES	YES	YES		8
20200401	***WRR0120***	***REQ***	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO	4	
		RAN	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO		4
20200402	***WRR0121***	***REQ***	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO	4	
		RAN	YES	YES	YES	NO	NO	NO	NO	NO	YES	NO		4
20200412	***WRR0122***	***REQ***	YES	NO	NO	NO	NO	NO	YES	YES	YES	YES	5	
		RAN	YES	NO	NO	NO	NO	NO	YES	YES	YES	YES		5
20200415	***WRR0123***	***REQ***	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	1	
		RAN	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO		0
ZULU DATES ONLY												TOTALS	141	127.25
PARTIAL = > 25% of Expected Runtime													RUN =	90.2%
													FAIL =	9.8%

Table 4. Ice nucleus generator operations are shown for each of the twelve seeding events during the 2019-2020 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 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 near average snowpack values and total hours of seeding.

Hours of Seeding - 2014-2020 Winter Seasons

	Nov	Dec	Jan	Feb	Mar	Apr	Season
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
Mean	24:37	61:51	44:14	60:44	42:23	16:21	222:41

**Project was suspended on February 11th, 2017.*
***Project started on December 9th, 2017, not December 1st.*

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

Though the 2017-2018 season had the fewest hours during which seeding has been conducted during a season (Table 5), more seeding hours, that is, more generators were operated during those opportunities (Table 6) than the first season (2014-2015). Viewed another way, it can be said that full advantage is being taken of those opportunities that present themselves.

Hours of Ice Nucleus Generator Operation - 2014-2020 Winter Seasons

	Nov	Dec	Jan	Feb	Mar	Apr	Season
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
Mean	67:52	344:14	257:07	320:46	196:07	36:05	1137:32

**Project was suspended on February 11th, 2017.*
***Project started on December 9th, 2017, not December 1st.*

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

It is here noted that 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 increasingly evident for the 2019-2020 season, where a more active storm track but shorter-duration snowfalls resulted in above average total seeding time but well below average combined generator operation.

5 GENERATOR SITE OPTIMIZATION STUDY

Of the ten ground-based ice nucleus generators used in the Wind River Range, two stand out as being used only infrequently. These two sites, Anderson Ridge and Sweetwater, are located the farthest south, and are frequently within airflow going around the range, rather than over it.

Since WMI began using the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) plume model to predict the dispersion of seeding plumes in 2017, the two southern-most sites were often found not to be in good positions to get seeding agent into the target area.

As part of the 2019-2020 season, WMI was tasked with reviewing the existing ground generator sites and if possible, identifying some better locations farther to the north to which the equipment at the less-frequently-used sites might be relocated.

After some "desktop exploration" of the area, Bruce Boe of WMI met Patrick Golden of Heritage Environmental Consultants, on site. On 6 October 2020, the two explored the possibilities identified by the desktop studies, and in general scouted the area for other potential sites. A total of five sites were identified, but access to all is not ensured. These sites are given in Table 7, and their locations are shown in Figure 20. Existing sites are also shown.

Potential Ground-Based Ice Nucleus Generator Sites

Site Name	Tentative Location		Elevation	Site Ownership	Access
	Longitude	Latitude			
Badger Creek	-110.06	43.18	7958'	State of Wyoming	through private property
Flattop Flats	-109.93	43.05	7693'	State of Wyoming	public road
Highland Irrigation District	-109.83	42.88	7552'	Private	private road
Meadow Lake	-109.69	42.88	7783'	WY Game & Fish	public road
Half Moon Mountain	-109.72	42.89	8089'	WY Game & Fish	to be determined

Table 7. Potential ground-based ice nucleus generator sites.

Badger Creek

This site is farthest north of the potential new sites, located on a bench on the west side of the Green River. In westerly and southwest flow, ice nuclei would travel from the generator site across the valley, and then—potentially—upward into clouds above the Wind River Range.

Being on the west side of the valley will allow additional time for the seeding plume to spread (disperse) before reaching the clouds, allowing a greater cloud volume to be effectively treated, depending upon the vertical wind profile and stability. This site has potential to directly benefit the headwaters of the Green River.

Though located on State lands, access to this site is only available through private lands, however, so the landowner must grant permission before this site can be seriously considered. In addition, the lessee of the State-owned lands must agree.

This site would be ineffective (and not used) in flow from the northwest, regardless of stability. Since this site could not immediately be visited, no photograph is available.

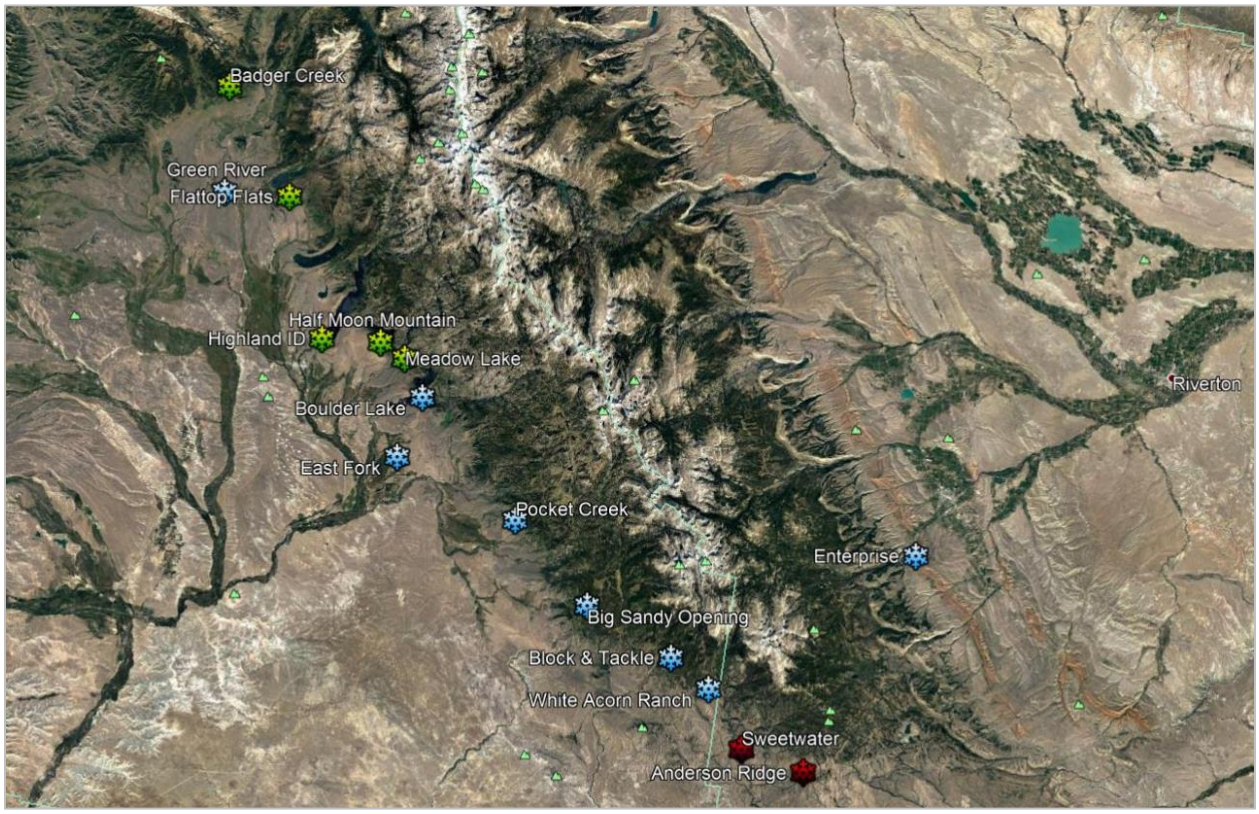

Figure 20. Cloud seeding ice nucleus generator sites are shown. The blue snowflakes are existing sites that are planned to be maintained. The two red sites, Sweetwater and Anderson Ridge, are used less frequently, and would be relocated to two of the five green sites, which denote potential locations under consideration.

Flattop Flats

Flattop Flats—or just "Flattop", is very close to the same latitude as Green River, so in westerly flow might well be redundant. That is, nuclei would go pretty much the same place. In southwesterly flow this would not be the case, however, but would help fill the gap between the Boulder Lake site and Green River. The view from the potential Flattop Flats site to the northeast, thus showing the area targeted when winds would be from the southwest, is shown in Figure 21.

In some cases, the greater proximity to the range (than the Green River site) might be enough to allow effective treatment in some circumstances when nuclei from Green River would tend to travel parallel to the range rather than entering the supercooled clouds above it. How often this might be the case is presently unknown.

Access to the site, which is on Wyoming State lands, is via public road, and thus does not pose any problem. The lessee of these lands would have to first grant approval, however.

Figure 21. The view to the northeast from the possible Flattop Flats site is shown. This is the direction the seeding plume would travel most times when this generate site would be used. The higher peaks of the range are not visible from the site because of the modestly higher intervening terrain, but this is not a negative. The slope is gradual, lessening the windspeed needed for transport upward and into the clouds.

Highland Irrigation District

This site is named such simply because it lies within the district. The site shown—preliminary—lies on private land, however, and at the time of this report the only contact information available was a mailing address. This potential site is roughly halfway between the existing Green River and Boulder Lake sites, and so, if for no other reason would help increase the seeding coverage. Outreach to the landowner, via mail, is ongoing.

Like Badger Creek and Flattop Flats, Highland Irrigation District would be effective in southwesterly to westerly flow regimes (Figure 22). At an elevation of about 7,500 feet, the site isn't all that high, but it has good exposure. With even modest winds and in the absence a stable layer (or temperature inversion), targeting of this as-yet largely untargeted portion of the range would be a step forward.

As noted, the Highland Irrigation District site is on private land, so permissions for access and siting would be needed.

Figure 22. Shown here, the view from near the potential Highland Irrigation District site reveals the undulating terrain to the northeast, where the crestline of the Wind River Range lies, some 18 miles distant. This distance allows the needed time for plume dispersion and the desired growth to precipitation after nucleation.

Meadow Lake

This site is located within the Half Moon Wildlife Habitat Management Area (WHMA). Preliminary consultation with the Wyoming Game and Fish Departments indicates that siting within the WHMA is likely feasible, if National Environmental Policy Act (NEPA) procedures are observed. Because of the very low impact of such a site, this could likely be accomplished. The Game and Fish Department has indicated that vehicle travel within the WHMA is on-road only, so a site in the area would have to be relatively close to an existing road, as is the site shown. Access is by public road.

The Meadow Lake site, if selected, would be most used in southerly to westerly flows, perhaps occasionally in flow from the west-northwest (Figure 23). At 7,700', it would be above the valley floor and perhaps less susceptible to the effects of inversions or stable layers. It is not far (2.5 miles) from the Half Moon Mountain site to the north, described immediately below.

Figure 23. The view to the northeast from the possible Meadow Lake site, located just southeast of Half Moon Mountain, is shown. Though the slope is clearly rising near the site, it crests near the horizon, just a few hundred yards away. Beyond, the terrain opens up into a broad, more gradual incline toward the west slope target. At just 2.5 miles from the possible Half Moon Mountain site, the Meadow Lake site could be a viable alternative.

Half Moon Mountain

The Half Moon Mountain site is also located on the Half Moon WHMA, on the southern "shoulder" of Half Moon Mountain. This site is at the highest elevation of all the possible new sites, at nearly 8,100' elevation.

Access would likely be from the north. This site was not known during the Boe-Golden October 2020 siting expedition, however, but about a week later. Had this potential site been identified earlier, an attempt to reach it from the existing road that approaches from the north might have been made. Post-field examination of recent Google Earth imagery suggests that the road from the north does reach the site, however, so use may be possible. The only way to determine this with certainty is to revisit the area.

The Half Moon Mountain site has very good exposure to flow from the south-southeast through the west-northwest, and because of the additional altitude would likely be less subject to the negative effects of capping stable layers and inversions. This could make it the preferred site if it and Meadow Lake should both prove feasible.

Because access would be a rather circuitous route from the north that winds around the backside of the mountain, winter access might be more time-consuming than some of the others, but likely not more difficult. As this site was not visited, no picture is available.

5.1 Testing in the 2020-2021 Field Season

Since 2017, WMI has been using the HYSPLIT model to predict the centerlines of seeding plumes from each of the ten generator sites. The model uses three-dimensional wind flow and stability in the context of complex terrain to predict how the plume from each generator will behave. This knowledge provides the project meteorologists with an "edge" in the selection of which generators to use in each seeding opportunity.

During the 2020-2021 seeding season, these five potential sites will be also run with HYSPLIT, to obtain a clearer picture of how each performs in actual seeding conditions, and also how often it might be used. This one-winter "snapshot" will be governed by the character of the opportunities that occur during the season but should illuminate which sites should be pursued. To avoid any confusion to those accessing the data on the web, these five will be shown in a separate graphic, apart from the ten currently in operation.

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, before any local outreach could occur the COVID-19 pandemic began, so such plans were shelved for the 2019-2020 season. WMI appreciates being asked to take part in this type of educational outreach, and has gladly conducted such events, which are done with the knowledge and support of the WWDO. 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.

WMI presented an update on the 2019-2020 Wind River operational seeding efforts at Wyoming weather modification stakeholders meeting held in a virtual format on 7 July 2020. That presentation included many of the summary tables included in this report, as well as a recapitulation of the season's weather and seeding opportunities.

7 SUMMARY

The 2019-2020 cloud seeding effort in the Wind River Range began on 15 November 2019 and officially concluded on 15 April 2020, a duration of 153 days (5 months). There were no seeding suspensions during the season.

In its conclusion, the 2019-2020 season struck comparatively average in terms of general operations and close to seasonal norms in snowpack. Overall, the dominant synoptic scale pattern was not favorable for extended moist southwesterly flow, which gives nearly continuous favorable seeding conditions. With semi-permanent ridging in the eastern Pacific and a shifting upper-atmosphere over the Rockies, quick-moving northwesterly clipper systems controlled the composition of winter storms this season. As such, constantly changing near-surface atmospheric conditions resulted in a preference towards shorter seeding intervals as seen in Figure 24. Outside of one 29-hour event on 12-13 December 2019, most seeding events stayed between 2.5 – 10 hours duration. In another visualization, Figure 25 shows cumulative (combined) generator hours for the season. Extended seeding events on 12-13 December 2019 and 12-15 January 2020 aside, numerous smaller incremental events were prevalent throughout the season, with only one lengthy inactive period in late January and early February.

Thirty-one seeding events were conducted releasing a total of 25.31kg of silver iodide, with only four events comprising north-easterly upslope snowfall.

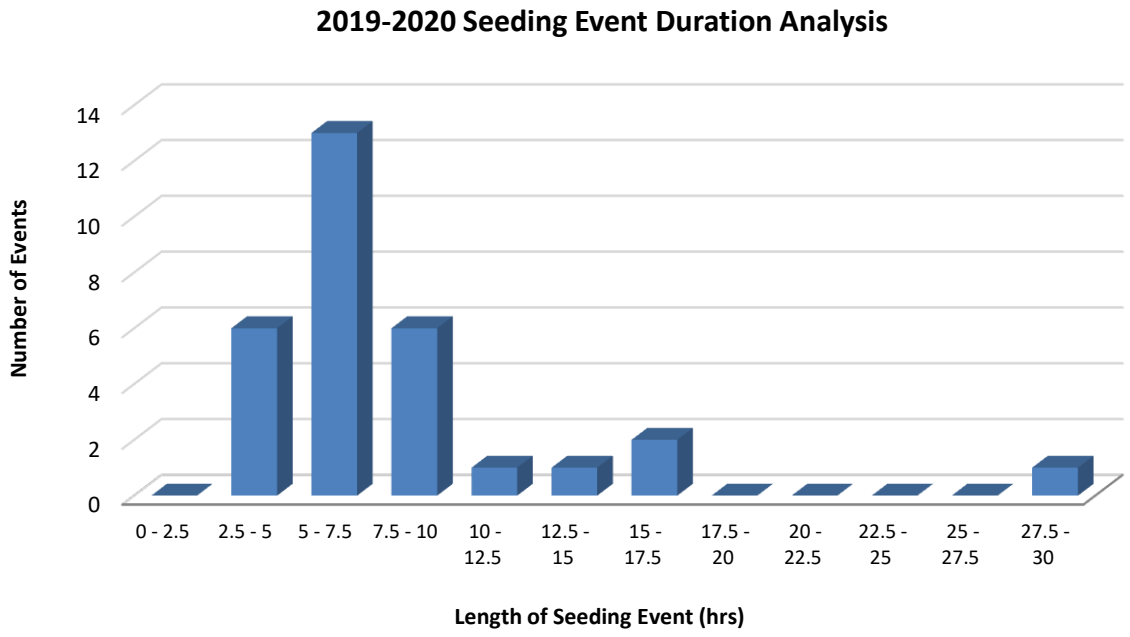

Figure 24. 2019-2020 Seeding Event Duration Analysis.

Referring to Tables 5 and 6, the 2019-2020 season recorded slightly above average total operational seeding time (224:29 hours), but well below average cumulative generator time (999:17 hours). This discrepancy can be explained through multiple attributing factors. Shorter-interval storms inherently have a more dynamic quality, producing somewhat variable conditions which results in decreased time that certain generators remain favorable for seeding operations. In addition, with the increasing prevalence of numerical modeling products for the project, more accurate operational timeframes for each generator are produced, refining and shortening total generator time. Finally, with the prevalence of northwesterly system trajectories, operational seeding time in the southern end of the range was further limited. It is also important to note that the three previous seasons did not undergo seeding operations during the months of November and April, skewing average seasonal totals lower. Furthermore, the 2016-2017 season was suspended in early February and the 2017-2018 season started later in December. Had those seasons commenced operations into November and April without suspensions or budget constraints, the 2019-2020 season would likely sit below average in both total seeding and cumulative generator time.

The ice nucleus generators operated reliably, seeding as intended over 90% of the time. Three generators operated flawlessly through the season, with the greater malfunctions confined to the Boulder Lake, Pocket Creek, and Green River sites.

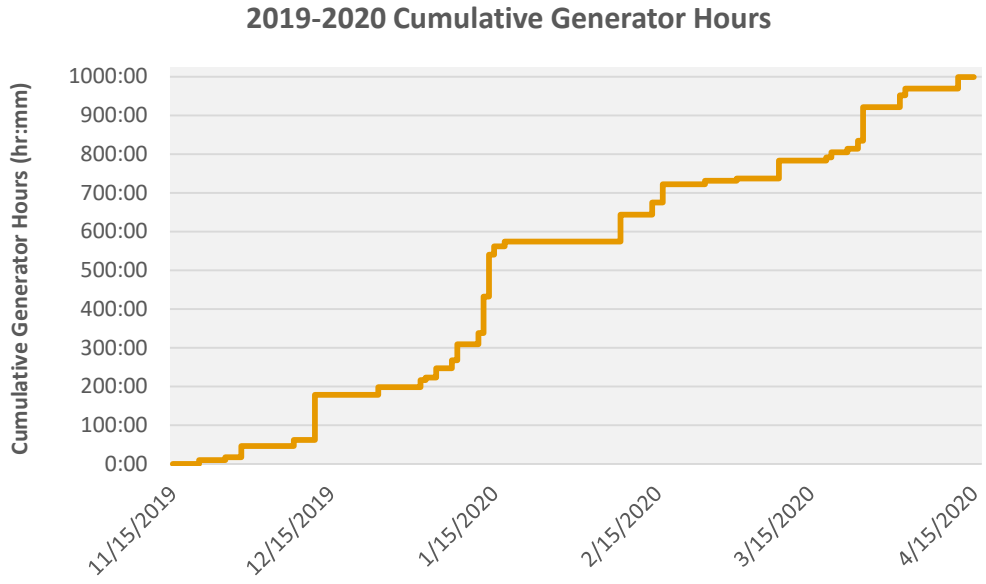

Figure 25. Cumulative generator hours through the 2019-2020 season are shown.

8 LIST OF TERMS AND ACRONYMS

Where applicable, definitions are those provided by the *Glossary of Meteorology*, published by the American Meteorological Society (2000), and are used by permission.

Accretion	See ***riming***.
Aerosol	A system in which particles, either solid or liquid, are dispersed in within a gas, usually air.
Ag	The chemical notation for silver.
AgI	See ***silver iodide***.
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
BTAC	Bridger-Teton Avalanche Center
CAP	Central Arizona Project
CCN	Cloud condensation nucleus
CSU	Colorado State University
DWWS	Daily Wyoming Wintertime Scale, a number from -3 to +2 indicating the likelihood of seeding operations.
GPS	Global Positioning System
Glaciogenic seeding	Cloud seeding with ice-forming aerosols
Ground generator	See ***ice nucleus generator***.
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.
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 ***supercooled liquid water***.
IN	See ***ice nucleus.***
mb	Millibar, same as hectopascal (***hPa***)
MOU	Memorandum of Understanding
MSL	Above mean sea level
NaCl	The chemical notation for sodium chloride, common table salt

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
NWS	National Weather Service, U.S. Department of Commerce
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.
Prognostic	A model used to predict future weather conditions. For example, model output showing the expected conditions over a specific area at a specified future time. The *RT-FDDA* model was run in a predictive mode.
Radiometer	A passive (non-transmitting) instrument that measures liquid water and water vaper in the atmosphere.
RAL	Research Applications Laboratory, NCAR, P.O. Box 3000, Boulder, CO 80307
Rawinsonde	Commonly called a ***weather balloon***, 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 ***supercooled*** cloud droplets that freeze wholly or partially upon contact.
RIW	The airport and meteorological station identifier for Riverton, Wyoming.
RT-FDDA	Real-time Four Dimensional Data Assimilation, a version of the WRF model run by NCAR
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 ***supercooled liquid water.***
SNOTEL	Sites instrumented, operated, and maintained by the ***NRCS***, to measure precipitation, ***SWE*** and other related parameters in the mountains.
SCCD	Sublette County Conservation District, Pinedale, WY
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)

TAT	The Wyoming Weather Modification Pilot Project ***Technical Advisory Team***, comprised of representatives of federal, state, and local agencies interested in or affected by the project.
Upslope	A term describing flow from a direction other than the climatological norm that produces orographic cloudiness and precipitation. In this report, the term refers to easterly flow against the Wind River Mountains, contrary to the westerly flow that generates the majority of the range's precipitation.
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
UTC	Universal Time Coordinates, formerly known as Greenwich Mean Time, and Zulu time.
UW	The University of Wyoming
WMI	Weather Modification, Inc., 3802 20th Street North, Fargo, ND 58102
WR	Wind River Mountain Range
WRDS	Water Resources Data System, University of Wyoming, Dept. 3943, 1000 E. University Ave., Laramie, WY 82071
WRF	The Weather Research and Forecasting numerical model
WRR	Wind River Range, Wyoming
WSEO	Wyoming State Engineer's Office, responsible for the issuance of Wyoming cloud seeding permits
WWDC	Wyoming Water Development Commission, the state body directing the WWDO
WWDO	Wyoming Water Development Office, 6920 Yellowtail Road, Cheyenne, WY 82002
WWMPP	Wyoming Weather Modification Pilot Project

9 REFERENCES

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Appendix A. Daily Operations Summaries

Wyoming Weather Modification Project - Wind River Mountains

2019-2020 Season – WMI Daily Project Summary

15 November, 2019 – 15 April, 2020

15 November 2019, Friday	
Mountain wave clouds existed on the NE side of the range until the mid afternoon, with a few passing mid level clouds the rest of the afternoon. Widespread high clouds moved through during the evening. Shallow low clouds spread down the range beginning before sunrise, with areas of light snowfall, but not fully covering the range. The temperature and wind was unfavorable for seeding operations also. Max/Min temperatures Pinedale: 52/18 Rock Springs: 53/26 Lander: 56/28 Observed ODC: -1	No ground-based seeding was conducted.
16 November 2019, Saturday	
Nearly continuous low and mid level clouds were over the range during the morning, then moved away throughout the afternoon, with a few low clouds lingering into the evening. Scattered light snowfall existed in the morning and early afternoon. The wind flow was unfavorable for seeding operations. There was minimal cloud coverage in the evening hours, then high clouds passed through overnight. Max/Min temperatures Pinedale: 43/18 Rock Springs: 49/23 Lander: 50/26 Observed ODC: 0	No ground-based seeding was conducted.
17 November 2019, Sunday	
Mid level clouds passed through during the morning and early afternoon. There were more continuous clouds in the late afternoon and early evening with some short lived low clouds at times. There were just a few flurries from these clouds. The clouds cleared during the evening.	No ground-based seeding was conducted.

Max/Min temperatures Pinedale: 48/18 Rock Springs: 51/25 Lander: 47/25 Observed ODC: -1	
18 November 2019, Monday	
A few periods of high clouds during the morning and early afternoon. Widespread high and a few mid level clouds then continued from the late afternoon through the evening and nighttime hours. Max/Min temperatures Pinedale: 50/23 Rock Springs: 51/34 Lander: 59/33 Observed ODC: -2	No ground-based seeding was conducted.
19 November 2019, Tuesday	
Areas of high and mid level clouds were around for most of the day. There were some low level clouds in the evening but no significant coverage. Max/Min temperatures Pinedale: 50/21 Rock Springs: 55/27 Lander: 52/31 Observed ODC: -2	No ground-based seeding was conducted.
20 November 2019, Wednesday	
Orographic cloud coverage began over the NE part of the range shortly after sunrise, with favorable seeding conditions. The snowfall became more widespread over the region by noon. The wind flow became less suitable for seeding just after sunset and the orographic cloud coverage diminished during the evening and the widespread snowfall moved out of the region too. Only shallow, thin clouds lingered through the night. Max/Min temperatures Pinedale: 41/25 Rock Springs: 40/21 Lander: 42/24 Observed ODC: +2	Seeding event WRR0093 was called at 0730 MST on 11/20/2019 and began at 0735 MST. **WRR0093 Summary:** Generators: WR07 Time: 0735 (11/20) to 1712 (11/20) MST 1435 (11/20) to 0012 (11/21) UTC Duration: 9:37 Total Time Seeding Material: 4.52 gallons (240.5 grams)

21 November 2019, Thursday	
Shallow, low clouds hung over the lowlands around the range through the afternoon and most of the evening hours. However, the WR range only had passing high clouds. No precipitation occurred from the low clouds. The sky then cleared during the night. Max/Min temperatures Pinedale: 28/7 Rock Springs: 24/17 Lander: 27/17 Observed ODC: -1	No ground-based seeding was conducted.
22 November 2019, Friday	
Completely clear skies dominated the Wind River range. Freezing fog, dense at times, developed shortly after dusk, and persisted into Saturday morning. Max/Min temperatures Pinedale: 30/1 Rock Springs: 32/16 Lander: 21/10 Observed ODC: -3	No ground-based seeding was conducted.
23 November 2019, Saturday	
Clear skies in the morning gave way to areas of high clouds and a few mid level clouds by noon. The evening brought mainly clear skies again until more high clouds moved in overnight. Max/Min temperatures Pinedale: 36/10 Rock Springs: 35/21 Lander: 34/7 Observed ODC: -2	No ground-based seeding was conducted.
24 November 2019, Sunday	
Areas of high clouds during the daylight hours. Orographic cloud began developing over the NW part of the range just before sunset. Light snowfall slowly spread southward down the range during the evening and by 04Z was fully covering the range. Favorable seeding conditions occurred until the middle of the night when the wind shifted and the snowfall over the range broke up. Widespread snowfall to the north and east of the range had developed before sunrise, though	Seeding event WRR0094 was called at 2130 MST on 11/24/2019 and began at 2140 MST. **WRR0094 Summary:** Generators: WR01, WR09, WR12, WR13 Time: 2140 (11/24) to 0249 (11/25) MST 0440 (11/25) to 0949 (11/25) UTC Duration: 5:09, 7:38 Total Time

the wind was unfavorable for seeding operations. Max/Min temperatures Pinedale: 41/10 Rock Springs: 40/21 Lander: 47/19 Observed ODC: +1	Seeding Material: 3.44 gallons (190.75 grams)
25 November 2019, Monday	
The area of snowfall increased in size through the morning hours and continued through most of the afternoon. By late afternoon the area of coverage began to shrink but snowfall continued on the north and east side of the range as well as southern WY through the night. PNA had light snowfall from the mid morning to mid afternoon. The wind flow was never right for proper seeding operations. The heaviest snowfall was at the base of the range on the NE side. This was a deep system with lots of natural ice and limited SLW. Max/Min temperatures Pinedale: 30/16 Rock Springs: 32/18 Lander: 40/22 Observed ODC: 0	No ground-based seeding was conducted.
26 November 2019, Tuesday	
A band of light snowfall slowly moved across the region during the late morning and early afternoon, getting enhanced over the range due to light southerly wind. There was little to no SLW with this first band. Broken areas of light snowfall continued over the range through the afternoon with some SLW as the clouds were more convective. The snowfall ended in the early evening. High clouds returned overnight, then mid level clouds producing areas of light snowfall began a little before sunrise. Max/Min temperatures Pinedale: 21/1 Rock Springs: 21/5 Lander: 24/8 Observed ODC: 0	No ground-based seeding was conducted.
27 November 2019, Wednesday	
Overcast skies with scattered flurries or light snow showers were observed in the valley Wednesday afternoon, ending	Seeding event WRR0095 was called at 2320 MST on 11/27/2019 and began at 2324 MST.

before dusk. The mountains remained enshrouded in cloud throughout the forecast period, with increasingly favorable wind flow and workable model-indicated SLW consistently depicted after 06Z. Seeding was performed until a sounding Thursday morning showed the 700mb temperature had warmed above the favorable seeding criteria. Max/Min temperatures Pinedale: 30/3 Rock Springs: 31/10 Lander: 17/2 Observed ODC: +1	**WRR0095 Summary** Generators: WR01, WR02, WR03, WR12 Time: 2324 (11/27) to 0638 (11/28) MST 0624 (11/28) to 1338 (11/28) UTC Duration: 7:14, 28:18 Total Time Seeding Material: 11.55 gallons, (707.25 grams)
28 November 2019, Thursday	
Orographic clouds covered the range throughout the day, with nearly continuous snowfall. Periods of widespread snowfall moved through the region too. The temperature and wind flow were not favorable for seeding operations at the same time. Max/Min temperatures Pinedale: 36/23 Rock Springs: 40/20 Lander: 20/4 Observed ODC: 0	No ground-based seeding was conducted.
29 November 2019, Friday	
Widespread snowfall from the morning through the evening, with heavy rates at times. The temperature was too warm with SE wind flow until after sunset when the wind shifted to NW with much colder air moving into the area. Continuous light snowfall persisted through the night over the range and the Lander area but was more broken in coverage in the Pinedale area. Max/Min temperatures Pinedale: 36/21 Rock Springs: 39/22 Lander: 22/17 Observed ODC: 0	No ground-based seeding was conducted.
30 November 2019, Saturday	
Most of the snowfall ended shortly after noon, with a few areas lingering for the next few areas. The wind flow was unfavorable for seeding operations. The clouds quickly	No ground-based seeding was conducted.

cleared in the afternoon with only small, shallow clouds left over the top of the range by sunset. The sky was clear overnight. Max/Min temperatures Pinedale: 23/0 Rock Springs: 23/12 Lander: 22/6 Observed ODC: 0	
01 December 2019, Sunday	
Clear skies in the morning, were covered by thin high clouds in the afternoon, with mid level clouds coming during the evening hours. A stratus cloud deck developed overnight, extending from the southern slopes to the SW over Pinedale, with minimal snowfall. Max/Min temperatures Pinedale: 14/-15 Rock Springs: 26/7 Lander: 11/-3 Observed ODC: -1	No ground-based seeding was conducted.
02 December 2019, Monday	
Stratus cloud deck on the south side of the range in the morning, expanded to cover most of the range by mid afternoon. There were areas of light snowfall over the range through the afternoon and early evening, before diminishing. The wind flow was never favorable for seeding operations. Most of the clouds cleared overnight, with just a few isolated areas by morning. Max/Min temperatures Pinedale: 27/16 Rock Springs: 33/5 Lander: 25/0 Observed ODC: 0	No ground-based seeding was conducted.
03 December 2019, Tuesday	
Clear skies were observed for the majority of the forecast period. A very thin and scattered layer of orographic clouds developed above the western foothills in the afternoon but were not remotely suitable for operations. Clear skies resumed overnight and continued into Wednesday.	No ground-based seeding was conducted.

Max/Min temperatures Pinedale: 32/5 Rock Springs: 36/24 Lander: 39/13 Observed ODC: -1	
04 December 2019, Wednesday	
The daytime had mostly clear skies, except for small clouds over the peaks of the range. Widespread snowfall, from a system centered in UT, moved into southern WY in the evening. The WR region got the mid level clouds from this system, but there were only scattered flurries over the range during the night. No significant low cloud coverage occurred. Max/Min temperatures Pinedale: 23/-6 Rock Springs: 38/20 Lander: 33/13 Observed ODC: -1	No ground-based seeding was conducted.
05 December 2019, Thursday	
Widespread cloud coverage moved away in the early afternoon hours, but small low clouds existed over the peaks of the range all afternoon. There were periods of high and mid level clouds passing through during the evening and early nighttime. The sky was clear by sunrise except for fog in the valley. Max/Min temperatures Pinedale: 30/5 Rock Springs: 32/21 Lander: 30/12 Observed ODC: -1	No ground-based seeding was conducted.
06 December 2019, Friday	
Clear skies in the morning, with thin high clouds coming across during the afternoon and evening. The only clouds overnight were some arch clouds on the NE side of the range for a short time. Max/Min temperatures Pinedale: 25/3 Rock Springs: 34/18 Lander: 30/11 Observed ODC: -2	No ground-based seeding was conducted.

07 December 2019, Saturday	
Orographic clouds developed over the range during the afternoon, nearly covering the range by sunset. Snowfall was limited at this time. The clouds thickened more during the evening with consistent snowfall overnight. The presence of an inversion made for unsuitable GGEN plumes and the temperature was warmer than the seeding threshold. Max/Min temperatures Pinedale: 23/0 Rock Springs: 22/9 Lander: 45/7 Observed ODC: 0	No ground-based seeding was conducted.
08 December 2019, Sunday	
Continued orographic cloud coverage over the range through the afternoon. The temperature and wind flow finally lined up to allow seeding operations during the afternoon. The wind became unfavorable for seeding around sunset. Areas of snowfall persisted through the evening before clearing overnight. Max/Min temperatures Pinedale: 25/9 Rock Springs: 31/8 Lander: 43/23 Observed ODC: +1	Seeding event WRR0096 was called at 1043 MST on 12/08/2019 and began at 1048 MST. **WRR0096 Summary:** Generators: WR01, WR09, WR10, WR12, WR13 Time: 1048 (12/8) to 1644 (12/8) MST 1748 (12/8) to 2344 (12/8) UTC Duration: 5:51, 14:55 Total Time Seeding Material: 6.34 gallons (373 grams)
09 December 2019, Monday	
Clear skies until some thin, high clouds came into the area just before sunset. Periods of high clouds existed through the night. A stratus cloud deck formed over the Pinedale valley during the night, with the clouds against southern slopes but not over the range. Max/Min temperatures Pinedale: 27/3 Rock Springs: 29/20 Lander: 29/15 Observed ODC: -2	No ground-based seeding was conducted.
10 December 2019, Tuesday	
Gradually increasing cloud cover was observed through the forecast period. A thin scattered line of stratus lingered over	No ground-based seeding was conducted.

the southwestern slopes beneath the range until evening, with periods of cirrus becoming thicker and more pervasive from Tuesday evening into Wednesday. Altostratus developed over the valley after dawn. Max/Min temperatures Pinedale: 28/0 Rock Springs: 27/18 Lander: 23/8 Observed ODC: -2	
11 December 2019, Wednesday	
Cloud coverage increased in the late morning with low and mid level clouds and light snowfall. There was no SLW until the mid level clouds moved away in the late afternoon but the wind flow was unfavorable for seeding operations. Status and areas of light snowfall continued on the south side of the range and southern slopes through the evening and night. During the middle of the night, the wind flow became favorable for proper plume transport and the clouds thickened over the range. Max/Min temperatures Pinedale: 21/-4 Rock Springs: 30/9 Lander: 30/8 Observed ODC: +1	Seeding event WRR0097 was called at 0312 MST on 12/12/2019 and began at 0318 MST. **WRR0097 Summary:** Generators: WR01, WR02, WR03, WR09, WR12 Time: 0318 (12/12) to 0827 (12/13) MST 1018 (12/12) to 1527 (12/13) UTC Duration: 29:09, 116:36 Total Time Seeding Material: 47.51 gallons (2915 grams)
12 December 2019, Thursday	
Orographic cloud over the range thickened throughout the morning, with continuous snowfall through the afternoon. In the middle of the evening, there was a brief period with thin clouds and less than favorable wind, but conditions improved again by the late evening. Snowfall again continued through the night but shortly after sunrise the wind shifted and the clouds began thinning. Max/Min temperatures Pinedale: 30/9 Rock Springs: 38/28 Lander: 44/17 Observed ODC: +2	Seeding event WRR0097 continued throughout the day and ended Friday morning, 12/13/2019 at 0827 MST.
13 December 2019, Friday	
Shallow low clouds over the range in the morning and most of	No ground-based seeding was conducted.

the afternoon before diminishing by the late afternoon. Snowfall was limited with no SLW and the wind was mainly parallel to the range. Widespread cloud coverage began moving into the area just before sunset and continued through the night. Overall snowfall was very light and the wind remained unfavorable for seeding operations. Max/Min temperatures Pinedale: 28/7 Rock Springs: 30/22 Lander: 40/19 Observed ODC: 0	
14 December 2019, Saturday	
The widespread cloud coverage and light snowfall continued for the morning and most of the afternoon. No SLW was detected and the wind flow was unfavorable for seeding operations. Most of the clouds left the range by sunset, then there were very few clouds overnight. Max/Min temperatures Pinedale: 23/-2 Rock Springs: 30/6 Lander: 26/12 Observed ODC: 0	No ground-based seeding was conducted.
15 December 2019, Sunday	
A broken mid-level cloud deck spread across much of the valley, with some orographic clouds near the range. Snow showers were seen on the NW slope in the afternoon, but accumulation was light. Winds were light from the NW. Skies cleared up overnight and winds increased to between 10 and 15 mph. The wind direction remained unfavorable for seeding, and little SLW was detected. Max/Min temperatures Pinedale 7/-17 Rock Springs 11/-3 Lander 15/3 Observed ODC: -1	No ground-based seeding was conducted.
16 December 2019, Monday	
A high cirrostratus cloud deck existed in the valley until around 2PM. Small and brief orographic clouds were also present in the morning, dissipating entirely by late afternoon.	No ground-based seeding was conducted.

Winds were primarily out of the WNW between 10 and 20 mph with gusts up to 29 mph measured in Pinedale. Winds died down by midnight, becoming light and variable. No snow accumulation occurred, and no significant SLW was detected. Max/Min temperatures Pinedale: 16/-15 Rock Springs:15/1 Lander: 19/0 Observed ODC: -1	
17 December 2019, Tuesday	
Broken upper and mid-level cloud layers were seen across much of the range with no orographic clouds. Winds were light and variable. No snowfall occurred, and no SLW was detected. Max/Min temperatures Pinedale: 18/-13 Rock Springs: 20/6 Lander: 12/-2 Observed ODC: -2	No ground-based seeding was conducted.
18 December 2019, Wednesday	
Another cold morning for the Pinedale area. Areas of high clouds passed by throughout the day. Thick mid level clouds existed for a few hours during the night but had moved away by sunrise. Max/Min temperatures Pinedale: 12/-17 Rock Springs: 14/-2 Lander: 19/2 Observed ODC: -2	No ground-based seeding was conducted.
19 December 2019, Thursday	
A stratus cloud layer spread down the valley from the NW to SE through the morning and afternoon. The clouds were banked against the southern slopes of the range but only scattered, small low clouds were over the top of the range. Broken stratus continued through the night. Max/Min temperatures Pinedale: 27/-6 Rock Springs: 23/2	No ground-based seeding was conducted.

Lander: 35/4 Observed ODC: -1	
20 December 2019, Friday	
A low-level could deck persisted across the valley and range, becoming clearer overnight. Surface winds were calm at first, and picked up in the evening, blowing from the WNW at around 5 mph. Some SLW was detected during the day but subsided by 7PM. Max/Min temperatures Pinedale: 32/5 Rock Springs: 31/18 Lander: 31/16 Observed ODC: -1	No ground-based seeding was conducted.
21 December 2019, Saturday	
Areas of high clouds were around throughout the daylight hours. Widespread cloud coverage began moving into the area during the evening with thick, mid level clouds through the night. No precipitation occurred and bases were above the peaks. Max/Min temperatures Pinedale: 21/-4 Rock Springs: 27/10 Lander: 33/15 Observed ODC: -2	No ground-based seeding was conducted.
22 December 2019, Sunday	
Widespread cloud coverage throughout the day. Cloud bases were above the peaks and no precipitation occurred. Max/Min temperatures Pinedale: 23/3 Rock Springs: 38/5 Lander: 29/15 Observed ODC: -2	No ground-based seeding was conducted.
23 December 2019, Monday	
A persistent altostratus deck took residence upwind and above the range during the afternoon, settling over the range overnight. LW was detected in these clouds by the radiometer at East Fork, but temperatures remained too warm for seeding until late this morning. Light snow showers	No ground-based seeding was conducted.

were observed at KPNA until about 15Z, after which valley stratus dissipated leaving only orographic cloud cover. Max/Min temperatures Pinedale: 28/10 Rock Springs: 34/24 Lander: 31/20 Observed ODC: 0	
24 December 2019, Tuesday	
Widespread, stratus cloud coverage with light snowfall diminished throughout the morning leaving orographic clouds over the range. Temperature and wind became favorable for seeding operations in the late morning. Conditions deteriorated during the afternoon, putting an end to seeding. Widespread mid level clouds moved through again during the evening but became scattered overnight. There were a few snow showers over the range during the night. Max/Min temperatures Pinedale: 32/19 Rock Springs: 37/21 Lander: 36/15 Observed ODC: +1	Seeding event WRR0098 was called at 0918 MST on 12/24/2019 and began at 0924 MST. **WRR0098 Summary:** Generators: WR01, WR02, WR03, WR12 Time: 0924 (12/24) to 1427 (12/24) MST 1624 (12/24) to 2127 (12/24) UTC Duration: 5:03, 20:11 Total Time Seeding: 8.73 gallons (504.50 grams)
25 December 2019, Wednesday	
A small area of light snowfall existed for a few hours over the far SE part of the range during the afternoon, with minimal accumulation and no SLW expected. Periods of mid level clouds moved through the rest of the period. Max/Min temperatures Pinedale: 28/3 Rock Springs: 28/21 Lander: 34/19 Observed ODC: 0	No ground-based seeding was conducted.
26 December 2019, Thursday	
Low clouds developed over the peaks of the range beginning in the late morning and persisted through most of the afternoon. The clouds didn't fully enshroud the range, no significant SLW existed and no measurable snowfall occurred. The low clouds were diminishing by sunset. Fog and low stratus developed over the lowlands around the range overnight.	No ground-based seeding was conducted.

Max/Min temperatures Pinedale: 19/-8 Rock Springs: 22/9 Lander: 30/18 Observed ODC: 0	
27 December 2019, Friday	
Mostly clear skies over the range during the daylight hours, but Lander reported fog most of the day. Mid level clouds moved in during the evening, with areas of light snowfall on the northern slopes beginning during the night. The clouds and snowfall never fully covered the range. Max/Min temperatures Pinedale: 10/-13 Rock Springs: 13/7 Lander: 21/5 Observed ODC: -1	No ground-based seeding was conducted.
28 December 2019, Saturday	
Broken cloud coverage over the range during the daylight hours, with small areas of light snow over portions of the northern slopes. There were also low clouds on the north side of the range. The wind was never favorable for seeding operations. The clouds diminished during the evening and the sky cleared overnight. Max/Min temperatures Pinedale: 18/-6 Rock Springs: 14/4 Lander: 24/10 Observed ODC: -1	No ground-based seeding was conducted.
29 December 2019, Sunday	
A mid-level cloud deck moved in from the west briefly during the day, but did not cover the much of the Winds. A few low level orographic clouds were seen near South Pass, but were short lived. Otherwise, clear skies prevailed across the range. Winds were primarily out of the WNW, but no significant SLW was detected. Max/Min temperatures Pinedale: 3/-20 Rock Springs: 12/-3	No ground-based seeding was conducted.

Lander: 20/5 Observed ODC: -1	
30 December 2019, Monday	
Skies were clear throughout the day. Higher clouds moved in from the north around 4AM. No SLW was detected, and winds were unfavorable for seeding. Max/Min temperatures Pinedale: 12/-22 Rock Springs: 11/-6 Lander: 11/-4 Observed ODC: -3	No ground-based seeding was conducted.
31 December 2019, Tuesday	
Broken cloud coverage was seen throughout the valley and the range. Orographic clouds were also seen hugging the mountains. Winds were out of the WNW at 10 to 20 mph and not favorable for seeding. Snow began developing Wednesday morning. Max/Min temperatures Pinedale: 21/-17 Rock Springs: 24/-6 Lander: 15/-6 Observed ODC: 0	No ground-based seeding was conducted.
01 January 2020, Wednesday	
Widespread cloud coverage with snowfall existed throughout the morning, afternoon and the early evening hours. The wind flow was favorable for seeding operations from mid morning to mid afternoon, with SLW most abundant in the morning and disappearing in the afternoon. The clouds diminished during the evening with only scattered mid level clouds overnight. Max/Min temperatures Pinedale: 27/12 Rock Springs: 34/22 Lander: 43/11 Observed ODC: +1	Seeding event WRR0099 was called at 0925 MST on 01/01/2020 and began at 0929 MST. **WRR0099 Summary:** Generators: WR01, WR02, WR03 Time: 0929 (01/01) to 1521 (01/01) MST 1629 (01/01) to 2221 (01/01) UTC Duration: 5:52, 17:36 Total Time Seeding Material: 7.81 gallons (440.25 grams)
02 January 2020, Thursday	
Shallow low clouds developed over the SW slopes of the range in the late morning. There were areas of light snowfall,	Seeding event WRR0100 was called at 1151 MST on 01/02/2020 and began at 1201 MST.

with radiometer detected SLW and the wind flow was just good enough to allow seeding operations for a few hours. The wind became more NW during the afternoon putting an end to seeding and the low clouds diminished. There were only a few clouds during the evening and early nighttime, but stratus cloud coverage moved in a few hours before sunrise. Max/Min temperatures Pinedale: 25/5 Rock Springs: 26/19 Lander: 36/19 Observed ODC: +1	**WRR0100 Summary:** Generators: WR09, WR12 Time: 1201 (01/02) to 1523 (01/02) MST 1901 (01/02) to 2223 (01/02) UTC Duration: 3:22, 6:44 Total Time Seeding Material: 2.56 gallons (168.50 grams)
03 January 2020, Friday	
There was a stratus layer of clouds over the SW slopes and the lowlands in the morning. The clouds thinned and diminished during the early afternoon hours with only minimal coverage by sunset. The wind was unfavorable for seeding operations. Widespread high and mid level clouds moved through during the night. Max/Min temperatures Pinedale: 32/3 Rock Springs: 33/20 Lander: 42/13 Observed ODC: 0	No ground-based seeding was conducted.
04 January 2020, Saturday	
Orographic cloud coverage slowly developed over the range throughout the afternoon and persisted into the evening hours. Temperature and wind flow were favorable for seeding operations for a few hours. The low clouds diminished during the evening. There were a few periods of mid level clouds throughout the day, mainly in the early afternoon and night. Max/Min temperatures Pinedale: 25/-4 Rock Springs: 33/19 Lander: 44/18 Observed ODC: 0	Seeding event WRR0101 was called at 1512 MST on 01/04/2020 and began at 1516 MST. **WRR0101 Summary:** Generators: WR01, WR02, WR03, WR09, WR10, WR12, WR13 Time: 1516 (01/04) to 1918 (01/04) MST 2216 (01/04) to 0218 (01/05) UTC Duration: 4:02, 24:00 Total Time Seeding Material: 9.95 gallons (599.61 grams)
05 January 2020, Sunday	
Cloud bases were low and snowfall was observed in the afternoon. SLW was only detected around 2AM during the	No ground-based seeding was conducted.

night meaning ice nucleation was naturally efficient throughout most of the day. Winds were generally from the WNW around 5 mph. Max/Min temperatures Pinedale: 19/-8 Rock Springs: 25/13 Lander: 27/17 Observed ODC: 0	
06 January 2020, Monday	
Scattered cloud layers were observed during the daylight hours with low clouds developing over the NW part of the range in the late afternoon and persisting through most of the evening. A few clouds moved through during the night, then a stratus cloud deck began developing over the area Tuesday morning. Max/Min temperatures Pinedale: 23/-6 Rock Springs: 26/17 Lander: 33/12 Observed ODC: 0	No ground-based seeding was conducted.
07 January 2020, Tuesday	
A stratus cloud deck had developed over the area in the morning with orographic enhancement over the range increasing throughout the morning. The wind gradually became less favorable for cross barrier flow during the afternoon, and the clouds diminished. Mid level clouds existed through the night with low clouds developing Wednesday morning again. Max/Min temperatures Pinedale: 30/5 Rock Springs: 37/21 Lander: 40/13 Observed ODC: +1	Seeding event WRR0102 was called at 0942 MST on 01/07/2020 and began at 0949 MST. **WRR0102 Summary:** Generators: WR01, WR02, WR03, WR12 Time: 0949 (01/07) to 1458 (01/07) MST 1649 (01/07) to 2158 (01/07) UTC Duration: 5:09, 20:33 Total Time Seeding Material: 8.38 gallons (513.75 grams)
08 January 2020, Wednesday	
Clouds were persistent across the region until about 3:30PM. Afterwards, skies partially cleared up in the valley, but orographic clouds remained over the mountains. Surface winds were light and variable throughout much of the day with periods of NW winds above 5 mph in the afternoon. SLW	Seeding event WRR0103 was called at 0934 MST on 01/08/2020 and began at 0942 MST. **WRR0103 Summary:** Generators: WR01, WR02, WR03, WR09, WR12

was detected mainly in the morning, and then again between 21Z and 22Z. Max/Min temperatures Pinedale: 21/-6 Rock Springs: 32/15 Lander: 39/15 Observed ODC: +1	Time: 0942 (01/08) to 1745 (01/08) MST 1642 (01/08) to 0045 (01/09) UTC Duration: 8:03, 42:02 Total Time Seeding Material: 15.97 gallons (1050.75 grams)
09 January 2020, Thursday	
Orographic clouds existed over the range from the morning to the early evening. With cold temps aloft, SLW was very sparse and inconsistent, preventing seeding operations. The orographic clouds diminished in the evening, but fog developed in the valley and persisted into the nighttime hours. A band of low clouds with light snowfall moved through during the night, but the wind was not favorable for seeding operations. Max/Min temperatures Pinedale: 21/-4 Rock Springs: 28/15 Lander: 31/14 Observed ODC: 0	No ground-based seeding was conducted.
10 January 2020, Friday	
A few low clouds around South Pass in the morning, while the rest of the range was clear. Mid level clouds started moving in just before sunset, becoming widespread by late evening. Low clouds with light snowfall and SLW existed for most of the nighttime hours, but the wind was not favorable for seeding operations. Only a few areas of light snowfall were left by sunrise. Max/Min temperatures Pinedale: 12/-11 Rock Springs: 16/6 Lander: 23/9 Observed ODC: 0	No ground-based seeding was conducted.
11 January 2020, Saturday	
Thin clouds were over the range during the morning, slowly thickening during the afternoon. The clouds did not fully cover the range until the mid afternoon, and by then the wind was beginning to weaken and become less favorable for	No ground-based seeding was conducted.

seeding operations. SLW was also limited due to cold temperatures aloft. Thin clouds remained through the evening and most of the night, but little to no snowfall occurred and the wind was not favorable for seeding operations. Max/Min temperatures Pinedale: 14/-6 Rock Springs: 27/7 Lander: 35/5 Observed ODC: 0	
12 January 2020, Sunday	
Low cloud coverage increased throughout the morning hours. Light snowfall began shortly before noon and favorable seeding conditions existed through the afternoon, though SLW was very limited. Low clouds continued through the evening, but the wind was not favorable for seeding and no snowfall occurred during that time. Snowfall began again around midnight as the wind developed a better cross barrier flow, and conditions continued into Monday morning. Max/Min temperatures Pinedale: 12/-4 Rock Springs: 20/10 Lander: 29/10 Observed ODC: +2	Seeding event WRR0104 was called at 1220 MST on 01/12/2020 and began at 1241 MST. **WRR0104 Summary:** Generators: WR04, WR05, WR10, WR13 Time: 1242 (01/12) to 1446 (01/12) MST 1942 (01/12) to 2146 (01/12) UTC WR01, WR02, WR03, WR09, WR12 Time: 1242 (01/12) to 1652 (01/12) MST 1942 (01/12) to 2352 (01/12) UTC Duration: 28:41 Total Time Seeding Material: 12.03 gallons (716.50 grams) Seeding event WRR0105 was called at 0038 MST on 01/13/2020 and began at 0044 MST. **WRR0105 Summary:** Generators: WR04, WR05 Time: 0044 (01/13) to 1303 (01/13) MST 0744 (01/13) to 2003 (01/13) UTC WR01, WR02, WR03, WR12 Time: 0044 (01/13) to 1701 (01/13) MST 0744 (01/13) to 0001 (01/14) UTC WR09 Time: 1304 (01/13) to 1701 (01/13) MST

	2004 (01/13) to 0001 (01/14) UTC Duration: 94:31 Total Time Seeding Material: 39.09 gallons (2362.75 grams)
13 January 2020, Monday	
There was thick, widespread cloud coverage in the morning, with the widespread clouds moving away by late morning, leaving shallow orographic clouds over the range. The orographic clouds were enhanced in the early afternoon allowing for seeding operations to continue until the wind became unfavorable by sunset. Light snowfall redeveloped during the evening, but no SLW existed until after midnight when the wind became favorable for seeding again. Those conditions continued through the night into Tuesday morning. Max/Min temperatures Pinedale: 19/5 Rock Springs: 24/9 Lander: 31/12 Observed ODC: +2	Seeding event WRR0105 continued until 1701 MST on 01/13/2020. Seeding event WRR0106 was called at 0051 MST on 01/14/2020 and began at 0100 MST. **WRR0106 Summary:** Generators: WR04, WR05 Time: 0058 (01/14) to 1436 (01/14) MST 0758 (01/14) to 2136 (01/14) UTC WR01, WR02, WR03, WR12 Time: 0058 (01/14) to 1612 (01/14) MST 0758 (01/14) to 2312 (01/14) UTC WR10 Time: 0955 (01/14) to 1436 (01/14) MST 1655 (01/14) to 2136 (01/14) UTC WR09, WR13 Time: 0955 (01/14) to 1612 (01/14) MST 1655 (01/14) to 2312 (01/14) UTC Duration: 108:17 Total Time Seeding Material: 42.45 gallons (2707.00 grams)
14 January 2020, Tuesday	
Widespread thick cloud coverage continued from Monday night with light snowfall and SLW over the range with favorable wind flow. The wind shifted during the afternoon putting an end to seeding operations. Thin clouds remained over the range during the evening, then a period of thicker clouds with favorable seeding conditions until the middle of the night. The clouds began diminishing before sunrise with only shallow, low clouds over the range by Wednesday morning.	Seeding event WRR0106 continued until 1612 MST on 01/14/2020. Seeding event WRR0107 was called at 2205 MST on 01/14/2020 and began at 2212 MST. **WRR0107 Summary:** Generators: WR01, WR02, WR03, WR12 Time: 2211 (01/14) to 0327 (01/15) MST

Max/Min temperatures Pinedale: 27/-6 Rock Springs: 33/13 Lander: 31/8 Observed ODC: +2	0511 (01/15) to 1027 (01/15) UTC Duration: 5:16, 21:03 Total Time Seeding Material: 8.88 gallons (526.50 grams)
15 January 2020, Wednesday	
Thin, shallow low cloud lingered over the SW slopes of the range throughout the morning and diminished in the early afternoon. No measurable precipitation occurred. High clouds began moving in around sunset with mid level clouds coming during the evening hours. The clouds became thicker before sunrise, but bases were above the peaks. Max/Min temperatures Pinedale: 12/-13 Rock Springs: 26/8 Lander: 30/9 Observed ODC: -1	No ground-based seeding was conducted.
16 January 2020, Thursday	
Mostly thin, widespread clouds around the region during the morning, afternoon, and evening except for thicker periods producing virga. Orographic clouds developed over the range beginning around midnight, with radiometer detected LW and continuous snowfall. The temperature cooled and the wind became favorable for seeding operations during the middle of the night. The wind became unfavorable for seeding Friday morning. Max/Min temperatures Pinedale: 23/-13 Rock Springs: 34/1 Lander: 25/4 Observed ODC: +1	Seeding event WRR0108 was called at 0343 MST on 01/17/2020 and began at 0352 MST. **WRR0108 Summary:** Generators: WR01, WR12 Time: 0352 (01/17) to 0908 (01/17) MST 1052 (01/17) to 1608 (01/17) UTC WR02, WR03 Time: 0628 (01/17) to 0908 (01/17) MST 1328 (01/17) to 1608 (01/17) UTC Duration: 12:27 Total Time Seeding Material: 5.23 gallons (311.50 grams)
17 January 2020, Friday	
A scattered mid-level cloud deck existed in the morning through 3PM before giving way to clear skies. Orographic clouds hugged the range all day but were mostly shallow and lacked SLW. A brief increase of SLW was detected between 2 and 2:30PM, was not detected for the rest of the day or night. Surface winds were breezy, generally out of the NW at	No ground-based seeding was conducted.

10 to 20 mph, diminishing to 5 to 10 mph after 8PM. Max/Min temperatures Pinedale: 23/-4 Rock Springs: 31/10 Lander: 40/14 Observed ODC: 0	
18 January 2020, Saturday	
A few, small low clouds existed around the range at times throughout the morning and afternoon. No significant coverage and no precipitation occurred. There were also periods of thick mid level clouds during the afternoon at times. Most of the clouds had moved away shortly after sunset. An area of stratus formed over the valley and SW slopes during the night but had diminished by sunrise. Max/Min temperatures Pinedale: 19/-11 Rock Springs: 25/11 Lander: 31/11 Observed ODC: -1	No ground-based seeding was conducted.
19 January 2020, Sunday	
Skies were clear throughout the day with no SLW detected. Upper-level clouds increased overnight, but orographic clouds were still absent. Surface winds in Pinedale were generally from the WNW around 5 to 10 mph. Max/Min temperatures Pinedale: 23/-9 Rock Springs: 29/10 Lander: 26/6 Observed ODC: -2	No ground-based seeding was conducted.
20 January 2020, Monday	
A stratus cloud deck covered the region with bases above the mountains. Lenticular clouds also hovered over the mountains for most of the day. Bases dropped below the mountain tops overnight, and snow was observed near South Pass Tuesday morning. SLW was after 4PM, but 700mb temperatures remained too warm for seeding. Surface winds near Pinedale were generally out of the NW around 5 mph. Max/Min temperatures	No ground-based seeding was conducted.

Pinedale: 21/-9 Rock Springs: 21/5 Lander: 22/6 Observed ODC: 0	
21 January 2020, Tuesday	
There was broken cloud coverage over the area throughout the daylight hours. The clouds were never consistent and no LW was detected by the radiometer. A shallow stratus layer developed over the valley and SW slopes by sunset and continued through the night. Snowfall was limited and the wind was not favorable for seeding operations. Max/Min temperatures Pinedale: 30/12 Rock Springs: 30/16 Lander: 34/18 Observed ODC: 0	No ground-based seeding was conducted.
22 January 2020, Wednesday	
There were a few shallow low clouds over the peaks of the range and areas of mid level clouds at times during the daylight hours. No significant coverage during that time. More mid level clouds moved through during the evening, then widespread stratus developed around the region during the night. Some light snowfall occurred mainly on the NW part of the range, but the wind was not favorable for seeding operations. Max/Min temperatures Pinedale: 28/7 Rock Springs: 32/15 Lander: 40/21 Observed ODC: 0	No ground-based seeding was conducted.
23 January 2020, Thursday	
Stratus clouds in the morning mostly diminished by noon but some areas of low clouds lingered through the afternoon. No significant coverage occurred. A few mid level clouds existed at times from the late afternoon through the evening. Widespread mid level clouds formed over the area during the night. Max/Min temperatures Pinedale: 30/1	No ground-based seeding was conducted.

Rock Springs: 35/15 Lander: 36/19 Observed ODC: -1	
24 January 2020, Friday	
Broken stratus clouds around the region throughout the daylight hours. A wave of thicker clouds moved through with a period of light snowfall from the late afternoon into the early evening. The wind was not favorable for seeding operations at that time. Shallow low and stratus clouds continued the rest of the evening, then scattered to broken clouds existed overnight. Max/Min temperatures Pinedale: 30/10 Rock Springs: 33/23 Lander: 34/17 Observed ODC: 0	No ground-based seeding was conducted.
25 January 2020, Saturday	
There was a lot of stratus cloud coverage throughout period. Widespread mid level clouds moved into the area by late afternoon but only lasted for a short time. Periods of mid level clouds moved through during the night. Overall, snowfall was very minimal and the wind flow was not favorable for seeding. Max/Min temperatures Pinedale: 32/10 Rock Springs: 35/23 Lander: 40/19 Observed ODC: 0	No ground-based seeding was conducted.
26 January 2020, Sunday	
A low cloud deck covered the region and brought with it snowfall during the night. SLW was detected throughout much of the day, but temperatures and mountain-level winds were not favorable for seeding. 24 hour snowfall analysis showed around an inch of snow accumulation around Pinedale, and 2”+ across much of the Winds. Max/Min temperatures Pinedale: 32/9 Rock Springs: 38/27 Lander: 38/19	No ground-based seeding was conducted.

Observed ODC: 0	
27 January 2020, Monday	
Skies were partly cloudy with orographic clouds persisting near the range. A low stratus covered the Upper Green River Basin starting late in the night, but remained clear throughout the night further SE of the mountains such as in South Pass. Up to 2" of snow fell across the basin, with higher amounts accumulating in the Winds, up to 14". SLW was detected, but winds were not favorable for seeding. Max/Min temperatures Pinedale: 30/18 Rock Springs: 34/21 Lander: 34/18 Observed ODC: 0	No ground-based seeding was conducted.
28 January 2020, Tuesday	
A low stratiform cloud deck covered the region for most of the day, and snow was observed intermittently between 2:30PM and 2:00AM. SLW was detected starting in the morning, and slowly diminished as the day went on. Low-level flow, however, remained unfavorable for seeding operations. 24 hour snowfall analysis showed a few tenths of an inch falling from Pinedale to South Pass, and higher amounts – between 2" and 4" – higher in the Winds. Max/Min temperatures Pinedale: 28/7 Rock Springs: 33/20 Lander: 28/14 Observed ODC: 0	No ground-based seeding was conducted.
29 January 2020, Wednesday	
Small, scattered low clouds existed over the range throughout the daylight hours. Widespread thick clouds moved into the area around midnight, continued through the night and cleared away shortly after sunrise. These clouds brought light snowfall and some SLW but the wind was not favorable for seeding operations. Most of the range had very little accumulation but a few isolated areas had over 1 inch snowfall. Max/Min temperatures Pinedale: 27/-2	No ground-based seeding was conducted.

Rock Springs: 31/20 Lander: 36/15 Observed ODC: 0	
30 January 2020, Thursday	
After widespread clouds moved away early in the morning, the range was clear until low clouds developed over the NE part of the range a little before noon. There were two short periods with thick clouds and light snowfall on the NE slopes; first in the early afternoon and the second a little before sunset. The wind was northerly but not quite right for seeding with the Enterprise GGEN. Broken low clouds existed over the rest of the range from the late afternoon into the early evening. Widespread clouds with areas of light snowfall moved into the region from the north during the night. Max/Min temperatures Pinedale: 28/3 Rock Springs: 31/18 Lander: 34/16 Observed ODC: 0	No ground-based seeding was conducted.
31 January 2020, Friday	
Widespread cloud coverage over western WY in the morning had begun thinning before noon. A few small low clouds existed over the range through the afternoon. Thick, widespread mid level clouds covered the region again during the night, diminishing after sunrise. Snowfall map shows only a dusting on the SE end and NW parts of the range. Max/Min temperatures Pinedale: 32/-2 Rock Springs: 31/16 Lander: 41/16 Observed ODC: -1	No ground-based seeding was conducted.
01 February 2020, Saturday	
Thin clouds were over the range during the morning and early afternoon hours. Then only a few high and mid level clouds at times for most of the period, except for small low clouds with high bases that developed on the southern slopes of the range a little before sunrise and continued into the morning. There was also fog around PNA for a few hours in the evening.	No ground-based seeding was conducted.

Max/Min temperatures Pinedale: 32/3 Rock Springs: 40/28 Lander: 55/23 Observed ODC: -1	
02 February 2020, Sunday	
Warmest temperatures across the region during the afternoon in quite a while (both LND and RKS was the highest since Nov 19th), then the weather turned ugly in a hurry as a large storm moved in during the evening. Mid level clouds began increasing in the afternoon then light snowfall began on the northern slopes of the range a little after sunset. Widespread snowfall developed over most of the state during the night. Despite NE low level flow, the wind was not favorable for seeding. The northern slopes of the range received 6 to 10+ inches of snowfall by Monday morning. Max/Min temperatures Pinedale: 37/-2 Rock Springs: 45/21 Lander: 52/19 Observed ODC: 0	No ground-based seeding was conducted.
03 February 2020, Monday	
Heavy snow continued across the eastern Wind River range through the afternoon, slowly tapering into light snow and flurries Monday night. NOHRSC estimated 24hr snow accumulations indicate 12-18" of snow fell in the mountains west and southwest of Lander, with more menial 1-2" totals west of the divide. Skies cleared across the western Winds overnight, while thin orographic clouds persisted on the eastern side into Tuesday morning. Max/Min temperatures Pinedale: 28/-8 Rock Springs: 23/5 Lander: 19/10 Observed ODC: 0	No ground-based seeding was conducted.
04 February 2020, Tuesday	
There were thin orographic clouds over the eastern part of the range in the early morning but those diminished throughout the morning. Scattered, small, low clouds existed over the range during the afternoon but were gone by late	No ground-based seeding was conducted.

afternoon. Mid level clouds began moving through the area during the night. Max/Min temperatures Pinedale: 7/-24 Rock Springs: 12/0 Lander: 15/-7 Observed ODC: -1	
05 February 2020, Wednesday	
Broken mid level clouds were around from the morning to the evening. There were some short periods of low clouds during the morning and afternoon as well, giving a dusting of snowfall. Thick, widespread clouds moved in after midnight, with some light snowfall over the NW part of the range. The wind flow was never right for seeding operations at any point during the day. Max/Min temperatures Pinedale: 19/1 Rock Springs: 19/4 Lander: 16/-5 Observed ODC: 0	No ground-based seeding was conducted.
06 February 2020, Thursday	
Broken cloud coverage in the morning around the region became completely overcast during the afternoon. Light snowfall on the NW part of the range during the morning, then spread to the rest of the range in the afternoon. Snowfall bands were orientated NW/SE along the predominate wind flow, which was unsuitable for seeding operations. Widespread light snowfall around the region began during the evening and continued through the night. Snowfall map shows 6+ inches on the NW part of the range, while the rest of the range received 0.5 to 2 inches. Max/Min temperatures Pinedale: 30/14 Rock Springs: 32/16 Lander: 25/5 Observed ODC: 0	No ground-based seeding was conducted.
07 February 2020, Friday	
Widespread cloud coverage around western WY in the morning and afternoon, with steady but light snowfall. The	No ground-based seeding was conducted.

clouds broke up during the evening, but shallow low clouds continued over the range through the night, though no snowfall occurred until just before sunrise when a new system moved into the area. Most of the southern slopes of the range received around 2 inches of snowfall with higher amount on the NW again. The wind was not favorable for seeding at any time, but improved Saturday morning. Max/Min temperatures Pinedale: 32/18 Rock Springs: 35/25 Lander: 24/18 Observed ODC: 0	
08 February 2020, Saturday	
Orographic cloud coverage from the morning through the afternoon as snow fell throughout the Winds. There was a period in the evening when clouds cleared up, and no orographic clouds were observed, but the mountains became enshrouded again after midnight. Conditions were very good for several hours of seeding from all western GGEN sites. NW regions of the range received 8"+ of snowfall, while other areas in the mountains received 1-4" dependent on elevation. Max/Min temperatures Pinedale: 32/9 Rock Springs: 40/16 Lander: 39/11 Observed ODC: +2	Seeding event WRR0109 was called at 0618 MST on 02/08/2020 and began at 0622 MST. **WRR0109 Summary:** Generators: WR01, WR02, WR03, WR09, WR12 Time: 0622 (02/08) to 1614 (02/08) MST 1322 (02/08) to 2314 (02/08) UTC WR04, WR05 Time: 0955 (02/08) to 1336 (02/08) MST 1655 (02/08) to 2036 (02/08) UTC WR10, WR13 Time: 0955 (02/08) to 1614 (02/08) MST 1655 (02/08) to 2314 (02/08) UTC Duration: 69:16 Total Time Seeding Material: 29.73 gallons (1732.25 grams)
09 February 2020, Sunday	
Scattered mid-level clouds in the morning cleared out in the afternoon, with orographic clouds persisting. A mid-level cloud deck returned overnight, but bases remained above the mountains. Snow began to fall Monday morning, but SLW was not detected, and winds are unfavorable for seeding. A few tenths of an inch of snow fell across the majority of the Upper Green River Basin, and over an inch fell on the NW side	No ground-based seeding was conducted.

of the Winds. Max/Min temperatures Pinedale: 19/-6 Rock Springs: 23/13 Lander: 26/9 Observed ODC: 0	
10 February 2020, Monday	
Scattered cloudiness prevailed across the Winds with orographic snow showers developing in the afternoon, and widespread showers moving in during the evening. SLW was detected starting around 5PM and ending around 9PM. Winds were not favorable for seeding. Snowfall analysis shows the majority of the range seeing over 1" with some areas above 3". Max/Min temperatures Pinedale: 16/-8 Rock Springs: 26/8 Lander: 26/5 Observed ODC: 0	No ground-based seeding was conducted.
11 February 2020, Tuesday	
High and mid level clouds moved through during the daylight hours. Waves of low clouds moved through during the late evening and overnight hours. These brought scattered flurries to light snowfall. Most of the range received very minimal accumulations, with a few spots between 1 and 2 inches. The wind was not favorable for seeding. Max/Min temperatures Pinedale: 14/-15 Rock Springs: 23/2 Lander: 29/-1 Observed ODC: 0	No ground-based seeding was conducted.
12 February 2020, Wednesday	
Scattered, low clouds developed over the range during the morning. These clouds increased in coverage during the afternoon but remained broken, with NW to SE movement. The clouds were most consistent over the SE part of the range where 2 to 4 inches of snow fell, while the rest of the range generally received rest than an inch. The low clouds diminished during the evening, then mid level clouds moved	No ground-based seeding was conducted.

through during the night. Max/Min temperatures Pinedale: 18/0 Rock Springs: 29/15 Lander: 29/15 Observed ODC: 0	
13 February 2020, Thursday	
Scattered, small low clouds existed over the range during the afternoon hours. The only snowfall that occurred was a dusting on the far NW part of the range. Mid level clouds were around for a few hours in the evening then clear skies overnight. Mid level clouds returned to the area Friday morning. Max/Min temperatures Pinedale: 19/-6 Rock Springs: 30/15 Lander: 18/4 Observed ODC: -1	No ground-based seeding was conducted.
14 February 2020, Friday	
Orographic cloud developed over the range throughout the late morning hours and persisted through the afternoon with light snowfall. Good LW was detected by the radiometer with favorable wind flow for plume transport. The wind began to shift to NW by the late afternoon and the clouds began to slowly diminish. Shallow low clouds existed during the evening, but no snowfall occurred. The sky was clear overnight until widespread mid level clouds moved in around sunrise. Total snowfall for the day was light, between 0.1 and 2 inches. Max/Min temperatures Pinedale: 28/-13 Rock Springs: 39/15 Lander: 44/1 Observed ODC: +1	Seeding event WRR0110 was called at 1052 MST on 02/14/2020 and began at 1056 MST. **WRR0110 Summary:** Generators: WR01, WR02, WR03 Time: 1056 (02/14) to 1637 (02/14) MST 1756 (02/14) to 2337 (02/14) UTC WR09, WR12 Time: 1056 (02/14) to 1825 (02/14) MST 1756 (02/14) to 0125 (02/15) UTC Duration: 32:01 Total Time Seeding Material: 14.14 gallons (800.25 grams)
15 February 2020, Saturday	
There was a stratus layer over the southern slopes and valley in the morning, but those clouds thinned in the early afternoon. Thin low clouds existed for most of the afternoon. The clouds thickened during the evening with light snowfall	No ground-based seeding was conducted.

during the night. The radiometer showed LW from late evening and through most of the night but had dropped off before sunrise. The wind was not favorable for seeding. Total snowfall for the day was between 0.5 and 2 inches. Max/Min temperatures Pinedale: 25/-8 Rock Springs: 31/13 Lander: 32/7 Observed ODC: 0	
16 February 2020, Sunday	
Thin, low clouds were over the range and the valley since Saturday night which continued into the afternoon, until thicker clouds moved in. Moderate snowfall occurred from the mid afternoon to the mid evening with favorable seeding conditions, though SLW was minimal. Areas of light snowfall persisted into the night despite that the wind had shifted to NW. Only minimal coverage existed by Monday morning. Most of the range received 3 to 6 inches of snowfall with some areas over 12 inches. Max/Min temperatures Pinedale: 28/12 Rock Springs: 35/24 Lander: 38/11 Observed ODC: +1	Seeding event WRR0111 was called at 1405 MST on 02/16/2020 and began at 1410 MST. **WRR0111 Summary:** Generators: WR10 Time: 1405 (02/16) to 1752 (02/16) MST 2105 (02/16) to 0052 (02/17) UTC WR01, WR02, WR03, WR09, WR12, WR13 Time: 1405 (02/16) to 2132 (02/16) MST 2105 (02/16) to 0432 (02/17) UTC Duration: 46:42 Total Time Seeding Material: 19.27 gallons (1167.50 grams)
17 February 2020, Monday	
Mostly clear skies and some orographic clouds in the morning gave way to widespread clouds with low bases and snowfall near the range in the evening. Skies cleared out overnight. Winds were not favorable for seeding, and no SLW was detected. 24 hour snowfall analysis shows less than 1” fell across most of the range, with higher amounts up to 3” falling in the higher elevations on the NW side of the range. Max/Min temperatures Pinedale: 19/-8 Rock Springs: 26/10 Lander: 27/14 Observed ODC: 0	No ground-based seeding was conducted.
18 February 2020, Tuesday	

Scattered upper-level cloudiness and shallow, short-lived orographic development during the day cleared out in the evening revealing clear skies overnight. No SLW was detected, and winds were not favorable for plume transport. 24 hour snowfall analysis ending at 12Z showed a trace amount to a few tenths of an inch of snow accumulation in the NW region of the range. Max/Min temperatures Pinedale: 16/-18 Rock Springs: 23/5 Lander: 22/2 Observed ODC: -1	No ground-based seeding was conducted.
19 February 2020, Wednesday	
Under dominating high pressure, there was very little cloud coverage over the entire western US. However, lingering low level moisture produced some small low clouds over the far NW corner of the range and the SE part during the afternoon. No significant coverage occurred and only the clouds on the NW produced light snowfall amounting to less than 1 inch. Max/Min temperatures Pinedale: 10/-22 Rock Springs: 19/-7 Lander: 18/-1 Observed ODC: -1	No ground-based seeding was conducted.
20 February 2020, Thursday	
Skies were mostly clear with a few upper-level clouds moving through in the evening. An altostratus cloud deck developed over the range in the evening as well but remained well above the peaks. All clouds dissipated shortly after sunset revealing clear skies for the remainder of the night. No precipitation fell near the Winds, and no SLW was detected. Max/Min temperatures Pinedale: 18/-22 Rock Springs: 22/-4 Lander: 13/-3 Observed ODC: -2	No ground-based seeding was conducted.
21 February 2020, Friday	
A few high clouds were around during the daylight hours, then a band of mid level clouds moved through during the	No ground-based seeding was conducted.

late afternoon. A few small mid level clouds lingered during the evening with clear skies overnight into Saturday morning. Max/Min temperatures Pinedale: 14/-22 Rock Springs: 27/-4 Lander: 18/-4 Observed ODC: -2	
22 February 2020, Saturday	
Clear skies during the daylight hours. High clouds ahead of a low to the south moved in around sunset and continued through most of the night, clearing just before sunrise. The clouds only reached the southeast half of the region. Max/Min temperatures Pinedale: 23/-13 Rock Springs: 38/3 Lander: 34/3 Observed ODC: -2	No ground-based seeding was conducted.
23 February 2020, Sunday	
Clear skies for most of the afternoon, until low clouds started developing over the southern slopes of the range just before sunset. The clouds thickened and snowfall increased during the evening as the wind developed a better cross barrier flow. Favorable seeding conditions existed for a few hours until a cold front moved through during the night, when the wind shifted to parallel to the range. Shallow low clouds lingered into Monday morning. Total snowfall was mostly between 1 to 2 inches over the range except for a few spots of 3 to 4 inches. Max/Min temperatures Pinedale: 30/-13 Rock Springs: 35/11 Lander: 40/8 Observed ODC: +1	Seeding event WRR0112 was called at 0445 MST on 02/24/2020 and began at 0450 MST. **WRR0112 Summary:** Generators: WR01, WR02, WR03, WR12 Time: 2150 (02/24) to 0209 (02/25) MST 0450 (02/25) to 0909 (02/25) UTC Duration: 4:19, 9:07 Total Time Seeding Material: 4.06 gallons (228.00 grams)
24 February 2020, Monday	
Broken low clouds with light snowfall existed over the range through the afternoon and evening hours. The clouds did not fully cover the range and the wind was not favorable for seeding operations. Most of the clouds diminished by midnight, but an area of snowfall continued over the NE part	No ground-based seeding was conducted.

of the range and LND area through the night into Tuesday morning. Most of the range received only 0.5 to 1 inch snowfall, but the NE corner had over 3 inches. Max/Min temperatures Pinedale: 27/3 Rock Springs: 33/12 Lander: 38/18 Observed ODC: 0	
25 February 2020, Tuesday	
Scattered low clouds were around the range during the daylight hours, then diminished shortly after sunset. Mid level clouds began moving into the area from the NW during the night. The snowfall map shows the NW part of the range received a dusting to 1 inch and a dusting on the southern part of the range. Max/Min temperatures Pinedale: 16/-8 Rock Springs: 22/12 Lander: 23/5 Observed ODC: -1	No ground-based seeding was conducted.
26 February 2020, Wednesday	
Scattered shallow low-level clouds persisted through the majority of the daytime with orographic development also occurring as well. Orographic clouds were short-lived and limited in coverage. The scattered low-level cloud deck cleared out by midnight while mid-level clouds developed around the same time. 24 hour snowfall analysis ending at 12Z showed a trace amount of accumulation in isolated areas such as in high elevations and to the NW of the range. Max/Min temperatures Pinedale: 32/-8 Rock Springs: 32/9 Lander: 26/0 Observed ODC: -1	No ground-based seeding was conducted.
27 February 2020, Thursday	
Mid- to upper-level clouds lingered in the morning to the early afternoon before clearing out by 1PM. Stratiform orographic clouds originating in the NW region of the range covered part of the Winds, but bases remained above the	No ground-based seeding was conducted.

peaks. Winds were breezy out of the NW, gusting as high as 26 mph in PNA. No SLW was detected, and no snowfall was observed in the project area. Max/Min temperatures Pinedale: 34/14 Rock Springs: 36/18 Lander: 42/20 Observed ODC: -1	
28 February 2020, Friday	
Clear skies during the daylight hours, until a very few high clouds came in just before sunset. A few mid level clouds and lenticular clouds existed during the evening and overnight, diminishing before sunrise. Max/Min temperatures Pinedale: 32/1 Rock Springs: 42/23 Lander: 37/19 Observed ODC: -2	No ground-based seeding was conducted.
29 February 2020, Saturday	
Scattered low level cloudiness persisted for the majority of the day with shallow orographic clouds near the range but bases were generally above the peaks. 700mb temps were warm (> -6C) while low-level wind was favorable for plume transport. Widespread snow began early Sunday morning as cloud coverage increased with bases below the mountain peaks. 24 snowfall analysis ending at 12Z shows less than an inch of accumulation across the Winds with higher amounts to the NW of the range. Max/Min temperatures Pinedale: 32/1 Rock Springs: 47/20 Lander: 50/19 Observed ODC: 0	No ground-based seeding was conducted.
01 March 2020, Sunday	
Widespread snowfall had begun before sunrise. The northerly wind flow became favorable for seeding during the morning, then became less favorable during the afternoon. The widespread snowfall was moving away by sunset, but the wind switched to NW and kept light snowfall over the	Seeding event WRR0113 was called at 1620 MST on 03/01/2020 and began at 1624 MST. **WRR0113 Summary:** Generators: WR07

southern slopes and PNA area until the middle of the night. Only, mid level clouds were left by Monday morning. Most of the range received 3 to 8 inches, while a small area on the NE had 10 inches. Max/Min temperatures Pinedale: 28/12 Rock Springs: 34/12 Lander: 41/12 Observed ODC: +1	Time: 0924 (03/01) to 1528 (03/01) MST 1624 (03/01) to 2228 (03/01) UTC Duration: 6:04 Total Time Seeding Material: 2.79 gallons (151.75 grams)
02 March 2020, Monday	
Thin, mid level clouds moved through the area during the morning, then left the area to the SE shortly after noon. The sky was clear until some mid level clouds returned in the evening. Shallow, low clouds developed over the southern slopes of the range around midnight and persisted into Tuesday morning. Light snowfall amounting to 1 to 2 inches occurred through the night. LW was detected by the radiometer but the wind was not favorable for seeding operations. Max/Min temperatures Pinedale: 28/0 Rock Springs: 26/9 Lander: 38/4 Observed ODC: 0	No ground-based seeding was conducted.
03 March 2020, Tuesday	
Thin clouds over the southern slopes in the morning slowly diminished through the early afternoon. The clouds didn't fully cover the range and the wind was not favorable for seeding operations. The sky was clear until some low clouds formed over the southern slopes again around midnight, but those clouds were short-lived. Low clouds began developing over the NW part of the range Wednesday morning. The snowfall map showed less than 0.5 inch accumulation. Max/Min temperatures Pinedale: 36/9 Rock Springs: 37/20 Lander: 47/17 Observed ODC: -1	No ground-based seeding was conducted.
04 March 2020, Wednesday	

Orographic cloud coverage developed over the range during the morning and persisted through the afternoon and evening. There were thicker periods, and times with thin cloud coverage. Overall, snowfall was very limited with less than 1 inch accumulation. A sounding at 20Z showed the temperature to be too warm for seeding operations. The clouds had diminished by midnight and the sky was clear overnight. Max/Min temperatures Pinedale: 36/1 Rock Springs: 42/24 Lander: 51/20 Observed ODC: 0	No ground-based seeding was conducted.
05 March 2020, Thursday	
Broken upper-level clouds prevailed through the day becoming scattered over night. A thin stratiform cloud layer hovered well above the mountains overnight and dissipated by morning. No snowfall was observed across the entire region and no SLW was detected either. Max/Min temperatures Pinedale: 36/5 Rock Springs: 49/28 Lander: 38/20 Observed ODC: -2	No ground-based seeding was conducted.
06 March 2020, Friday	
Thin upper-level clouds covered the project area throughout the day with lenticular clouds developing over the range in the late afternoon. Small amounts of LW were detected between 7Z and 11Z with favorable wind flow, but temperatures were too warm for seeding. No snow accumulation was recorded across the Winds. Max/Min temperatures Pinedale: 37/7 Rock Springs: 54/25 Lander: 38/20 Observed ODC: -2	No ground-based seeding was conducted.
07 March 2020, Saturday	
Broken cloud coverage persisted in the morning with clouds increasing during the day. Orographic clouds enshrouded the	No ground-based seeding was conducted.

mountains in the evening and at night. Winds were favorable and SLW was detected, but temperatures were too warm for seeding. Snow fell in the higher elevations, with up to 6" falling in the NW region of the range, and 2" mostly everywhere else. Only a trace amount of accumulation fell in some areas of the valley, generally closer to the mountains. Max/Min temperatures Pinedale: 41/7 Rock Springs: 54/25 Lander: 56/27 Observed ODC: 0	
08 March 2020, Sunday	
Skies were partly cloudy with thin orographic clouds over the range throughout the day. A low stratiform cloud formation moved in from the west at around 6PM providing light scattered snowfall an hour later. No LW was detected with the exception of a spike at around 8PM. 24 hour snowfall analysis shows a few tenths of an inch accumulating near PNA and in most of the range, and up to 2" accumulating towards the SW region of the range, near South Pass. Max/Min temperatures Pinedale: 37/23 Rock Springs: N/A Lander: 48/27 Observed ODC: 0	No ground-based seeding was conducted.
09 March 2020, Monday	
Orographic cloud coverage formed over the range during the morning, with favorable seeding conditions developing through the morning hours. These conditions persisted through the afternoon and then deteriorated after sunset. Light snowfall with radiometer detected LW occurred again during the night but the wind was not favorable for seeding at that time. The clouds persisted into Tuesday morning. The top of the range received 2+ inches, with 6 to 10 inches on the NW, while the PNA area received 1 to 2 inches. Max/Min temperatures Pinedale: 36/14 Rock Springs: N/A Lander: 45/21 Observed ODC: +2	Seeding event WRR0114 was called at 0953 MDT on 03/09/2020 and began at 0958 MDT. **WRR0114 Summary:** Generators: WR02, WR03 Time: 0957 (03/09) to 1834 (03/09) MDT 1557 (03/09) to 0034 (03/10) UTC WR01, WR12 Time: 0957 (03/09) to 2036 (03/09) MDT 1557 (03/09) to 0236 (03/10) UTC WR09 Time: 1506 (03/09) to 2036 (03/09) MDT

	2106 (03/09) to 0236 (03/10) UTC Duration: 46:01 Total Time Seeding Material: 20.01 gallons (1150.50 grams)
10 March 2020, Tuesday	
Low clouds with light snowfall and some radiometer detected LW were over the range in the morning. By late morning, the clouds were diminishing and the snowfall had mostly ended. The clouds slowly weakened through the afternoon and were gone by sunset. Only a few high and mid level clouds existed during the evening and overnight, except a small area of low clouds developed by sunrise. A good portion of the range received some snowfall, but it was less than 2 inches. Max/Min temperatures Pinedale: 34/14 Rock Springs: N/A Lander: 48/23 Observed ODC: 0	No ground-based seeding was conducted.
11 March 2020, Wednesday	
Low clouds with high bases developed over the range during the morning and continued through the afternoon. The clouds thickened by late afternoon with areas of very light snowfall. These conditions persisted through the evening into the night, but overall accumulation was limited to less than 1 inch. The temperature was too warm for seeding operations. Max/Min temperatures Pinedale: 37/5 Rock Springs: N/A Lander: 51/21 Observed ODC: 0	No ground-based seeding was conducted.
12 March 2020, Thursday	
Thin and broken low cloud coverage in the morning slowly faded during the morning, with only scattered, small clouds during the afternoon. The snowfall map showed most of the range received some snowfall but was less than 1 inch. There were a few high clouds overnight. A stratus layer developed over the valley on the north side of the range by Friday morning.	No ground-based seeding was conducted.

Max/Min temperatures Pinedale: 36/14 Rock Springs: N/A Lander: 43/26 Observed ODC: 0	
13 March 2020, Friday	
A low stratus deck existed on the north side of the range from the morning through the evening. Widespread mid level clouds pushed into the area during the afternoon as a system just missed the area to the east. Some light snowfall occurred around South Pass in the late afternoon and evening from this system. Orographic clouds developed over the range during the night with radiometer detected LW, but the wind was not favorable for seeding and cloud bases were relatively high. Also, little to no snowfall occurred. The SE part of the range, around South Pass, received over 1 inch snowfall, while the rest of the range had only a dusting for the day. Max/Min temperatures Pinedale: 32/3 Rock Springs: N/A Lander: 31/21 Observed ODC: 0	No ground-based seeding was conducted.
14 March 2020, Saturday	
Orographic clouds over the range at sunrise, strengthened during the morning as cross barrier flow improved. Continuous snowfall with radiometer detected LW existed from the late morning through the afternoon. The snowfall became lighter and somewhat broken in coverage during the evening but continued through the night. SW wind flow brought warmer air to the region and the temperature was too warm for seeding operations. Snowfall map shows most of the range received 1 inch, with a few areas up to 4 inches. Max/Min temperatures Pinedale: 39/14 Rock Springs: N/A Lander: 44/19 Observed ODC: 0	No ground-based seeding was conducted.
15 March 2020, Sunday	
There were scattered low clouds across over the basin with lasting orographic clouds near the range throughout the	No ground-based seeding was conducted.

period. LW was detected and winds were favorable, but 700mb temperatures were above the seeding threshold. 24 hour snowfall analysis ending at 12 UTC shows a few inches of snow accumulation in the Winds with little to none falling in the valley. Max/Min temperatures Pinedale: 43/27 Rock Springs: N/A Lander: 55/28 Observed ODC: 0	
16 March 2020, Monday	
Scattered low level clouds prevailed throughout the day with high clouds moving into the region by mid-afternoon. Orographic clouds lingered, but bases remained above the peaks. The high clouds cleared out after midnight, but the low-level clouds remained. LW was not detected until 6AM the Tuesday morning. 24 hour snowfall analysis ending at 12UTC shows a few tenths of an inch fell across the range, with no accumulation in the valley. Max/Min temperatures Pinedale: 43/21 Rock Springs: 53/28 Lander: 41/21 Observed ODC: -1	No ground-based seeding was conducted.
17 March 2020, Tuesday	
Small low clouds were over the range during the morning, then became shallow and scattered by mid day. These clouds lingered through the afternoon before diminishing by sunset. Periods of mid level clouds passed through during the evening and overnight, then low clouds began developing over the range before sunrise. The temperature was too warm for seeding throughout the whole day. The NW half of the range received around 1 inch snowfall. Max/Min temperatures Pinedale: 46/19 Rock Springs: 55/24 Lander: 51/25 Observed ODC: 0	No ground-based seeding was conducted.
18 March 2020, Wednesday	

Low clouds over the range improved during the morning as the wind developed a better cross barrier flow. A sounding confirmed the temperature to be right around the seeding threshold, with favorable cloud conditions and seeding plume trajectories. The temperature warmed during the afternoon putting an end to seeding, but the clouds continued for another hour before diminishing. By sunset, the low clouds had completely diminished. Mid level clouds moved through during the night, then low clouds began developing on the NE side of the range by sunrise. Most of the top of the range received 2 inches of snowfall with an area of 4 inches shown in the middle of the range. Max/Min temperatures Pinedale: 36/21 Rock Springs: 49/31 Lander: 47/31 Observed ODC: +1	Seeding event WRR0115 was called at 1052 MDT on 03/18/2020 and began at 1058 MDT. **WRR0115 Summary:** Generators: WR01, WR09, WR12 Time: 1058 (03/18) to 1439 (03/18) MDT 1658 (03/18) to 2039 (03/18) UTC Duration: 3:41, 8:10 Total Time Seeding Material: 3.81 gallons (204 grams)
19 March 2020, Thursday	
Low clouds on the north side of the range thickened during the morning, as northerly flow became more favorable for cross barrier flow. Favorable seeding conditions existed on the north side during the morning, afternoon and most of the evening before the wind became unfavorable for seeding and the light snowfall in the South Pass area diminished. Widespread mid level clouds pushed in from the south during the afternoon, then light snowfall in the valley on the south side of the range began around sunset and continued through the night. Snowfall map shows 4-5 inches on NE slopes and 1-2 on the rest of the range. Max/Min temperatures Pinedale: 41/21 Rock Springs: 34/21 Lander: 36/25 Observed ODC: +2	Seeding event WRR0116 was called at 0850 MDT on 03/19/2020 and began at 0853 MDT. **WRR0116 Summary:** Generators: WR07 Time: 0853 (03/19) to 2232 (03/19) MDT 1453 (03/19) to 0432 (03/20) UTC Duration: 13:39 Total Time Seeding Material: 6.42 gallons (341.25 grams)
20 March 2020, Friday	
A deep layer of clouds over the region in the morning thinned out by the afternoon with orographic clouds prevailing near the range. Snow fell close to the mountains in the mid afternoon. Conditions were never consistent enough for seeding operations. Clouds over the valley became scattered in the late afternoon before a brief period of snowfall	No ground-based seeding was conducted.

occurred near sunset. Skies became partly cloudy overnight with fog developing the following morning. Snowfall analysis shows a few tenths of an inch fell across the valley with higher totals, up to 4", towards the peaks. Max/Min temperatures Pinedale: 34/23 Rock Springs: 37/18 Lander: 41/22 Observed ODC: 0	
21 March 2020, Saturday	
Low clouds developed over the range during the morning and continued through the afternoon. The clouds were shallow, broken in coverage from being convective and didn't fully cover the range. No LW was detected by the radiometer and snowfall was limited. The clouds diminished after sunset. Short periods of low clouds moved through during the night. Snowfall map showed only a dusting in a few areas over the range, with up to 1 inch around PNA. Max/Min temperatures Pinedale: 37/16 Rock Springs: 45/24 Lander: 53/22 Observed ODC: 0	No ground-based seeding was conducted.
22 March 2020, Sunday	
Low cloud coverage over the range increased during the morning. The radiometer detected LW beginning a little before noon. Favorable seeding conditions existed during the afternoon, with convective snow squalls passing through. The wind became unfavorable in the late afternoon and the clouds began to diminish. Some mid level clouds existed during the evening and night, with shallow low clouds developing over the range before sunrise. Snowfall map showed 1 to 3 inches on the top of the range. Max/Min temperatures Pinedale: 37/19 Rock Springs: 46/27 Lander: 53/27 Observed ODC: +1	Seeding event WRR0117 was called at 1335 MDT on 03/22/2020 and began at 1343 MDT. **WRR0117 Summary:** Generators: WR09, WR12, WR13 Time: 1343 (03/22) to 1800 (03/22) MDT 1943 (03/22) to 0000 (03/23) UTC Duration: 4:24, 8:55 Total Time Seeding Material: 3.95 gallons (223.00 grams)
23 March 2020, Monday	

Shallow low clouds over the range in the morning increased in size beginning around noon, but it was short-lived as coverage became less during the afternoon and snowfall was broken with convective snow showers. The temperature warmed in the early afternoon. Continuous orographic clouds developed around sunset. 05Z sounding showed the temperature to be too warm for seeding. The clouds weakened during the night as the wind became less favorable for cross barrier flow. The clouds began developing again Tuesday morning. Snowfall map showed a few scattered areas over the range received 1 to 2 Max/Min temperatures Pinedale: 41/14 Rock Springs: 47/24 Lander: 54/28 Observed ODC: 0	No ground-based seeding was conducted.
24 March 2020, Tuesday	
Skies were partly sunny in the morning before thicker clouds and snow bands moved through in the afternoon. Clouds remained in the evening and overnight with snow persisting, especially in the southern portion of the range. LW was present in the morning and early afternoon, then became less available after 4PM. LW spiked at 8PM, but traj were unfavorable. Favorable seeding conditions began developing Wednesday morning. 24 hour precipitation analysis shows 0.4" of SWE accumulation across most of the range, with up to 1" accumulating near South Pass. Max/Min temperatures Pinedale: 39/23 Rock Springs: 46/29 Lander: 54/32 South Pass: 34/27 Observed ODC: +2	Seeding event WRR0118 was called at 1045 MDT on 03/24/2020 and began at 1054 MDT. **WRR0118 Summary:** Generators: WR13 Time: 1054 (03/24) to 1600 (03/24) MDT 1654 (03/24) to 2200 (03/24) UTC WR01, WR12 Time: 1054 (03/24) to 1852 (03/24) MDT 1654 (03/24) to 0052 (03/25) UTC Duration: 7:58, 21:02 Total Time Seeding Material: 8.06 gallons (526.00 grams)
25 March 2020, Wednesday	
The wind flow became favorable for seeding operations in the early morning and the clouds thickened with light continuous snowfall over the range through the morning and afternoon. Detected LW was low throughout the afternoon. The wind flow became unfavorable for seeding around sunset and the clouds over the north and middle portion of the range diminished. South Pass reported continuous light snowfall	Seeding event WRR0119 was called at 0816 MDT on 03/25/2020 and began at 0826 MDT. **WRR0119 Summary:** Generators: WR10, WR13 Time: 0826 (03/25) to 1821 (03/25) MDT

through the night. The range received between 0.1 and 0.5 inch SWE with the highest on the southern half, while the area between Boulder and Farson received just over 0.25 inch SWE. Max/Min temperatures Pinedale: 34/18 Rock Springs: 37/27 Lander: 48/32 South Pass: 28/23 Observed ODC: +2	1426 (03/25) to 0021 (03/26) UTC WR01, WR02, WR03, WR04, WR05, WR12 Time: 0826 (03/25) to 1932 (03/25) MDT 1426 (03/25) to 0132 (03/26) UTC Duration: 11:06, 86:04 Total Time Seeding Material: 36.43 gallons (2153.50 grams)
26 March 2020, Thursday	
A thin layer of low-level clouds lingered around the valley with orographic clouds enshrouding the range throughout the day. High clouds moved in overnight as low clouds and orographic cloud cleared out after midnight. Snow was recorded near South Pass all day, while snow was only recorded briefly in Pinedale in the mid afternoon. 24 hour precipitation analysis shows SWE accumulation of a trace to a few hundredths of an inch to the SW of the range. Max/Min temperatures Pinedale: 32/18 Rock Springs: 37/24 Lander: 48/26 South Pass: 27/19 Observed ODC: 0	No ground-based seeding was conducted.
27 March 2020, Friday	
Skies were clear over the valley for the majority of the day with a few clouds developing near sunset. The range was clear until noon when orographic clouds began to develop for the remainder of the day. Orographic clouds diminished after sunset revealing a clear night. No LW was detected over the range. 24 hour snowfall analysis shows a trace amount of accumulation near PNA, but the local station did not detect such. Regardless, a few tenths of an inch accumulated higher in the Winds. Max/Min temperatures Pinedale: 32/9 Rock Springs: 36/21 Lander: 44/23 South Pass: 27/16	No ground-based seeding was conducted.

Observed ODC: -1	
28 March 2020, Saturday	
Scattered low clouds developed over the range beginning around noon and lasted through the afternoon, diminishing just after sunset. More continuous low clouds existed on the NW side of the range for most of the night, fading just before sunrise. An area of low clouds formed in the middle of the range early Sunday morning. Snowfall map showed up to 2 inches in the narrow band over the ridge line, highest on the SE part of the range where the strongest convective showers existed. Max/Min temperatures Pinedale: 36/18 Rock Springs: 41/20 Lander: 51/19 South Pass: 30/19 Observed ODC: -1	No ground-based seeding was conducted.
29 March 2020, Sunday	
Shallow low clouds over the southern slopes in the morning developed into convective showers by late morning. Scattered showers existed around the region through the afternoon diminishing by sunset. Some mid level clouds existed in the evening and night, with shallow low clouds forming again after 11z. Snowfall map showed a dusting of snowfall around the region, with one area receiving up to 1 inch accumulation. Max/Min temperatures Pinedale: 39/14 Rock Springs: 45/22 Lander: 54/25 South Pass: 32/18 Observed ODC: -1	No ground-based seeding was conducted.
30 March 2020, Monday	
There were a few small clouds over the southern slopes in the morning. Convective clouds began developing shortly after noon and continued until sunset with broken coverage. A regular orographic cloud developed over the range in the evening hours and persisted through the night into Tuesday morning. Two soundings were done and showed the temperature to be warmer than the seeding threshold.	No ground-based seeding was conducted.

Max/Min temperatures Pinedale: 41/18 Rock Springs: 49/24 Lander: 56/26 South Pass: 34/27 Observed ODC: 0	
31 March 2020, Tuesday	
Thick orographic cloud with continuous snowfall and a high amount of LW was over the range during the morning, afternoon and evening. The cloud had weakened by midnight as moisture flow was becoming less and snowfall rates dropped but the snowfall continued through the night. A sounding in the morning and another shortly after midnight showed the temperature to be too warm for seeding. The temperature cooled by Wednesday morning, but the wind became unfavorable for seeding operations. Snowfall map shows 6+ inches accumulation over most of the range with the highest elevations receiving 12 to 16 inches. Max/Min temperatures Pinedale: 45/27 Rock Springs: 54/31 Lander: 57/35 South Pass: 36/27 Observed ODC: 0	No ground-based seeding was conducted.
01 April 2020, Wednesday	
Continued thick orographic cloud coverage over the range during the morning and afternoon. The temperature had cooled in the early morning and the wind became favorable for seeding by mid morning. The temperature warmed in the late afternoon. The wind flow became northerly for a short time in the evening as more widespread clouds and snowfall moved through but was not quite right for seeding with Enterprise. The wind switched back to westerly overnight with improved orographic development on the southern portion of the range, allowing for seeding operations again. The clouds thinned Thursday morning. Most of the range received 1 to 3 inches, with 5 to 6 on the southern part and around Lander. Max/Min temperatures Pinedale: 41/28	Seeding event WRR0120 was called at 0944 MDT on 04/01/2020 and began at 0951 MDT. **WRR0120 Summary** Generators: WR01, WR02, WR03, WR12 Time: 0951 (04/01) to 1745 (04/01) MDT 1551 (04/01) to 2345 (04/01) UTC Duration: 7:54, 31:08 Total Time Seeding Material: 12.15 gallons (778.25 grams) Seeding event WRR0121 was called at 0457 MDT on 04/02/2020 and began at 0512 MDT. **WRR0121 Summary** Generators: WR01, WR02, WR03, WR12 Time: 0512 (04/02) to 0927 (04/02) MDT

Rock Springs: 50/22 Lander: 55/18 South Pass: 34/12 Observed ODC: +2	1112 (04/02) to 1527 (04/02) UTC Duration: 4:15, 17:00 Total Time Seeding Material: 7.31 gallons (425.00 grams)
02 April 2020, Thursday	
Scattered low-level clouds lingered during the day with thin orographic clouds also developing early. Coverage decreased overnight as clouds diminished. Light snow fell in the valley in the morning with a few tenths of an inch accumulation in most areas according to a 24 hour snowfall analysis map. Up to 4" fell in higher elevations. LW was detected in the range near Pinedale in the morning and midafternoon but became absent after 3PM. Max/Min temperatures Pinedale: 30/14 Rock Springs: 30/14 Lander: 21/9 South Pass: 16/9 Observed ODC: 0	No ground-based seeding was conducted.
03 April 2020, Friday	
Skies were clear in the morning with thin orographic clouds near the mountains. Scattered low clouds increased in coverage in the afternoon with a few snow showers in the region. Low clouds mostly cleared out overnight with a few thin clouds remaining along with a few orographic clouds. LW was detected near Pinedale in the afternoon but diminished again after 6PM. A few tenths of an inch of snow accumulation occurred in the range with high values near the peaks according to a 24 hour snowfall analysis map. Max/Min temperatures Pinedale: 32/5 Rock Springs: 37/11 Lander: 32/2 South Pass: 23/10 Observed ODC: -1	No ground-based seeding was conducted.
04 April 2020, Saturday	
Skies were mostly clear during the daylight hours with a few thin upper-level clouds in the afternoon. Mid-level clouds began to develop in the early evening, becoming overcast overnight as cloud bases descended below the peaks. Station	No ground-based seeding was conducted.

observations at PNA recorded no snowfall, but a 24 hour snowfall analysis map shows a trace to a few tenths of an inch of snow accumulation in the project area. LW was detected Sunday morning but was absent during the day prior. Warm temps was the main factor preventing seeding operations. Max/Min temperatures Pinedale: 43/10 Rock Springs: 50/20 Lander: 49/15 South Pass: 34/13 Observed ODC: 0	
05 April 2020, Sunday	
The orographic cloud over the range weakened during the morning but then increased in the early afternoon as convective activity began. Precipitation across the region and the range was not continuous with heavier periods as convective cells passed through during the afternoon and evening. Light snowfall periods existed overnight, becoming more continuous by Monday morning. The snowfall map shows the uneven snowfall, with most of the range receiving 1 inch and a few areas over 3 inches. Max/Min temperatures Pinedale: 43/28 Rock Springs: 52/27 Lander: 60/27 South Pass: 36/32 Observed ODC: 0	No ground-based seeding was conducted.
06 April 2020, Monday	
Orographic clouds over the range throughout the period producing snowfall but not fully continuous. The coverage was somewhat broken during the afternoon with convective activity around the region, which produced stronger precipitation rates. The temperature was much too warm for seeding operations. Snowfall map showed most of the range received 3 inches with a few locations of 8 to 10 inches. Max/Min temperatures Pinedale: 48/30 Rock Springs: 59/36 Lander: 62/35	No ground-based seeding was conducted.

South Pass: 43/32 Observed ODC: 0	
07 April 2020, Tuesday	
Continued thick orographic cloud over the range during the morning. The clouds weakened and became broken in the early afternoon but persisted into the evening. Despite the cloud coverage, the snowfall map only shows very little accumulation, with no amounts greater than 1 inch. The temperature was much too warm for seeding operations. Mid level clouds existed overnight with bases above the peaks but moved away early Wednesday morning. Max/Min temperatures Pinedale: 50/30 Rock Springs: 60/34 Lander: 63/36 South Pass: 43/32 Observed ODC: 0	No ground-based seeding was conducted.
08 April 2020, Wednesday	
A very few small clouds with bases well above the peaks in the morning lasting through the mid afternoon before they disappeared. Otherwise, the sky was clear. Max/Min temperatures Pinedale: 54/27 Rock Springs: 61/31 Lander: 64/36 South Pass: 48/32 Observed ODC: -2	No ground-based seeding was conducted.
09 April 2020, Thursday	
Clear skies prevailed during the daylight hours with the exception of a few passing cirrus clouds. After midnight, scattered cirrostratus clouds developed over the region extending into the morning hours. No snowfall was observed over this 24 hour period. Max/Min temperatures Pinedale: 61/23 Rock Springs: 63/28 Lander: 58/29 South Pass: 46/32 Observed ODC: -2	No ground-based seeding was conducted.

10 April 2020, Friday	
Thin, mid level cloud coverage in the morning. Small low clouds developed over the range in the afternoon as well as scattered cumulus clouds around the region. Thick mid level clouds expanded over the area in the late afternoon and continued until the middle of the night. Shallow low clouds formed over the range early Saturday morning. Max/Min temperatures Pinedale: 55/23 Rock Springs: 62/36 Lander: 69/31 South Pass: 52/34 Observed ODC: -1	No ground-based seeding was conducted.
11 April 2020, Saturday	
Skies over the region were mostly cloudy through the morning and afternoon, then became cloudy in the evening. Scattered rain/snow showers occurred in the valley with snow showers in the mountains, mostly in the evening. Additional snowfall accumulated overnight totaling 8" across most of the range with significantly less, up to 0.5", in the valley according to a 24 hour snowfall analysis map ending 12 UTC. Most of the snowfall was to the north and east of the range. Warm temperatures and unfavorable wind flow prevented seeding operations. Max/Min temperatures Pinedale: 46/27 Rock Springs: 57/19 Lander: 64/20 South Pass: 43/14 Observed ODC: 0	No ground-based seeding was conducted.
12 April 2020, Sunday	
Scattered snowfall and mostly cloudy skies in the morning gave way to partly cloudy skies in the afternoon with orographic clouds lingering until just before sunset. Towards South Pass, however, intermittent snowfall persisted throughout the day, only letting up by sunset. Clear skies ensued across the region until a stratus deck developed after midnight. Skies were mostly cloudy from then until sunrise. LW was detected in the morning until 1830 UTC, and then intermittent during the afternoon. Between 4" and 6" fell in	Seeding event WRR0122 was called at 0752 MDT on 04/12/2020 and began at 0757 MDT. **WRR0122 Summary:** Generators: WR01, WR09, WR10, WR12 Time: 0757 (04/12) to 1445 (04/12) MDT 1357 (04/12) to 2045 (04/12) UTC

the range favoring the SE side with greater totals towards higher elevations. Max/Min temperatures Pinedale: 30/14 Rock Springs: 32/13 Lander: 24/15 South Pass: 14/9 Observed ODC: +1	WR13 Time: 1135 (04/12) to 1445 (04/12) MDT 1735 (04/12) to 2045 (04/12) UTC Duration: 6:48, 30:01 Total Time Seeding Material: 13.57 gallons (750.50 grams)
13 April 2020, Monday	
Broken cloud coverage around the region during the morning and afternoon. Light snowfall existed over the range, which amounted to 1 to 3 inches. The wind was not favorable for seeding. The clouds were mainly driven by daytime heating and started to diminish as the sun was setting. No significant clouds existed during the evening and overnight. Max/Min temperatures Pinedale: 28/10 Rock Springs: 31/8 Lander: 26/9 South Pass: 14/1 Observed ODC: -1	No ground-based seeding was conducted.
14 April 2020, Tuesday	
Mid level clouds increased during the morning, then broken low and mid level clouds existed during the afternoon with areas of light snowfall. Areas of light snowfall continued through the evening and night, from shallow orographic clouds and passing mid level clouds. The wind flow was not favorable for seeding operations. Snowfall map shows total accumulation was less than 2 inches. Max/Min temperatures Pinedale: 34/7 Rock Springs: 40/13 Lander: 40/9 South Pass: 28/9 Observed ODC: 0	No ground-based seeding was conducted.
15 April 2020, Wednesday	

A large storm system moved into WY from the NW during the day. The snowfall increased over the WR during the morning with WNW wind, but it wasn't quite right for seeding operations. The flow switched around to northerly during the afternoon with moderate to heavy snowfall reported at South Pass during the evening and overnight. SLW was low but some was as expected from late afternoon through the evening and then became less overnight. Snowfall map shows 6 inches over the entire range with 24+ inches between LND and South Pass. Max/Min temperatures Pinedale: 39/23 Rock Springs: 43/22 Lander: 39/23 South Pass: 32/18 Observed ODC: +2	Seeding event WRR0123 was called at 1625 MDT on 04/15/2020 but the lone GGEN to be used failed to ignite. Seeding probably would have ended before 0400 MDT on 04/16/2020.

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

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.

NOAA FILE NUMBER

[ ] INTERIM REPORT [X] 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 11/15/2019 TO 04/15/2020

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	10	10					376	9,265				
FEBRUARY	4	4					157	4,089				
MARCH	7	7					190	4,956				
APRIL	3	3					78	2,010				
MAY												
JUNE												
JULY												
AUGUST												
SEPTEMBER												
OCTOBER												
NOVEMBER	3	3					46	1,187				
DECEMBER	3	3					153	3,807				
TOTAL	30	30	0	0	0	0	999	25,314	0	0	0	0
TOTALS FOR FINAL REPORT	30	30	0	0	0	0	999	25,314	0	0	0	0

DATE ON WHICH FINAL WEATHER MODIFICATION ACTIVITY OCCURRED *(For Final Report only.)* 04/12/2020

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: 04/22/2020

Appendix C. Ice Nucleus Generator Operations Summary – 2019-2020

2019-2020 Generator Operations Summary - WIND RIVER RANGE

LAST UPDATED 20200417

GRAND TOTAL OPERATIONAL "SEED" HOURS=	999:10
Total Seeding Solution (Gallons)=	416.08

Monthly Totals	194:26	161:11	167:56	42:43	42:45	29:20	81:00	35:27	199:26	44:56	999:10	999.17
November sub-total	7:14	6:36	7:14	0:00	0:00	9:37	5:09	0:00	9:43	0:00	45:33	45.55
December sub-total	38:46	34:12	34:12	0:00	0:00	0:00	5:30	0:00	40:02	0:00	152:42	152.70
January sub-total	69:36	65:26	67:21	27:59	28:01	0:00	29:48	8:43	70:12	8:35	375:41	375.68
February sub-total	25:37	23:29	27:19	3:39	3:39	0:00	24:48	10:01	24:48	13:46	157:06	157.10
March sub-total	34:23	19:30	19:41	11:05	11:05	19:43	9:18	9:55	35:54	19:25	189:59	189.98
April sub-total	18:50	11:58	12:09	0:00	0:00	0:00	6:27	6:48	18:47	3:10	78:09	78.15

UTC DATE	WR01 Big Sandy	WR02 Block & Tackle	WR03 White Acorn	WR04 Sweetwater	WR05 Anderson	WR07 Enterprise	WR09 Boulder Lake	WR10 East Fork	WMI-WR12 Pocket Creek	WMI-WR13 Green River	DAILY TOTAL		Operation #	Solution Used (gallons)
11/20/2019						9:37					9:37	9.62	WRR0093	4.52
11/25/2019							5:09		2:29		7:38	7.63	WRR0094	3.44
11/28/2019	7:14	6:36	7:14						7:14		28:18	28.30	WRR0095	11.55
12/8/2019	4:34						5:30		5:51		15:55	15.92	WRR0096	6.34
12/12/2019	29:09	29:09	29:09						29:09		116:36	116.60	WRR0097	47.51
12/24/2019	5:03	5:03	5:03						5:02		20:11	20.18	WRR0098	8.73
1/1/2020	5:52	5:52	5:52								17:36	17.60	WRR0099	7.81
1/2/2020							3:22		3:22		6:44	6.73	WRR0100	2.56
1/4/2020	4:02	4:02	4:02				4:02	1:48	4:02	2:02	24:00	24.00	WRR0101	9.95
1/7/2020	5:09	5:09	5:09						5:06		20:33	20.55	WRR0102	8.38
1/8/2020	8:03	8:03	8:03				8:03		9:50		42:02	42.03	WRR0103	15.97
1/12/2020	4:10	4:10	4:10	2:04	2:04		4:10	2:04	5:46		28:38	28.63	WRR0104	12.03
1/13/2020	16:17	16:17	16:17	12:19	12:19		3:57		17:05		94:31	94.52	WRR0105	39.09
1/14/2020	15:31	15:30	15:53	13:36	13:38		6:14	4:51	16:21	6:33	108:07	108.12	WRR0106	42.39
1/15/2020	5:16	5:16	5:15						5:16		21:03	21.05	WRR0107	8.88
1/17/2020	5:16	1:07	2:40						3:24		12:27	12.45	WRR0108	5.23
2/8/2020	9:52	9:52	9:52	3:39	3:39		9:52	6:19	9:52	6:19	69:16	69.27	WRR0109	29.73
2/14/2020	5:41	5:41	5:41				7:29		7:29		32:01	32.02	WRR0110	14.14
2/16/2020	5:45	7:27	7:27				7:27	3:42	7:27	7:27	46:42	46.70	WRR0111	19.28
2/24/2020	4:19	0:29	4:19								9:07	9.12	WRR0112	4.06
3/1/2020						6:04					6:04	6.07	WRR0113	2.79
3/9/2020	11:39	8:37	8:36				5:30		11:39		46:01	46.02	WRR0114	20.01
3/18/2020	3:41						3:41		0:48		8:10	8.17	WRR0115	3.80
3/19/2020						13:39					13:39	13.65	WRR0116	6.42
3/22/2020							0:07		4:24	4:24	8:55	8.92	WRR0117	3.95
3/24/2020	7:58								7:58	5:06	21:02	21.03	WRR0118	8.06
3/25/2020	11:05	10:53	11:05	11:05	11:05			9:55	11:05	9:55	86:08	86.13	WRR0119	36.43
4/1/2020	7:47	7:43	7:54						7:44		31:08	31.13	WRR0120	12.15
4/2/2020	4:15	4:15	4:15						4:15		17:00	17.00	WRR0121	7.31
4/12/2020	6:48						6:27	6:48	6:48	3:10	30:01	30.02	WRR0122	13.57
4/15/2020						0:00					0:00	0.00	WRR0123	0.00
END OF PROJECT														