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**FLIGHT
OPERATIONS
REPORT**

FINAL SUMMARY



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, & Laramie Mountains
(with extension over Colorado's Never Summer Mountains)

WINTER AERIAL OPERATIONS 2019-2020

weathermodification.com

Airborne Cloud Seeding Operations 2019-2020 Winter Operations Report

For the

Sierra Madre, Medicine Bow, and Laramie Mountain Ranges, Wyoming
Never Summer Mountain Range, Colorado

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JULY 2020



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
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WINTER AERIAL OPERATIONS 2019-2020

EXECUTIVE SUMMARY

This report summarizes the aerial cloud seeding activities conducted by Weather Modification LLC, dba Weather Modification International (WMI) during the 2019-2020 winter operational season from 15 November 2019¹ – 15 April 2020. The program, facilitated by the Wyoming Water Development Office (WWDO), utilized a WMI seeding aircraft to increase snowfall in the mountains in the Upper North Platte River and Colorado River Basins for additional water runoff. This was the 2nd season Weather Modification International has provided pilot and aircraft services to conduct aerial cloud seeding operations for the State of Wyoming and the Jackson County Water Conservancy District.

Primary funding for the project was provided by the Wyoming Water Development Commission (WWDC), with funds appropriated by the Wyoming Legislature, in the amount of \$588,981. Additional funding was provided by the Board of Public Utilities (BOPU) of the City of Cheyenne, in the amount of \$45,000. The Jackson County Water Conservancy District (JCWCD) provided an additional \$75,849.25 for operations conducted for the Never Summer Mountains within the State of Colorado, primarily through a grant from the Colorado Water Conservation Board (CWCB).

The target area was defined by the client as the Medicine Bow, Sierra Madre, and Laramie Mountain Ranges (MBSMLR) located within the North Platte and Little Snake River Basins (western flanks of the Sierra Madre) in south-central Wyoming, and the Never Summer Mountain Range (NS) located in north-central Colorado. WMI's meteorological team provided operational guidance and was responsible for detailing seeding mission parameters, forecasting, and determining when flights were undertaken. More about these two target areas is provided in Section 1.0 of this report.

A WMI-modified Beechcraft King Air B200 seeding aircraft (US FAA registration N23MN) was equipped with two wing-mounted burn-in-place flare racks and three belly-mounted ejectable flare racks for glaciogenic seeding. The aircraft also featured a data-logging computer system for recording position and seeding events, the capability to receive in-flight weather and radar updates, and satellite phone texting to extend communication ranges.

Experienced WMI flight crewmembers (pilot-in-command and first officer) operated the aircraft during seeding missions, handled the seeding agent, and performed seeding equipment maintenance as needed. The aircraft and crew were based in Cheyenne, Wyoming. This location was selected to expedite safe and speedy aircraft climbs to the seeding tracks, and because it has an instrument approach and adequate hangar and maintenance facilities.

¹ The 2019-2020 winter season contractually started on 15 November 2019; however, due to customs delays with WMI's King Air 200 returning from India, the program aircraft did not arrive until 4 December 2019. Operations commenced immediately with the first seeding flight on 5 December 2019.

Operations for the Never Summer Range did not begin at the same time as the Wyoming operations, but were delayed until the last week of December. The Colorado seeding permit was issued on 23 December 2019, and Weather Modification International and the WWDO were notified by the Colorado Water Conservation Board on 27 December 2019. No seeding occurred in the Never Summer Mountains in the month of December.



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Flight operations were conducted according to basic guidelines established by WMI and the WWDO. The seeding method used on the 2019-2020 project was glaciogenic (or “cold cloud”) seeding - treating clouds with nuclei composed of a silver-iodide (AgI) complex to induce freezing and accelerate precipitation formation. Seeding was conducted when weather conditions were determined to be suitable, employing standard winter storm broadcast seeding track techniques. The WMI personnel discussed relevant weather information on a daily basis, in order to determine the best mission timing, altitudes, and seeding tracks based on the expected winds and temperatures at flight altitudes.

The project aircraft was ferried by Captain Kirk Hamilton to Cheyenne, WY on 4 December 2019. The first mission took place in the Medicine Bow Range on 5 December 2019. The last seeding event of the 2019-2020 season took place in the Medicine Bow Range on 15 April 2020. The program ended on 15 April 2020.



Figure 1. WMI copilot Tyler Couch snapped this image on 8 December 2019 while enroute for a mission to the Medicine Bow target areas. A total of 3.7 flight hours were flown and 6,290 grams of material dispensed on this flight. This was the second flight on 8 December 2019. The first mission was flown for the Sierra Madre target area.



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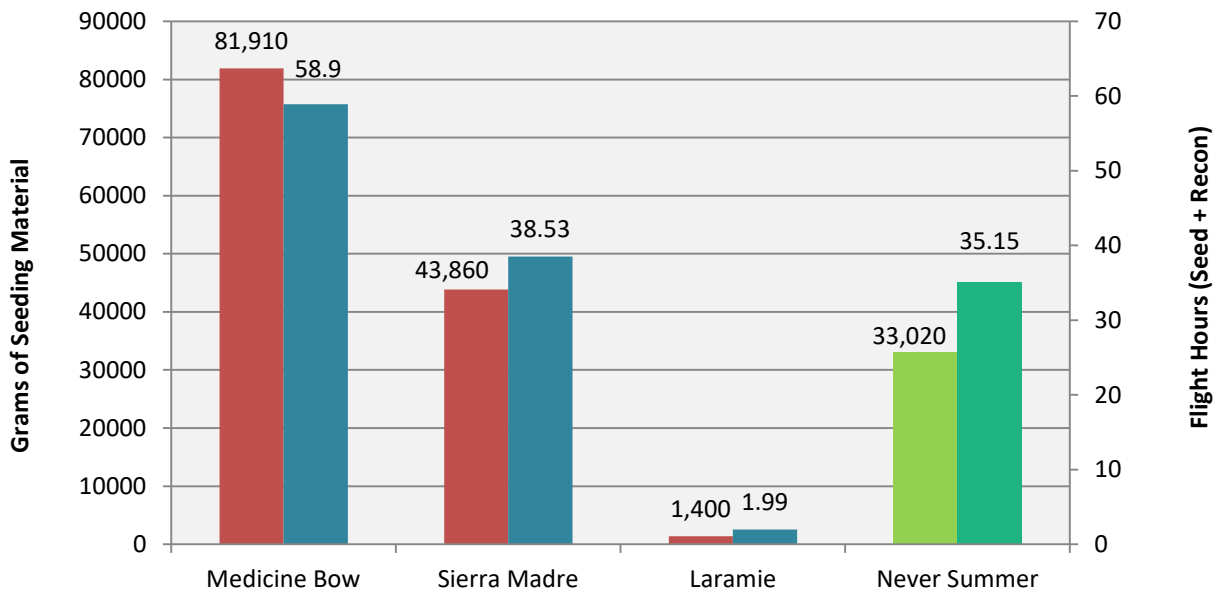
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In the Medicine Bow, Sierra Madre, and Laramie Mountain Ranges, twenty two (22) flights were conducted for a total of 99.42 flight hours, consisting of twenty one (21) seed and one (1) reconnaissance mission. Of the 99.42 flight hours, 58.9 hours were conducted for the Medicine Bow Range, 38.53 were conducted for the Sierra Madre Range, and 1.99 were conducted for the Laramie Range. A total of 127,170 grams of seeding agent were dispensed via 3441 ejectable flares (20 grams each) and 389 burn-in-place flares (150 grams each).

When seeding opportunities were not present in Wyoming but existed over the Never Summer Range of Colorado, seeding operations were conducted in Colorado on behalf of the Jackson County Water Conservancy District. Additional details regarding seeding priorities were provided in an MOU between the Wyoming Water Development Commission (WWDC) and the Jackson County Water Conservancy District (JCWCD).

In the Never Summer Mountain Range of Colorado, nine (9) flights were conducted for a total of 35.15 flight hours. Seeding was conducted on eight missions. One mission was conducted for reconnaissance. A total of 33,020 grams of seeding agent were dispensed via 1471 ejectable flares (20 grams each) and 24 burn-in-place flares (150 grams each).

2019-2020 Flight Hours & Seeding Material Dispensed



The WMI team is proud to have been a part of the 2019-2020 Wyoming Weather Modification Program with extension over Colorado's Never Summer Mountains; we look forward to future seasons!



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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.

Funding for all operations in the Medicine Bow, Sierra Madre, and Laramie target areas within Wyoming was largely made possible by the Legislature of the State of Wyoming, through the Wyoming Water Development Commission. The project budget for the Medicine Bow and Sierra Madre target area was enhanced by the City of Cheyenne Board of Public Utilities. Seeding flights that targeted the Never Summer Mountain Range in Colorado were made possible by the Jackson County Water Conservancy District, primarily through a grant from the Colorado Water Conservation Board.

Project guidance and direction on behalf of the State of Wyoming was provided by Ms. Julie Gondzar and Mr. Barry Lawrence of the Wyoming Water Development Office. The WMI seeding aircraft crew was comprised of Captain Kirk Hamilton assisted by copilot Tyler Couch. Meteorological services, which included forecasting, weather monitoring (for seeding conditions), and direction of operations were provided primarily by Mr. Daniel Gilbert. Numerical weather prediction services and a meteorological web interface for the project was provided by Mr. Adam Brainard. Additional meteorological support was provided by Mr. Jason Goehring. Bruce Boe, Vice President of Meteorology, provided scientific program oversight.

From the Fargo corporate office, logistical and technical support for the airborne seeding equipment was provided by Mr. Dennis Afseth. Mr. Jake Van Ornum and Ms. Erin Fischer (Client Services), provided administrative and recordkeeping support, with the assistance of Ms. Ramona Adams and Ms. Cindy Dobbs. Aircraft maintenance and servicing were coordinated by Mr. Mike Clancy in cooperation with Mr. Jody Fischer, who managed the flight operations team.

Seeding agent, in the form of glaciogenic pyrotechnics, were provided by Ice Crystal Engineering LLC. We here acknowledge the excellent performance of these flares, and thank ICE Manager, Mr. Charlie Harper, and his entire manufacturing team.

The Jackson County Water Conservancy District board was very supportive and helpful throughout, especially Mr. Kent Crowder and Mr. Ty Wattenberg. The support and assistance of the Colorado Water Conservation Board and the Colorado Department of Natural Resources, namely Mr. Andrew Rickert, was also greatly appreciated.



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1 BACKGROUND & TARGET AREA

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. The Wyoming Weather Modification Program, with extension over Colorado's Never Summer Mountains, is designed to augment snowfall over select portions of the North Platte River Basin and the Little Snake River Basin (western flanks of the Sierra Madres). By increasing the snowpack and resultant spring runoff, subsequent water supplies downstream are increased. In addition to easing the necessity for other more costly means of power generation, cloud seeding increases the water availability for municipal, recreational, and environmental interests.

The program conducted aerial cloud seeding operations, as described herein. A modified Beechcraft King Air B200 aircraft owned and operated by WMI released silver iodide-based ice nuclei using pyrotechnic flares. The aim is to produce artificial ice nuclei which will cause additional snow to form and precipitate in the target area.

The target area included portions of South-Central Wyoming and North-Central Colorado, as defined:

- Medicine Bow, Sierra Madre, and Laramie Range (MBSMLR) – Portions of the Medicine Bow, Sierra Madre, and Laramie Mountain Ranges located in Carbon, Albany, Natrona, Converse and Platte Counties, Wyoming. The ranges run mostly north to south. The Continental Divide extends along the high points of the Sierra Madre Mountains, with runoff from the western slopes draining into the Colorado River Basin and the eastern slopes draining to the North Platte River Basin. Run-off from the Medicine Bow Mountains drains into the North Platte Basin.
- Never Summer Range (NS) – Located in north-central Colorado, the Never Summer Mountain Range, lies within the Upper North Platte River Basin and includes Jackson, Grand, and Larimer Counties. Only portions within Jackson County were targeted in the 2019-2020 program.

Standard winter broadcast-seeding techniques were employed. Seeding of winter storms was conducted whenever WMI meteorologists determined conditions were suitable. Project meteorologists issued daily forecasts and updated the project pilots on a frequent basis. The wind direction determined which "set" of tracks would be used, the temperature determined the seeding altitude, and the wind speeds at that altitude determined the distance flown upwind from the target. WMI, in cooperation with the WWDO and the CWCB, established the tracks prior to the field program. Generally, the WMI meteorologists attempted to provide the flight crew a 2-hour advance notice prior to the desired commencement of seeding operations.

Table 1 lists the exact location of each track's endpoints and wind speed limits for their use. The WMI crew has the ability to modify the seeding tracks during storms to optimize targeting during seeding flights. This past season, flight tracks were shortened and/or extended on multiple missions due to weather conditions. This illustrates the versatility of the aircraft and crew to ensure proper targeting.



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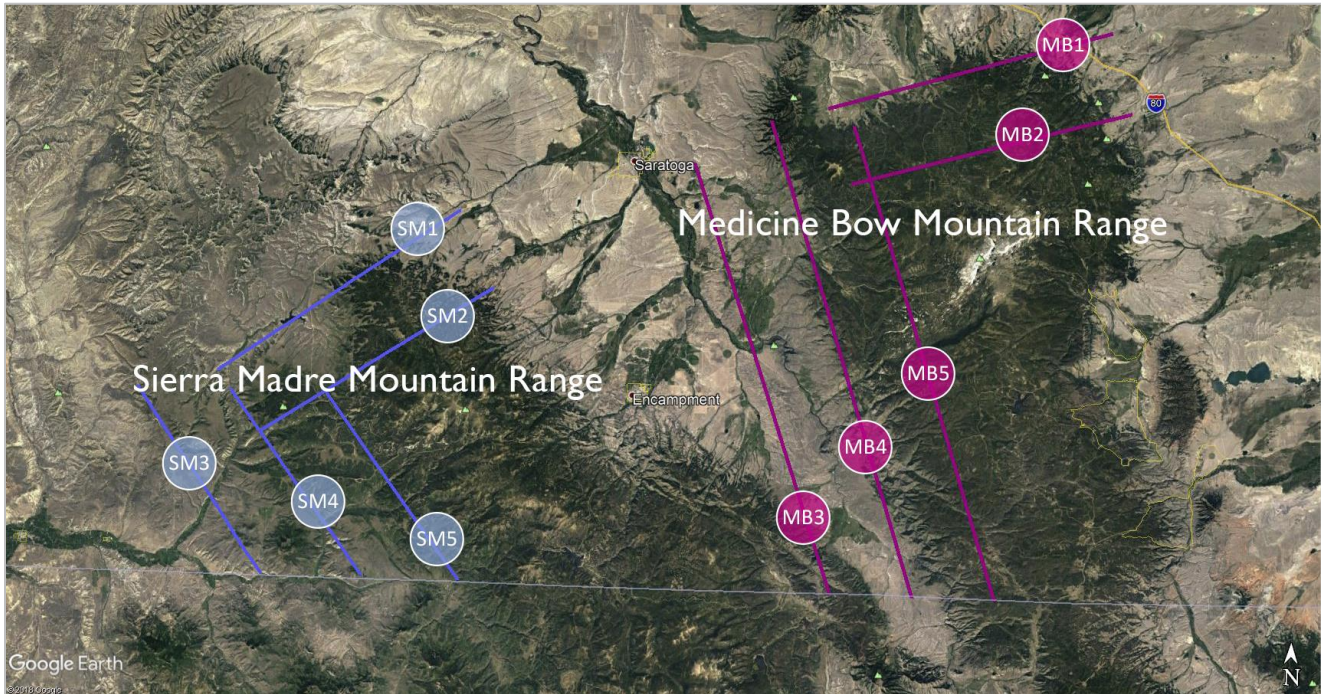


Figure 2. Medicine Bow and Sierra Madre Target Areas located in the State of Wyoming. The predetermined flight tracks are visible in purple (Sierra Madre Mountain Range) and magenta (Medicine Bow Mountain Range).

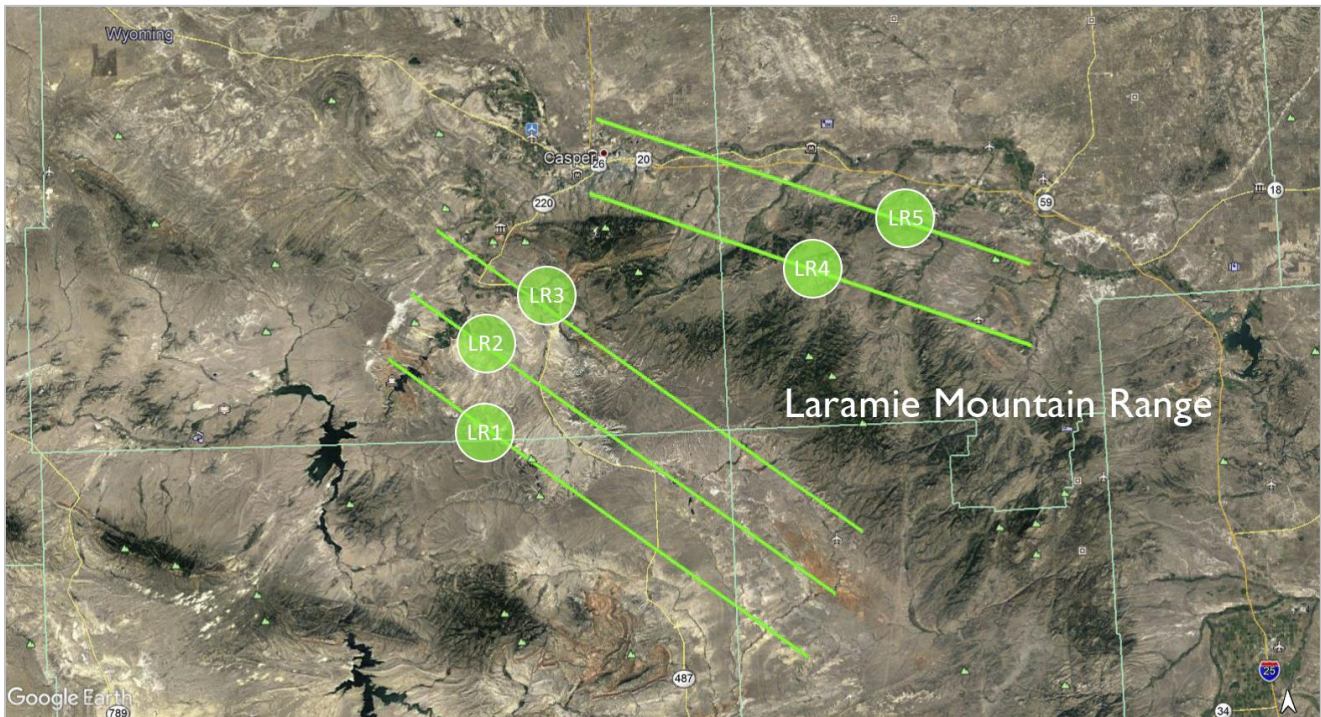


Figure 3. Laramie Range Target Areas located in the State of Wyoming. The predetermined flight tracks are visible in green.



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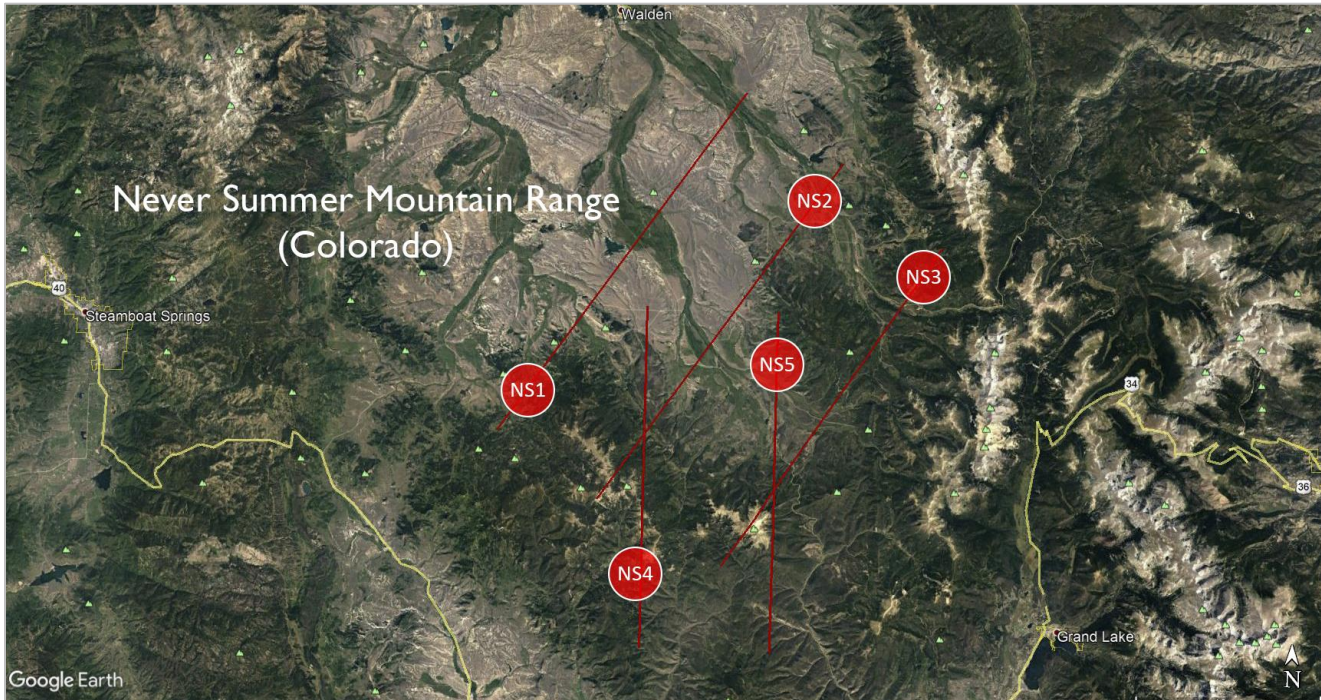


Figure 4. Never Summer Target Area located in the State of Colorado. The predetermined flight tracks are visible in red.



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Table 1. The locations of each track's endpoints and wind speed limits are given.

SIERRA MADRE					
	TRACK	LAT	LONG	VOR/RADIAL/DME	WIND SPEED (KTS)
SM1	SM1E	41'24	107'03	CKW/116/032	30-55
	SM1W	41'16	107'17	CKW/150/033	
SM2	SM2E	41'19	107'00	CKW/120/037	<30
	SM2W	41'12	107'14	CKW/147/038	
SM3	SM3N	41'12	107'30	CKW/159/033	55+
	SM3S - WY	41'00	107'19	CKW/151/046	
SM4	SM4N	41'12	107'22	CKW/149/035	30-55
	SM4S -WY	41'00	107'10	CKW/143/048	
SM5	SM5N	41'12	107'14	CKW/139/037	<30
	SM5S -WY	41'00	107'02	CKW/136/051	

MEDICINE BOW					
	TRACK	LAT	LONG	VOR/RADIAL/DME	WIND SPEED (KTS)
MB1	MB1E	41'36	106'08	LAR/296/025	30-55
	MB1W	41'31	106'32	LAR/272/038	
MB2	MB2E	41'31	106'06	LAR/288/021	<30
	MB2W	41'26	106'30	LAR/265/036	
MB3	MB3N	41'27	106'43	LAR/265/046	55+
	MB3S	41'00	106'31	LAR/226/041	
MB4	MB4N	41'30	106'37	LAR/270/041	30-55
	MB4S	41'00	106'24	LAR/222/037	
MB5	MB5N	41'30	106'30	LAR/271/036	<30
	MB5S	41'00	106'17	LAR/217/033	

NEVER SUMMER					
	TRACK	LAT	LONG	VOR/RADIAL/DME	WIND SPEED (KTS)
NS1	NS1N	40'40	106'09	RLG/004/042	30-55
	NS1S	40'24	106'24	RLG/350/024	
NS2	NS2N	40'37	106'03	RLG/012/041	<30
	NS2S	40'21	106'18	RLG/004/022	
NS3	NS3N	40'33	105'57	RLG/020/040	55+
	NS3S	40'18	106'10	RLG/020/022	
NS4	NS4N	40'30	106'15	RLG/002/031	30-55
	NS4S	40'14	106'15	RLG/019/016	
NS5	NS5N	40'30	106'07	RLG/012/033	<30
	NS5S	40'14	106'07	RLG/034/020	



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LARAMIE

	TRACK	LAT	LONG	VOR/RADIAL/DME	WIND SPEED (KTS)
LR1	LR1N	42'19	106'20	MBW/307/56	30-55
	LR1M	42'38	105'43	MBW/318/33	
	LR1S	42'05	105'56	MBW/359/15	
LR2	LR2N	42'25	106'16	MBW/313/59	<30
	LR2M	42'23	106'14	MBW/326/37	
	LR2S	42'10	105'52	MBW/003/21	
LR3	LR3N	42'46	106'40	MBW/318/62	55+
	LR3M	42'31	106'14	MBW/331/41	
	LR3S	42'16	105'48	MBW/005/27	
LR4	LR4N	42'55	106'20	DDY/180/17	30-55
	LR4M	42'48	105'54	DDY/134/30	
	LR4S	42'40	105'25	DDY/119/50	
LR5	LR5N	42'48	106'21	DDY/179/10	<30
	LR5M	42'42	105'54	DDY/124/25	
	LR5S	42'32	105'26	DDY/112/45	

WMI utilized in-house high-resolution numerical modeling to identify suitable times for seeding. The modeling tools identified periods when seedable clouds were likely (based on winds, temperatures, and liquid water content). When models forecast seedable cloud conditions, project pilots and meteorology staff worked in tandem, continuously monitoring satellite imagery, radiometer data, webcams, pilot reports, and occasionally NEXRAD radar data. When real-time observations indicated the likely presence of suitable targets, a flight was launched. Upon reaching seeding tracks, pilots checked temperatures, winds, and supercooled liquid water content. If conditions were indeed suitable, seeding commenced and continued until conditions deteriorated or the aircraft ran low on fuel or flares. If suitable conditions were not encountered during a flight, no seeding occurred, and the aircraft returned to base having conducted "reconnaissance". After a seeding or reconnaissance flight ended, flight crews and meteorologists immediately prepared for another flight if warranted.

General cloud seeding criteria established for the Wyoming/Colorado project were:

Requirements to initiate a flight:

- WMI models indicate supercooled liquid water (SLW), wind speed and direction, and temperature profiles suitable for targeting clouds in the -4° to -15°C range.
- The range selected is based on which will likely have the greatest SLW. Because the aircraft can be flown lower, down to 13,000 feet, on the Sierra Madre, that range may be chosen in certain temperature profiles or cloud depths.
- Seeding altitude varies between 13,000 to 16,000 feet, depending on temperature profile, cloud depth, and observed supercooled liquid water (icing rate).



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- In daytime hours webcams and visible satellite imagery provide information on cloud depth and coverage.
- At night, infrared and water-vapor satellite imagery provide reasonable cloud coverage information.
- The ground conditions at the Cheyenne Airport (KCYS) must be safe for departure and expected to be suitable for return at end of flight. This is mostly taken from the TAFs (Terminal Area Forecasts) and occasionally PIREPS (Pilot Reports), AIRMETS (Airman's Meteorological Information), and SIGMETS (Significant Meteorological Information).
- Radar echoes over the Medicine Bow Range (the only range covered by radar, and only partially) are not required. We have observed that cloud SLW is often marginal when echoes are present over the Medicine Bow Range (again, the only range covered by radar).

Procedures en route to seeding track:

- The aircraft will climb above the expected altitude of the icing layer (over the targeted range) while in transit. This avoids beginning seeding with ice already on the airframe. Altitudes are indicated by the model cross-sections of SLW and temperatures.
- Note 0°C, -5°C, and -10°C levels and report to meteorologist, along with overall cloud conditions and winds/icing conditions.
- Communicate with meteorologist to confirm/adjust based on observed conditions.

Required to begin seeding once on track:

- When the seeding track is approached, the aircraft will carefully descend into the target layer from above, to be sure not to accumulate rapid airframe icing. If severe icing is encountered, the aircraft may immediately climb out of it and contact the meteorologist. Depending on temperature and observed cloud conditions, it may be determined that seeding should occur with ejectable flares.
- SLW must be present in the -4°C to -15°C layer at altitude targetable by ejectable flares, burn-in-place flares, or both. It is preferred that the seeding be conducted below the -10°C level whenever possible, but ejectables may be dropped from as cold as -15°C once the existence of SLW is confirmed below. The presence of SLW below should be confirmed before beginning seeding. It should be checked at least hourly.
- The targetable SLW must be present (at seedable temperatures) at reasonable horizontal distance from the target area to allow for fallout of precipitation in the target (20-30 min upwind).



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2 PROJECT PERSONNEL

WMI provided an experienced flight crew for the winter cloud seeding season, which consisted of one pilot in-command (PIC) and one copilot (first officer). WMI employs copilots on seeding flights to enhance flight safety and targeting, as cockpit workload and recordkeeping responsibilities can be shared.

The Cheyenne team was led by Captain Kirk Hamilton, assisted by first officer Tyler Couch. Hamilton had two aerial winter seasons experience in California and one previous aerial winter season in Wyoming. This past summer, Hamilton was a King Air C90 Captain on a WMI rain enhancement project in Maharashtra, India. This was Couch's first season as a WMI wintertime copilot; he was previously a captain on the North Dakota Cloud Modification Project, flying a Piper Seneca II aircraft.

Prior to the start of the project, Hamilton conducted ground and flight training in Fargo and Cheyenne with WMI's Director of Operations, Jody Fischer. Fischer is a Weather Modification Association (WMA) Certified Operator. This was Fischer's seventeenth winter season; he has several hundred hours of flight experience in Wyoming mountainous terrain.



Figure 5. The 2019-2020 flight crew from left to right – Tyler Couch and Kirk Hamilton stand in front of the WMI King Air B200 seeding aircraft (N23MN) outside Legend AeroServ in Cheyenne, WY. Photo submitted by Kirk Hamilton.



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Daniel Gilbert, WMI Chief Meteorologist; Jason Goehring, Field Meteorologist; and Adam Brainard, Meteorologist/Numerical Modeler, formed WMI's meteorology team. This was Gilbert's sixteenth year of winter seeding operations and forecasting. He also has seventeen seasons experience on summer seeding programs. This was Goehring's fifteenth year of Wyoming seeding operations and forecasting, in addition to his working five summers of airborne seeding operations in Alberta, Canada. Gilbert and Goehring have worked together for eleven seasons on Wyoming programs dating back to the Wyoming Weather Modification Pilot Project. Brainard has been involved with the Wyoming seeding programs since 2016, providing numerical modeling support. This was his second year in the field in Pinedale, WY. Brainard has also completed seven years of summer seeding operations in North Dakota and Alberta. Gilbert, Goehring, and Brainard 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.

Additional project coordination and administrative support was provided by WMI headquarters in Fargo, ND.



Figure 6. The WMI Forecasting team from left to right – Dan Gilbert (Chief Meteorologist), Jason Goehring (Field Meteorologist), and Adam Brainard (Meteorologist/Numerical Modeler). Goehring is based in Long Lake, SD, and Gilbert in Fort Dodge, IA. Brainard resided in Pinedale, WY during the winter season to forecast and assist with the Wyoming Wind River ground operations program. Photos by Gilbert, Goehring, and Brainard.

2.1 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.



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Figure 7. 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.



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3 EQUIPMENT

3.1 Beechcraft King Air B200

WMI Beechcraft King Air B200, U.S. FAA registration N23MN, arrived on site 4 December 2019. It was ferried by Captain Kirk Hamilton. N23MN was dedicated for full-time use on the program and its crew provided 24 hours-a-day, 7-days-a-week support for cloud seeding activities. The aircraft and crews were based at the Cheyenne Regional Airport. Hangar, deicing, maintenance, and fueling services were obtained from Legend Aero at the Cheyenne airport.



Figure 8. WMI Beechcraft King Air CB200, N23MN rests on the ramp at the Cheyenne Regional Airport. Photo by Kirk Hamilton.

The Beechcraft King Air platform is a high performance twin-engine turboprop aircraft that has proven itself with numerous operators in a wide variety of weather research and cloud seeding operations. Standard equipment includes full dual VFR/IFR instrumentation, an FAA instrument-approach certified GPS navigation system, on board digital weather radar, pressurized cabin, and emergency oxygen.



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The high performance of the turbine-powered King Air provides the power needed to climb safely above the dangerous icing zone (-10°C to -15°C) when required, even after accumulation of significant ice on the airframe. The endurance of this aircraft allowed coverage of the entire project area from the Cheyenne base of operation with a time-on-station of approximately 5-6 hours in ideal conditions.

In addition to pressurization, an oxygen system with masks is installed in the event of a loss in cabin pressure. All WMI aircraft are equipped and certified for instrument flight (IFR), day and night. This equipment includes VHF communication and navigation radios, GPS navigation, onboard weather radar system, and an emergency locator beacon system. GPS-based terrain mapping systems provide the crews with increased situational awareness during IFR and nighttime seeding operations, further enhancing safety.

There were multiple crew seats available in the aircraft; however, WMI aircraft are operated in U.S. Federal Aviation Administration "Restricted" category when in seeding configuration and so only project personnel are allowed on board per these regulations.

A total of 9,069 gallons of Jet -A fuel was consumed on the project (6,742 gallons for the MBSMLR and 2,327 gallons for the NS target area), an average of 62 gallons per aircraft flight hour. All project fuel was purchased by WMI at the aircraft base location. Fuel costs ranged from \$3.21 to \$4.69 per/gallon with an average of \$3.95 per/gallon. This was six cents higher than the 2018-2019 winter season. Fluctuation in pricing was a result of the COVID-19 pandemic and worldwide supply and demand.

One aircraft issue was encountered during the season:

- 6 February – An inverter failure (after the 6 February mission ending at 0813Z) rendered the aircraft un-airworthy. A new inverter was installed and the aircraft was returned to service in the early afternoon on 7 February. Impact on the program: a second flight opportunity on 6 February was missed.

The WMI flight crew was directed by ATC to change altitude on two missions this year due to restrictions concerning terrain while on seeding track MB4, later descending back to their requested altitude. Additionally, on one mission the crew was required to depart the track and suspend seeding operations for 7 minutes due to ATC restriction with conflicting traffic while on track MB2.

- 30 January - Diverted (from track MB2) to the north and suspended seeding operations for 7 minutes due to ATC restrictions with conflicting traffic before returning to track and resuming seeding.
- 10 March - Climbed from 14,000 to 15,000 feet for ATC restrictions due to terrain, later descended back to 14,000 feet. Seeding was not suspended and the aircraft was able to stay on track.
- 15 April - Climbed from 14,000 to 15,000 feet for ATC restrictions due to terrain, later descended back to 14,000 feet. Seeding was not suspended and the aircraft was able to stay on track.



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3.1.1 Flight in Known Icing Conditions

The B200 is FAA-certified and equipped for flight into “known icing” conditions with pneumatic deicing boots on the wings, horizontal and vertical stabilizers, exhaust-heated engine inlets, electrically-heated propeller blades, pitot/static ports, and heated windshield strip. WMI pilots are trained prior to any project on weather recognition, proper seeding procedures, flight operations in icing conditions, crew coordination, flight safety and judgment. Having a two-pilot crew helps ensure that proper attention is paid to changing flight and seeding conditions. WMI has an exemplary safety record, and takes extremely seriously the safety of the general public, WWDO employees, and its company personnel.

Known-icing certification should in no way be interpreted to mean that the aircraft’s manufacturer expected it to fly for extended periods within icing conditions. Such certification means that the FAA has certified that the aircraft is equipped with the necessary deicing equipment and has the required power to safely transit (climb or descend through) layers of icing. This constraint will always be kept in mind during operations, ensuring the flight crew can deal safely with winter storm conditions.

In the Wyoming area, there are no lower terrain areas nearby to which the aircraft can escape severe icing encounters and melt off airframe icing, and usually the only option is to return for an instrument approach to the Cheyenne airport. Since this sometimes means icing conditions all the way to the ground, the pilots must have complete discretion in their decisions in dealing with excessive airframe icing; this has always been the policy and practice of WMI.

Generally, about 15-20% of WMI wintertime seeding flights are forced to divert to lower altitudes at some point during winter missions to melt airframe icing. This year in Wyoming the crew had to descend or climb for excessive icing conditions on three missions. Two of these missions were over the Medicine Bow Range and one mission was over the Sierra Madre Range. This was approximately 10% of the missions which is less than average for wintertime operations. The crew did not suspend seeding or prematurely end any missions due to icing conditions this season. These statistics are based on the 29 combined missions in Wyoming and Colorado.



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Figure 9. Images of in-flight airframe icing during WY missions on 1 Jan 2020 (left) and 9 December 2019 (right). Left – WMI copilot Tyler Couch holds a piece of ice off the propeller spinner after a mission for the Medicine Bow target area. Photo by Tyler Couch. Right – Airframe icing after a mission on 8 December 2019 over the Laramie and Medicine Bow target area. Visible is the difference between the ice accumulations on the wing area without de-icing boots vs. the area with boots (black, far right of image) where the ice was intermittently shed throughout the flight. Photo by Kirk Hamilton.



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3.1.2 Weather Availability In-Flight

As an enhancement to safety, all WMI seeding aircraft are also equipped with a GPS-based terrain mapping and warning system, which displays surrounding terrain features and aviation navigation graphics. The system also provides real-time colored (yellow and red) terrain warnings based upon its database and GPS aircraft position during missions. This system enabled thorough and accurate positional and terrain awareness during instrument and night flights, and allowed decisive action whenever heavy icing conditions dictated flight diversions.

WMI flight crews were also equipped with ADS-B real-time weather and traffic information on a company-issued iPad. Real-time weather and radar data are displayed, overlaid on a moving map of the target area. The ability to visualize weather conditions upstream allowed the pilots to make timely seeding decisions and optimize use of their fuel and flares.

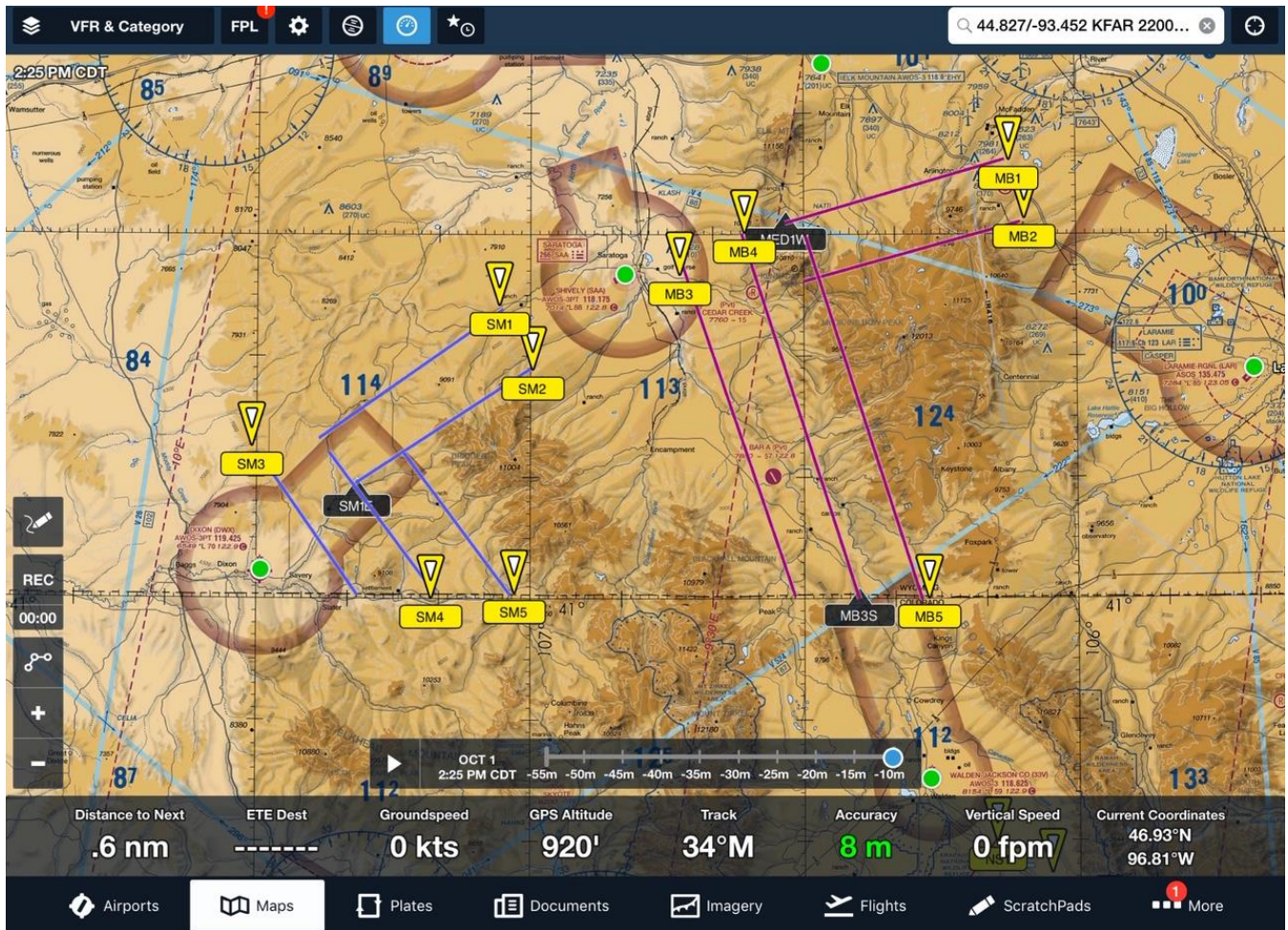


Figure 10. Image from a WMI iPad showing ADS-B weather information visible to the cloud seeding pilot while conducting operations. The Medicine Bow and Sierra Madre target areas in Wyoming overlay is shown on the ForeFlight application. The target area at the time of this photo was void of weather.



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Figure 11. Like Figure 10, but with the Laramie Mountain Range target area (green tracks) overlay shown on the ForeFlight application. Also visible are the Medicine Bow (magenta) and Sierra Madre (lavender) tracks to the south. The target area at the time of this photo was void of weather.



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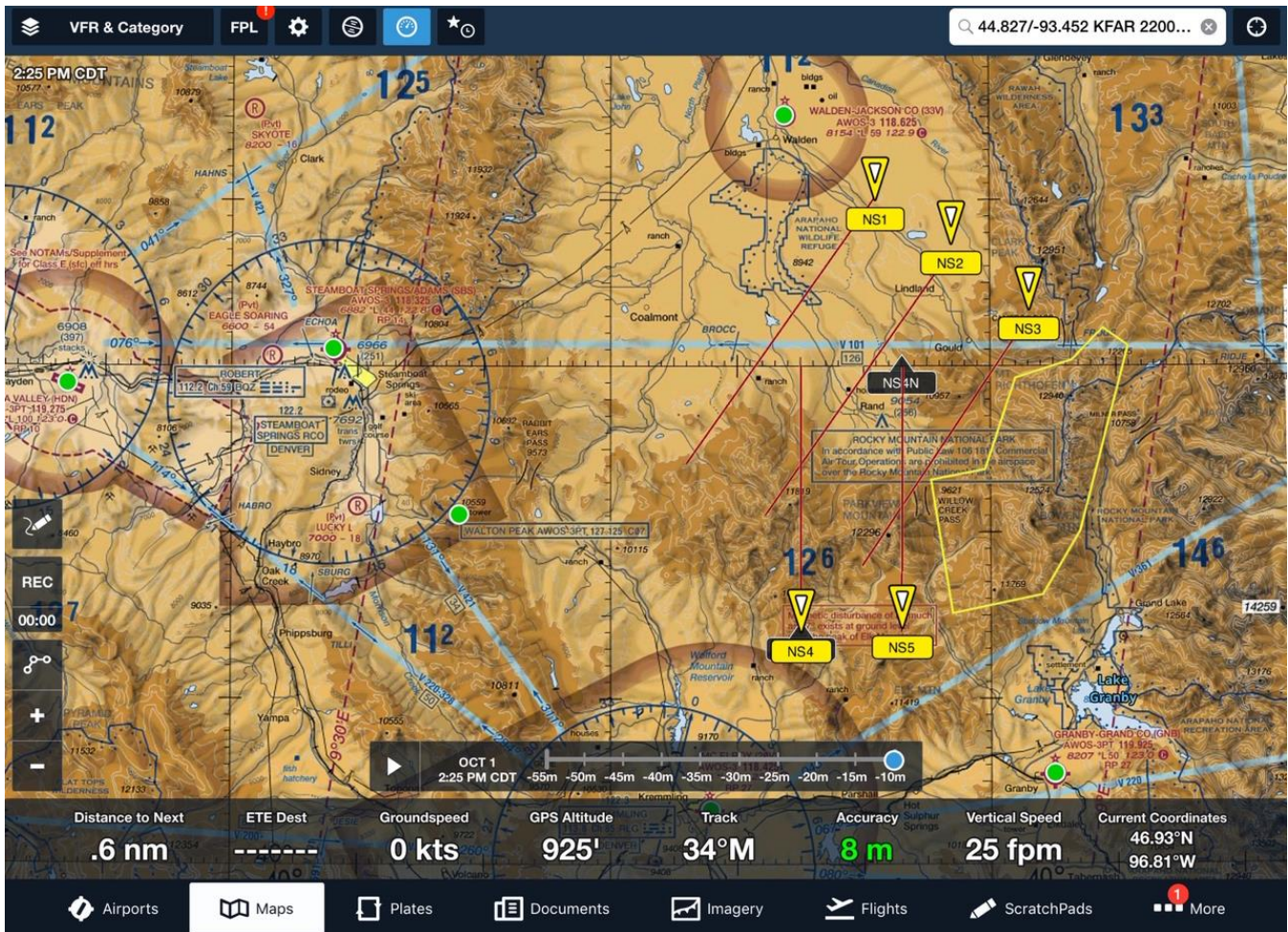


Figure 12. Like Figure 10 and 11, the overlay for the Never Summer Mountain Range target area (red tracks) in Colorado is shown on the ForeFlight application. The target area at the time of this photo was void of weather.



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3.2 In-Flight Communications

The WMI seeding aircraft was equipped with satellite voice and text messaging service through Iridium GO!®. This is a robust, military-grade device that withstands the turbulence of rugged cloud seeding flights. Its communication features include real-time ability to send texts, weather updates, emergency alerts (SOS), and GPS tracking. It allows for connection to smartphones and tablets compatible with Apple and Android operating systems along with the option to interface with the pilot's headset (hands-free). The system provided reliable long-range communications with the meteorologists directing operations, which was extremely advantageous for the remotely-positioned meteorologists.

3.3 Seeding Equipment and Agents

The project aircraft was modified with two (2) wing-mounted burn-in-place flare racks and three (3) ejectable flare racks. Seeding equipment was fabricated and installed by WMI in accordance with U.S. Federal Aviation Administration approvals (US FAA Form 337), and seeding data were ingested along with GPS position information into a WMI "Datalogger" computer.

3.3.1 Burn-in-place (ICE-BIP™) Flares

Burn-in-place flares were ignited whenever especially large amounts of supercooled liquid water (SLW) or bands of embedded cumuliform clouds were encountered during seeding operations. In wintertime operations, seeding is usually performed using tracks upwind of the target areas, as was done on this program. This is called *broadcast seeding*, with the idea being that the seeding crystals produced by the flares will mix with the available cloud mass and activate when they encounter SLW and thus result in snow downwind in the target area.

Each burn-in-place flare rack was mounted to the wing such that the flares themselves are positioned aft of the trailing edge. Each rack held 24 flares, for a full capacity of 48. The flares can be burned in any quantity throughout the flight, one at a time or in multiples. These glaciogenic flares yield 150 grams of seeding material and burn for about 4+ minutes each. The flare formulation has been tested for nucleus yield at Colorado State University.



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Figure 13. N23MN carried two dual burn-in-place flare racks. The flares shown are 150g ICE-EB™ Ice Crystal Engineering LLC glaciogenic flares. A total of 413 ICE-EB™ flares were expended during the 2019-2020 season. Photo by Tyler Couch.

3.3.2 Ejectable (ICE-EJ™) Flares

Ejectable flares fall away from the aircraft and drop while burning about 2500 ft (in the absence of up- or down-drafts). These flares are used when there is sufficiently thick cloud mass in the seeding zone and enable storms to be effectively treated while the aircraft remains above the peak aircraft icing altitude, increasing on-station time. The seeding aircraft were all equipped with three belly-mounted ejectable flare racks. Each rack holds 102 flares, for a full capacity of 306 per aircraft. The rack is designed with removable baskets which hold the 20mm diameter flare cartridges. This allows quick reloading of flares between missions.

The seeding equipment controls are mounted in the cockpit for pilot or copilot operation. WMI owns and manufactures the seeding equipment. All equipment construction is aircraft-quality, and systems are easily accessed for routine maintenance. Equipment installation was completed and flight-tested at WMI's maintenance facility in Fargo, North Dakota, prior to project start. The pilots regularly checked all the equipment to ensure functionality. All WMI aircraft modifications and equipment installations are US FAA-approved.



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Figure 14. Ejectable flare belly racks installed on the project aircraft. Each ejectable flare yields 20g. All three project aircraft were equipped as pictured with 306 ejectable flares. A total of 4,912 ICE-EJ™ were expended during the 2019-2020 season. Photo by Kirk Hamilton.

All glaciogenic seeding materials used were manufactured by Ice Crystal Engineering LLC (ICE) of Kindred, North Dakota. ICE pyrotechnic output, as a function of cloud temperature, has been established at the Colorado State University (CSU) Cloud Simulation and Aerosol Laboratory (SimLab), in Fort Collins, Colorado (DeMott 1999). ICE pyrotechnics have established an excellent record in the field and are well known for their extremely low failure rate. All ICE products are ISO9001:2015 certified. This ensures that strict manufacturing standards and processes are followed, including suppliers, customer service, and quality control. For more information on ICE Crystal Engineering please visit: www.iceflares.com.

A total of 389 burn-in-place and 3441 ejectable flares were expended during this winter season for the Medicine Bow, Sierra Madre, and Laramie Mountain Ranges in Wyoming. In the Upper North Platte River Basin of Colorado, 24 burn-in-place and 1471 ejectable flares were expended for the Never Summer Range.

3.3.3 Flight Data and Recording

The aircraft carried a WMI Datalogger system, which recorded and displayed selected flight data. The core of the system is a purpose-built computer that records all parameters during each flight. The Datalogger ingested GPS position, altitude, groundspeed, and cloud water inertial probe (CWIP, see Sec. 3.3.4) data. Each seeding event



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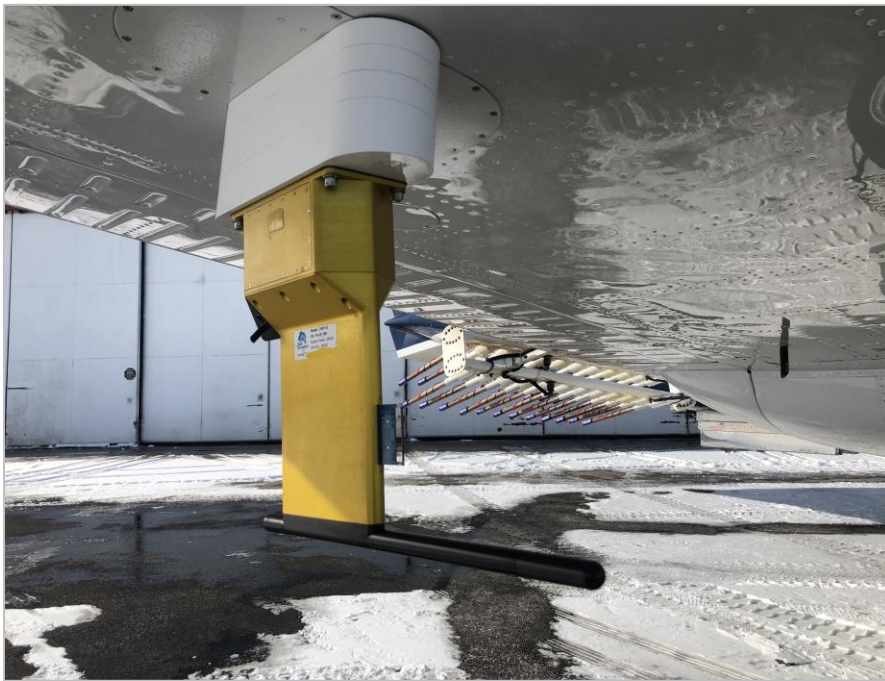
(firing of a burn-in-place flare or ejectable flares) was also recorded. The flight file was then archived and replayed on a ground-based computer using WMI's *AirLink II* software to create a complete flight track of the mission, as shown later in this report. Such plots also contain a basic map of the target area and terrain, see Section 6.0.

The WMI flight crew kept paper records of the flight notes and regular seeding agent inventories. The flight forms were recorded and transmitted to the client, as requested.

3.3.4 Cloud Water Inertial Probe (CWIP)

The WMI King Air B200 featured a Cloud Water Inertial Probe (CWIP) this season at no cost to the WWDO. It was provided for field testing in Wyoming's rugged terrain, extreme cold temperatures, and heavy icing conditions. The CWIP measured and recorded a number of parameters including: GPS altitude, wind speed and direction, temperature, humidity, airspeed, angle of attack, updraft speed, and liquid water content. Data from the instrument was displayed on an iPad for cockpit access during operations.

Figure 15. Cloud Water Inertial Probe (CWIP) installed under the aircraft wing. Photo by Kirk Hamilton.



Data were reviewed post-mission by WMI's Instrument technicians (Kurt Hibert) and archived for WWDO later use. We are excited to provide this advanced data stream from one of the newest probes on the market, but we note that it is still being tested and so comes with a number of unknowns and learning curves.

WMI thanks the field team and the WMI electronics department for their dedication to working with this new instrument. We look forward to using this technology in the future to enhance operations.



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4 METEOROLOGICAL SERVICES

WMI meteorologists provided meteorological support for Wyoming Weather Modification Program. Portions of weather systems deemed to have seeding potential were monitored, on a 24-hours-per-day, 7 days-per-week basis (24/7) by the WMI meteorology team. This team provided the pilots with forecasts and relevant weather information throughout the season. They would also routinely call the flight crew to discuss the current weather situations as each evolved. In addition to the weather forecasts, these discussions included anticipated cloud conditions, temperatures, upper level winds, and the timing of upcoming opportunities.

Dan Gilbert (WMI Chief Meteorologist), Adam Brainard (WMI Meteorologist/Modeler) and Jason Goehring (WMI Field Meteorologist) alternated duties, preparing the project forecasts and, along with the flight crews, monitoring opportunities for operations. Gilbert, Brainard, and Goehring are all WMA-Certified Operators.

The standard reference time chosen for the project field operations was “universal time coordinates” (UTC). This time, also called Greenwich Mean Time (GMT) or Coordinated Universal Time (CUT), is the accepted international standard of time for general aviation and meteorological observations, reporting, and communication. The shorthand notation for UTC is the letter Z, so 1800 UTC can also be written 1800Z or 18Z.

4.1 Suspension of Cloud Seeding Operations

From time to time, cloud seeding operations may be suspended as part of the standard operating procedures of the program. At times, additional precipitation could pose a potential threat to life or property. At other times, the public may perceive (rightly or wrongly) that seeding activities pose or increase such a threat. For these reasons, seeding suspension criteria have been established and strictly adhered to by the operators in accordance with industry standards. Suspension criteria were monitored by WMI's meteorology team in close partnership with the WWDO and JCWCD.

During the 2019-2020 season, just one suspension occurred. On Friday, 20 December 2019, the WWDO suspended seeding operations in the Laramie Range. Concerns with the integrity of the La Prele Dam, discovered in the course of an on-going study, showed concern that high run-off into the reservoir could exceed its capacity to safely pass the resultant flows and manage the water level in the reservoir. This WWDO decision was a precautionary step determined by the risk associated with the basin hydrology. The Laramie Range target area remained suspended through the end of the season.

4.1.1 2019-2020 Suspension Criteria

Snowfall histories are used to determine the Historic Range of Natural Variability (HRNV) for a given SNOTEL facility. These historic snow-water equivalents are then combined and a ‘median’ is established for a period of time, usually 30 years. This ‘median’ is then used to set the HRNV by the day or month of any recorded year.



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Thresholds at which cloud seeding will be suspended for this operation are identified below. These criteria will be implemented to govern all seeding decisions. The criteria for this Wyoming operation were determined using an HRNV at the upper range of 140%, using historic data.

Cloud seeding will be suspended if any of the criteria listed below are met:

1. Seeding shall be suspended in any target area if and when range-wide snow water equivalents (SWE) indicated by designated NRCS SNOTEL sites exceed a percentage of the long-term median defined by a linear upper limit of 85% of the thirty-year (1981-2010) median April 1 SWE for the site on November 15 (normal program start), and increasing to 140% of the median April 1 SWE as of April 1².
2. Insufficient reservoir storage for flood control, based upon hydrologic estimates of total snowpack using all available data.
3. Potential for significant rain events above 8,500 feet MSL. The area of risk would not be targeted until the risk had passed. This is very rare at the latitude of the target area (rain in winter is uncommon.)
4. Severe winter weather events, as forecast by the National Weather Service office having responsibility for the target. For Never Summer operations, this is the Boulder Weather Service Office. The area forecast to be affected would not be targeted until the risk had passed.
5. Extreme avalanche risk in a specific target area, as indicated by the Colorado Avalanche Information Center (CAIC). The area of risk would not be targeted until the risk had passed.
6. If a significant wildfire occurs within the watersheds of the target area, the Forest Service shall be consulted prior to the next cloud seeding season to determine if there is need for suspension(s) that account(s) for the newly burned areas.
7. Care will be taken to avoid targeting major highways to avoid impact on transportation corridors. In the case of the Never Summer Range, there are no major highways in immediate proximity to the target area.
8. Seeding may be suspended at any time in the Never Summer target area, upon direction from the Colorado Water Conservation Board or the Jackson County Water Conservancy District.
9. Seeding may be suspended at any time in the Medicine Bow and/or Sierra Madre target area, upon direction from the Wyoming Water Development Office.

²During the Wyoming Weather Modification Pilot Project, a research program, the upper limit was conservatively set at 120% of the 1971-2000 mean SWE. However, when the 1981-2010 thirty-year period of record became available, the Natural Resources Conservation Service (NRCS), which operates the SNOTELs, decided to publish (on the NRCS SNOTEL web sites) the long-term median, rather than the mean, as they determined the medians were more indicative of typical values. Thus the operational criteria now use medians rather than means, and also the 1981-2010 period of record. The upper limit was raised from 120% to 140% because this corresponds approximately to one standard deviation above the long-term medians, meaning that snowpack at this level would still be well within the limits of natural variability. We note that the *lowest* SWE suspension threshold currently employed in the western United States is 140%, including programs in Idaho, Utah, Nevada, and California.



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4.2 WMI Numerical Model

Almost all weather and forecast data are obtained via the internet, regardless of forecaster location. Data included in real-time monitoring and forecasting this season consisted of: live radar data from the National Weather Service network of WSR-88D radars, lightning data, satellite imagery (NOAA GOES and POES satellites), surface observations, a variety of numerical models (NAM, GFS, HRRR etc.), aviation weather sites (for icing reports), and in-house modeling tools. Visual observations were available from a number of webcams. When weather conditions deviated from those forecast or rapidly changing conditions otherwise warrant, weather updates were initiated by the meteorologist.

For the 2019-2020 season, WMI operated a single nest limited area domain of the Weather Research and Forecasting (WRF) model, with the inner high-resolution nest covering both the Wind River Range ground-based generator program and for this aerial project. The high-resolution inner nest, whose boundaries are shown with a thick black border on the plot below, was initialized from the High Resolution Rapid Refresh (HRRR) model, and was given the North American Model (NAM) forecast for boundary conditions at 3-hour intervals. The outer domain grid spacing was 9km and the inner higher-resolution nest grid spacing was 3km. The model was routinely run twice per day to a 48-hour forecast duration, but was run four times per day when active weather with potential seeding opportunities was expected or was ongoing. It provided very specific tools that greatly improve targeting and effectiveness of seeding, such as the explicit forecasting of supercooled water content over the flight tracks, and winds/temps aloft at a high spatiotemporal resolution. A large number of graphical outputs were developed specifically to aid the cloud seeding decision-making. Examples of some of the meteorologists' favorites are shown in the following figures.



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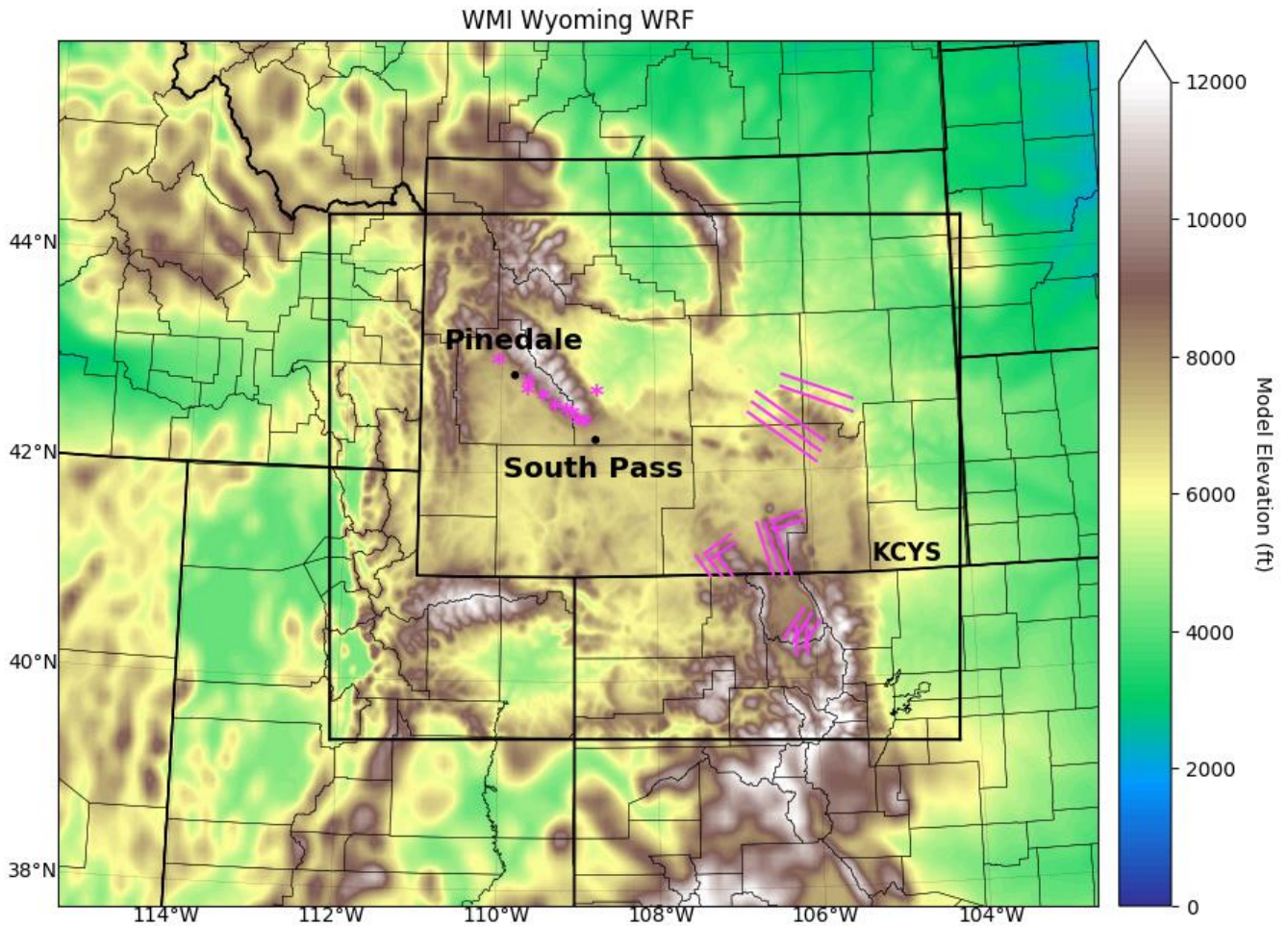


Figure 16. WMI Wyoming Single Nest 3km WRF Domain. Solid pink lines show the established aerial seeding tracks, selected from or modified based on the meteorological conditions present during each seeding event. Graphical output and BUFKIT format model soundings from WMI's Wyoming WRF domain were published to <http://wmiradar.com/ny> as soon as the data was available.



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Sierra Madre - Med Bow Cross Section 2020-02-16 1400 UTC

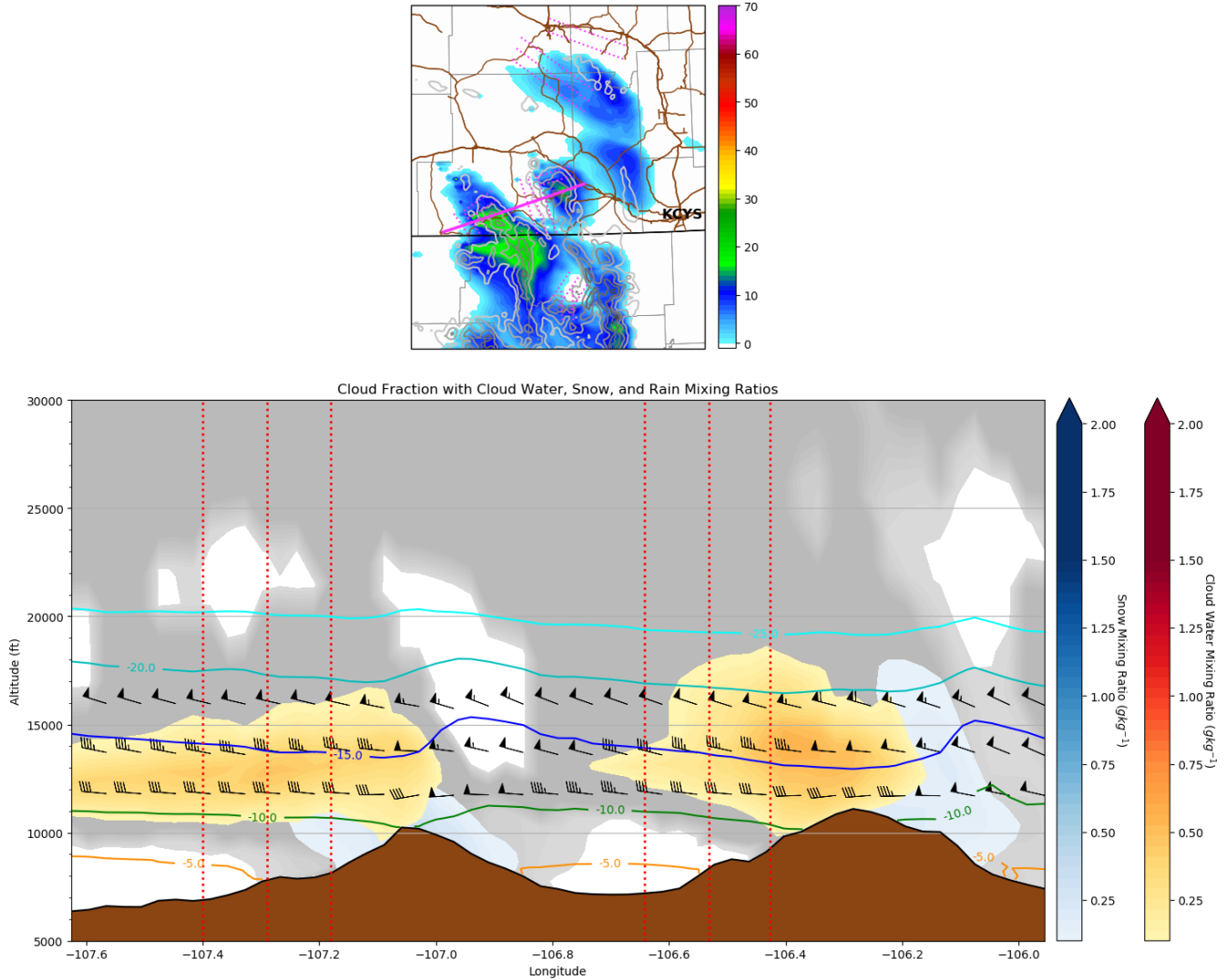


Figure 17. Plot of model simulated composite reflectivity is shown at the top, with a vertical cross section in the bottom half spanning the western flight tracks of the Sierra Madre and Medicine Bow Range. The plot is made for 14:00 UTC on 16 February, or 7 AM MST. See text for interpretation and discussion.

Figure 17, designed specifically to show an overview of weather in the Sierra Madre and Medicine Bow Ranges, shows a vertical cross section from southwest to northeast along the pink track in the composite reflectivity plot above. Horizontal distance, denoted by lines of longitude, is depicted along the x-axis, while vertical depth from the model surface (brown fill) up to 30,000 ft MSL is shown on the y-axis. This cross section intersects six project flight tracks at the vertical red dotted lines. Depicted on the cross section are a number of atmospheric variables. 3-dimensional model-simulated clouds are shown in a gray fill, model-predicted liquid cloud water (SLW when



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colder than freezing) is shown in warm (orange/red) colors, and model-predicted snow is shown in blue. Plot fill priority is given to cloud water, followed by snow, then cloud fraction. Isotherm contours at -25°C , -20°C , -15°C , -10°C , -5°C , and 0°C are shown in cyan, teal, blue, green, orange, and red respectively, and horizontal wind barbs at various heights at or near common seeding aircraft altitudes are also depicted (strong west winds around 50 kts are shown in this example).

Figure 18, much like Figure 17, shows a vertical cross section along the solid pink line in the composite reflectivity plot in the top half of the figure. This cross section, spanning from the western Never Summer flight tracks to the KCYS airport, again shows horizontal distance denoted by lines of longitude on the x-axis and vertical depth from the model surface (brown fill) up to 40,000 ft MSL on the y-axis. The cross section depicts isotherms, cloud fraction, cloud water, and snow in the same manner as Figure 17. In contrast to the previous figure, however, horizontal wind barbs are withheld, and the cross section is drawn over a broader distance from the seeding tracks to the base airport. This cross section is an example of a plot adapted from input from pilots, who appreciated the meteorological-focused meteograms like in Figure 17, but desired a cleaner design, and with the entire flight path between the seeding tracks and KCYS depicted.



WYOMING WEATHER MODIFICATION Medicine Bow, Sierra Madre, and Laramie Mountains (with extension over Colorado's Never Summer Mountains)



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NS1 Cross Section 2020-02-07 2300 UTC

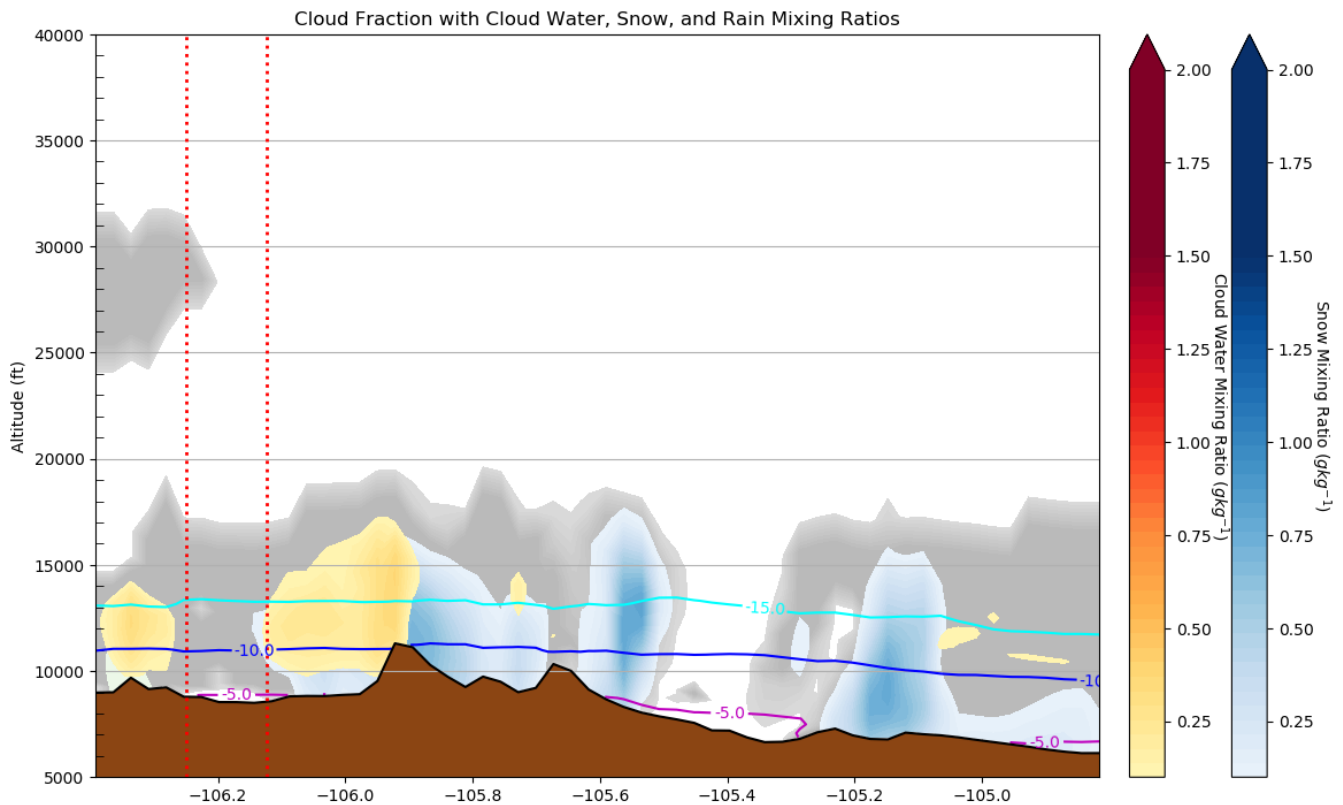
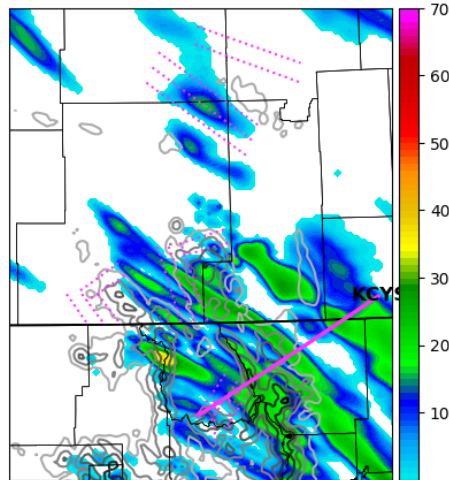


Figure 18. This plot, similar to Figure 13, shows model composite reflectivity in the top portion with a vertical cross section beneath. The cross section is drawn from the western most Never Summer Range flight track to the Cheyenne Airport. The plot is made for 23:00 UTC on 7 February, or 4 PM MST. See text for interpretation and discussion.



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WINTER AERIAL OPERATIONS 2019-2020

WRF Predicted 1-hr QPF and Snow Ratio at SNOTELs

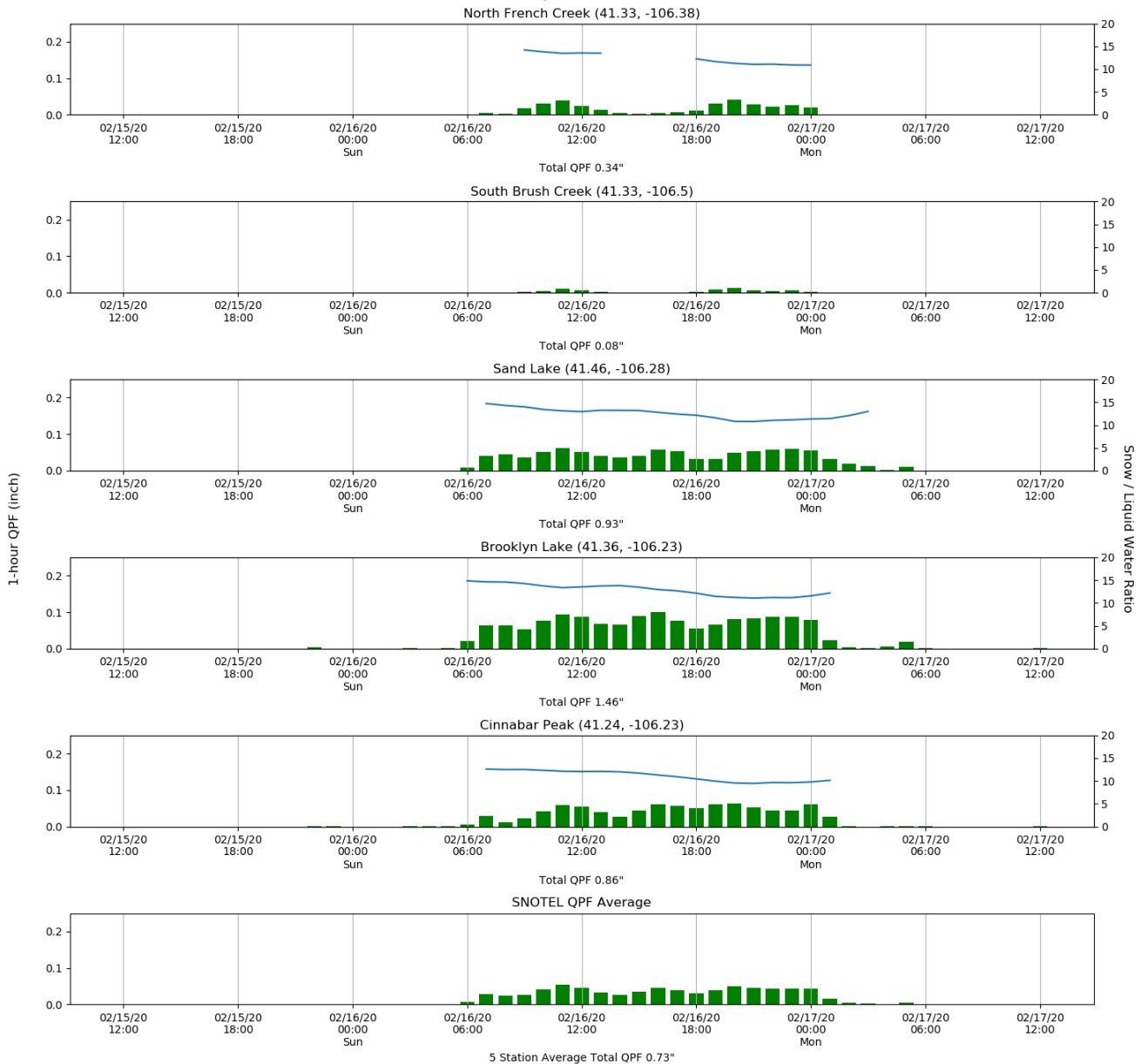


Figure 19. This plot shows hourly quantified precipitation forecast (QPF) outputs for five different SNOTEL locations in the Medicine Bow Range. A five-station average is shown in the bottom plot.

In Figure 19, a meteogram showing hourly model-predicted precipitation (a.k.a quantitative precipitation forecast, or QPF) at predefined locations, outputs are chosen based on the existing locations of SNOTEL sites. This type of meteogram was made for all three target ranges for each model cycle, with this plot showing an example for the Medicine Bow Range from the 12 UTC WRF run on 15 February, 2020. A double y-axis is used to show model predicted snow-liquid water ratios on the right. The meteogram duration is 48-hours, the same as the model duration of the inner high-resolution nest.



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Bridger Peak (SM)

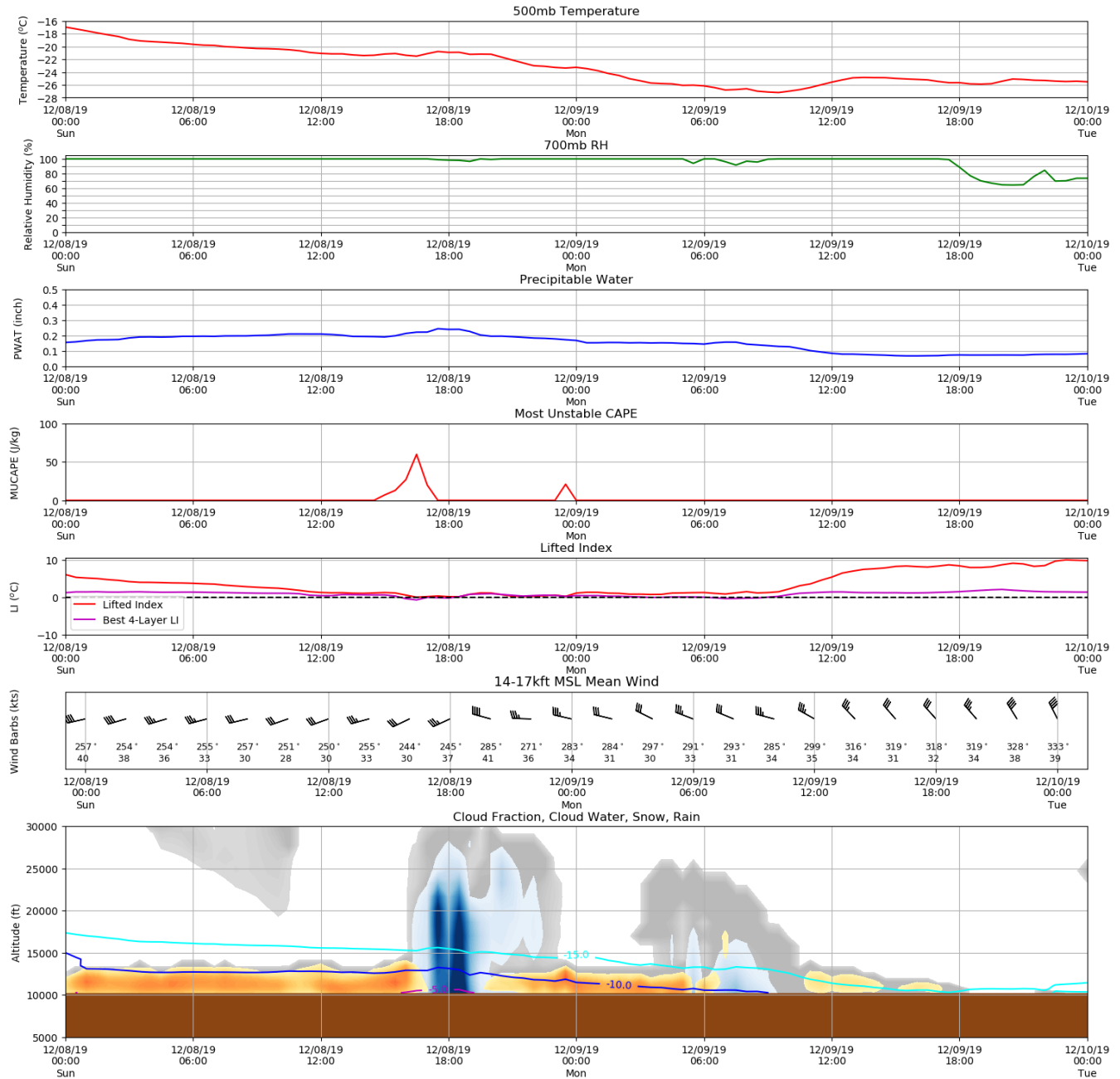


Figure 20. This figure, another meteogram, shows the forecasted evolution of a selection of mid-tropospheric, convective, and precipitation variables through time. The location is fixed at Medicine Bow Peak. Further explanation is provided in the text below.



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One final plot example is Figure 20. This multi-variable meteogram shows the forecasted progression of 500mb temperature, 700mb relative humidity (RH), precipitable water, most unstable convective available potential energy (CAPE), lifted index, 14,000-17,000 foot altitude average wind direction and speed, and a time-height cross section of isotherms, cloud fraction, cloud water, and snow. 500mb temperature and 700mb relative humidity are important lower troposphere tracers to monitor for warm/cold air advection and the presence of moisture in the air that can be lifted along the upwind side of the mountains. Precipitable water depicts the overall evolution of tropospheric moisture, while most unstable CAPE and lifted index are used to monitor the potential for convection accompanying precipitation, which may be hazardous to seeding operations. An average 14kft -17kft wind speed and direction is predicted and displayed as a wind barb every two hours, as this block of altitude is frequently utilized by our aircraft during seeding operations. Finally, the time-height cross section shows a breakdown of the model simulated cloud, cloud water, and snow expected throughout the identified time period. Location is held constant, in this case on the Bridger Peak in the Sierra Madre range, for all variables, though adjacent valley locations are used for lower tropospheric variables and precipitable water to provide a better free-atmosphere approximation of these model values.

4.3 Use of Weather Radar Data

While evaluating timely radar information has always been an aspect of the meteorological services involved in this cloud seeding program, WMI began ingesting live radar data from the nationwide network of NOAA NEXRAD radars this project season. Using radar software called TITAN, Thunderstorm Identification Tracking Analysis and Nowcasting, a mosaic of NEXRAD radars was created, and customizable overlays of aerial flight tracks and select geopolitical features (e.g. counties, interstates) were added for context. Further, timely aircraft position information was added, allowing a real-time fusion of radar information with seeding aircraft position. Web images of both a regional radar mosaic and a closer view of any airborne seeding/patrol operations (such as above) were created and published in real-time on the project operations webpage when potentially seedable weather occurred.



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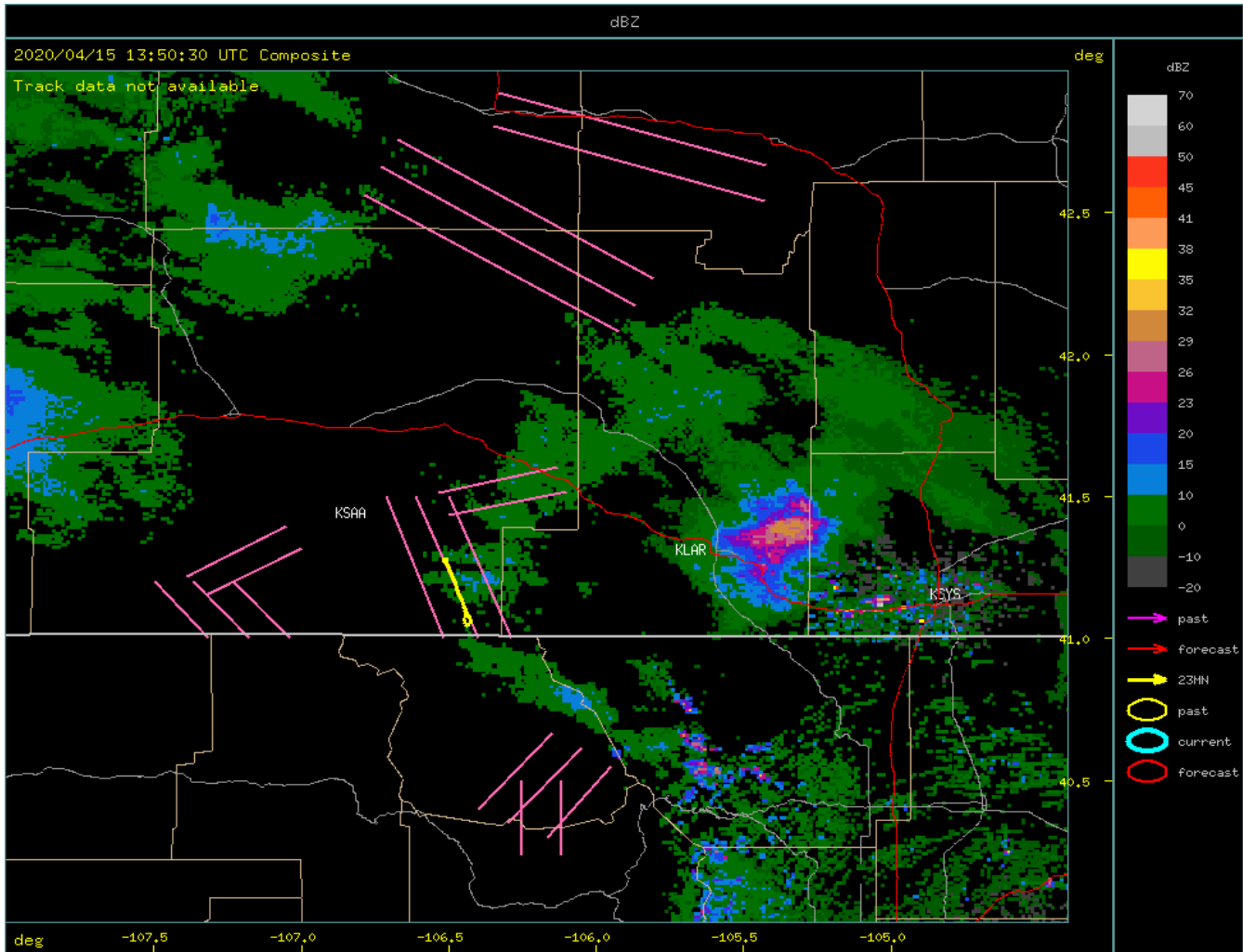


Figure 21. This is a mosaic of composite reflectivity from NOAA NEXRAD radars located in Riverton, WY, Cheyenne, WY, and Denver, CO. Aerial seeding track lines are shown in pink, while the aircraft flight track is shown in yellow.



WYOMING WEATHER MODIFICATION Medicine Bow, Sierra Madre, and Laramie Mountains (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

4.4 WMI Forecast Sheet



 Today's ODC +2	SYNOPSIS Upper level charts show a trough passing through the region today. The axis will move through the region late this evening. A cold front will push south through the region late tonight as well. Decent moisture will be in place this afternoon, and then it starts to slowly fade away tonight as we shift to a more northwest colder flow behind the trough. Winds in the low levels are favorable for orographic lift this afternoon and evening, generally westerly around 40 kts, becoming WNW by late evening. As the trough moves east late tonight, WY will be under some NNW flow aloft as a high amplitude ridge moves into the western states. Ridging is likely Tuesday, and then a shortwave trough passes through on Wednesday with some modest moisture. Wednesday's system looks to be a quick-hitter.
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FORECAST

Excellent seeding conditions are likely for the MB this afternoon and again late this evening. Conditions are decent for the SM as well, but the MB will be better. Seedable SLW depth looks likely for the NS for a window after midnight through the late night hours. The LR will have only thin orographic clouds and inadequate SLW for any operations this evening and tonight. Orographic clouds and SLW will drop off after around 3am after the cold front and trough axis pass through, and only thin low clouds are likely by dawn. Tomorrow will see some marginal orographic clouds early in the period, but not seedable. Gradual clearing is likely by tomorrow night. Dry conditions are expected tomorrow night and Tuesday. The next chance for precipitation and possible seeding will be Wednesday. Better details regarding Wednesday will be pinned down tomorrow and Tuesday as we get closer.

Mostly VFR conditions are expected in CYS, but we will have a wave of frontal precipitation after midnight with several hours of light snow and mist which could be a factor for the end of the second flight around 1-3am MST.

ACTION: A seeding flight is ongoing at forecast time for track MB4 and will continue for several more hours. There will then be a few hour lull in activity before another flight is expected for the late evening again on the MB tracks. Operations will likely end by 3am MST.

Day 2 Outlook ODC: 0

WRF MODEL SOUNDING		YESTERDAY'S WEATHER	Observed ODC: +1
SAA	00Z, 9 December	Temps Max/Min: Cheyenne 50/26 Saratoga 39/23 Walden 39/18 Weather Summary: Orographic clouds increased throughout the afternoon and evening, particularly for the SM/MB/NS ranges. The LR had marginal orographic clouds and only patchy SLW at times, not seedable. Deep orographic clouds were present over the southern ranges with excellent seedable SLW over the SM during the late evening into overnight hours, but then SLW gave way to mostly ice crystals in the early morning hours. SLW was less favorable for the MB, but probably worthy of a flight in the late evening if the SM had not been favored. The NS had periods of decent orographic clouds, but SLW was not quite deep enough for a hypothetical seeding flight (higher altitude minimums down there). Flights: One seeding flight occurred on track SM4 late Saturday evening with continuous good SLW. The mission began at approximately 19:54 MST (7 th) and ended at 2:00 MST (8 th) after utilizing 280 ejectable flares. Mission duration was over six hours. Initial plans for a second flight were scrapped due to insufficient SLW depth and ice crystals.	
0 °C level	n/a		
-5 °C level	8.8 kft		
-10 °C level	11.3 kft		
-20 °C level	16.1 kft		
Precipitable Water	0.27 inches		
14 kft T/wind	-15.3°C 277@35 kts		
16 kft T/wind	-19.9°C 270@39 kts		
700 mb T/wind	-6.6°C 276@28 kts		
500 mb T/wind	-24.5°C 264@42 kts		

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

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Figure 22. A WMI forecast sheet from 8 December 2019; all forecast were submitted to the client via email daily.



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5 PROJECT FLIGHT DATA

The first 2019-2020 winter mission was flown on 5 December 2019 for the Sierra Madre Mountain Range. A map of each seeding event is provided. The pre-established flight tracks are shown in blue and actual aircraft tracks are shown in black. Yellow dots denote where ejectable flares were fired, and red triangles denote where burn-in-place flares were ignited. The table beneath each map details the mission and includes flight data (engine on/off, total time), flares used, pilot(s) observations, a description of observed weather conditions, and area forecast relevant to that mission.

All flights for the Wyoming target areas are summarized in Table 2. Those flown for the Never Summer Range in Colorado are given in Table 3.

Table 2. Flight operations for the Medicine Bow, Sierra Madre, and Laramie Mountain Ranges are summarized.

2019-20 WY N23MN FLIGHT SUMMARY

	SNOW	RECON	REPO	WMI OTHER	BILLABLE TOTAL	MX FLIGHTS	BIP	EJ	TRACK(S)	TARGET AREA	CREW	Flight #
DATE	21	1	0									
12/5/2019	5.72				5.72	0.00		264	SM-5	MBSMLR	KHTC	1
12/8/2019	6.10				11.82	0.00		280	SM-4	MBSMLR	KHTC	2
12/8/2019	3.70				15.52	0.00	21	157	MB-4	MBSMLR	KHTC	3
12/9/2019	5.30				20.82	0.00	22	221	LR-3, LR-2, MB-5	MBSMLR	KHTC	4
12/11/2019	5.17				25.99	0.00	25	147	MB-3, MB-5, MB-4	MBSMLR	KHTC	5
12/12/2019	6.10				32.09	0.00	38	260	SM-4	MBSMLR	KHTC	6
12/13/2019	2.48				34.57	0.00		46	SM-4, MB-4, MB-3	MBSMLR	KHTC	7
12/14/2019	3.03				37.60	0.00	16	75	SM-3, SM-4, SM-5, MB-4	MBSMLR	KHTC	8
1/1/2020	3.68				41.28	0.00	33	215	MB-3	MBSMLR	KHTC	9
1/1/2020	5.45				46.73	0.00	48	305	MB-4	MBSMLR	KHTC	10
1/2/2020	5.48				52.21	0.00	1	291	SM-4, MB-4, MB-5	MBSMLR	KHTC	11
1/6/2019	1.83				54.04	0.00		18	MB-4	MBSMLR	KHTC	12
1/12/2020	4.97				59.01	0.00	12	168	SM-5	MBSMLR	KHTC	13
1/13/2020		1.75			60.76	0.00			SM-4, SM-5, MB-5	MBSMLR	KHTC	14
1/30/2020	2.95				63.71	0.00	2	92	MB-1, MB-2	MBSMLR	KHTC	15
2/5/2020				1.42	63.71	1.42						
2/8/2020	5.12				68.83	1.42	39	8	SM-3, SM-4	MBSMLR	KHTC	16
2/15/2020	4.95				73.78	1.42	40	31	MB-4, MB-5	MBSMLR	KHTC	17
2/16/2020	5.20				78.98	1.42	28	151	MB-3	MBSMLR	KHTC	18
2/16/2020	6.42				85.40	1.42	2	204	MB-3, MB-4	MBSMLR	KHTC	19
3/10/2020	1.98				87.38	1.42	2	39	MB-4	MBSMLR	KHTC	20
3/25/2020	6.00				93.38	1.42	12	167	SM-4, MB-4	MBSMLR	KHTC	21
4/15/2020	6.03				99.41	1.42	48	302	MB-4	MBSMLR	KHTC	22
TOTALS	97.66	1.75	0.00	1.42	99.41	1.42	389	3441				



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Table 3. Flight operations for the Never Summer Mountain Range are summarized.

2019-20 CO N23MN FLIGHT SUMMARY

	SNOW	RECON	REPO	WMI OTHER	BILLABLE TOTAL	MX FLIGHTS	BIP	EJ	TRACK(S)	TARGET AREA	CREW	Flight #
DATE	8	1	0									
1/1/2020	1.32				1.32	0.00	4	44	NS-2	NS	KHTC	1
1/3/2020	3.62				4.94	0.00		212	NS-2	NS	KHTC	2
1/6/2019		0.73			5.67	0.00			NS-2	NS	KHTC	3
1/22/2020	6.00				11.67	0.00		306	NS-2	NS	KHTC	4
1/27/2020	3.48				15.15	0.00	15	73	NS-3	NS	KHTC	5
2/6/2020	5.00				20.15	0.00		204	NS-2	NS	KHTC	6
2/7/2020	6.38				26.53	0.00	5	253	NS-1	NS	KHTC	7
2/27/2020	4.70				31.23	0.00		179	NS-2	NS	KHTC	8
3/10/2020	3.92				35.15	0.00		200	NS-2	NS	KHTC	9
TOTALS	34.42	0.73	0.00	0.00	35.15	0.00	24	1471				

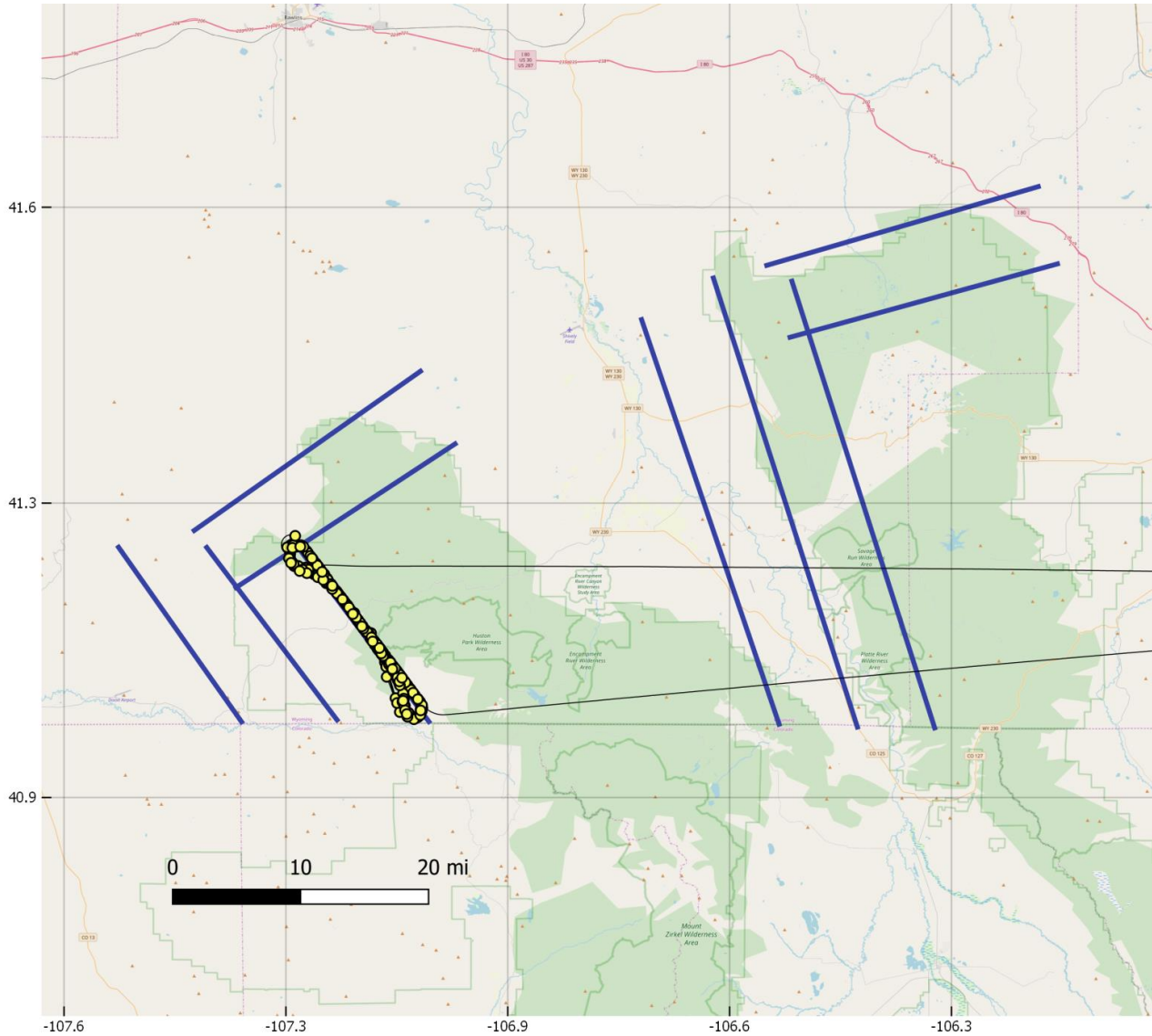


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5.1 Mission Flight Tracks – Medicine Bow, Sierra Madre, and Laramie Ranges, WY



N23MN		OPS #:	01		SEED
Track(s)/Basin:		SM-5			
UTC Date:	December 5, 2019		MST Date:	December 5, 2019	
UTC Engines ON:	17:11		MST Engines ON:	10:11 am	
UTC Engines OFF:	22:54		MST Engines OFF:	3:54 pm	
Total Time:	5:43	5.72hr	Flares Used:	0 BIP	264 EJECT
Pilot's Flight Summary:	Departed CYS and flew to Sierra Madre range, track 5. We leveled off at 13kft for operations. Made north and south passes along track, firing an ejectable flare once per minute. As we turned onto the track we were just below the cloud tops for about 20				



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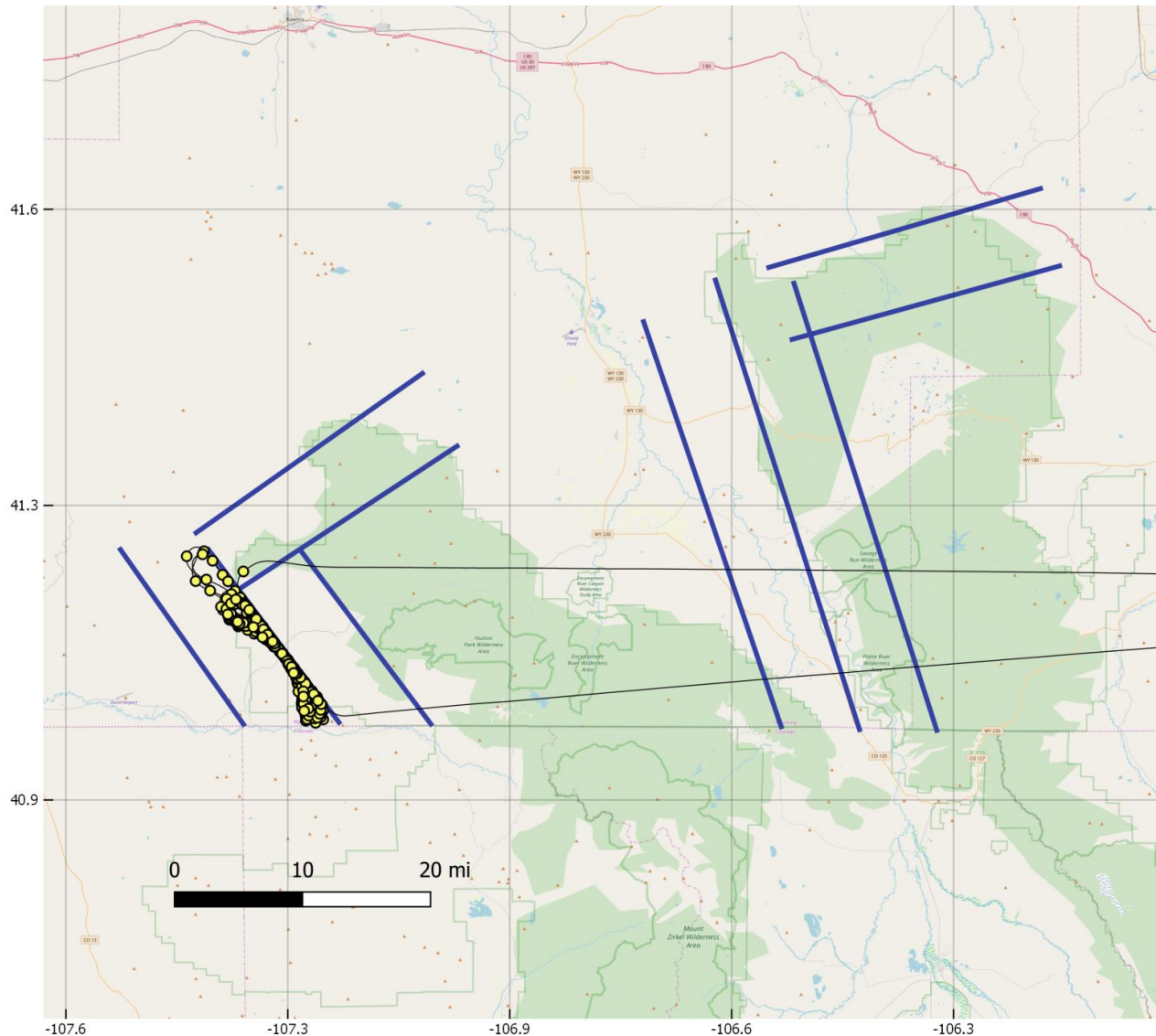
	<p>minutes, then clouds lowered for about 4 hours. Clouds then rose for our last half hour on station. We encountered light amounts of SLW when in clouds. Due to fuel considerations, we RTB.</p>
<p>Synoptic Analysis:</p>	<p>Jet energy remains south of the region. Ridging will continue through the day. Low level RH remains high while PWAT is unimpressive this afternoon. A shortwave (remnants of the large Pacific system from past few days) will pass through the Four Corners tonight through tomorrow. PWAT will increase this evening and tonight as the wave passes through. Winds will be relatively light in the low levels tonight/tomorrow, and orographic lift will be unremarkable. Models indicate some marginal SLW tonight into tomorrow afternoon for the southern ranges, but this looks to be more stratiform than orographic. SLW depth is unimpressive for most of this event, but may become favorable for a brief time around midday tomorrow. The LR will be mostly unaffected by this southern wave. Dry air and more ridging return tomorrow evening through Saturday. The next significant system will be a low that is developing off the PACNW coast later today. This system will reach WY Sunday into Monday.</p>
<p>Area Forecast:</p>	<p>The more southern ranges will see some thin low level clouds hugging the peaks this afternoon while mountain wave clouds continue above and downwind. Stratus and deep mid-to-upper level layers will increase late tonight with some moderate snowfall beginning overnight in the MB/SM/NS. Seeding level winds will be light, and SLW depth will be inadequate for seeding through noon tomorrow. Low stratus clouds will be enshrouding the mountains tomorrow afternoon with some slightly deeper SLW which could be worthy of a seeding flight, depending on the light wind speeds and ability to target this layer. Snow will taper off later tomorrow afternoon. Light snow with low ceilings are possible in CYS tomorrow morning, but this should improve after noon. For now, we will forecast a slight chance for seeding in the SM/MB ranges tomorrow early afternoon. Shallow stratus continues tomorrow evening/overnight with no chance of ops. Dry weather is likely Friday and Saturday, and then the next round of widespread snowfall is Sunday through Monday which will likely bring some seeding windows.</p>
<p><i>Flight occurred in the afternoon hours of Dec. 5th; weather information is from Dec. 4th.</i></p>	



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N23MN	OPS #:	02	SEED		
	Track(s)/Basin:	SM-4			
UTC Date:	December 8, 2019		MST Date:	December 7, 2019	
UTC Engines ON:	02:54		MST Engines ON:	7:54 pm	
UTC Engines OFF:	09:00		MST Engines OFF:	2:00 am	
Total Time:	6:06	6.1hr	Flares Used:	0 BIP	280 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track SM-4. Crossed ridge at 14kft and encountered light to moderate SLW. Began dropping ejectable flares once on track every minute. As cloud tops lowered and rose, we descended and climbed to remain above them. Elected to cut 4 miles off northern end of track due to winds. Light to moderate SLW when in cloud tops.				



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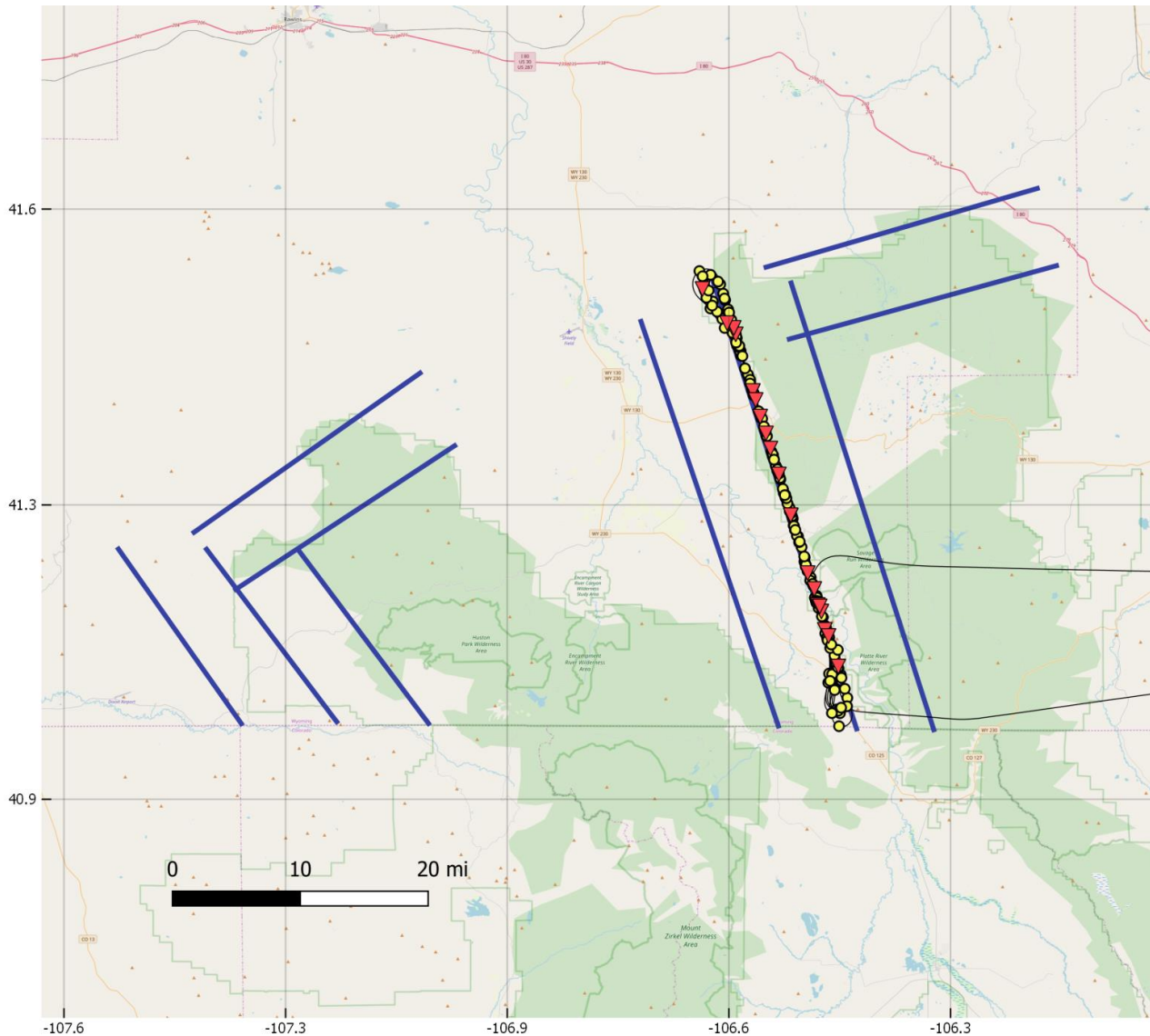
Synoptic Analysis:	<p>Upper level charts show the ridge moving off to the east this afternoon, and we have returned to a strong southwest flow. A southwesterly jet streak will be nosing into the region tonight. The cutoff low near the coast is moving onshore today as an open wave trough. Moisture is returning today and tomorrow ahead of the trough. The trough axis will reach the project region late Sunday night, and then cold drier air will be in place Sunday night and Monday. PWAT will be rising this afternoon through dawn, and then slowly dropping tomorrow as a colder air mass moves in. Low level temps will be rather mild today. A cold front will push southward through our region late Sunday night bring much lower surface temps late Sunday night and Monday. A high-amplitude ridge will approach the Rockies Tuesday while we remain under stronger cold northwest flow. A shortwave moves through quickly on Wednesday with a small batch of moisture.</p>
Area Forecast:	<p>Continuous excellent seeding conditions are expected for the SM range this evening and tonight. The MB will also see shorter periods of good seeding conditions late tonight. Marginal conditions are likely in the NS, probably not quite good enough for seeding in latest model runs. The LR will only see fleeting periods of SLW late tonight with otherwise inadequate cloud coverage for ops. Orographic clouds will deepen over the southern ranges through the afternoon becoming workable around 3z in the SM. Deep orographic clouds with heavy SLW will continue through the night into tomorrow morning and afternoon. Thinner orographic clouds with less SLW are expected tomorrow evening/night as moisture wanes and colder air arrives. This will be a mostly orographic event, as midlevel dynamics are not impressive with only some small vort lobes pushing through tonight. Passing waves of midlevel snowfall will be short-lived, allowing for long periods of deep targetable SLW. Winds at seeding altitudes will be W or WSW around 30 knots. There will be more targetable SLW tomorrow afternoon, but we may not be able to target this for several reasons including pilot duty day limitations and some modest instability. Extensive operations are expected tonight, and then only a slight chance exists for tomorrow.</p>
<p><i>Flight occurred in the evening hours of Dec. 7th; weather information is from Dec. 7th.</i></p>	



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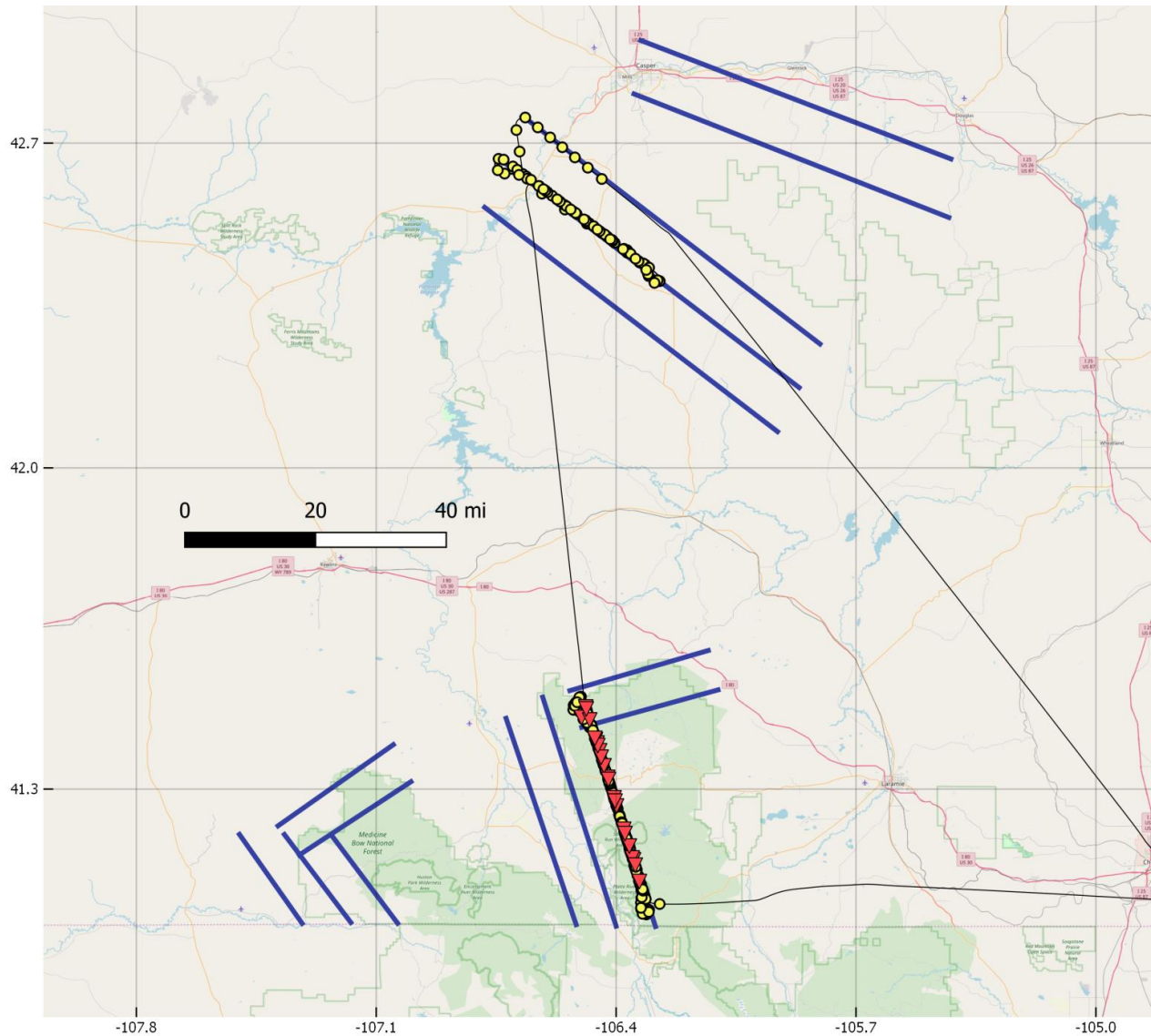
N23MN		OPS #:	03	SEED	
		Track(s)/Basin:	MB-4		
UTC Date:	December 8, 2019		MST Date:	December 8, 2019	
UTC Engines ON:	19:22		MST Engines ON:	12:22 pm	
UTC Engines OFF:	23:04		MST Engines OFF:	4:04 pm	
Total Time:	3:42	3.7hr	Flares Used:	21 BIP	157 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to MB-4. Moderate SLW crossing the ridge. Began seeding at 16kft once on track. EJs once per minute, lighting BIPs when SLW was present. Light SLW present in areas of track. Descended throughout flight to remain in or just above cloud tops. RTB Cheyenne due to lack of seedable conditions.				
<i>Flight occurred in the afternoon hours of Dec. 8th; weather information remains the same as MBSMLR Ops. #2.</i>					



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N23MN		OPS #:	04	SEED	
		Track(s)/Basin:	LR-3, LR-2, MB-5		
UTC Date:	December 9, 2019		MST Date:	December 8, 2019	
UTC Engines ON:	02:26		MST Engines ON:	7:26 pm	
UTC Engines OFF:	07:44		MST Engines OFF:	12:44 am	
Total Time:	5:18	5.3hr	Flares Used:	22 BIP	221 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track LR-3. Began seeding at 11.2kft, dropping EJs once per minute once on track. We changed to track LR-2 due to winds, and air traffic control asked us to climb to 11.5kft for a few passes. Occasional light SLW on this track. We were then told we could descend down to 11.2kft again, and made a few passes at this altitude before SLW became sparse. Under the direction of the meteorologist, we				



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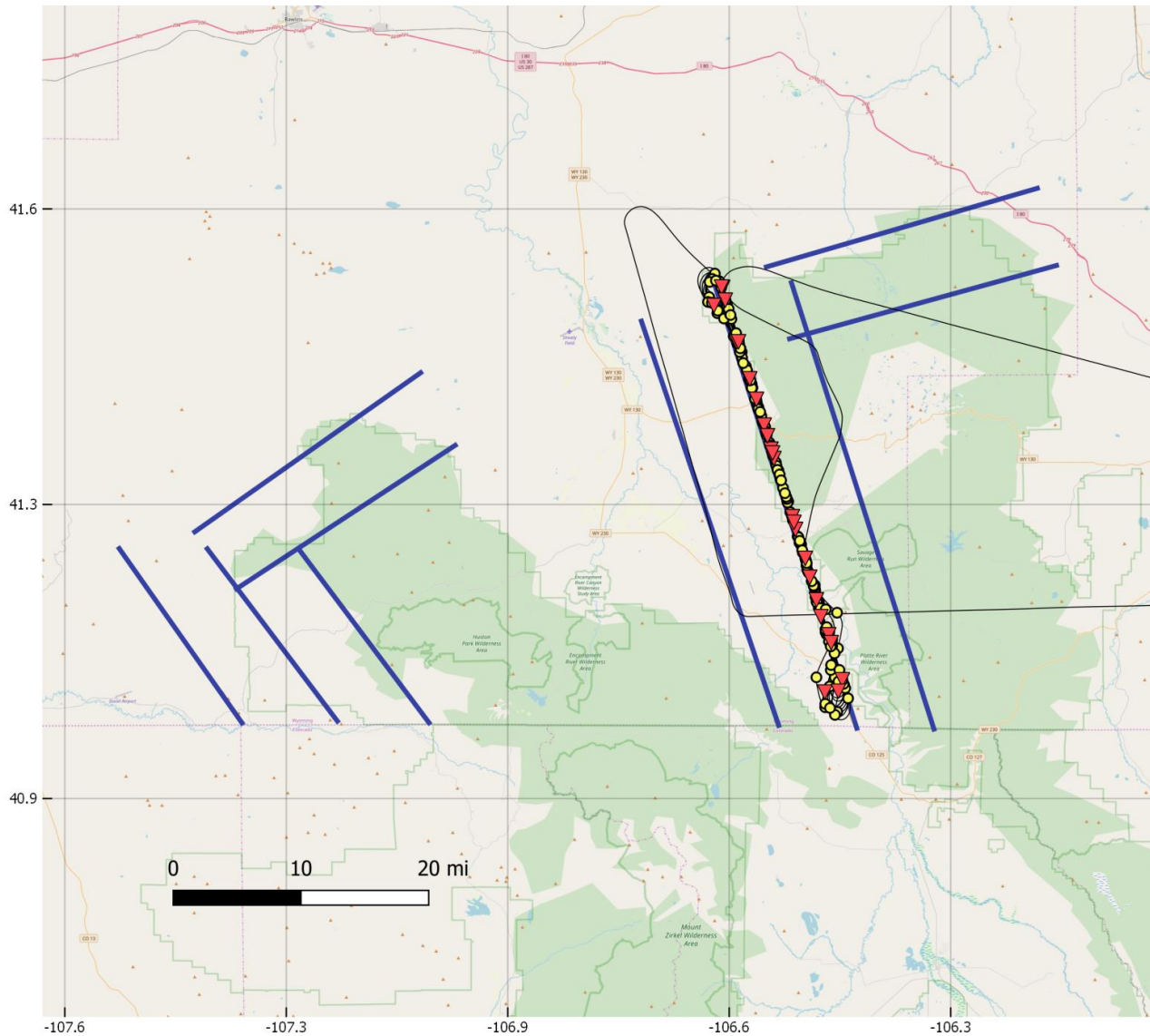
	<p>changed to track MB-5, and dropped EJs once per minute. BIP flares were lit in the northern half of the track, where the SLW was encountered more often. Stayed on this track and altitude for several hours. Due to low fuel, we then RTB.</p>
<p>Synoptic Analysis:</p>	<p>Upper level charts show a trough passing through the region today. The axis will move through the region late this evening. A cold front will push south through the region late tonight as well. Decent moisture will be in place this afternoon, and then it starts to slowly fade away tonight as we shift to a more northwest colder flow behind the trough. Winds in the low levels are favorable for orographic lift this afternoon and evening, generally westerly around 40 kts, becoming WNW by late evening. As the trough moves east late tonight, WY will be under some NNW flow aloft as a high amplitude ridge moves into the western states. Ridging is likely Tuesday, and then a shortwave trough passes through on Wednesday with some modest moisture. Wednesday's system looks to be a quick-hitter.</p>
<p>Area Forecast:</p>	<p>Excellent seeding conditions are likely for the MB this afternoon and again late this evening. Conditions are decent for the SM as well, but the MB will be better. Seedable SLW depth looks likely for the NS for a window after midnight through the late night hours. The LR will have only thin orographic clouds and inadequate SLW for any operations this evening and tonight. Orographic clouds and SLW will drop off after around 3am after the cold front and trough axis pass through, and only thin low clouds are likely by dawn. Tomorrow will see some marginal orographic clouds early in the period, but not seedable. Gradual clearing is likely by tomorrow night. Dry conditions are expected tomorrow night and Tuesday. The next chance for precipitation and possible seeding will be Wednesday. Better details regarding Wednesday will be pinned down tomorrow and Tuesday as we get closer.</p> <p>Mostly VFR conditions are expected in CYS, but we will have a wave of frontal precipitation after midnight with several hours of light snow and mist which could be a factor for the end of the second flight around 1-3am MST.</p>
<p><i>Flight occurred in the evening hours of Dec. 8th; weather information is from Dec. 8th.</i></p>	



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WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	05	SEED		
	Track(s)/Basin:	MB-3, MB-5, MB-4			
UTC Date:	December 11, 2019		MST Date:	December 11, 2019	
UTC Engines ON:	23:24		MST Engines ON:	4:24 pm	
UTC Engines OFF:	04:34		MST Engines OFF:	9:34 pm	
Total Time:	5:10	5.17hr	Flares Used:	25 BIP	147 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to a modified MB-3 track. We cut the southern 7 miles off the track and added 7 miles to the northern end. Arrived on track, but did not seed. Shortly after arriving on track we switched to MB-4 as directed by meteorologist. Initially unable to find SLW so we tried MB-5. We encountered SLW so we returned to MB-4 and began lighting BIPs. After about an hour on track we began dropping EJs at a				



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WINTER AERIAL OPERATIONS 2019-2020

	<p>rate of once per minute. Ceased the use of BIPs due to cloud tops lowering below us. Climbed and descended as necessary to remain just above cloud tops. BIP usage began again and ended as directed by the meteorologist. Stayed on stayed for several hours, until lack of seedable targets forced us to RTB.</p>
<p>Synoptic Analysis:</p>	<p>A shortwave trough is passing through our area this afternoon and early evening with a small wave of moisture and weak dynamics. Behind the trough, a potent jet streak will be nosing into the region with WNW flow. An Atmospheric River event is occurring for the West Coast, and excellent moisture will be advecting into the target ranges starting around midday tomorrow and lingering through Saturday. Low level winds are strong from the WNW at seeding altitudes today, around 50 knots. PWAT will increase during the late afternoon and early evening and then drop off a big overnight. 700MB RH has been low this morning, but it is steadily rising at forecast time and should reach saturation before sunset. A very cold and much drier air mass will move in Sunday and Monday, and no operations will be possible.</p>
<p>Area Forecast:</p>	<p>Thick seedable orographic clouds will develop in the late afternoon and persist through the evening. A seeding flight will be possible starting around 00Z. SLW looks to be best for the MB range, and with 50 knot winds, track MB-3 looks to be favored from 14-15 kft. This is a relatively brief seeding window that will only last about five hours. Seeding will end around 5z. As moisture wanes tonight, the orographic cloud depth will become too shallow for operations, and no seeding is expected overnight, though marginal SLW and clouds will persist through morning. By late tomorrow morning, another major wave of moisture will arrive with favorable orographic winds, and deep SLW is expected tomorrow afternoon through Saturday with extensive operations likely during this time.</p>

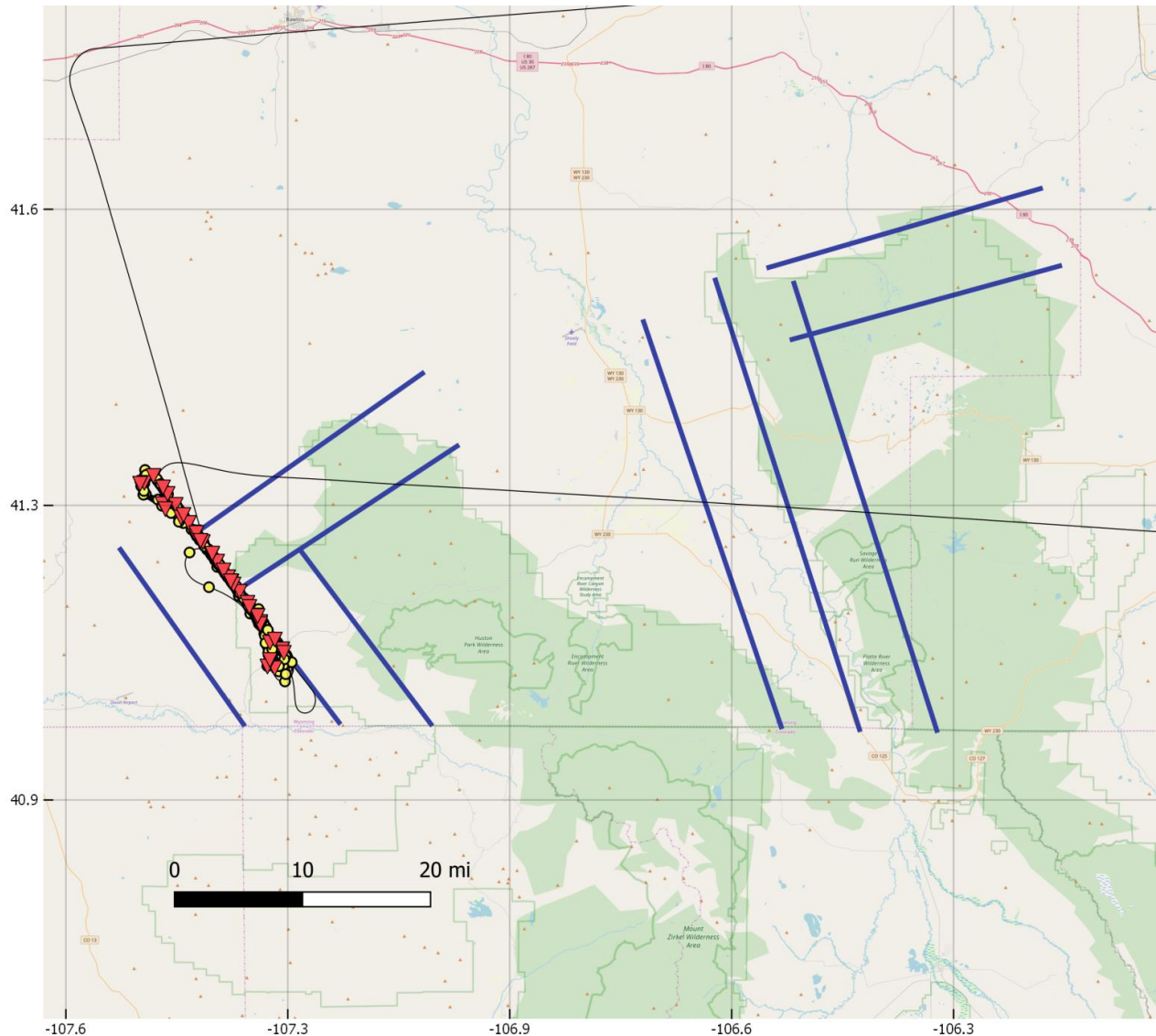
Flight occurred in the evening hours of Dec. 11th; weather information is from Dec. 11th.



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 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	06	SEED		
	Track(s)/Basin:	SM-4			
UTC Date:	December 12, 2019		MST Date:	December 12, 2019	
UTC Engines ON:	18:35		MST Engines ON:	11:35 am	
UTC Engines OFF:	00:41		MST Engines OFF:	5:41 pm	
Total Time:	6:06	6.1hr	Flares Used:	38 BIP	260 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to the SM-4 track. We took a route north of the ranges and flew at 20kft to avoid icing on the way. Arrived on track and began firing EJs at a rate of once per minute. Descended/climbed as necessary due to lowering/rising cloud tops. After about an half and a half on station, our meteorologist advised us to start using BIPs. Light SLW on south end of track. Eventually cloud tops rose to the point				



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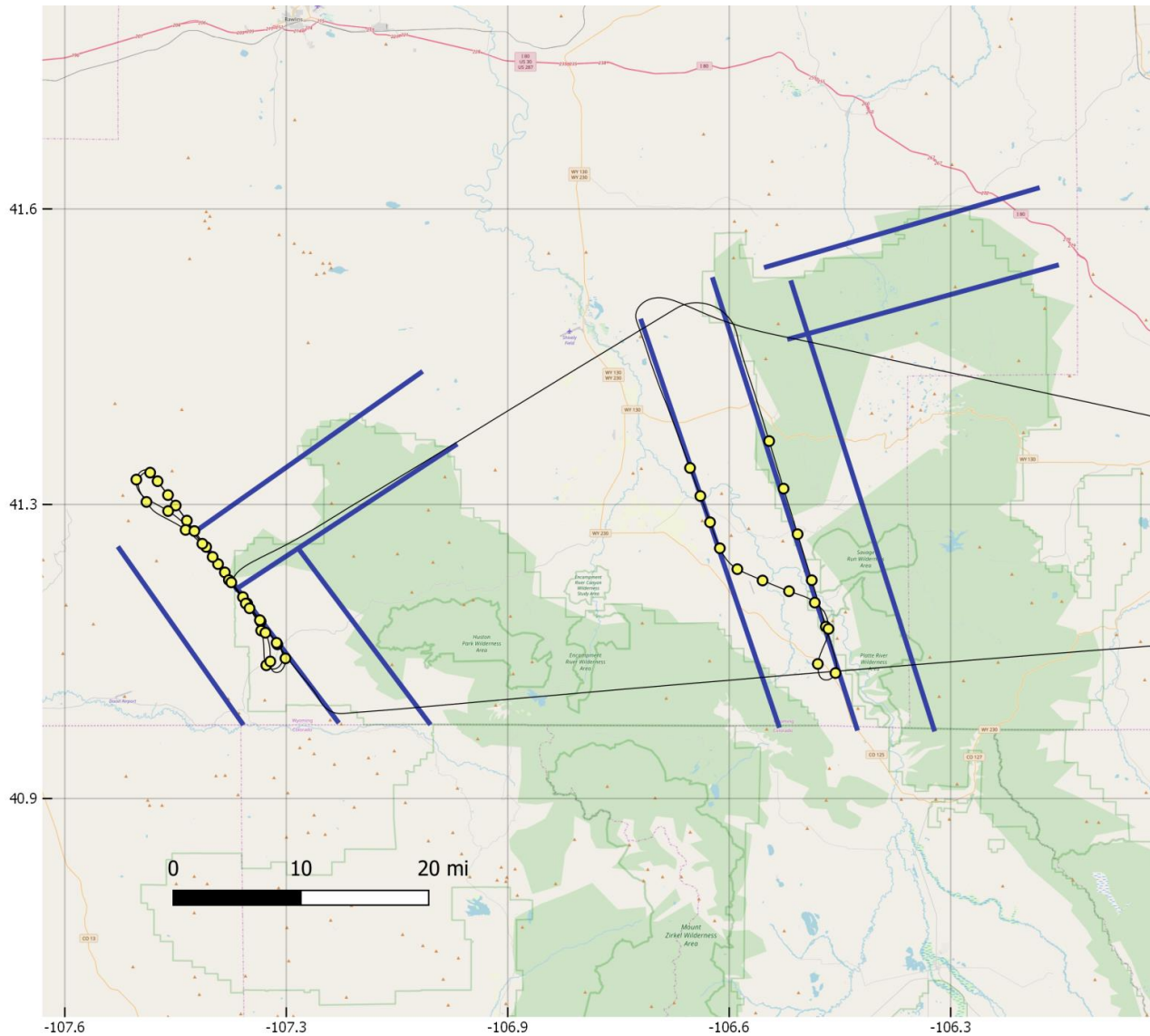
	where we were in cloud tops along entire track. Due to low fuel, we RTB.
<i>Flight occurred in the afternoon hours of Dec. 12th; weather information remains the same as MBSMLR Ops. #5.</i>	



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WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	07		SEED	
	Track(s)/Basin:	SM-4, MB-4, MB-3			
UTC Date:	December 13, 2019		MST Date:	December 12, 2019	
UTC Engines ON:	01:20		MST Engines ON:	6:20 pm	
UTC Engines OFF:	03:49		MST Engines OFF:	8:49 pm	
Total Time:	2:29	2.48hr	Flares Used:	0 BIP	46 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track SM-4, modified with the southern 6 miles cut off with 6 miles added to the northern end of the track. Moderate SLW crossing the Medicine Bow range at 16kft. Arrived on SM-4 and began dropping EJs at a rate of once per minute. Descended to get closer to cloud tops and better SLW. Stayed on station for approximately 20 minutes before being redirected to MB-4. Resumed dropping EJs				



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	<p>at a rate of once per minute. Shortly after arriving we were redirected to MB-3. After about 5 minutes on track, we RTB due to lack of seedable targets and direction from radar.</p>
<p>Synoptic Analysis:</p>	<p>A very powerful westerly jet streak is nosing into WY today. A major plume of Pacific moisture continues to flow into the region from an Atmospheric River pushing into Oregon and Northern California. Wind flow in the lower levels is quite strong from the WNW. This combined with the excellent moisture is creating outstanding conditions for deep orographic clouds and snowfall. Midlevel dynamics are generally weak this afternoon, though some lobes of vorticity will push through this evening and tomorrow bringing waves of deeper midlevel clouds (and natural seeder feeder mechanism off and on). Between these waves, very deep targetable SLW will be present through Friday evening. Winds at seeding altitudes will be from the WNW to NW around 40-60kts. A cold drier air mass invades Sunday and Monday bringing an end to this prolonged orographic snow event.</p>
<p>Area Forecast:</p>	<p>Nearly continuous seedable clouds are anticipated for the SM/MB/NS ranges through tomorrow evening, and extensive seeding is expected to occur today and tomorrow. There looks to be a lull in the SLW Friday night, and then SLW returns Saturday with even more operations likely. With seeding level winds from the NW today, modified tracks will be used to optimize targeting. Pilot duty day restrictions will preclude overnight seeding tonight after two long day flights, but ops will likely pick up again tomorrow morning after some rest. The LR does not look very favorable at any point during this multiday system due to the wind direction and position of the moisture plume. Conditions are CYS will be workable for operations throughout the period, though winds will be quite gusty and some low level wind shear is indicated in the TAFs today. Downslope winds will keep temps warm in CYS today with highs around 45°F. Due to the heavy nature of the SLW today, ejectable flares will be the primary seeding method in order to keep the aircraft above cloud layers and extend on-station time. Extensive operations will end Saturday night, and then no seeding will occur Sunday or Monday as a cold air mass moves in.</p>

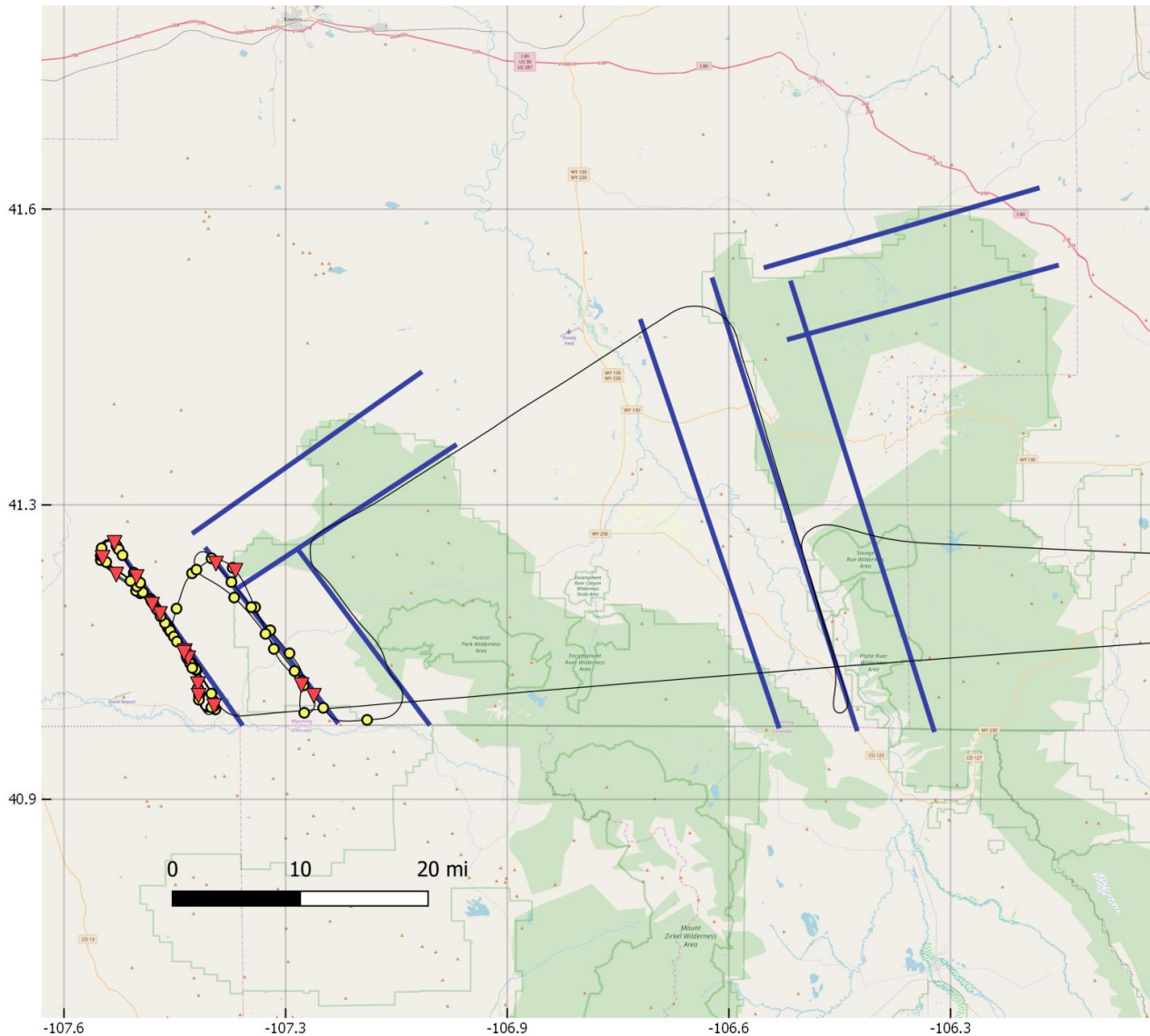
Flight occurred in the evening hours of Dec. 12th; weather information is from Dec. 12th.



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WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	08	SEED		
	Track(s)/Basin:	SM-3, SM-4, SM-5, MB-4			
UTC Date:	December 14, 2019	MST Date:	December 14, 2019		
UTC Engines ON:	07:16	MST Engines ON:	12:16 am		
UTC Engines OFF:	10:18	MST Engines OFF:	3:18 am		
Total Time:	3:02	3.03hr	Flares Used:	16 BIP	75 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to rack SM-3. Encountered light to moderate SLW crossing the ridge at 19kft. Arrived on station and began dropping EJs at a rate of once per minute, and BIPs at the direction of the meteorologist. We slowly descended looking for SLW. We were then directed by our meteorologist to move to tracks SM-4 and SM-5 to look for SLW. We weren't able to find any so we repositioned to track MB-				



WYOMING WEATHER MODIFICATION
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WINTER AERIAL OPERATIONS 2019-2020

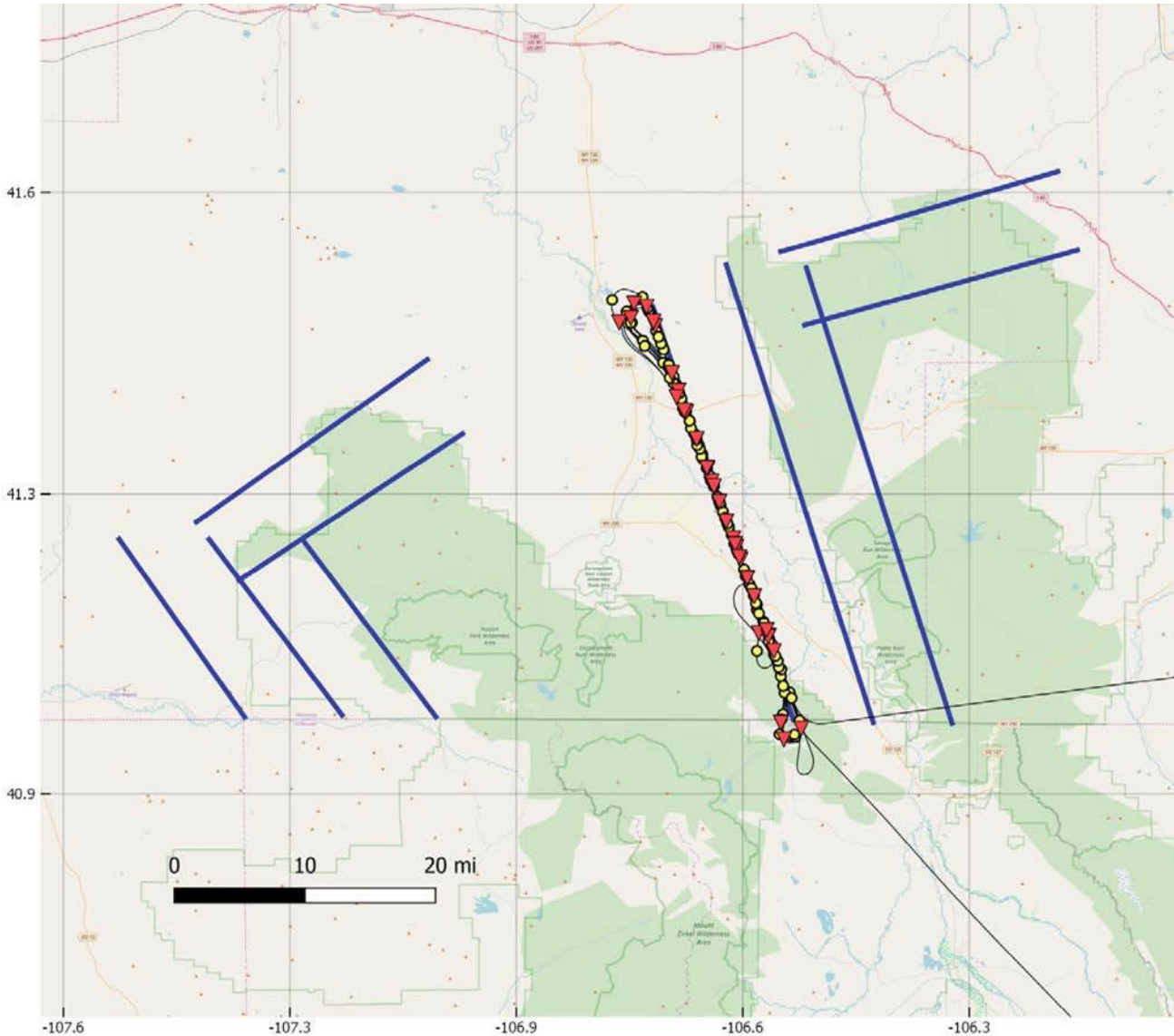
	<p>4. Arrived at MB-4 and made a pass to look for SLW. We were unable to find any so we RTB at the direction of the meteorologist.</p>
<p>Synoptic Analysis:</p>	<p>A very powerful westerly jet streak is nosing into WY today. A major plume of Pacific moisture continues to flow into the region from an Atmospheric River pushing into Oregon and Northern California. Wind flow in the lower levels is quite strong from the WNW. This combined with the excellent moisture is creating outstanding conditions for deep orographic clouds and snowfall. Midlevel dynamics are generally weak this afternoon, though some lobes of vorticity will push through this evening and tomorrow bringing waves of deeper midlevel clouds (and natural seeder feeder mechanism off and on). Between these waves, very deep targetable SLW will be present through Friday evening. Winds at seeding altitudes will be from the WNW to NW around 40-60kts. A cold drier air mass invades Sunday and Monday bringing an end to this prolonged orographic snow event.</p>
<p>Area Forecast:</p>	<p>Due to the strong winds at seeding levels, the existing orographic clouds over the ranges are not seedable due to insufficient snow growth and fallout time. This will continue through midnight, though some light snowfall will likely occur this afternoon and evening. After midnight, moisture returns, and orographic clouds will become deeper and broader in coverage stretching well upwind of the ranges. A single seeding flight looks possible late tonight, probably for the SM range at 13 kft. The limiting factor for possible operations tonight looks to be a possibility of freezing mist at CYS around 5am. We will wait to see the evening 00z model runs before making firm decisions regarding a night flight. Clouds now look to be marginal on Saturday as well with insufficient fallout time/coverage mixed with periods of deep midlevel ice crystals and poor SLW. Seeding is still possible Saturday, however. No operations will occur Sunday through Tuesday.</p>
<p><i>Flight occurred in the morning hours of Dec. 14th; weather information is from Dec. 13th.</i></p>	



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WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	09			SEED
	Track(s)/Basin:	MB-3			
UTC Date:	January 1, 2020		MST Date:	January 1, 2020	
UTC Engines ON:	14:15		MST Engines ON:	7:15 am	
UTC Engines OFF:	17:56		MST Engines OFF:	10:56 am	
Total Time:	3:41	3.68hr	Flares Used:	33 BIP	215 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track MB-3. No SLW crossing ridge at 22kft. Arrived on station and found light SLW at 18kft. Began firing EJ's at a rate of once per minute and BIP's as directed by the meteorologist. After 15 minutes, we descended to 17kft to				



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	<p>check conditions. We gradually climbed back up to 18.5kft due to spots of heavy SLW increasing our airframe icing rate. After about an hour of seeding, we increased our EJ rate to once every 45 seconds. As SLW weakened, we gradually descended to 16.5kft. We found some light SLW but conditions deteriorated so we moved to track NS-2. Arrived on station and resumed dropping EJ's at a rate of once per minute and BIPs as directed by the meteorologist. We descended to 16kft and made several more passes with EJ's, discontinuing the use of BIP's. Due to lack of seedable targets, we returned to base Cheyenne.</p>
<p>Synoptic Analysis:</p>	<p>A Baja low lingers to our south while a strong jet streak noses into the PACNW. Northerly flow aloft will become northwesterly today, and PWAT will be on the rise. 700mb RH is only around 60% at forecast time, but it will rise throughout the day becoming saturated by around midnight. Midlevel warming is occurring today, and 500mb temps will climb to -15C by midnight. Winds at seeding altitudes will be around 35 kts at midnight, increasing to around 50 kts later tonight. Orographic lift will be favorable tonight. Deep orographic clouds are expected late tonight through tomorrow with good SLW. Lobes of midlevel vorticity will pass through late tonight into tomorrow creating some intervals of deep midlevel cloud and natural seeder-feeder ice crystals from above. This will deplete low level SLW at times, but we should be able to work around it, targeting the better periods of SLW. This pattern will continue through Thursday evening, and then moisture wanes on Friday and Saturday as a ridge moves into the Rockies.</p>
<p>Area Forecast:</p>	<p>Partly clear skies are expected this afternoon, and then orographic clouds and deep upper cloud layers will move in overnight with periods of targetable SLW. The SM and MB ranges appear favorable for ops perhaps as early as midnight tonight. The NS becomes favorable closer to dawn. There will be waves of midlevel clouds and ice crystals as the deeper more widespread snowfall bands push through from midlevel forcing. We will attempt to seed between these waves while also managing pilot duty day limitations. More seedable clouds are expected tomorrow into tomorrow night. We may be able to get a flight later tomorrow depending on how extensively we utilize the pilot crew overnight into tomorrow morning. Heavy mountain snowfall is expected tonight through tomorrow. Conditions at CYS look to be favorable for ops through the night according to the latest TAFs. Flurries are expected Friday, but seeding looks unlikely. Dry conditions return Saturday.</p>

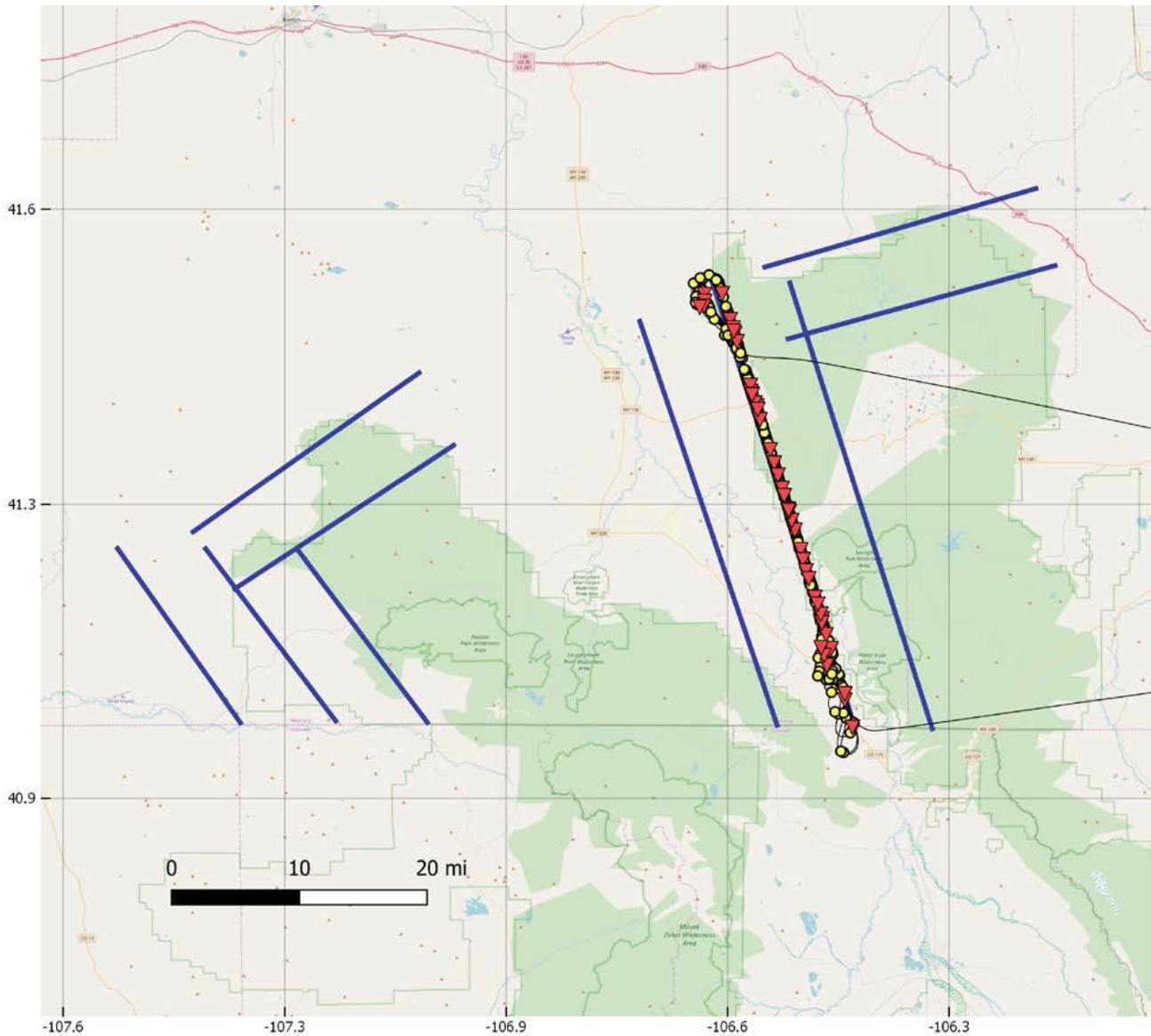
Flight occurred in the morning to afternoon hours of Jan. 1st; weather information is from Dec. 31st.



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N23MN	OPS #:	10	SEED	
	Track(s)/Basin:	MB-4		
UTC Date:	January 1, 2020	MST Date:	January 1, 2020	
UTC Engines ON:	21:45	MST Engines ON:	2:45 pm	
UTC Engines OFF:	03:12	MST Engines OFF:	8:12 pm	
Total Time:	5:27	5.45hr	Flares Used:	48 BIP 305 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track MB-4. Arrived on track and found light to moderate SLW at 14kft. Our meteorologist asked us to begin firing EJ's at a rate of once per minute and start the usage of BIP flares. After a pass, our meteorologist asked us to remove the southernmost five miles of the track due to unfavorable conditions. We			



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WINTER AERIAL OPERATIONS 2019-2020

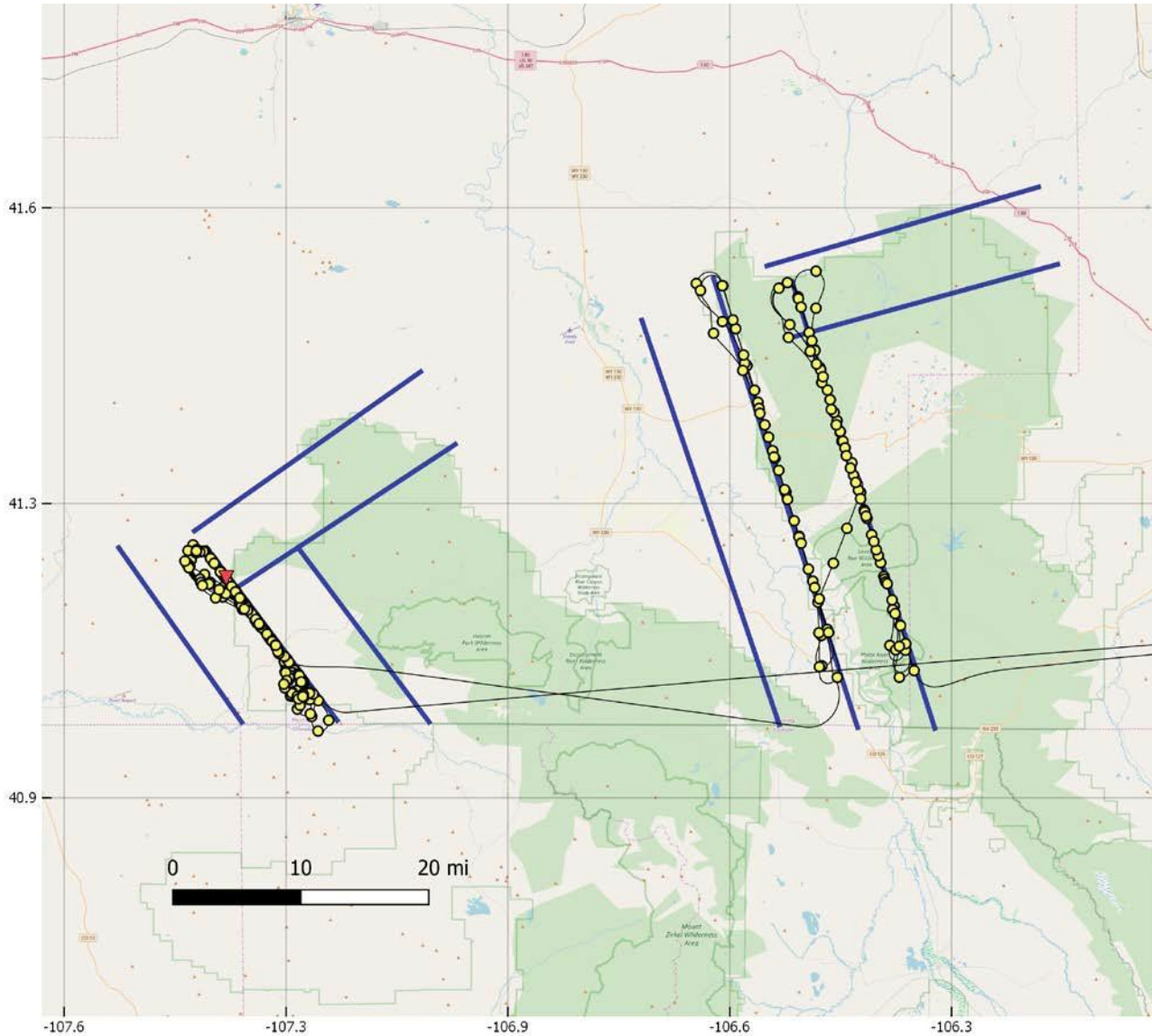
	<p>made passes along MB-4 for several hours, then our meteorologist asked us to increase EJ frequency to twice per minute due to moderate with pockets of light SLW. SLW lightened up so we reduced EJ rate to once per minute with about 10 minutes left on station. Due to expensing all seeding materials, we RTB.</p>
<p>Synoptic Analysis:</p>	<p>Jet level charts continue to show strong northwest flow with a potent jet streak pushing into the PACNW. A shortwave trough will pass through WY this evening, and multiple small lobes of vorticity are likely this afternoon, tonight, and tomorrow. Ridging is likely Thursday night and Friday. Another shortwave passes through on Saturday with limited moisture. PWAT is good today, around a quarter inch. The 700mb RH will remain saturated through tomorrow. Strong seeding level winds are creating excellent orographic lift and deep orographic clouds with some windows of very seedable clouds today and tomorrow. The best SLW is expected this afternoon, with a bit of a lull overnight, and then deep SLW again tomorrow afternoon and evening in any of the southern three ranges.</p>
<p>Area Forecast:</p>	<p>Seedable clouds will continue over the MB/SM through this evening. The SLW will be less favorable in the NS, but there is some. Clouds are not suitable in the LR, but it is suspended anyway. A seeding flight will occur this afternoon into the evening hours on the MB/SM ranges. Wind speeds on track will be around 50 kts from the WNW. Marginally seedable conditions may persist through the night, but crew will need to rest tonight. More seeding appears likely tomorrow afternoon and evening when the SLW becomes deep and continuous again. Nearly continuous snow accumulation will occur in the southern three ranges through tomorrow. Snow will taper off to flurries tomorrow night. Seeding is not expected tomorrow night or Friday. A moisture starved trough passes through on Saturday, but this does not look to be particularly favorable for seeding. We'll reevaluate later in the week as it gets closer.</p>
<p><i>Flight occurred in the afternoon to evening hours of Jan. 1st; weather information is from Jan. 1st.</i></p>	



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 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	11	SEED		
	Track(s)/Basin:	SM-4, MB-4, MB-5			
UTC Date:	January 2, 2020	MST Date:	January 2, 2020		
UTC Engines ON:	22:17	MST Engines ON:	3:17 pm		
UTC Engines OFF:	03:46	MST Engines OFF:	8:46 pm		
Total Time:	5:29	5.48hr	Flares Used:	1 BIP	291 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track SM-4. Once on track, we descended to 13kft and began picking up light to moderate SLW, all the while in cloud tops. Our meteorologist asked us to begin firing EJ's at a rate of twice per minute. We were also asked to remove the southernmost three miles of track from each pass. After about an				



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WINTER AERIAL OPERATIONS 2019-2020

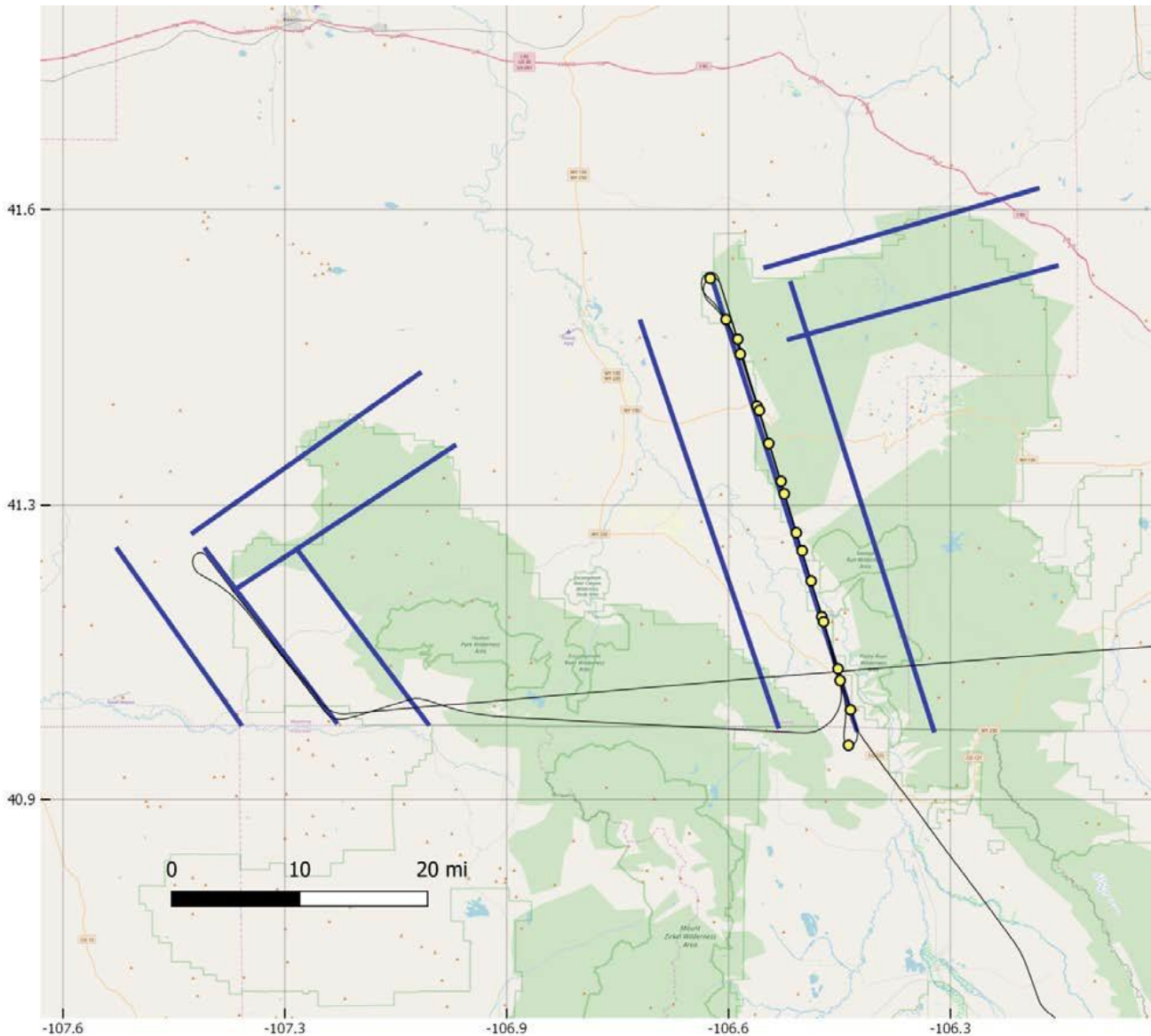
	<p>hour of seeding, we returned to EJ's at a rate of once per minute, as directed by our meteorologist. After about another hour, our meteorologist asked us to move to track MB-4. We arrived at MB-4 and resumed seeding with EJ's at a rate of once per minute. We removed the southern five miles of the track due to unfavorable conditions. After about 45 minutes on station, we were asked to investigate conditions on MB-5. We resumed seeding on MB-5. After a few passes, our meteorologist asked us to reduce EJ use to once every two minutes. As we found light SLW, our meteorologist asked us to increase EJ use to once per minute. Due to low fuel, we RTB.</p>
<p>Synoptic Analysis:</p>	<p>Jet level charts show a trough axis now east of the project and strong northwest flow aloft as a potent jet streak drifts from the PACNW into the Rockies. Ridging and dry conditions will take over later tomorrow. Until then, decent moisture remains in place through tomorrow afternoon. Favorable northwest winds are expected at seeding altitudes today and tomorrow, and thick orographic clouds will persist throughout the period into tomorrow morning. SLW will be deep enough for seeding at times. Midlevel temps will be warming steadily through tomorrow. The 700mb RH will remain saturated through around sunset tomorrow and then drops off sharply tomorrow evening. Midlevel vorticity will push through the region this afternoon, and a cold front will also pass through from west to east this evening.</p>
<p>Area Forecast:</p>	<p>Deep orographic clouds with seedable SLW are expected in the MB and SM ranges this afternoon and evening. A seeding flight is scheduled to depart shortly. Latest models runs indicate SLW will not be deep enough for a second flight overnight, though snow and clouds will remain. We will not rule out a possible late night flight at this time, as evening models may show better conditions tonight. We will wait to decide later this evening and update the crew. There is also a chance for a morning flight after sunrise tomorrow in the NS range. The chances for morning ops tomorrow will depend partly on whether we seed overnight in the SM/MB and pilot rest requirements. SLW does not appear to be extensive enough for ops in the MB/SM tomorrow, but some orographic clouds and snow are likely until sunset. Dry conditions are expected under the transient ridge tomorrow night into Saturday. A shortwave pushes through the region late Saturday into Sunday, but this system looks somewhat moisture-starved, and only a slight chance of weekend seeding is apparent for now.</p>
<p><i>Flight occurred in the afternoon to evening hours of Jan. 2nd; weather information is from Jan. 2nd.</i></p>	



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N23MN	OPS #:	12	SEED		
	Track(s)/Basin:	MB-4			
UTC Date:	January 6, 2020	MST Date:	January 5, 2020		
UTC Engines ON:	00:57	MST Engines ON:	5:57 pm		
UTC Engines OFF:	02:47	MST Engines OFF:	7:47 pm		
Total Time:	1:50	1.83hr	Flares Used:	0 BIP	18 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track SM-4. Made one pass along SM-4 before being asked to move to MB-4. Arrived on station and began seeding with EJ's. After a few passes we were asked to move to track NS-2. Arrived on track and made a recon pass. Due to lack of seedable targets and the request of radar, we returned to base				



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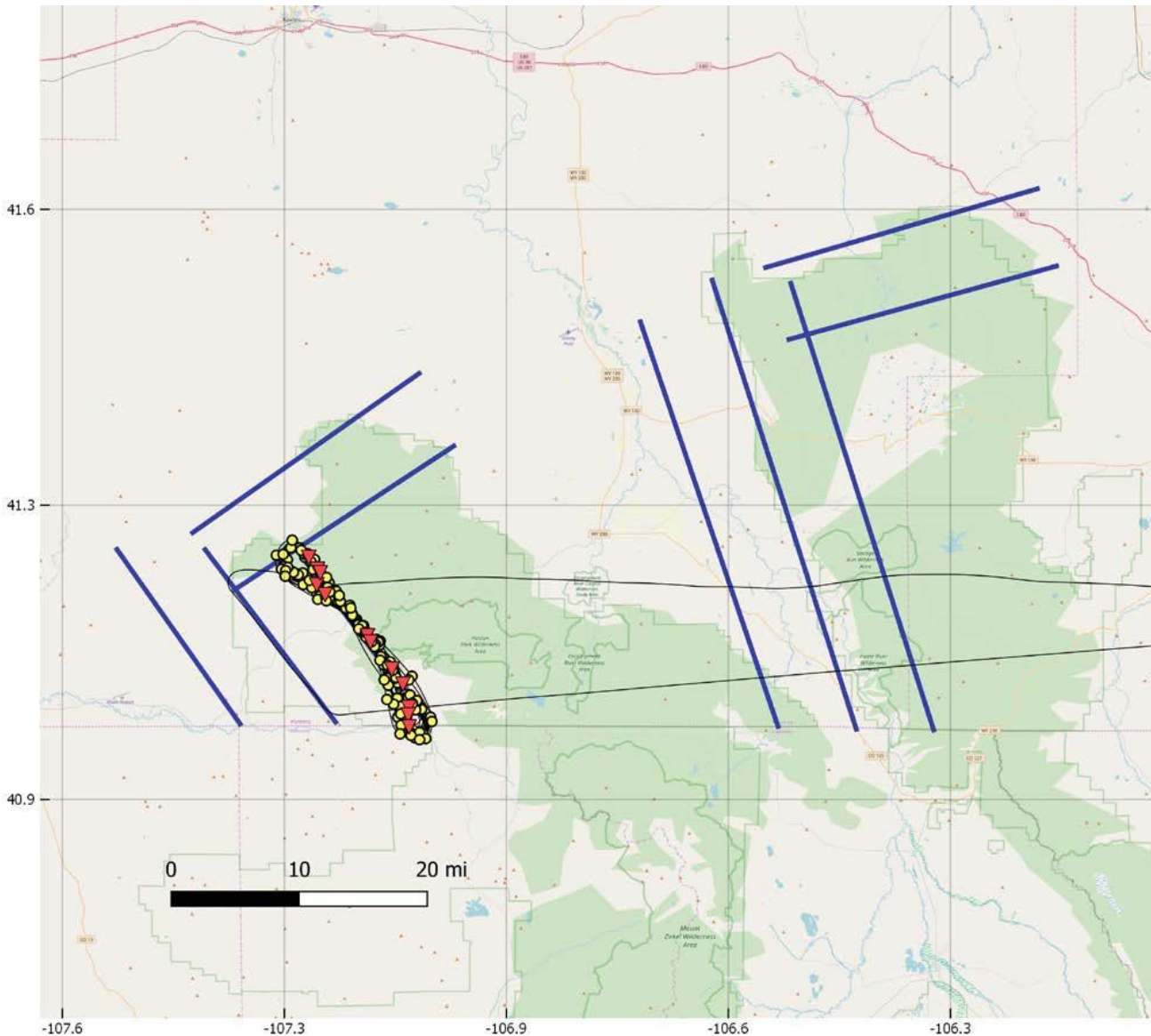
	Cheyenne.
Synoptic Analysis:	An active but less amplified pattern has taken shape across the CONUS, with considerably cooler mid-level temperatures compared to 24-hours ago. A shortwave trough is progressing into Wyoming at the time of the forecast, bringing synoptic scale lift and a weak push of moisture across our region later this afternoon and evening. This incoming system has already brought thicker mid-level clouds to S. WY along with a few menial orographic clouds, with the peak moisture expected in the vicinity of the trough axis passage in the 3-6 UTC time this evening. NVA behind the trough axis will dampen low-level moisture briefly in the middle of the night, before a second smaller scale trough cuts through the northwest flow and enhances orographic lift again early Monday morning. Unsettled northwest flow persists into Tuesday, though moisture wanes.
Area Forecast:	Increasing low- and mid-level moisture is already bringing increased cloud cover across S. WY and will further increase in the coming hours. Synoptic scale precipitation accumulation will be insignificant this forecast period, though higher SWE totals up to around a quarter inch are possible over the SM, NS, and MB ranges. While precipitation should not play a factor in flight operations from CYS, high winds might, with wind gusts increasing through the night up to 50kts Monday morning. A high wind warning has been issued from 3 UTC tonight through 15 UTC Tuesday. Orographic clouds will gradually wane through the day Monday, but perturbed northwest flow continues into Tuesday. Meager moisture will continue to reside in the low- and mid-levels, with at least shallow orographic cloud cover persisting.
<i>Flight occurred in evening hours of Jan. 5th; weather information is from Jan. 5th.</i>	



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WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	13		SEED	
	Track(s)/Basin:			SM-5	
UTC Date:	January 12, 2020		MST Date:	January 12, 2020	
UTC Engines ON:	09:15		MST Engines ON:	2:15 am	
UTC Engines OFF:	14:13		MST Engines OFF:	7:13 am	
Total Time:	4:58	4.97hr	Flares Used:	12 BIP	168 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track SM-4. Arrived on station but immediately moved to SM-5. Began seeding with EJ's, eventually adding BIP's. EJ dispersal rate varied between once per minute and once every two minutes. Eventually we ceased BIP usage and stuck to EJ's. After several hours on station, low fuel forced us to RTB.				



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WINTER AERIAL OPERATIONS 2019-2020

Synoptic Analysis:	A longwave trough pattern remains in place over the Rockies with shortwave impulses moving through the flow into the region from the northwest for at least the next few days. Midlevel vorticity will be pushing through the project region today through this evening. Another wave passes through on Monday, and yet another on Tuesday. PWAT will be modest, but enough for some periods of targetable SLW at times between midlevel snowfall bands. 700mb RH remains saturated through at least Monday. A cold air mass will be in place by this evening with 500mb temps bottoming around -33C late tonight and then warming a few degrees tomorrow. Winds at seeding altitudes will be westerly around 35kts through tomorrow morning. While SLW and orographic clouds look to persist through the next 48 hours, the best windows for targeting look to be late tonight and then again tomorrow evening.
Area Forecast:	Snowfall will occur in the SM/MB/NS throughout the period while the LR has only marginal clouds. With midlevel clouds and natural ice crystals this afternoon and evening, the low level SLW will be intermittent through midnight. The natural seeder-feeder snowfall diminishes overnight, and SLW improves during the late night hours, likely allowing for a seeding window in the MB/SM ranges. SLW will drop off again by morning allowing for pilot rest tomorrow morning and afternoon. Another window for ops looks likely tomorrow evening into the late night hours. Based on current model runs, the cloud depth does not look deep enough for seeding the NS range today or tomorrow, though this might improve in later models so we will keep an eye on it. For now, operations are planned for the MB/SM late tonight with only a single flight expected, and then we will reevaluate the situation tomorrow morning for possible additional flight/s later tomorrow.

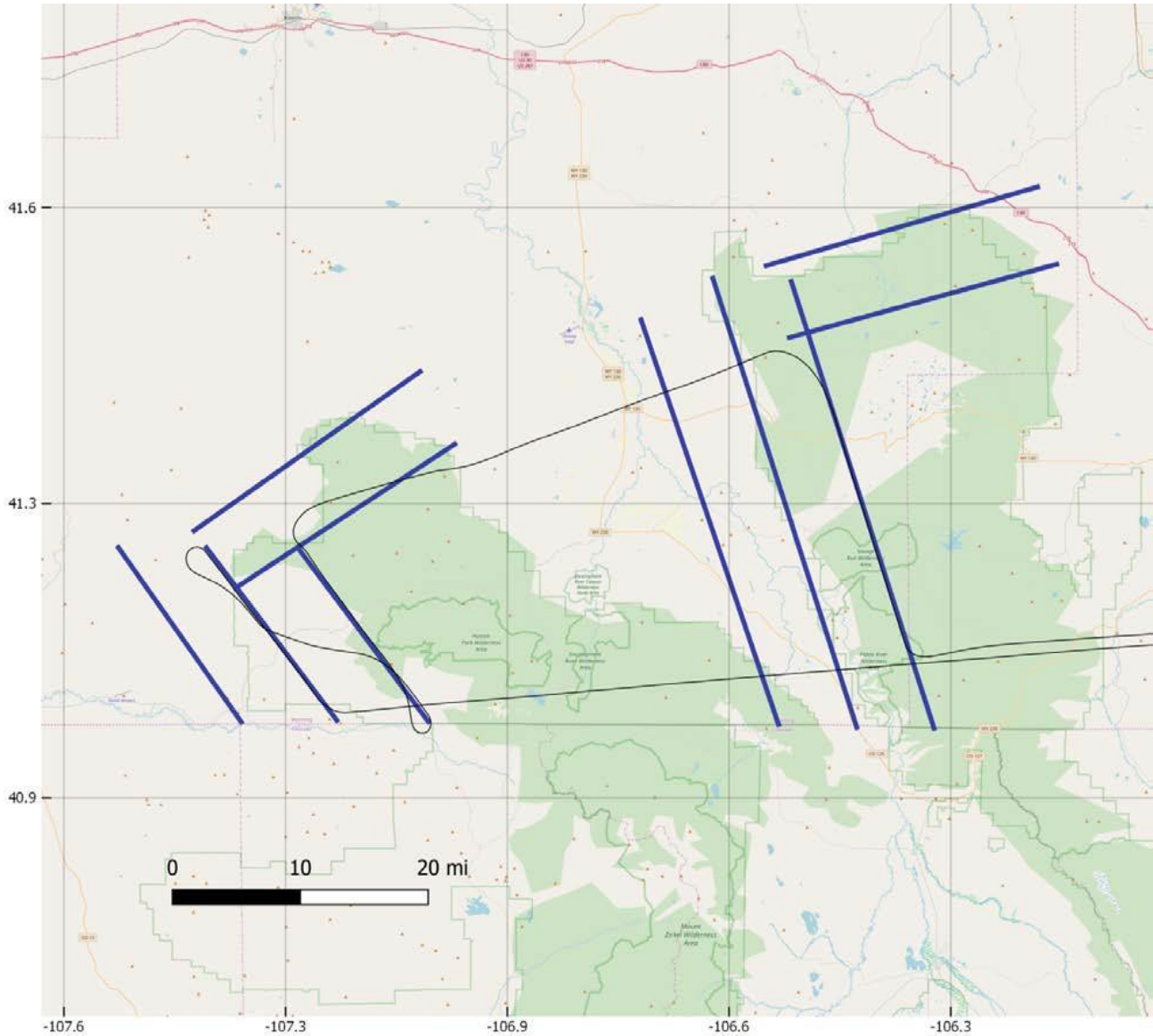
Flight occurred in the morning hours of Jan. 12th; weather information is from Jan. 11th.



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	14	RECON		
	Track(s)/Basin:	SM-4, SM-5, MB-5			
UTC Date:	January 13, 2020	MST Date:	January 12, 2020		
UTC Engines ON:	03:12	MST Engines ON:	8:12 pm		
UTC Engines OFF:	04:57	MST Engines OFF:	9:57 pm		
Total Time:	1:45	1.75hr	Flares Used:	0 BIP	0 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track SM-4. Upon arrived we were requested by our meteorologist to move to SM-5 for possible better conditions. Unable to find seedable targets so we were requested to move to MB-5. Also unable to find seedable targets there, so for this reason and by request of our meteorologist, we RTB.				



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

<p>Synoptic Analysis:</p>	<p>The longwave trough pattern over the Rockies will continue most of the week while a large ridge remains over the Pacific. Several more shortwaves will push through in this flow over the next two days. Midlevel vorticity pushes through Monday, and then another impulse pushes through Tuesday night. The flow will become zonal on Wednesday. Moisture remains marginal with a cold airmass in place. However, the low level RH and wind speeds have been enough to create at least a few periods of targetable SLW with continuous thick orographic clouds. Last night's flight saw seeding level temps of around -17C, but excellent SLW was still observed. Temps are recovering this morning with the 500mb temps around -27C to -30C today and tonight. Flight level winds will remain westerly today and tonight around 40-45 kts. The NS will see only patchy shallow SLW throughout the period. The MB/SM will see some periods of deeper targetable SLW while the LR will not be seedable at any point.</p>
<p>Area Forecast:</p>	<p>Continuous snowfall is expected in the ranges throughout the period with alternating periods of orographic driven snowfall and some midlevel waves. The best SLW for seeding looks to be during the late evening through late night hours in the MB/SM. A flight appears likely this evening, probably in the SM where we can get somewhat lower. A cold airmass is in place, and temps at seeding altitudes are definitely on the cold side, but this doesn't seem to be a major issue as the SLW is still there. SLW looks shallower and more intermittent tomorrow, so seeding appears unlikely. Beyond this evening, the next chance for a flight might be early Tuesday morning, but we do not have to nail that down yet so we will mostly focus on today and tonight for now.</p>

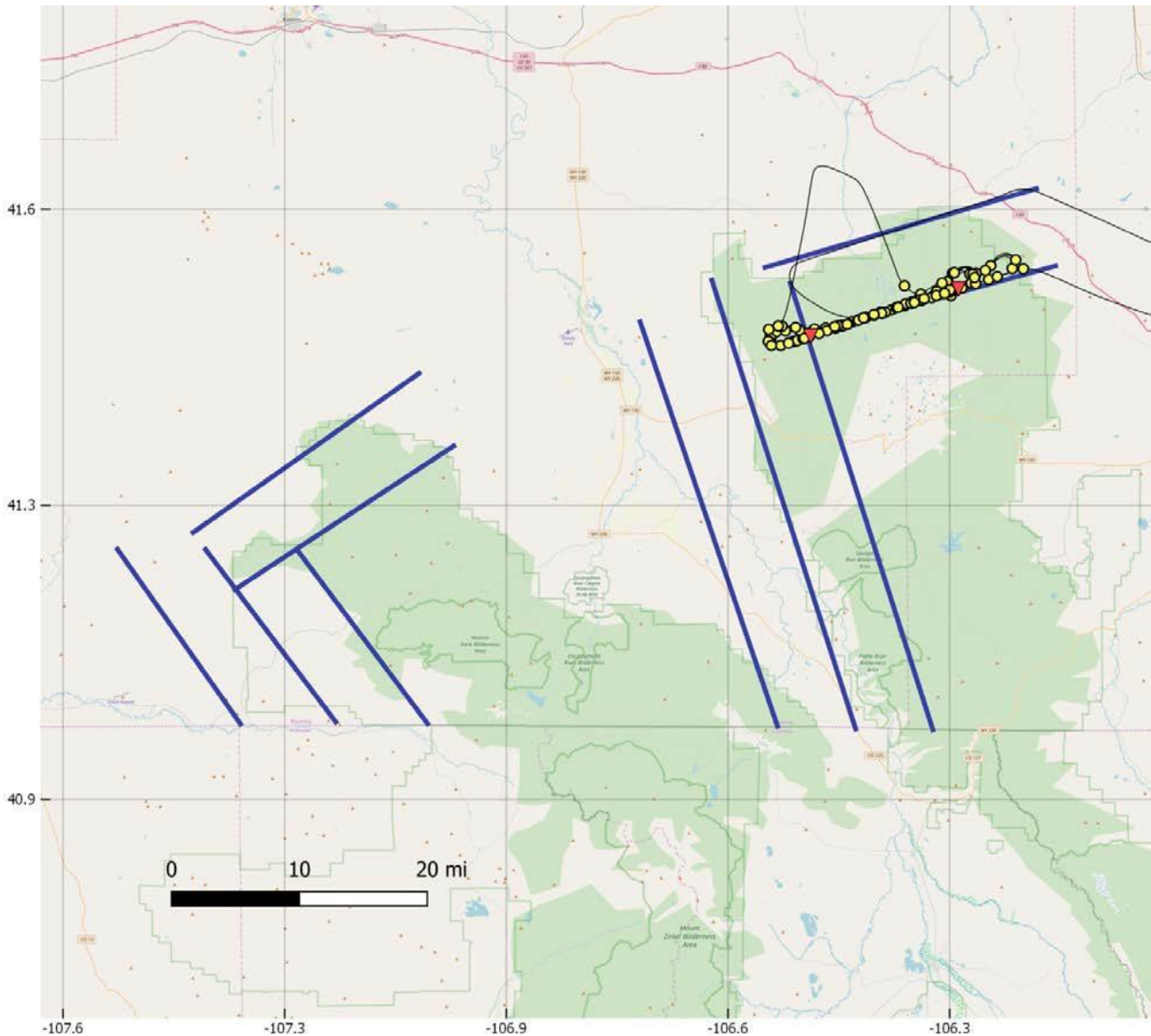
Flight occurred in the evening hours of Jan. 12th; weather information is from Jan. 12th.



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	15	SEED		
	Track(s)/Basin:	MB-1, MB-2			
UTC Date:	January 30, 2020		MST Date:	January 30, 2020	
UTC Engines ON:	23:21		MST Engines ON:	4:21 pm	
UTC Engines OFF:	02:18		MST Engines OFF:	7:18 pm	
Total Time:	2:57	2.95hr	Flares Used:	2 BIP	92 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track MB-1. Moved after one pass to a modified MB-2 track and began the use of BIP's and EJ's, as directed by our meteorologist. Made passes for several hours along track, with EJ rates varying between once per minute and once every two minutes. Lack of seedable targets and a request from radar forced us to RTB.				



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WINTER AERIAL OPERATIONS 2019-2020

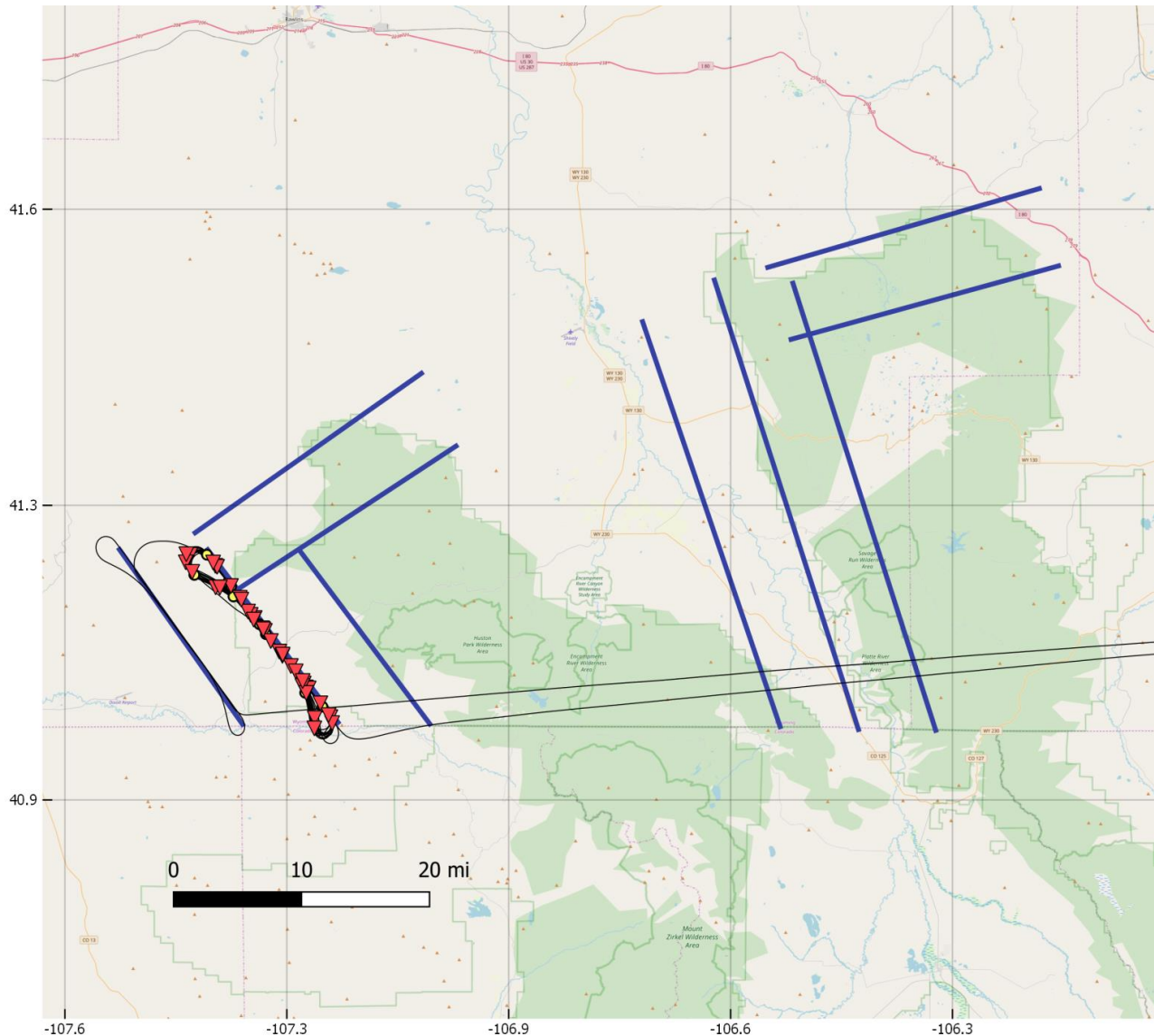
<p>Synoptic Analysis:</p>	<p>Jet level charts show moderate NW flow aloft and an approaching jet streak expected to bring strong northerly flow to WY this evening and tonight. Shortwave energy will push eastward through the target ranges this afternoon through early evening bringing widespread snowfall. A wave of low level moisture continues flowing through the area until around 3z this evening, and then dry air invades overnight through the weekend. PWAT has dropped off as midlevel moisture has decreased. However the low level 700mb RH remains elevated through early evening. Seeding level winds are stronger today at around 40 kts from the NNW and orographic lift is substantial. A large scale ridge will move in tomorrow through Sunday bringing generally dry clear warm conditions and potentially record setting high temps in some areas. The next major storm will arrive late Sunday into Monday when a potent digging trough pushes into the Rockies from the NW.</p>
<p>Area Forecast:</p>	<p>Decent SLW is expected in the MB and NS ranges today. The northerly winds will make NS seeding difficult due to the terrain on the norther side of the NS range and the minimum seeding altitudes of around 16kft if we were to try to target the range in this wind direction. This will preclude NS seeding because modeled SLW is not deep enough to target from that high. Seeding of the MB range looks possible beginning around 00z with a few hours of deep SLW. Winds and SLW will favor the MB1 track on the north side of the target area which is uncommon. We will schedule a flight for 23:30z this afternoon. This will not be an extended flight, but a few hours of good seeding conditions are likely. We will be targeting the last few hours of the good low level moisture wave that is pushing through, and as the moisture wanes around 3z, the clouds will thin out quickly this evening and overnight. Low IFR conditions are likely at CYS this afternoon, expected to improve right around departure time. However, if airport conditions take longer to improve than forecast, we will likely scrap the flight because the seeding window is not particularly long to begin with. Dry warm conditions are likely tomorrow through Sunday, and then the next chance for seeding will be Sunday night through Monday with a powerful colder system.</p>
<p><i>Flight occurred in the evening hours of Jan. 30th; weather information is from Jan. 30th.</i></p>	



WYOMING WEATHER MODIFICATION Medicine Bow, Sierra Madre, and Laramie Mountains (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #: 16		SEED		
	Track(s)/Basin:		SM-3, SM-4		
UTC Date:	February 8, 2020		MST Date:	February 8, 2020	
UTC Engines ON:	20:58		MST Engines ON:	1:58 pm	
UTC Engines OFF:	02:05		MST Engines OFF:	7:05 pm	
Total Time:	5:07	5.12hr	Flares Used:	39 BIP	8 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track SM-3. Light SLW crossing the ridge. Arrived on station but were directed to move to SM-4 to check conditions. Began seeding with BIP's upon arriving on track. SLW was excellent on this track. As SLW increased, we were instructed to begin seeding with EJ's at a rate of once every two minutes. SLW proved inconsistent, however, so we discontinued use of EJ's soon after. Continued				



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

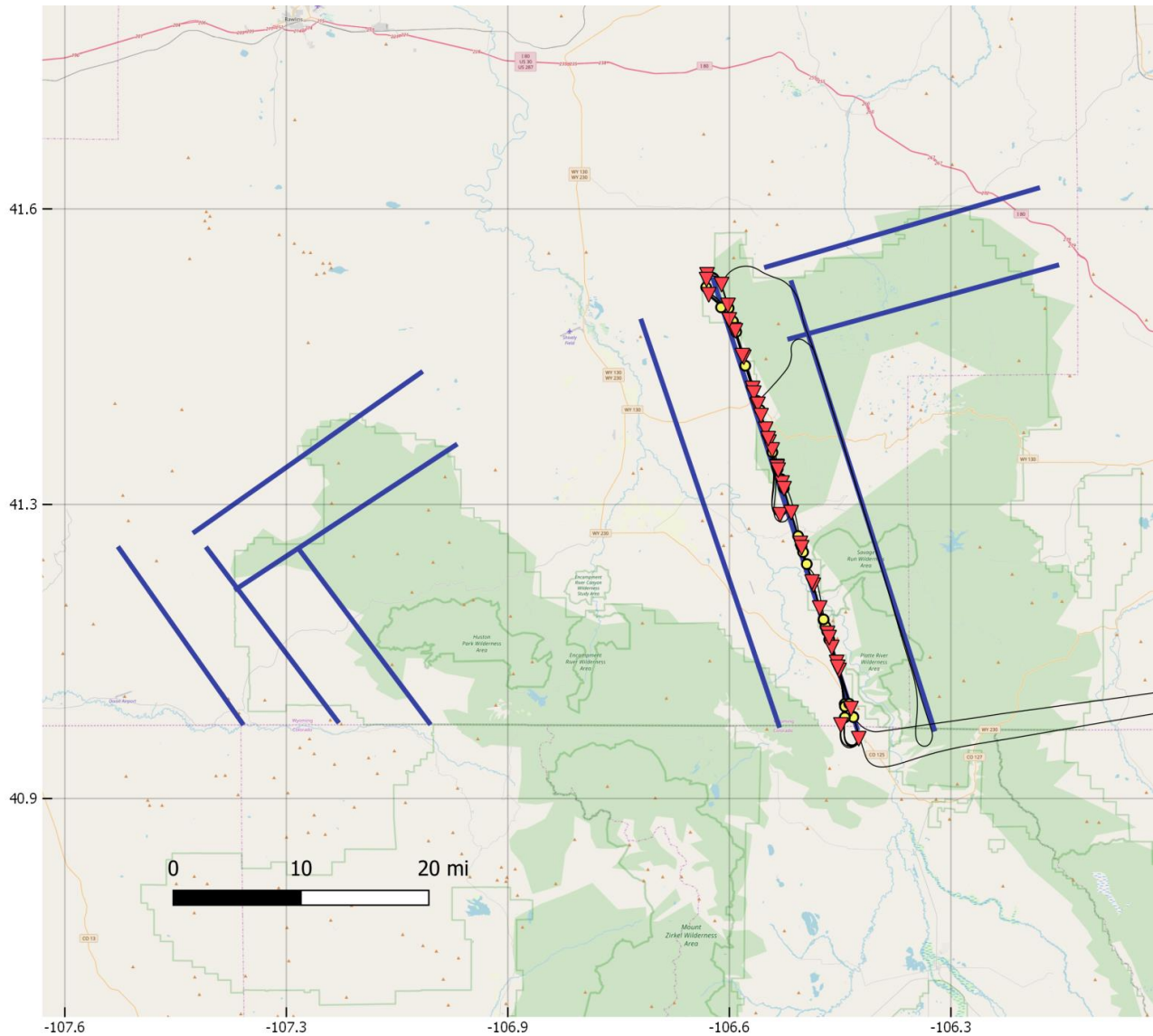
	<p>seeding with BIP's for several hours until SLW waned and lack of seedable targets prevailed. Due to this, radar requested we RTB.</p>
<p>Synoptic Analysis:</p>	<p>Jet level charts continue to show strong NW flow aloft through early evening. Later this evening, upper level winds will become moderate and westerly as a trough moves through the region. Midlevel charts show westerly flow and potent vorticity moving through this afternoon and evening. Another trough will glance our area late Monday. Lower levels continue to show good moisture flowing through the region today, and then low level RH will drop steadily after dawn tomorrow. Winds at seeding altitudes are strong westerlies, around 50 knots through this evening and then becoming light and variable by morning. A cold front will push through the region during the late afternoon and early evening hours. As the front passes through, deep targetable SLW is expected for about 4 hours, and then SLW will drop off rapidly behind the front.</p>
<p>Area Forecast:</p>	<p>The last wave of snowfall with this system will occur this afternoon into the evening hours as a cold front transits the region. Deep targetable SLW will exist around 22Z-02Z lasting for only a few hours, but it looks quite good. Both the SM and MB ranges look to be targetable, but we have chosen the SM for an afternoon mission. SLW drops off later this evening, and then only shallow orographic clouds and stratus are expected overnight into tomorrow morning. Clouds will continue to erode tomorrow as moisture wanes and partial clearing is likely during the day tomorrow. Mostly clear conditions are likely by tomorrow night as low level RH drops to around 30% by Monday morning. The next chance for snowfall looks to be a light system Monday evening/night, but this system has light moisture, and winds look to be unfavorable for seeding. Chances for seeding late Monday are poor, but not completely ruled out yet. Tuesday through Thursday look to be dry, and then another light system moves in on Friday followed by a more robust system next weekend.</p>
<p><i>Flight occurred in the afternoon to evening hours of Feb. 8th; weather information is from Feb. 8th.</i></p>	



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 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	17	SEED		
	Track(s)/Basin:	MB-4, MB-5			
UTC Date:	February 15, 2020	MST Date:	February 14, 2020		
UTC Engines ON:	03:08	MST Engines ON:	8:08 pm		
UTC Engines OFF:	08:05	MST Engines OFF:	1:05 am		
Total Time:	4:57	4.95hr	Flares Used:	40 BIP	31 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track MB-4. Arrived on station but repositioned to MB-5 shortly after. Moved back to MB-4 after confirming the presence of SLW on MB-5. Then began seeding with BIP's on a modified MB-4 track. After several passes, we were able to begin seeding along the entire track. After a couple of hours we began seeding with EJ's as requested by our meteorologist. Eventually, lack of seedable				



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WINTER AERIAL OPERATIONS 2019-2020

	<p>targets prevailed and radar asked us to RTB.</p>
<p>Synoptic Analysis:</p>	<p>Jet level charts show a small ridge exiting the region this afternoon while the ranges are under mostly clear skies. By late afternoon, a moisture-starved trough will be approaching with a small band of moisture expected this evening. The best vorticity advection with this passing wave looks to stay north of the target ranges this evening allowing for some decent SLW in the orographic clouds. A cold front will push through the ranges from late afternoon through early evening. Winds at seeding altitudes will be strong westerlies this evening around 50 kts, and orographic lift will be favorable for targetable SLW for a short window from 3-8z. The trough exits by late evening, and then we will be under strong NW flow for the weekend with some minor lobes of vorticity and good moisture advection. Excellent orographic lift and favorable moisture will create some periods of deep seedable SLW Saturday evening through Sunday morning in all ranges.</p>
<p>Area Forecast:</p>	<p>Skies will be mostly clear for the afternoon, and then clouds will increase rapidly by early evening as the small wave of moisture and cold front approach. This will be a quick-hitter system with only a few hours of snowfall and deep cloud expected. A 3 to 4 hour seeding window looks likely for the MB range this evening, and a flight is scheduled. Conditions do not look favorable for seeding in any other range, though the NS is close. Snow accumulation will be light this evening, lasting only a few hours. Clouds will diminish overnight with no chance of seeding tonight through dusk tomorrow evening. Excellent moisture and impressive SLW are likely tomorrow evening through tomorrow night. One seeding flight looks quite likely tomorrow evening into the late night hours, and there is some potential for a second flight early Sunday morning as well. There will be minimal midlevel snowfall which will allow for heavy SLW at times as this will be a mostly orographic event. Another trough moves through Sunday and Monday bringing widespread snowfall to the region and possible seeding windows (but more natural efficiency).</p>
<p><i>Flight occurred in the evening hours of Feb. 14th; weather information is from Feb. 14th.</i></p>	



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WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	18	SEED		
	Track(s)/Basin:	MB-3			
UTC Date:	February 16, 2020	MST Date:	February 16, 2020		
UTC Engines ON:	13:19	MST Engines ON:	6:19 am		
UTC Engines OFF:	18:31	MST Engines OFF:	11:31 am		
Total Time:	5:12	5.2hr	Flares Used:	28 BIP	151 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to a modified MB-3 track. Light SLW crossing the ridge at 20kft. Began seeding with BIP's almost immediately, while starting EJ's approximately 20 minutes after arriving. Alternated rolling BIP's with EJ's every minute and a half, and EJ's more frequent with no BIP's for several hours. Occasional light to moderate SLW present on track for some of flight. Made passes on track until low fuel forced us to				



WYOMING WEATHER MODIFICATION
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WINTER AERIAL OPERATIONS 2019-2020

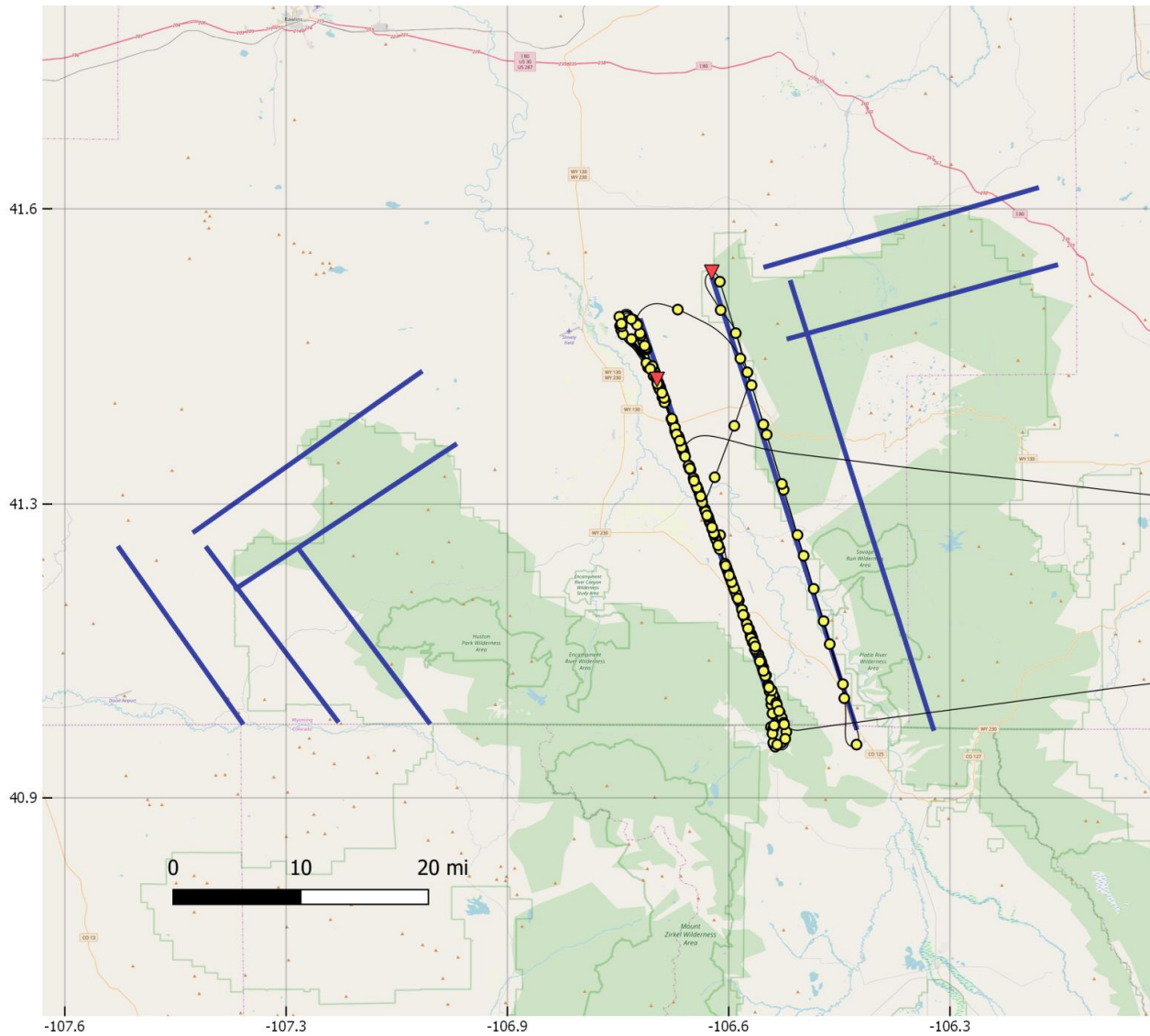
	RTB.
Synoptic Analysis:	<p>This is a major winter storm for the mountains. Jet level charts show a trough exiting to the east while a northwesterly jet will be in place over WY through morning becoming westerly later tomorrow. Midlevel charts show minimal forcing through 24 hours other than some minor vorticity lobes late tonight and tomorrow. Low level charts show excellent moisture flowing into the region this evening through Monday. We look to be under a moist northwest or westerly flow with good orographic winds this evening through Monday. A trough passes through Monday into Monday night with potent vorticity. Moisture wanes on Tuesday behind the trough with colder and lighter northerly flow aloft. A small shortwave is expected Wednesday with only minor moisture, and then ridging is likely late in the week with drier conditions expected. A cold front will sweep through the region Sunday evening. Winter Storm Warning</p>
Area Forecast:	<p>Marginal low clouds are likely through this evening along with increasing upper level cloud cover throughout the period. Deep impressive SLW and thick orographic clouds will develop around midnight and persist through Monday. There will be an extended period of excellent seedable cloud with periods of heavy SLW tonight through Monday. With such a broad window for seeding, we will need to schedule our flights carefully to target the best conditions and optimize pilot duty day. The current plan is to forego seeding late tonight and begin operations on the MB/SM around dawn tomorrow. A second flight looks likely following the morning flight tomorrow. The MB/SM look quite good for most of the day tomorrow until around sunset, and then the NS looks decent late tomorrow night. Winds at seeding altitudes will be nearly due west around 55kts for tomorrow's seeding windows. Heavy snow accumulation is expected in the mountains tonight through Monday afternoon. This will be mostly orographic in the mountains tonight. Conditions at CYS look mainly VFR tonight and most of tomorrow as the bulk of the first part of this storm ahead of the trough is confined to the mountains. CYS conditions will likely deteriorate late in the storm with the midlevel forcing and widespread snowfall Monday.</p>
<p><i>Flight occurred in the morning hours of Feb. 16th; weather information is from Feb. 15th.</i></p>	



WYOMING WEATHER MODIFICATION Medicine Bow, Sierra Madre, and Laramie Mountains (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #: 19		SEED		
	Track(s)/Basin:		MB-3, MB-4		
UTC Date:	February 16, 2020		MST Date:	February 16, 2020	
UTC Engines ON:	20:20		MST Engines ON:	1:20 pm	
UTC Engines OFF:	02:45		MST Engines OFF:	7:45 pm	
Total Time:	6:25	6.42hr	Flares Used:	2 BIP	204 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track MB-3. Began seeding with EJ's almost immediately after arriving on track. Briefly moved to MB-4, but determined MB-3 would be better due to winds. Throughout the mission, occasional light SLW was found on most passes. After several hours of seeding, low fuel forced us to RTB. Moderate SLW crossing the ridge going home.				



WYOMING WEATHER MODIFICATION
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(with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

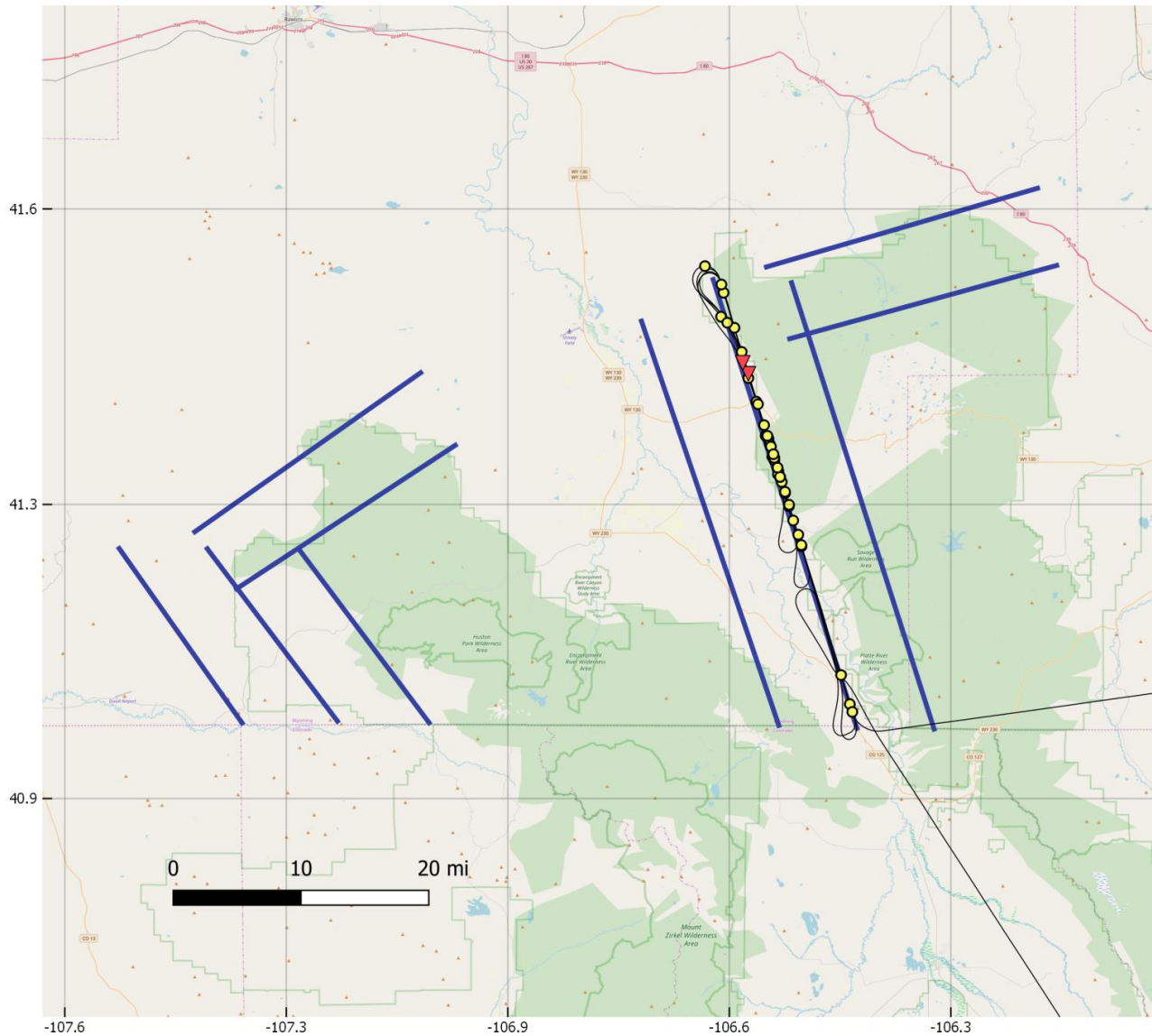
Flight occurred in the afternoon to evening hours of Feb. 16th; weather information remains the same as MBSMLR Ops. #18.



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 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	20		SEED	
	Track(s)/Basin:	MB-4			
UTC Date:	March 10, 2020		MDT Date:	March 10, 2020	
UTC Engines ON:	17:58		MDT Engines ON:	11:58 am	
UTC Engines OFF:	19:57		MDT Engines OFF:	1:57 pm	
Total Time:	1:59	1.98hr	Flares Used:	2 BIP	39 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track MB-4. Initially began seeding with BIP's, but switched to EJ's shortly after due to convection. Made several passes firing EJ's when in suitable conditions. Altitudes varied due to ATC restrictions. After roughly an hour and a half on station we were asked to move to NS-2. Arrived on station and began firing EJ's. Continued firing EJ's at a rate of once per minute for several hours until low fuel				



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WINTER AERIAL OPERATIONS 2019-2020

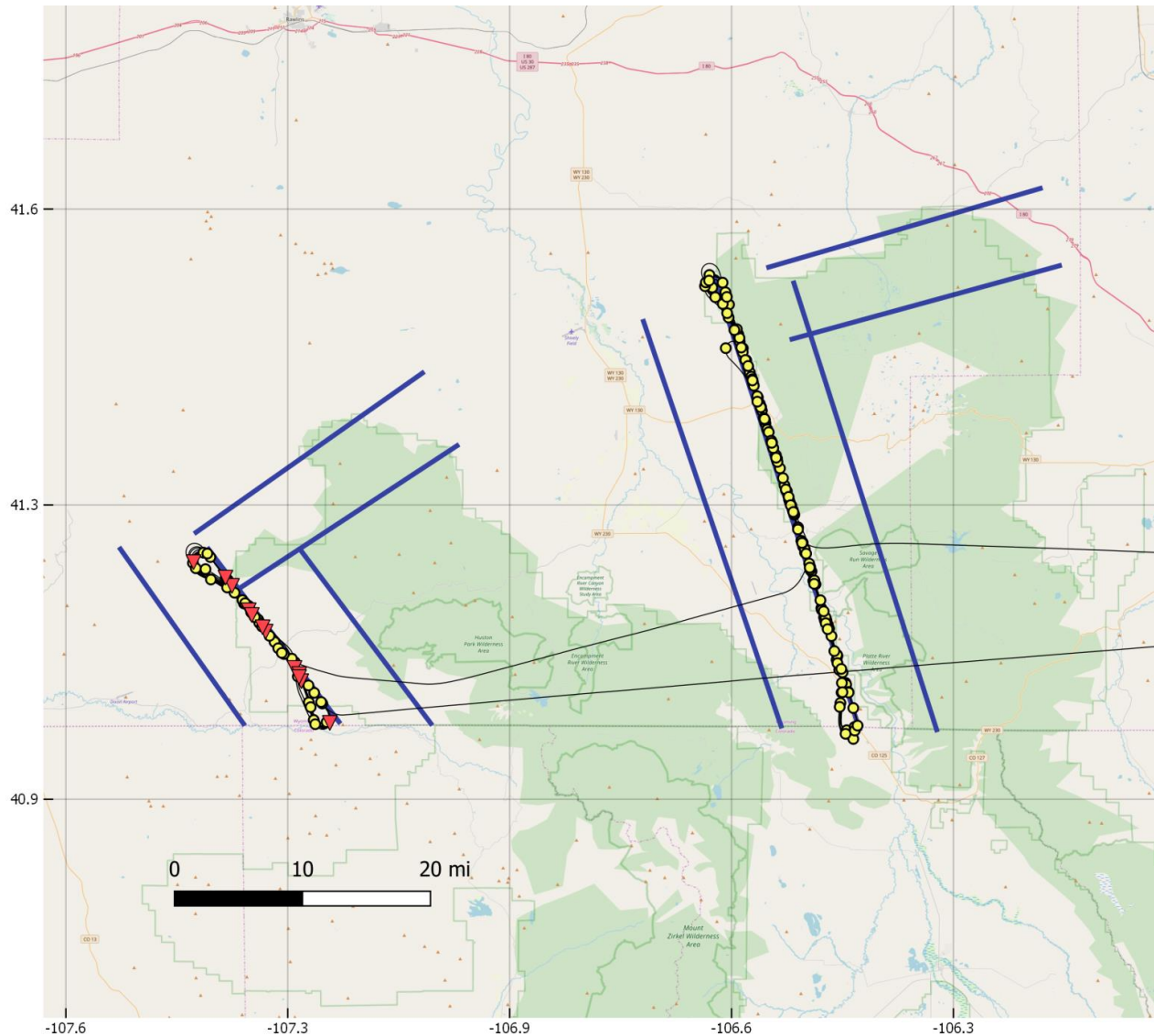
	forced us to RTB.
Synoptic Analysis:	<p>The upper jet core is well south of WY, and we are under moderate westerly flow today. A deep low is in place along the California coast. The low will remain quasi stationary along the coast, meandering southeastward for the next several days. Late in the week, Thursday-Friday, the low will finally push eastward through the Desert Southwest, but timing of this is difficult for now. Total moisture will be increasing throughout the period, however 700mb RH will dip slightly during the afternoon, becoming saturated again after dusk. Decent moisture lingers through tomorrow. Seeding level winds will be westerly around 35-40 kts through tomorrow. A shortwave will push through tomorrow afternoon along with a cold front. Another trough glances the region Wednesday night into Thursday, but the best dynamics will stay to the north. Longer range models show a potent low pushing southward into the Great Basin over the weekend.</p>
Area Forecast:	<p>Marginal orographic clouds and flurries are in place at forecast time, but they will erode throughout the day as RH wanes. Orographic clouds return this evening, increasing through the night as moisture continues to improve, but SLW looks too patchy for seeding throughout the period. Light snowfall is expected overnight. Moderate snowfall is likely during the day tomorrow with some periods of deeper SLW, but with the shortwave pushing through, it will be mixed with ice crystals from midlevel snow. There looks to be a slight chance for seeding during the day tomorrow, but latest model runs do not show an obvious window with consistent deep SLW. We will leave the chance for ops in place during the day Tuesday and update in the morning with later model runs. Another round of brief snowfall is likely Wednesday night into early Thursday morning. As the offshore low pushes through the Desert Southwest Thurs-Fri, seeding is not expected. A period of heavy precipitation is expected this weekend into early next week with the next incoming low from the northwest. This looks to be a better setup for seeding.</p>
<p><i>Flight occurred in the afternoon hours of Mar. 10th; weather information is from Mar. 9th.</i></p>	



WYOMING WEATHER MODIFICATION Medicine Bow, Sierra Madre, and Laramie Mountains (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	21	SEED		
UTC Date:	March 25, 2020	MDT Date:	March 25, 2020		
UTC Engines ON:	12:26	MDT Engines ON:	6:26 am		
UTC Engines OFF:	18:26	MDT Engines OFF:	12:26 pm		
Total Time:	6:00	6hr	Flares Used:	12 BIP	167 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track SM-4. Moderate SLW crossing the ridge. Began seeding with BIP flares after finding light SLW. Eventually switched to EJ's at a rate of once every ninety seconds. Descended as necessary on track to stay in good seeding conditions. After a couple hours on track we were asked to move to MB-4 by our meteorologist. Resumed seeding with EJ's once on track. Continued for several				



WYOMING WEATHER MODIFICATION
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WINTER AERIAL OPERATIONS 2019-2020

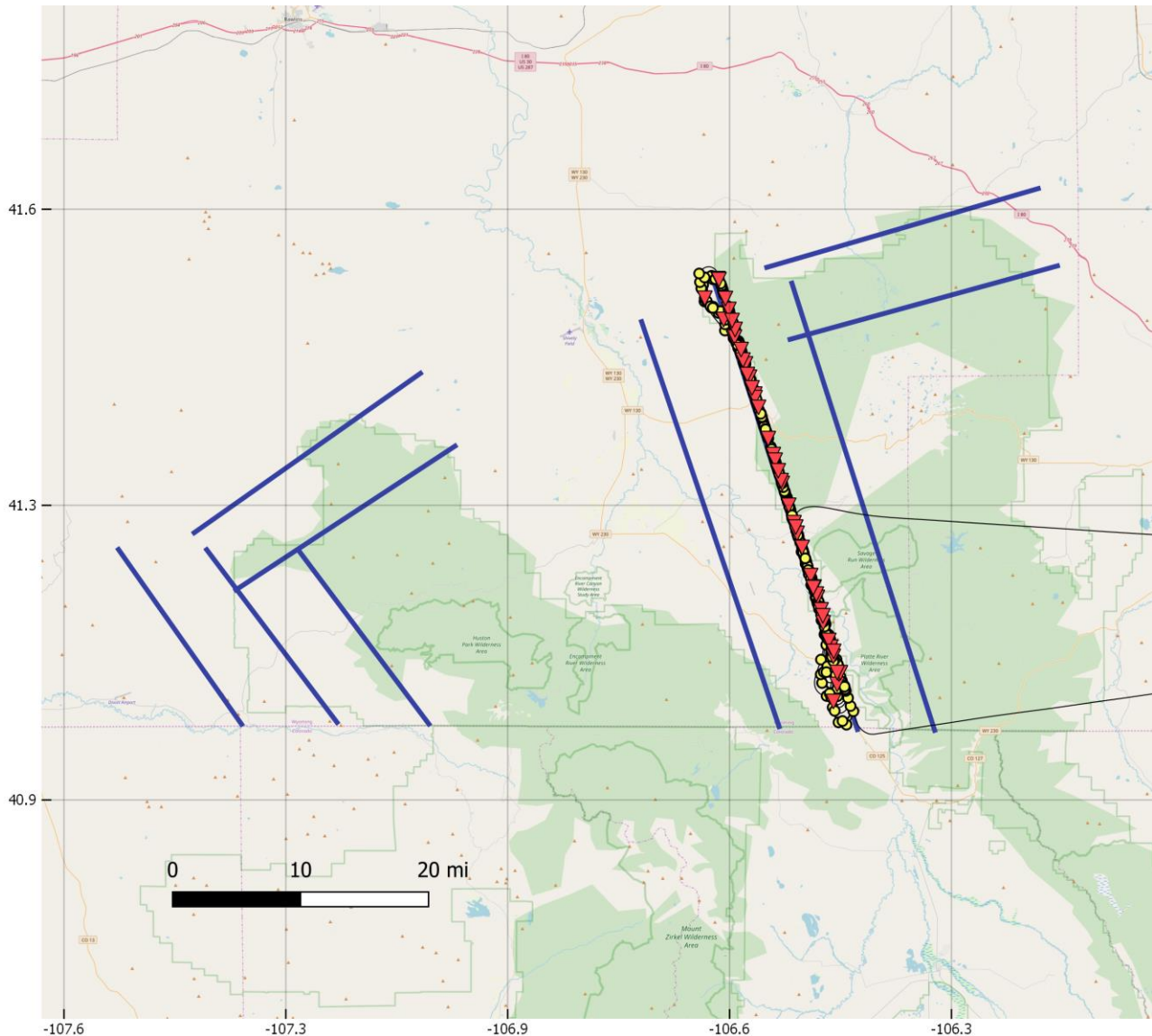
	hours on track until low fuel forced us to RTB.
Synoptic Analysis:	The coming few days will see a slowly evolving system. Upper level charts show a westerly jet streak over the Four Corners region and moderate westerly flow aloft over WY early in the period. The jet streak will shift northward throughout the period, and westerly winds aloft will increase by tomorrow morning from the SW. A large trough is moving onshore over the PACNW this morning, and midlevel vorticity lobes will push through our region this evening through Friday as the trough slowly shifts southeastward. Some weak CAPE is expected this evening and tonight. Moisture increases throughout the afternoon and remains elevated for the next several days. Seeding level winds will be SW around 45 kts during the day, increasing to 65 kts tonight. A cold front pushes through early tomorrow morning from the north.
Area Forecast:	Intermittent showers are likely throughout the day, and then orographic snowfall and marginal orographic clouds are expected this evening and tonight. There will be some periods of deep SLW. However, with the higher wind speeds, the SLW will not extend far enough upwind to the high speed seeding tracks, which means there would be an issue with fall-out time. A band of heavy precipitation passes through with the cold front around 12Z in the morning. Behind the front, SLW will be lighter but may extend further upwind of the peaks. There are no obviously extended periods of good SLW behind the front, but that is probably our next best chance for anything targetable. For now, we will rule out seeding through dawn tomorrow, and then we might see a chance of seeding later the day tomorrow.
<i>Flight occurred in the morning hours of Mar. 25th; weather information is from Mar. 24th.</i>	



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Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	22		SEED	
	Track(s)/Basin:	MB-4			
UTC Date:	April 15, 2020		MDT Date:	April 15, 2020	
UTC Engines ON:	11:22		MDT Engines ON:	5:22 am	
UTC Engines OFF:	17:24		MDT Engines OFF:	11:24 am	
Total Time:	6:02	6.03hr	Flares Used:	48 BIP	302 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to a modified MB-4 track. Light SLW crossing the ridge. Began seeding with EJ's immediately after arriving on track. Shortly after, we began seeding with BIP's as well. Seeded for several hours along this track, only having to change altitude once. Several areas of light SLW were found along track as flight progressed. Eventually we had expended all available seeding materials and were low in				



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WINTER AERIAL OPERATIONS 2019-2020

	fuel, so we RTB.
Synoptic Analysis:	A highly amplified ridge lingers along the west coast of the US and Canada. Strong NNW flow from Alaska is flowing through BC and into WY today with a jet streak nosing into our region tonight. A broad trough pattern remains over the Upper Midwest and the Great Lakes. Midlevel charts show a shortwave trough in British Columbia this morning which will impact WY tomorrow and Thursday with potent PVA. An unusually cold dry air mass is in place for this time of year with near record lows recorded last night. Temps aloft will be rising slowly through tomorrow evening, and PWAT will gradually improve through tomorrow as well. 700mb RH finally becomes saturated just before dawn tomorrow morning and remains so through tomorrow night. Weak shallow instability is likely today and tomorrow. A cold front passes through our region tomorrow afternoon from the north. With strong forcing, good moisture and a cold air mass in place, a major winter storm is on tap for tomorrow and Thursday with heavy widespread snow accumulation likely across the region.
Area Forecast:	Scattered cumulus and weak convective showers are expected this afternoon, but nothing remotely seedable through late tonight due to poor low level RH and no targetable SLW. Deep orographic clouds will develop just before dawn, and model cross-sections indicate some light but targetable SLW over the MB. A seeding flight is planned for MB4 to begin seeding around 5am MDT. By midday tomorrow, instability and convection are likely along with continued orographic clouds. Depending on the intensity of these convective elements, a second seeding flight could be possible during the afternoon tomorrow, but only if convection is very light. Due to the convective nature of the activity tomorrow afternoon, SLW is intermittent yet quite seedable at times. Deeper more consistent SLW and orographic precipitation are likely tomorrow evening and through the night after the convective threat subsides. However, CYS conditions are expected to deteriorate in the evening hours which will likely preclude evening or late night flights. Heavy snow accumulation is expected in Cheyenne tomorrow night and Thursday.
<i>Flight occurred in the morning hours of Apr. 15th; weather information is from Apr. 14th.</i>	

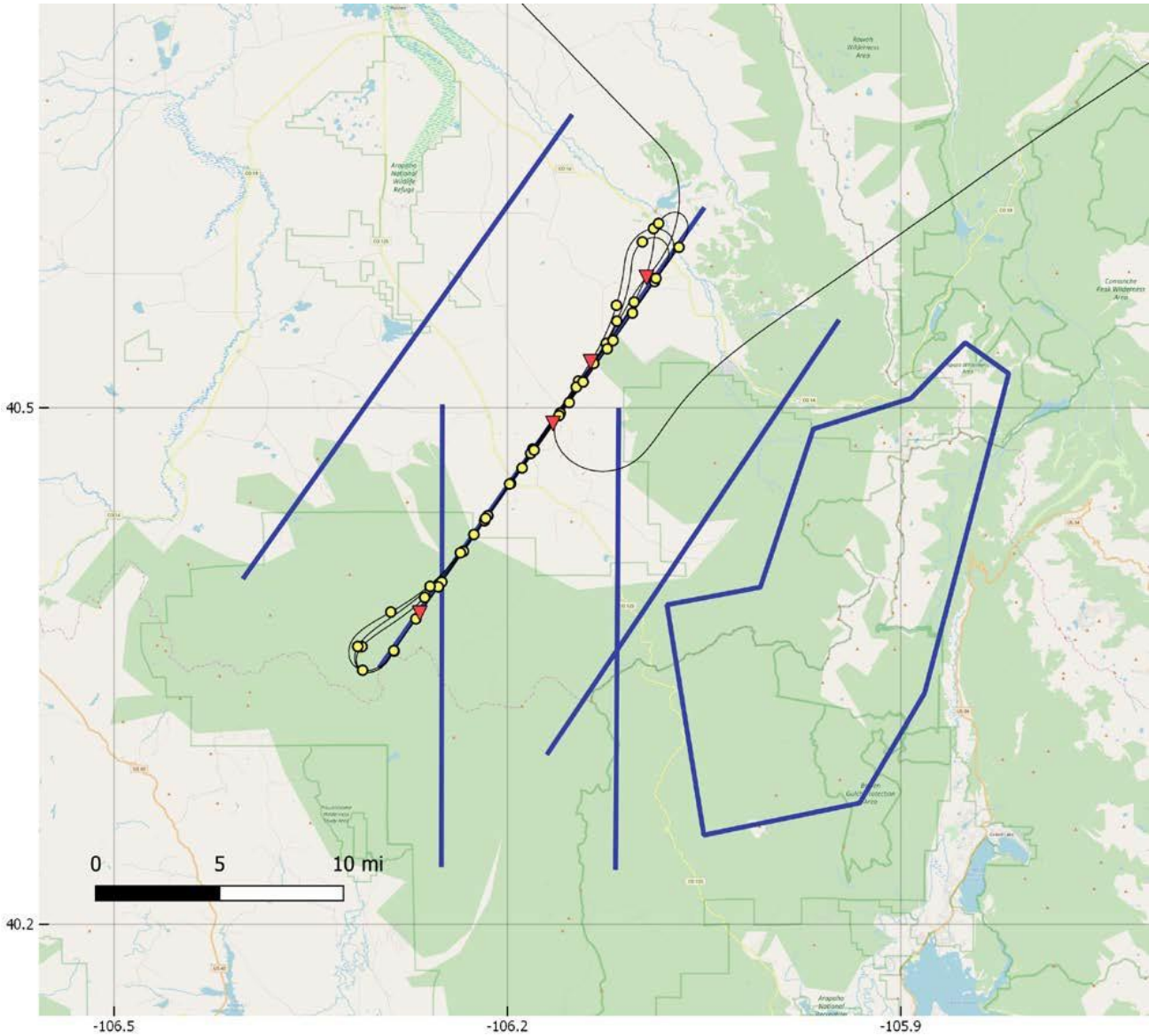


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 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

5.2 Mission Flight Tracks – Never Summer Range, CO



N23MN	OPS #:	01		SEED	
	Track(s)/Basin:	NS-2			
UTC Date:	January 1, 2020		MST Date:	January 1, 2020	
UTC Engines ON:	17:56		MST Engines ON:	10:56 am	
UTC Engines OFF:	19:15		MST Engines OFF:	12:15 pm	
Total Time:	1:19	1.32hr	Flares Used:	4 BIP	44 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track MB-3. No SLW crossing ridge at 22kft. Arrived on station and found light SLW at 18kft. Began firing EJ's at a rate of once per minute and BIP's as directed by the meteorologist. After 15 minutes, we descended to 17kft				



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

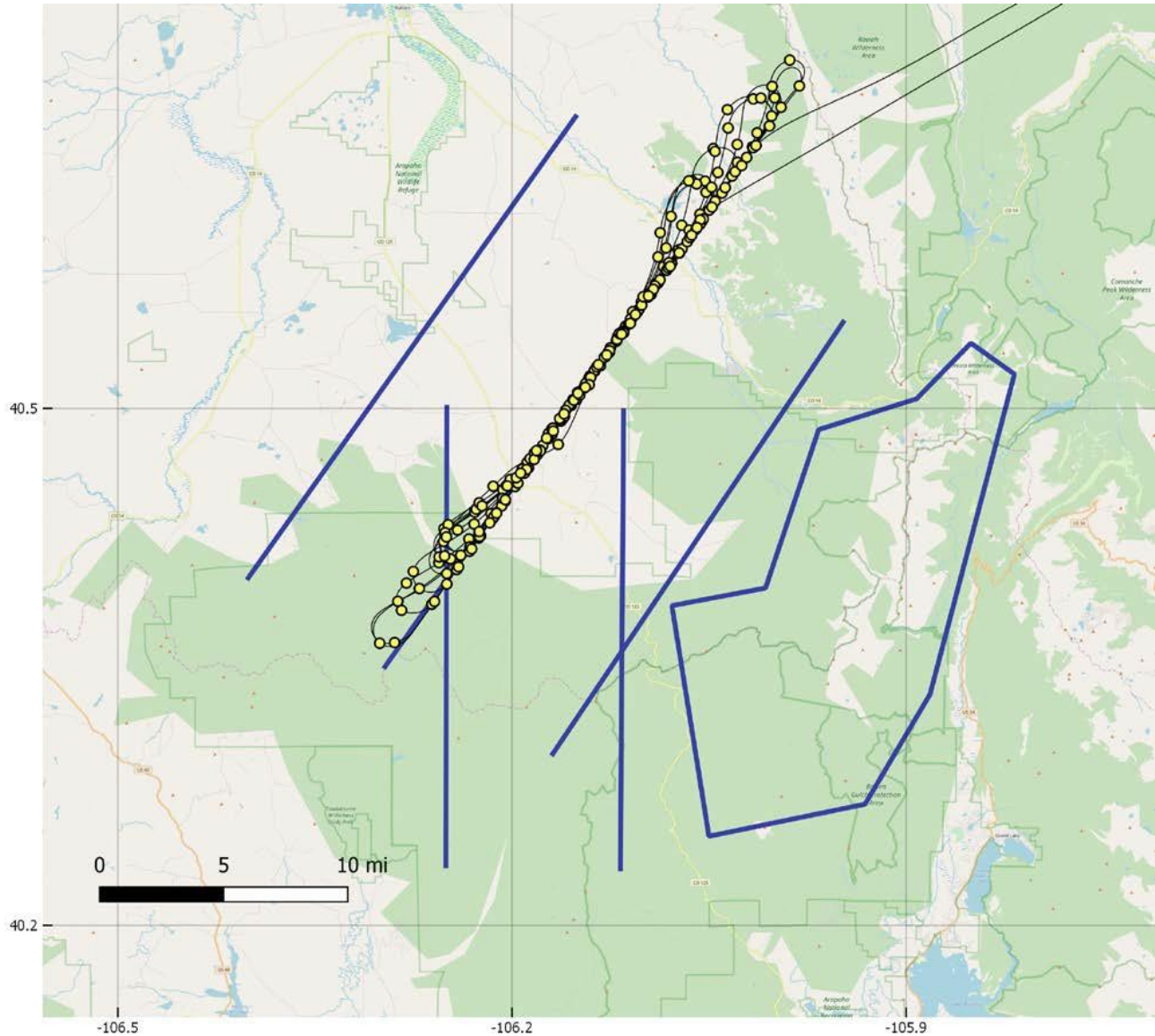
	<p>to check conditions. We gradually climbed back up to 18.5kft due to spots of heavy SLW increasing our airframe icing rate. After about an hour of seeding, we increased our EJ rate to once every 45 seconds. As SLW weakened, we gradually descended to 16.5kft. We found some light SLW but conditions deteriorated so we moved to track NS-2. Arrived on station and resumed dropping EJ's at a rate of once per minute and BIPs as directed by the meteorologist. We descended to 16kft and made several more passes with EJ's, discontinuing the use of BIP's. Due to lack of seedable targets, we RTB.</p>
<p>Synoptic Analysis:</p>	<p>A Baja low lingers to our south while a strong jet streak noses into the PACNW. Northerly flow aloft will become northwesterly today, and PWAT will be on the rise. 700mb RH is only around 60% at forecast time, but it will rise throughout the day becoming saturated by around midnight. Midlevel warming is occurring today, and 500mb temps will climb to -15C by midnight. Winds at seeding altitudes will be around 35 kts at midnight, increasing to around 50 kts later tonight. Orographic lift will be favorable tonight. Deep orographic clouds are expected late tonight through tomorrow with good SLW. Lobes of midlevel vorticity will pass through late tonight into tomorrow creating some intervals of deep midlevel cloud and natural seeder-feeder ice crystals from above. This will deplete low level SLW at times, but we should be able to work around it, targeting the better periods of SLW. This pattern will continue through Thursday evening, and then moisture wanes on Friday and Saturday as a ridge moves into the Rockies.</p>
<p>Area Forecast:</p>	<p>Partly clear skies are expected this afternoon, and then orographic clouds and deep upper cloud layers will move in overnight with periods of targetable SLW. The SM and MB ranges appear favorable for ops perhaps as early as midnight tonight. The NS becomes favorable closer to dawn. There will be waves of midlevel clouds and ice crystals as the deeper more widespread snowfall bands push through from midlevel forcing. We will attempt to seed between these waves while also managing pilot duty day limitations. More seedable clouds are expected tomorrow into tomorrow night. We may be able to get a flight later tomorrow depending on how extensively we utilize the pilot crew overnight into tomorrow morning. Heavy mountain snowfall is expected tonight through tomorrow. Conditions at CYS look to be favorable for ops through the night according to the latest TAFs. Flurries are expected Friday, but seeding looks unlikely. Dry conditions return Saturday.</p>
<p><i>Flight occurred in the morning to afternoon hours of Jan. 1st; weather information is from Dec. 31st.</i></p>	



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	02		SEED	
	Track(s)/Basin:	NS-2			
UTC Date:	January 3, 2020		MST Date:	January 3, 2020	
UTC Engines ON:	18:35		MST Engines ON:	11:35 am	
UTC Engines OFF:	22:12		MST Engines OFF:	3:12 pm	
Total Time:	3:37	3.62hr	Flares Used:	0 BIP	212 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track NS-2. Upon arriving on station, we started seeding with EJ's twice per minute. After about an hour we decreased EJ rate to once per minute. We descended to remain in the cloud tops until we were eventually above them. We modified our track as necessary, shortening the southern end and adding track to the northern end. Due to lack of seedable targets, the meteorologist requested				



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

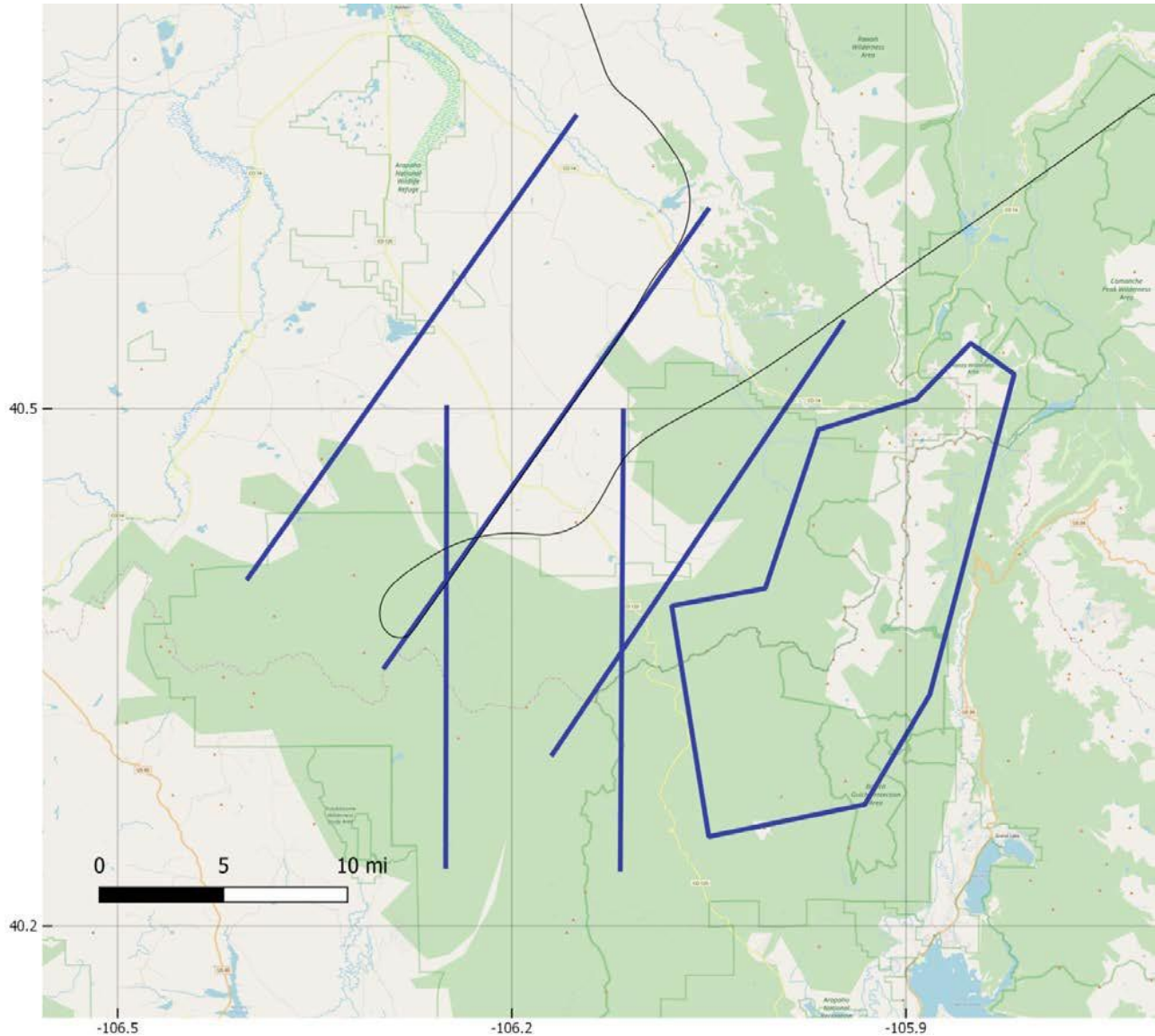
	we RTB.
Synoptic Analysis:	Jet level charts show a trough axis now east of the project and strong northwest flow aloft as a potent jet streak drifts from the PACNW into the Rockies. Ridging and dry conditions will take over later tomorrow. Until then, decent moisture remains in place through tomorrow afternoon. Favorable northwest winds are expected at seeding altitudes today and tomorrow, and thick orographic clouds will persist throughout the period into tomorrow morning. SLW will be deep enough for seeding at times. Midlevel temps will be warming steadily through tomorrow. The 700mb RH will remain saturated through around sunset tomorrow and then drops off sharply tomorrow evening. Midlevel vorticity will push through the region this afternoon, and a cold front will also pass through from west to east this evening.
Area Forecast:	Deep orographic clouds with seedable SLW are expected in the MB and SM ranges this afternoon and evening. A seeding flight is scheduled to depart shortly. Latest models runs indicate SLW will not be deep enough for a second flight overnight, though snow and clouds will remain. We will not rule out a possible late night flight at this time, as evening models may show better conditions tonight. We will wait to decide later this evening and update the crew. There is also a chance for a morning flight after sunrise tomorrow in the NS range. The chances for morning ops tomorrow will depend partly on whether we seed overnight in the SM/MB and pilot rest requirements. SLW does not appear to be extensive enough for ops in the MB/SM tomorrow, but some orographic clouds and snow are likely until sunset. Dry conditions are expected under the transient ridge tomorrow night into Saturday. A shortwave pushes through the region late Saturday into Sunday, but this system looks somewhat moisture-starved, and only a slight chance of weekend seeding is apparent for now.
<i>Flight occurred in the afternoon to evening hours of Jan. 3rd; weather information is from Jan. 2nd.</i>	



WYOMING WEATHER MODIFICATION
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 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	03			RECON
	Track(s)/Basin:	NS-2			
UTC Date:	January 6, 2020		MST Date:	January 5, 2020	
UTC Engines ON:	02:47		MST Engines ON:	7:47 pm	
UTC Engines OFF:	03:31		MST Engines OFF:	8:31 pm	
Total Time:	0:44	0.73hr	Flares Used:	0 BIP	0 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track SM-4. Made one pass along SM-4 before being asked to move to MB-4. Arrived on station and began seeding with EJ's. After a few passes we were asked to move to track NS-2. Arrived on track and made a recon pass. Due to lack of seedable targets and the request of radar, we RTB.				



WYOMING WEATHER MODIFICATION
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WINTER AERIAL OPERATIONS 2019-2020

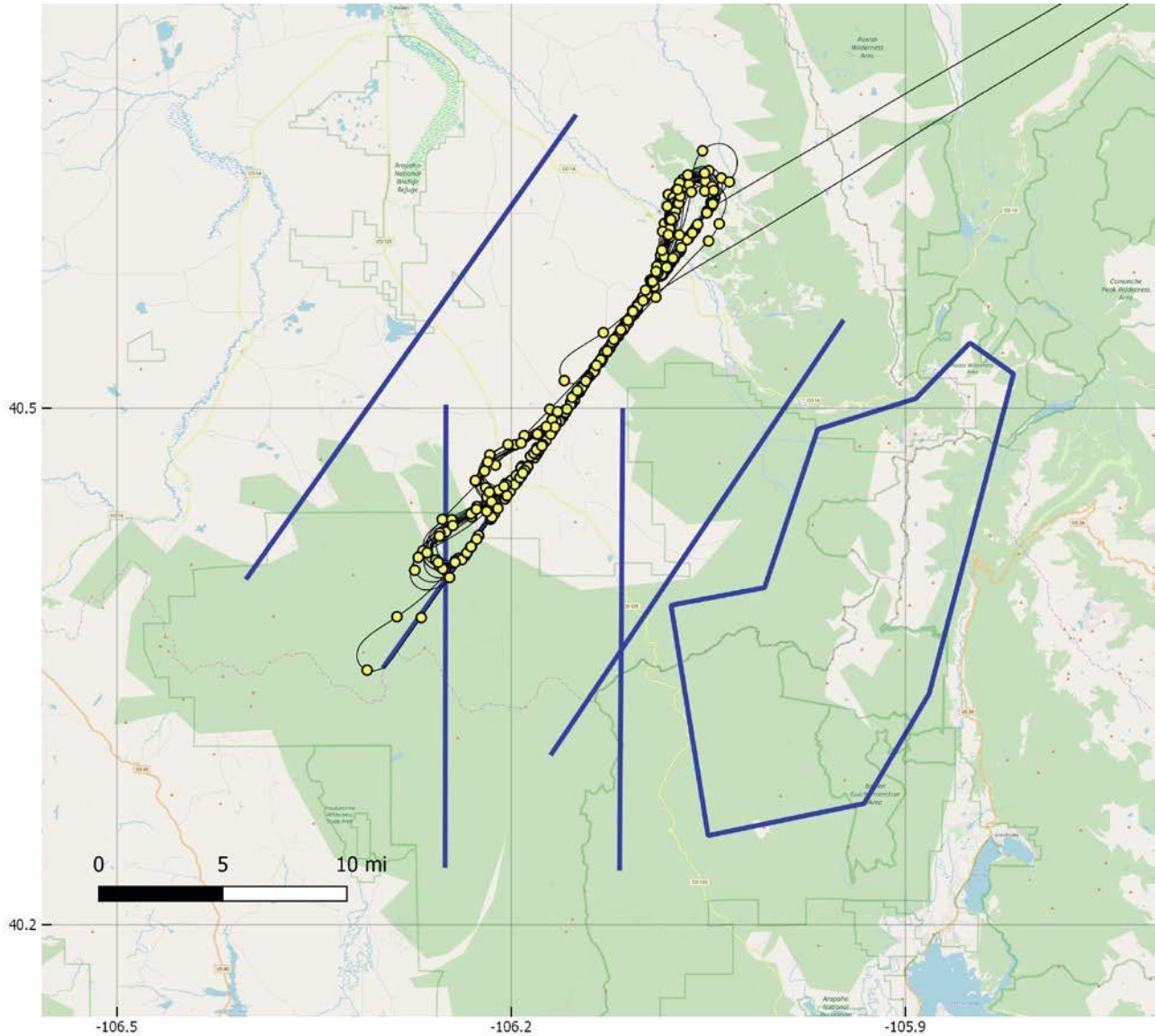
<p>Synoptic Analysis:</p>	<p>An active but less amplified pattern has taken shape across the CONUS, with considerably cooler mid-level temperatures compared to 24-hours ago. A shortwave trough is progressing into Wyoming at the time of the forecast, bringing synoptic scale lift and a weak push of moisture across our region later this afternoon and evening. This incoming system has already brought thicker mid-level clouds to S. WY along with a few menial orographic clouds, with the peak moisture expected in the vicinity of the trough axis passage in the 3-6 UTC time this evening. NVA behind the trough axis will dampen low-level moisture briefly in the middle of the night, before a second smaller scale trough cuts through the northwest flow and enhances orographic lift again early Monday morning. Unsettled northwest flow persists into Tuesday, though moisture wanes.</p>
<p>Area Forecast:</p>	<p>Increasing low- and mid-level moisture is already bringing increased cloud cover across S. WY and will further increase in the coming hours. Synoptic scale precipitation accumulation will be insignificant this forecast period, though higher SWE totals up to around a quarter inch are possible over the SM, NS, and MB ranges. While precipitation should not play a factor in flight operations from CYS, high winds might, with wind gusts increasing through the night up to 50kts Monday morning. A high wind warning has been issued from 3 UTC tonight through 15 UTC Tuesday.</p> <p>Orographic clouds will gradually wane through the day Monday, but perturbed northwest flow continues into Tuesday. Meager moisture will continue to reside in the low- and mid-levels, with at least shallow orographic cloud cover persisting.</p>
<p><i>Flight occurred in evening hours of Jan. 5th; weather information is from Jan. 5th.</i></p>	



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	04		SEED	
	Track(s)/Basin:	NS-2			
UTC Date:	January 22, 2020		MST Date:	January 22, 2020	
UTC Engines ON:	10:21		MST Engines ON:	3:21 am	
UTC Engines OFF:	16:21		MST Engines OFF:	9:21 am	
Total Time:	6:00	6hr	Flares Used:	0 BIP	306 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track NS-2. Light to moderate SLW crossing the ridge. Arrived on station and began seeding with EJ's at a rate of once per minute, as directed by our meteorologist. Additionally, we were asked to remove the southern 5 miles of track by our meteorologist. After several hours, winds changed and we removed the southern 8 miles of track. After a couple more hours we had expended				



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

	all our EJ's. This and low fuel forced us to RTB.
Synoptic Analysis:	The project area lies in a broad area of perturbed southwest flow, devoid of any broadscale forcings with a shortwave trough passing through the four-corners area and a subtle shortwave ridge in Montana. Appreciable Pacific moisture has accompanied the southwest flow, however, with the morning RIW sounding showing precipitable water at 0.36". Current satellite and webcam imagery shows a thick layer of mid-level cloudiness across much of WY and CO, with orographic enhancement evident in the NS, MB, and SM ranges. Flight level winds will slowly pivot northwest this forecast period as the four-corners trough lifts into far southern Colorado, and low-level moisture appears to increase enough for at least a chance for effective seeding operations aftermidnight.
Area Forecast:	Thick mid-level cloudiness will become broken this afternoon but will persist through the remainder of the day and into tonight. Light southwesterly flow continues to promote orographic cloudiness and occasional light snow over the peaks, but remains too light and shallow for operations in the MB and SM ranges at least until tomorrow morning. The NS range, closest to the moisture and forcing accompanying the shortwave trough to our south, stands he best chance for operations late tonight as the trough approaches. A glancing blow of PVA and moisture moves across the southern WY ranges Wednesday morning from a negatively tilted trough sliding by to our north, bringing a conditional chance for a seeding opportunity in those ranges before midafternoon. Dry air then infiltrates the mid-levels by tomorrow evening, with strong NVA accompanying a building ridge across the Great Basin. This ridge will stagnate the upper level pattern across the CONUS, and leave our area in a relatively benignweather pattern through Friday.

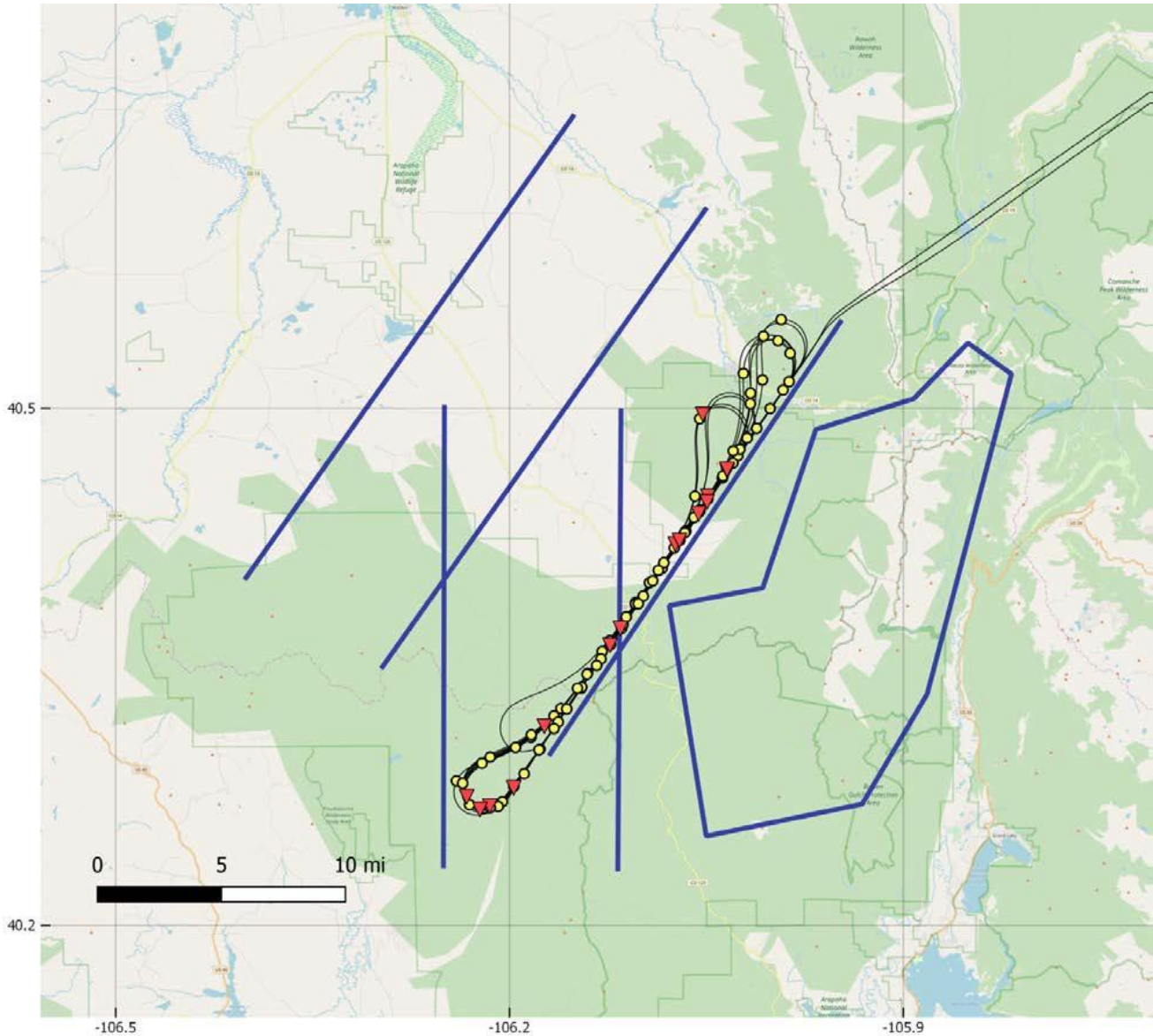
Flight occurred in the evening hours of Jan. 22th; weather information is from Jan. 21st.



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	05			SEED
	Track(s)/Basin:	NS-3			
UTC Date:	January 27, 2020		MST Date:	January 27, 2020	
UTC Engines ON:	16:45		MST Engines ON:	9:45 am	
UTC Engines OFF:	20:14		MST Engines OFF:	1:14 pm	
Total Time:	3:29	3.48hr	Flares Used:	15 BIP	73 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to track NS-3. Began flying a modified NS-3 track, seeding with BIP's. Conditions changed after about an hour and we ceased the use of BIP's and began firing EJ's. After about another hour, conditions changed again and we stopped EJ usage, switching back to BIP's. Continued seeding until there were no more seedable targets and our meteorologist asked us to RTB.				



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
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WINTER AERIAL OPERATIONS 2019-2020

Synoptic Analysis:	Jet level charts indicate a small ridge passing through the region during the day. The next in a series of troughs will move into WY late tonight into tomorrow. Shortwave ridging is likely Tuesday followed by another trough Tuesday night into Wednesday. A larger ridge pattern develops over the western states later in the week, but we will likely see several small lobes of vorticity passing through the region bringing some flurries and showers. Unseasonably warm conditions are likely next weekend. Low level RH will remain saturated through the afternoon, dipping a bit this evening, and then becoming saturated again overnight. Winds at seeding altitudes will be from the NW at 35kts this afternoon, becoming SW around 20-30kts tonight as the trough moves in.
Area Forecast:	Marginal orographic and low level clouds are expected through around sunset, and then some partial clearing of the low clouds is expected during the evening while upper level cloudiness gradually increases ahead of the next system. PVA and moisture late tonight will bring deep cloud layers and some marginal orographic clouds after midnight through tomorrow. This will continue through tomorrow evening with lots of natural ice crystals and only modest orographic lift. SLW amounts look light and intermittent in the MB/SM with no obvious seeding window in those ranges through tomorrow. The best looking potential seeding window looks to be in the NS tomorrow morning around sunrise, but it does not last long. For now, we will keep the option open for a NS flight in the morning tomorrow. Seeding in the MB/SM looks unlikely throughout the period, though widespread moderate snow accumulation is expected tonight and tomorrow.

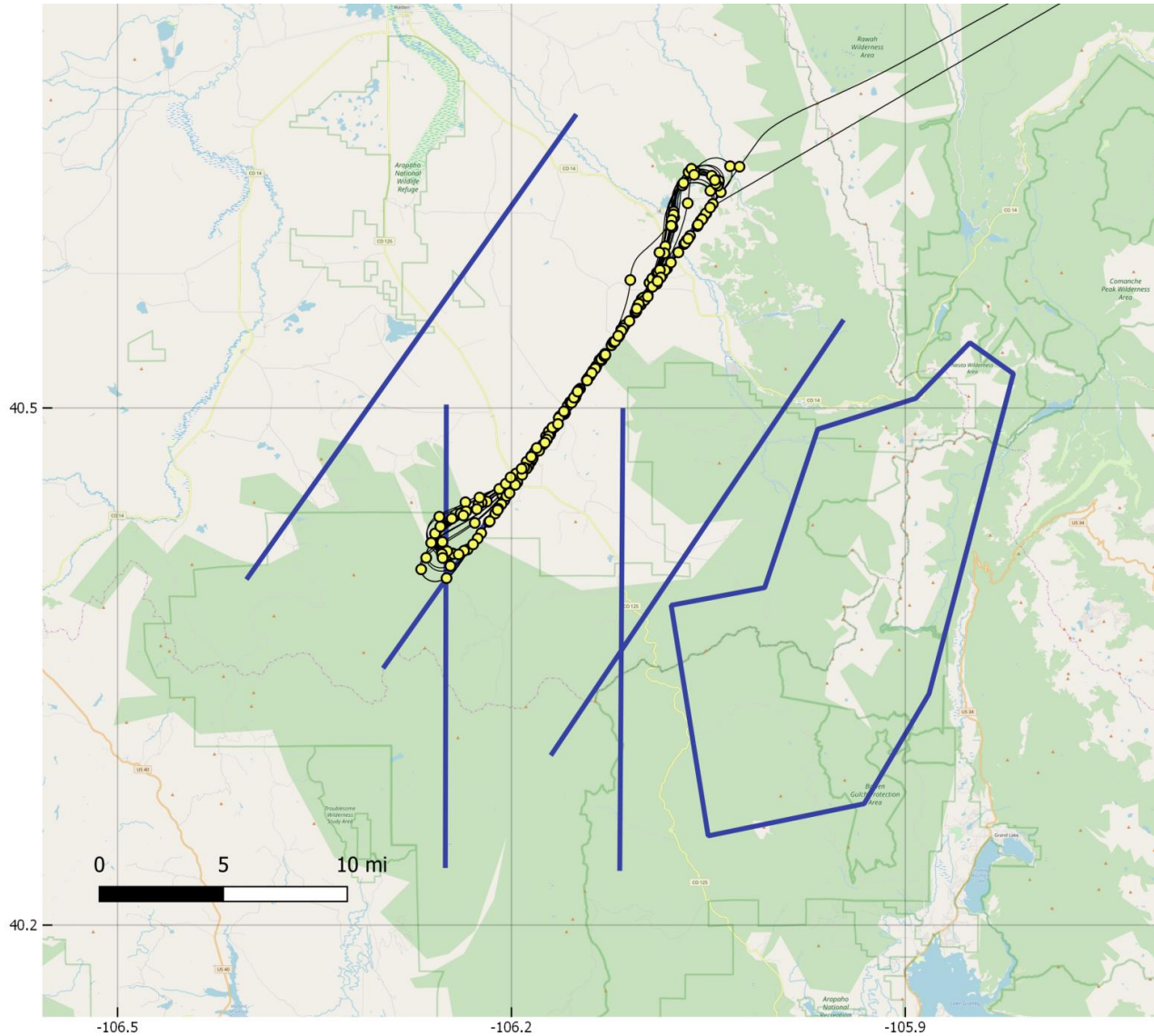
Flight occurred in the morning hours of Jan. 27th; weather information is from Jan. 26th.



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN		OPS #:	06	SEED	
		Track(s)/Basin:	NS-2		
UTC Date:	February 6, 2020		MST Date:	February 5, 2020	
UTC Engines ON:	03:13		MST Engines ON:	8:13 pm	
UTC Engines OFF:	08:13		MST Engines OFF:	1:13 am	
Total Time:	5:00	5hr	Flares Used:	0 BIP	204 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to a modified NS-2 track. Light SLW crossing the ridge. Began seeding with EJ's, initially at a rate of once every two minutes. Gradually increasing to once per minute as SLW improved on station. Cloud tops slowly lowered, and after a few hours, they were below us. Seeded on station for several more hours until lack of seedable targets and direction from radar made us RTB.				



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

<p>Synoptic Analysis:</p>	<p>A northerly jet will be over the region this afternoon, slowly shifting to the NW tonight. Strong northwest flow will then continue through at least Saturday. For the next few days, we will not see any large scale impulses passing through WY, however there look to be numerous small lobes of vorticity pushing through the region today through late Friday evening. A weak ridge pushes through Friday night into Saturday morning, and then a more potent trough moves through Saturday afternoon through Sunday. An Atmospheric River event over the PACNW states will pump copious moisture into WY through Friday evening. There will be a lull in moisture as the small ridge moves through, and then modest moisture is expected with the trough Saturday/Sunday. Seeding level winds will be moderate from the NW this afternoon, gradually increasing this evening into tomorrow when they become quite strong. Excellent moisture and orographic winds will mean deep SLW tomorrow into Sunday.</p>
<p>Area Forecast:</p>	<p>Cloud cover will increase throughout the afternoon and evening with orographic clouds slowly thickening as moisture increases and wind speeds improve. There will be a window for seeding this evening in the NS range beginning around 3z. SLW looks spotty overnight in all ranges, and then deep SLW is likely tomorrow through Friday afternoon. There will be an extended period of good seedable conditions tomorrow through Friday in strong NW flow. Several flights look possible tomorrow, perhaps on the NS and SM according to latest models. There is some concern about the CYS airport conditions late tomorrow evening as we may see a return of the freezing mist tomorrow night into Friday. For this reason, we will likely be fairly aggressive with operations for the first half of this storm today through tomorrow evening, expecting to perhaps be hindered by mist for the tail end of the event.</p>

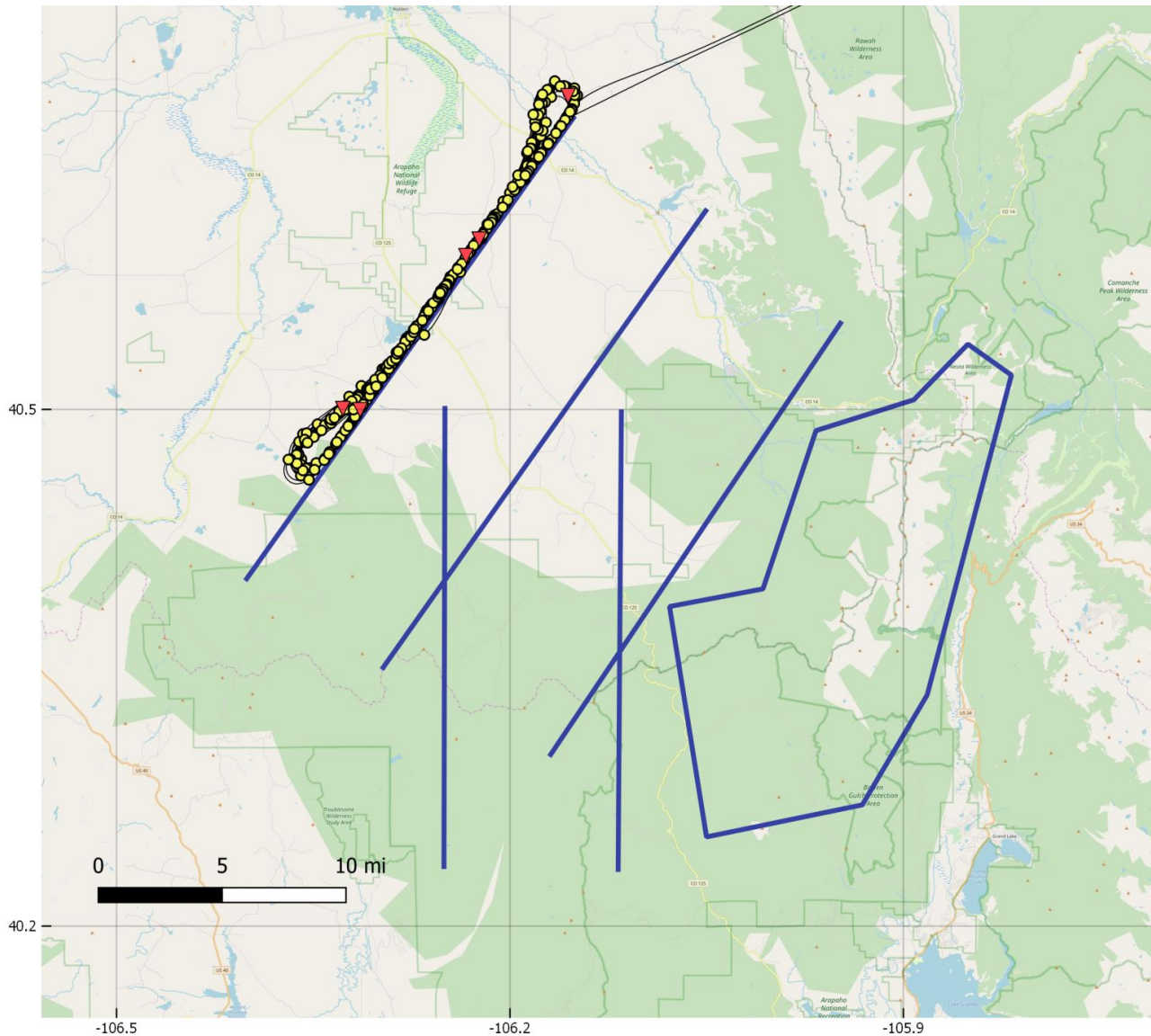
Flight occurred in the evening hours of Feb. 5th; weather information is from Feb. 5th.



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Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	07		SEED	
	Track(s)/Basin:	NS-1			
UTC Date:	February 7, 2020		MST Date:	February 7, 2020	
UTC Engines ON:	21:20		MST Engines ON:	2:20 pm	
UTC Engines OFF:	03:43		MST Engines OFF:	8:43 pm	
Total Time:	6:23	6.38hr	Flares Used:	5 BIP	253 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to a modified NS-1 track. Began seeding with EJ's almost immediately after arriving on station. Started mission skimming cloud tops and eventually was in cloud tops for most of track, for the majority of the flight. Remained on station for several hours. When we ran out of EJ's, we switched to seeding with BIP's until low fuel forced us to RTB. Light SLW crossing the ridge on the way home.				



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

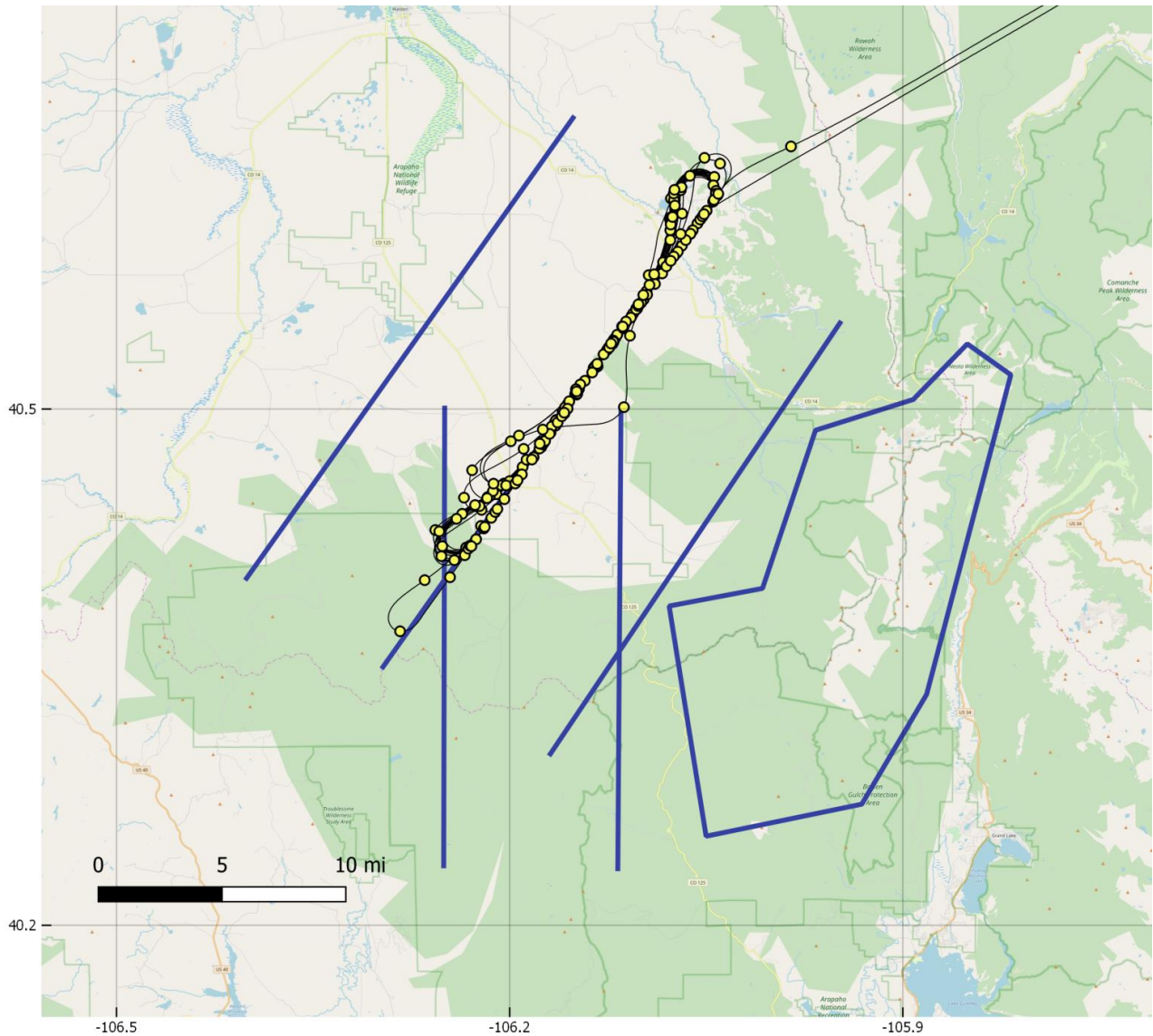
<p>Synoptic Analysis:</p>	<p>A northwesterly upper jet remains over WY through tomorrow afternoon. Midlevel charts show some small lobes of vorticity passing through this afternoon. Weak midlevel ridging is expected this evening and tonight with a brief dip in the 700RH, and then a potent trough moves in tomorrow. Excellent low level moisture continues to flow through our area through this evening. Moisture wanes slightly tonight into tomorrow morning. Low level RH increases again tomorrow afternoon and evening as the trough moves in. A cold front will sweep through the region late tomorrow afternoon. For today/tonight, intermittent deep SLW is expected in the MB/SM during the day and then marginal shallower SLW overnight. For the NS, however, deep targetable SLW look likely in the late afternoon and evening. Winds at seeding altitudes are strong around 55-60 kts from the NW.</p>
<p>Area Forecast:</p>	<p>Heavy snowfall continues throughout the period. Targetable consistent SLW is likely in the NS range this afternoon into the evening hours, and then SLW is a bit too shallow overnight in the NS. The SM/MB will have intermittent good SLW, but with these small vort lobes passing through, the midlevel ice crystals are making it difficult to find a period with consistent continuous SLW. For this reason, the NS will be favored for ops today. Overnight, the MB/SM will not be favorable for seeding. Moisture wanes briefly tonight into the morning, and clouds will thin out a bit, only to return by tomorrow afternoon ahead of the incoming trough with another wave of good low level moisture. Deep targetable SLW is likely in the SM/MB tomorrow afternoon into the evening, and a flight looks likely on either of those ranges tomorrow.</p> <p>Conditions at CYS are far from ideal today with IFR conditions likely this evening and potentially some snowfall if it makes it far enough east. The latest TAFs have removed the freezing mist, but 2000 ft ceilings and 2 mile vis are forecast after 00z. Winds at CYS will be light and westerly. This will be a factor to consider for a potential NS flight.</p>
<p><i>Flight occurred in the afternoon to evening hours of Feb. 7th; weather information is from Feb. 7th.</i></p>	



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	08	SEED		
	Track(s)/Basin:	NS-2			
UTC Date:	February 27, 2020		MST Date:	February 27, 2020	
UTC Engines ON:	09:29		MST Engines ON:	2:29 am	
UTC Engines OFF:	14:11		MST Engines OFF:	7:11 am	
Total Time:	4:42	4.7hr	Flares Used:	0 BIP	179 EJECT
Pilot's Flight Summary:	Departed Cheyenne and headed to a modified NS-2 track. Light to moderate SLW crossing the ridge. Arrived on track and immediately began seeding with EJ's. Made passes for several hours along track. SLW gradually increased on the north end as time went by. Modified track as necessary to stay in areas of good conditions. EJ rates varied from once every minute to once every 90 seconds. Lack of seedable targets prevailed				



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

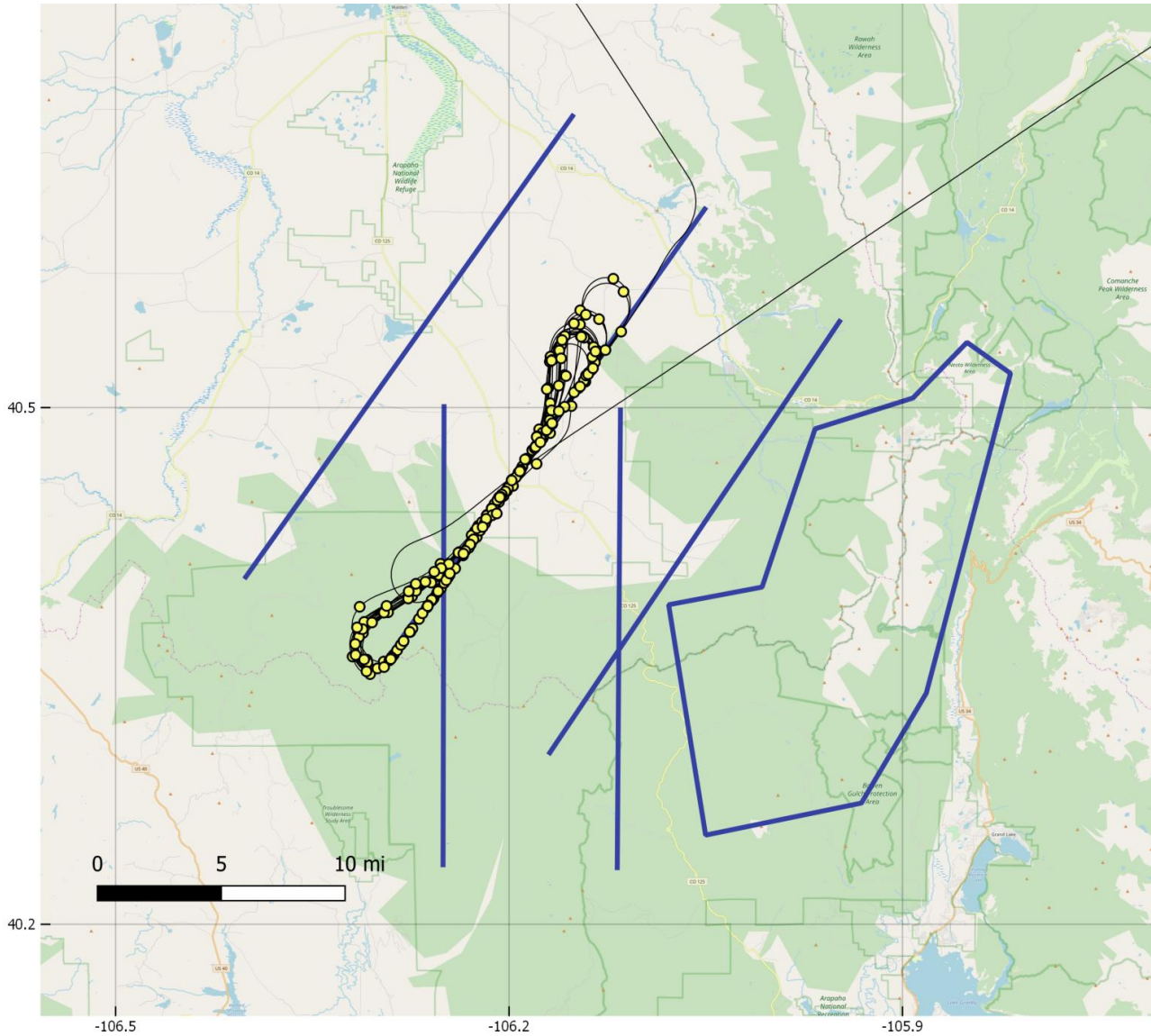
	and we RTB.
Synoptic Analysis:	<p>Jet level charts show a very large ridge to the west and northwest flow over WY today. A modest northwesterly jet streak will nose into WY late in the period. Midlevel charts show a minor shortwave will glance our region late tonight. This will bring very little in the way of dynamics, but a batch of moisture will push through overnight. 700mb RH will be saturated after midnight through midday tomorrow. Seeding level winds will be northwesterly around 40 kts tonight, and there will be some fair orographic clouds and SLW from midnight through dawn. Extent of the SLW will be likely seedable, but not particularly impressive tonight. The best SLW will be in the NS and MB ranges tonight. The moisture drops off tomorrow morning as the ridge starts to take hold, and we will see the effects of the ridge tomorrow through Saturday with a nice period of warming and 700mb temps climbing to near freezing by the end of the week. The next potent system then comes in on Sunday, followed by another system around the middle of next week.</p>
Area Forecast:	<p>Seedable clouds are likely after midnight in the NS and MB ranges, but the depth and extent of the SLW are not particularly impressive and we will likely forego operations in favor of a better storm unless the evening model runs looks much better (not expected). Low and midlevel cloud layers will continue to increase this afternoon and evening as moisture increases. Light snow accumulation is expected overnight in the MB and NS ranges while the LR and SM will have only flurries or very minor accumulation. Total QPF is light with this system, and only 2-3 inches of snowfall look likely in the highest peaks of the MB/NS. Clouds will erode tomorrow morning giving way to clear skies tomorrow afternoon. The ridge will bring clear warm conditions for the rest of the week into Saturday. Moisture returns Saturday night. Snowfall returns Sunday as an intense positively tilted trough pushes through (timing of this system will likely evolve). There will be a bit of a lull in activity behind the trough, and then another potent system moves in from the northwest around Tuesday night to Wednesday. After this second system, dry conditions are likely for the rest of next week.</p>
<p><i>Flight occurred in the morning hours of Feb. 27th; weather information is from Feb. 26th.</i></p>	



WYOMING WEATHER MODIFICATION Medicine Bow, Sierra Madre, and Laramie Mountains (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020



N23MN	OPS #:	09		SEED	
UTC Date:	March 10, 2020	Track(s)/Basin:		NS-2	
UTC Engines ON:	19:57	MDT Date:		March 10, 2020	
UTC Engines OFF:	23:52	MDT Engines ON:		1:57 pm	
Total Time:	3:55	MDT Engines OFF:		5:52 pm	
Pilot's Flight Summary:	Departed Cheyenne and headed to track MB-4. Initially began seeding with BIP's, but switched to EJ's shortly after due to convection. Made several passes firing EJ's when in suitable conditions. Altitudes varied due to ATC restrictions. After roughly an hour and a half on station we were asked to move to NS-2. Arrived on station and began firing EJ's. Continued firing EJ's at a rate of once per minute for several hours until low fuel				
	3:55	3.92hr	Flares Used:	0 BIP	200 EJECT



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

	forced us to RTB.
Synoptic Analysis:	<p>The upper jet core is well south of WY, and we are under moderate westerly flow today. A deep low is in place along the California coast. The low will remain quasi stationary along the coast, meandering southeastward for the next several days. Late in the week, Thursday-Friday, the low will finally push eastward through the Desert Southwest, but timing of this is difficult for now. Total moisture will be increasing throughout the period, however 700mb RH will dip slightly during the afternoon, becoming saturated again after dusk. Decent moisture lingers through tomorrow. Seeding level winds will be westerly around 35-40 kts through tomorrow. A shortwave will push through tomorrow afternoon along with a cold front. Another trough glances the region Wednesday night into Thursday, but the best dynamics will stay to the north. Longer range models show a potent low pushing southward into the Great Basin over the weekend.</p>
Area Forecast:	<p>Marginal orographic clouds and flurries are in place at forecast time, but they will erode throughout the day as RH wanes. Orographic clouds return this evening, increasing through the night as moisture continues to improve, but SLW looks too patchy for seeding throughout the period. Light snowfall is expected overnight. Moderate snowfall is likely during the day tomorrow with some periods of deeper SLW, but with the shortwave pushing through, it will be mixed with ice crystals from midlevel snow. There looks to be a slight chance for seeding during the day tomorrow, but latest model runs do not show an obvious window with consistent deep SLW. We will leave the chance for ops in place during the day Tuesday and update in the morning with later model runs. Another round of brief snowfall is likely Wednesday night into early Thursday morning. As the offshore low pushes through the Desert Southwest Thurs-Fri, seeding is not expected. A period of heavy precipitation is expected this weekend into early next week with the next incoming low from the northwest. This looks to be a better setup for seeding.</p>
<p><i>Flight occurred in the afternoon hours of Mar. 10th; weather information is from Mar. 9th.</i></p>	



WYOMING WEATHER MODIFICATION Medicine Bow, Sierra Madre, and Laramie Mountains (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

5.3 2019-2020 Operational Compression Map

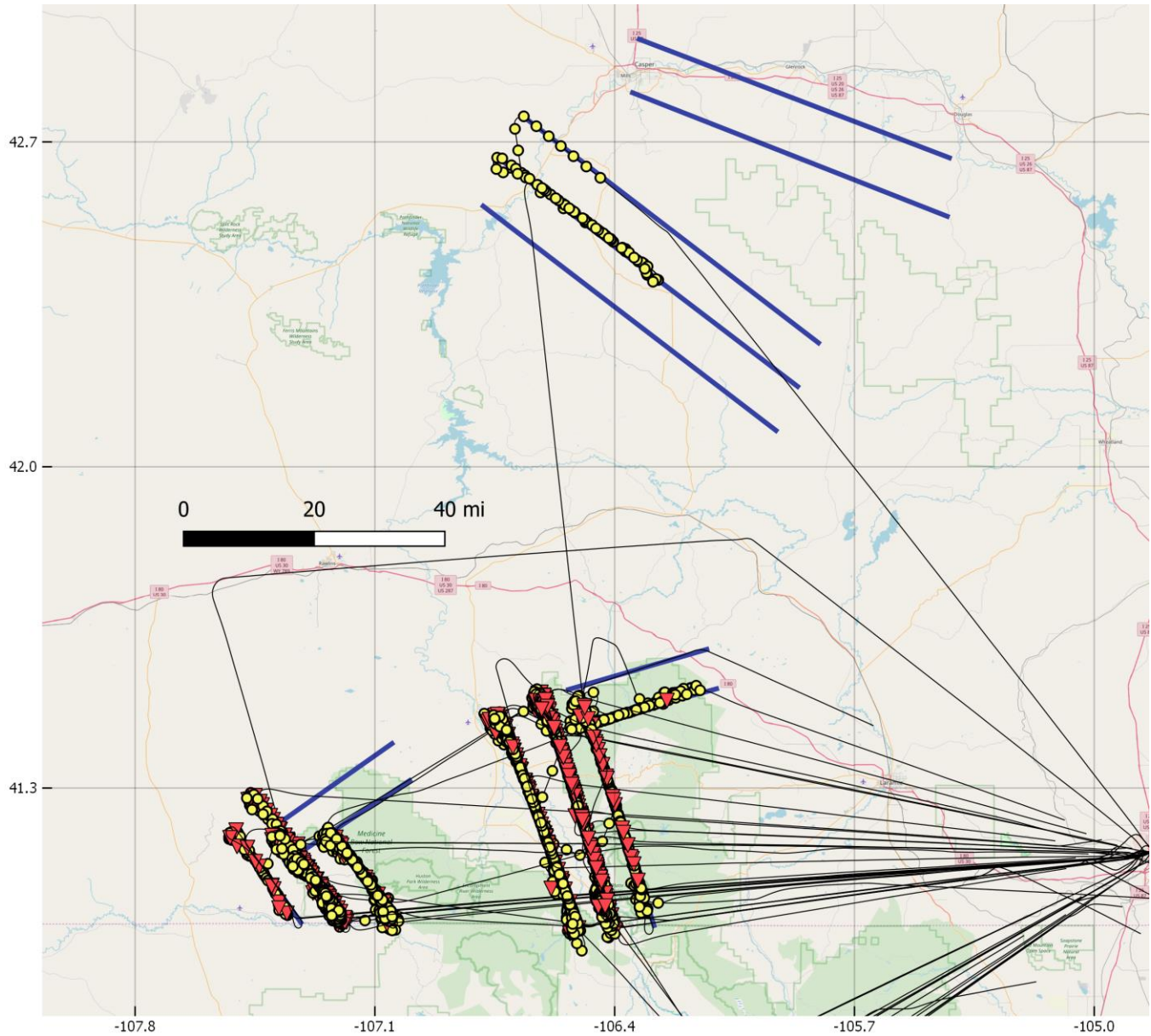


Figure 23. All flights conducted for the 2019-2020 winter season in the Medicine Bow, Sierra Madre, and Laramie Mountain Ranges of Wyoming.



WYOMING WEATHER MODIFICATION Medicine Bow, Sierra Madre, and Laramie Mountains (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

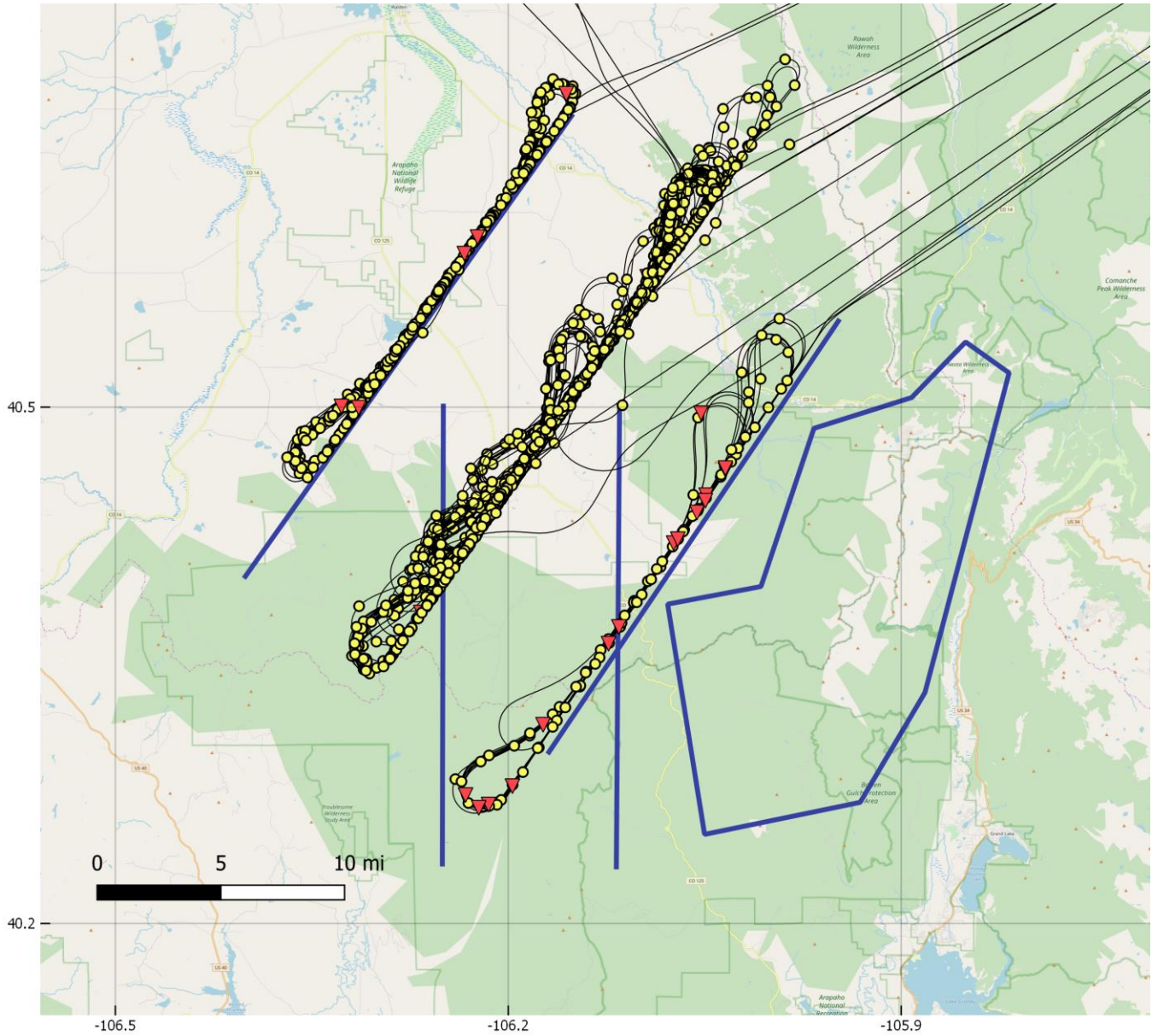


Figure 24. All flights conducted for the 2019-2020 winter season in Colorado's Never Summer Mountain Range.



WYOMING WEATHER MODIFICATION
Medicine Bow, Sierra Madre, and Laramie Mountains
 (with extension over Colorado's Never Summer Mountains)



WINTER AERIAL OPERATIONS 2019-2020

6 2019-2020 OPERATIONS SUMMARY

The hour in which seeding missions began (aircraft departure time from Cheyenne) is shown in Figure 20.

Seeding Start Time of Day (UTC)
2019-2020 WY & CO Target Area Combined

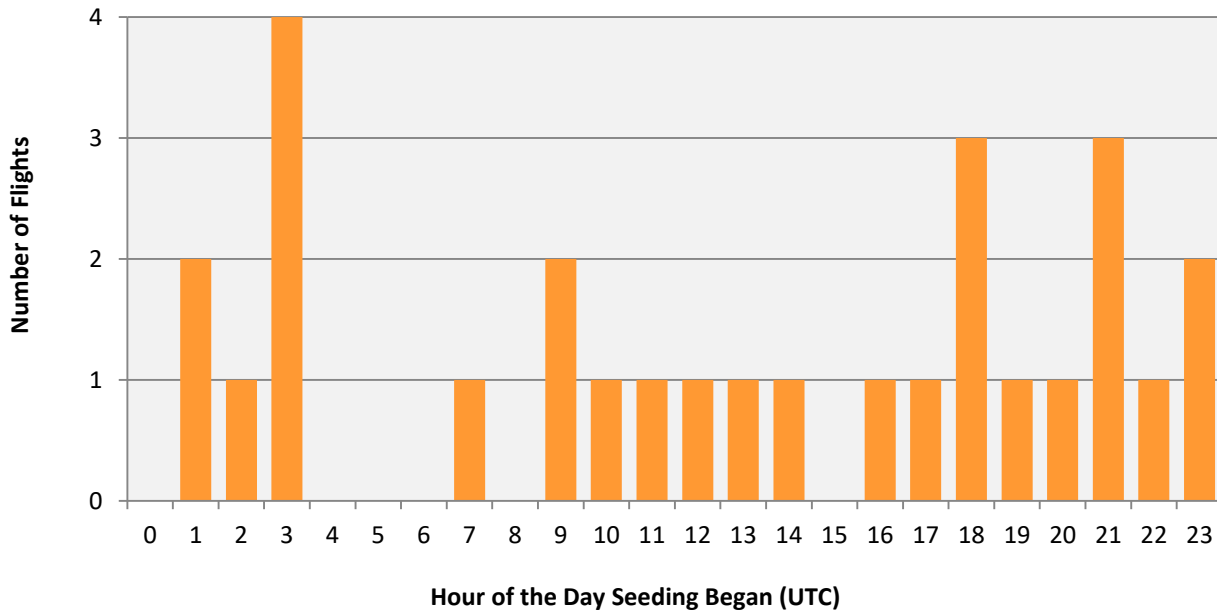


Figure 25. Hour of the day seeding began for each seed mission (in UTC). Subtract 7 hours for Mountain Standard Time.

Season flight operations are summarized in Table 4. Each flight is represented by its own column, so when there are two flights on a single day, for example, 8 December, there are two columns. Project-billable flights include only seeding and reconnaissance (Recon), but non-billable flights (usually flown for maintenance reasons) are not listed.

A total of 28 project-billable flights were flown. Of these 28 missions, time was split between WY and CO on 3 flights - 1 January, 6 January, and 10 March. Seeding was conducted on 26 of the 28 missions, with reconnaissance time flown on 6 January in the Never Summer Range and on 13 January for the Medicine Bow and Sierra Madre Ranges. January and December were the most active, with ten and eight missions flown, respectively. December and March each saw two missions, but April, only one. Coincidentally, the busiest months of the 2018-2019 winter season were also January and December!

A little over 132 hours were flown in the course of the seeding missions and 2.48 on the reconnaissance missions. It should be noted that of the 28 missions, 15 were five hours or more duration. The mean duration of seeding missions was 4.9 hours. The B200's endurance paid off in a big way.

Table 4. Flight operations for the 2019-2020 season are summarized.



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WINTER AERIAL OPERATIONS 2019-2020

Wyoming Operations Summary (MBSMLR)

Date	Engine On (UTC)	Engine Off (UTC)	Duration (hrs)	Monthly Flight Hours	Flight Hours Season Total	Seeding Agent Released (kg)	Seeding Agent Monthly Total	Seeding Agent Season Total
No seeding missions were flown between 15 November and the end of the month								
12/5/2019	17:11	22:54	5:43	5:43	5:43	5.28	5.28	5.28
12/8/2019	2:54	9:00	6:06	11:49	11:49	5.60	10.88	10.88
12/8/2019	19:22	23:04	3:42	15:31	15:31	6.29	17.17	17.17
12/9/2019	2:26	7:44	5:18	20:49	20:49	7.72	24.89	24.89
12/11/2019	23:24	4:34	5:10	25:59	25:59	6.69	31.58	31.58
12/12/2019	18:35	0:41	6:06	32:05	32:05	10.90	42.48	42.48
12/13/2019	1:20	3:49	2:29	34:34	34:34	0.92	43.40	43.40
12/14/2019	7:16	10:18	3:02	37:36	37:36	3.90	47.30	47.30
1/1/2020	14:15	17:56	3:41	3:41	41:17	9.25	9.25	56.55
1/1/2020								
1/1/2020	21:45	3:12	5:27	9:08	46:44	13.30	22.55	69.85
1/2/2020	22:17	3:46	5:29	14:37	52:13	5.97	28.52	75.82
1/3/2020								
1/6/2020	0:57	2:47	1:50	16:27	54:03	0.36	28.88	76.18
1/6/2020								
1/12/2020	9:15	14:13	4:58	21:25	59:01	5.16	34.04	81.34
1/13/2020	3:12	4:57	1:45	23:10	60:46	0.00	34.04	81.34
1/22/2020								
1/27/2020								
1/30/2020	23:21	2:18	2:57	26:07	63:43	2.14	36.18	83.48
2/6/2020								
2/7/2020								
2/8/2020	20:58	2:05	5:07	5:07	68:50	6.01	6.01	89.49
2/15/2020	3:08	8:05	4:57	10:04	73:47	6.62	12.63	96.11
2/16/2020	13:19	18:31	5:12	15:16	78:59	7.22	19.85	103.33
2/16/2020	20:20	2:45	6:25	21:41	85:24	4.38	24.23	107.71
2/27/2020								
3/10/2020	17:58	19:57	1:59	1:59	87:23	1.08	1.08	108.79
3/10/2020								
3/25/2020	12:26	18:26	6:00	7:59	93:23	5.14	6.22	113.93
4/15/2020	11:22	17:24	6:02	6:02	99:25	13.24	13.24	127.17
Shaded rows indicate days on which flight(s) occurred in Colorado, but not Wyoming								



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Colorado Operations Summary (NS)

Date	Engine On (UTC)	Engine Off (UTC)	Duration (hrs)	Monthly Flight Hours	Flight Hours Season Total	Seeding Agent Released (kg)	Seeding Agent Monthly Total	Seeding Agent Season Total
No seeding missions were flown between 15 November and the end of the month								
12/5/2019								
12/8/2019								
12/8/2019								
12/9/2019								
12/11/2019								
12/12/2019								
12/13/2019								
12/14/2019								
1/1/2020								
1/1/2020	17:56	19:15	1:19	1:19	1:19	1.48	1.48	1.48
1/1/2020								
1/2/2020								
1/3/2020	18:35	22:12	3:37	4:56	4:56	4.24	5.72	5.72
1/6/2020								
1/6/2020	2:47	3:31	0:44	5:40	5:40	0.00	5.72	5.72
1/12/2020								
1/13/2020								
1/22/2020	10:21	16:21	6:00	11:40	11:40	6.12	11.84	11.84
1/27/2020	16:45	20:14	3:29	15:09	15:09	3.71	15.55	15.55
1/30/2020								
2/6/2020	3:13	8:13	5:00	5:00	20:09	4.08	4.08	19.63
2/7/2020	21:20	3:43	6:23	11:23	26:32	5.81	9.89	25.44
2/8/2020								
2/15/2020								
2/16/2020								
2/16/2020								
2/27/2020	9:29	14:11	4:42	16:05	31:14	3.58	13.47	29.02
3/10/2020								
3/10/2020	19:57	23:52	3:55	3:55	35:09	4.00	4.00	33.02
3/25/2020								
4/15/2020								
Shaded rows indicate days on which flight(s) occurred in Wyoming, but not Colorado								



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WINTER AERIAL OPERATIONS 2019-2020

Seeding Material Dispensed per Track 2019-2020
Medicine Bow, Sierra Madre & Laramie Mountain Ranges, WY

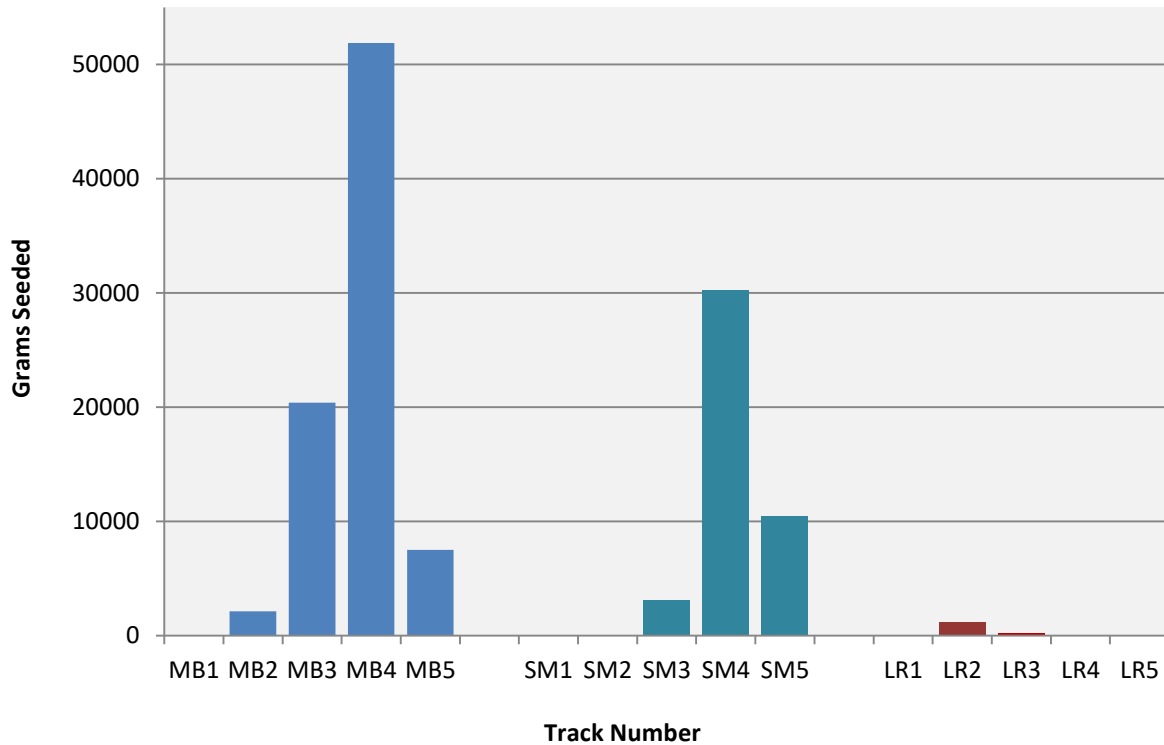


Figure 26. Grams of seeding material dispensed per track over the Medicine Bow, Sierra Madre, and Laramie Mountain Ranges in Wyoming.

Seeding Material Dispensed per Track 2019-2020
Never Summer Mountain Range, CO

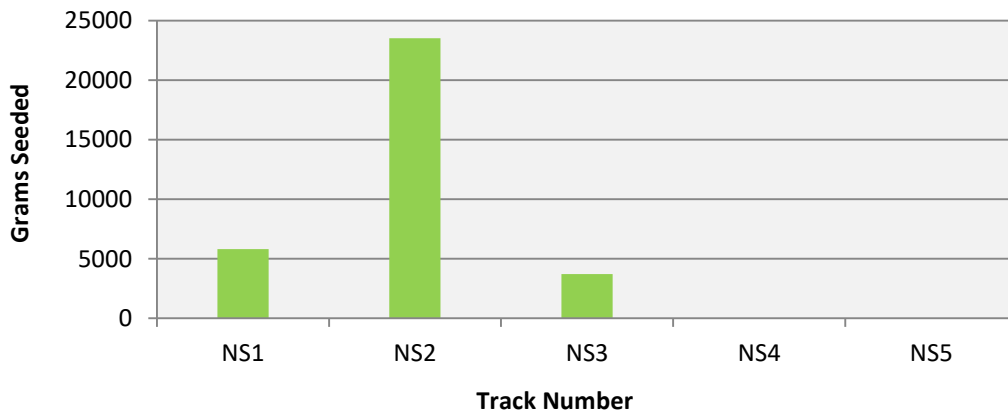


Figure 27. Grams of seeding material dispensed per track over the Never Summer Mountain Range in Colorado.



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WINTER AERIAL OPERATIONS 2019-2020

Number of Seeding Flights per Track 2019-2020
Medicine Bow, Sierra Madre & Laramie Ranges, WY

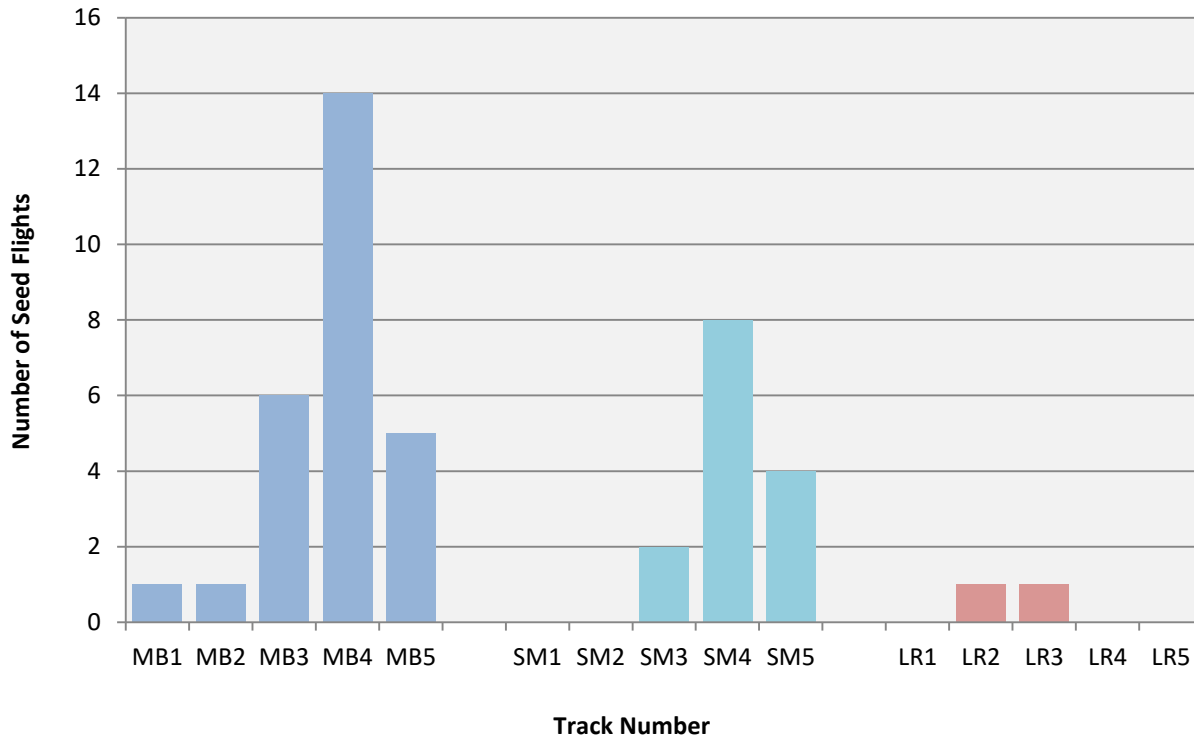


Figure 28. Number of seeding flights per track in the Medicine Bow, Sierra Madre, and Laramie Mountain Ranges in WY. Some flights may utilize multiple tracks.

Number of Seeding Flights per Track 2019-2020
Never Summer Mountain Range, CO

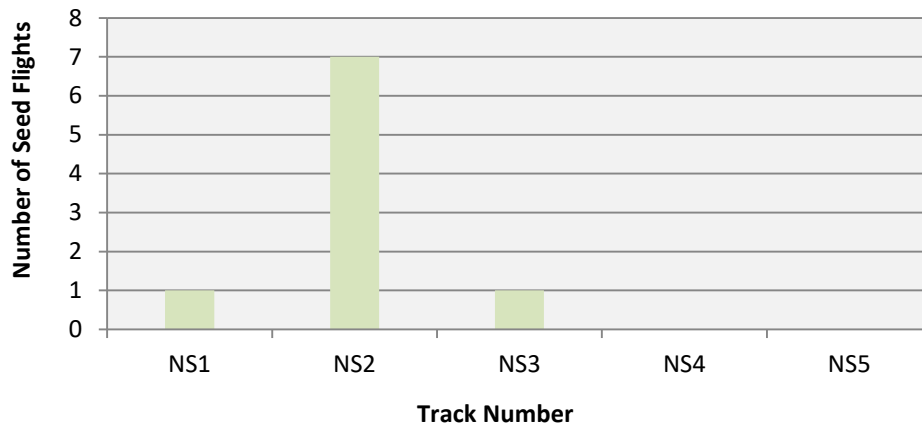


Figure 29. Number of seeding flights per track in the Never Summer Mountain Range in CO. Some flights may utilize multiple tracks.



WYOMING WEATHER MODIFICATION
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WINTER AERIAL OPERATIONS 2019-2020

Number of Seeding Flights per Track - 2018-2019 vs. 2019-2020
Never Summer Mountain Range, CO

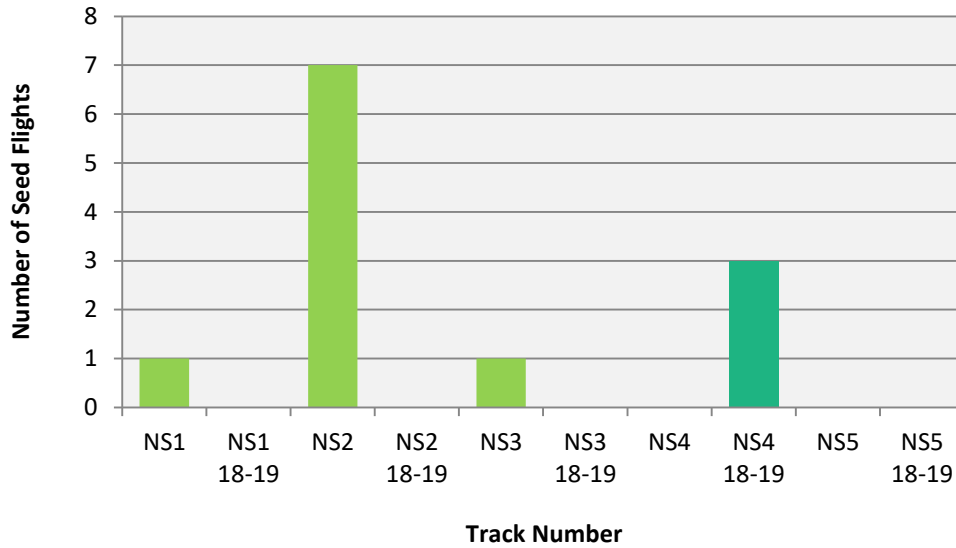


Figure 30. Number of seeding flights per track in the Never Summer Mountain Range, CO in 2018-2019 vs. 2019-2020.



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WINTER AERIAL OPERATIONS 2019-2020

Number of Seeding Flights per Track - 2018-2019 vs. 2019-2020
Medicine Bow & Sierra Madre Mountain Ranges, WY

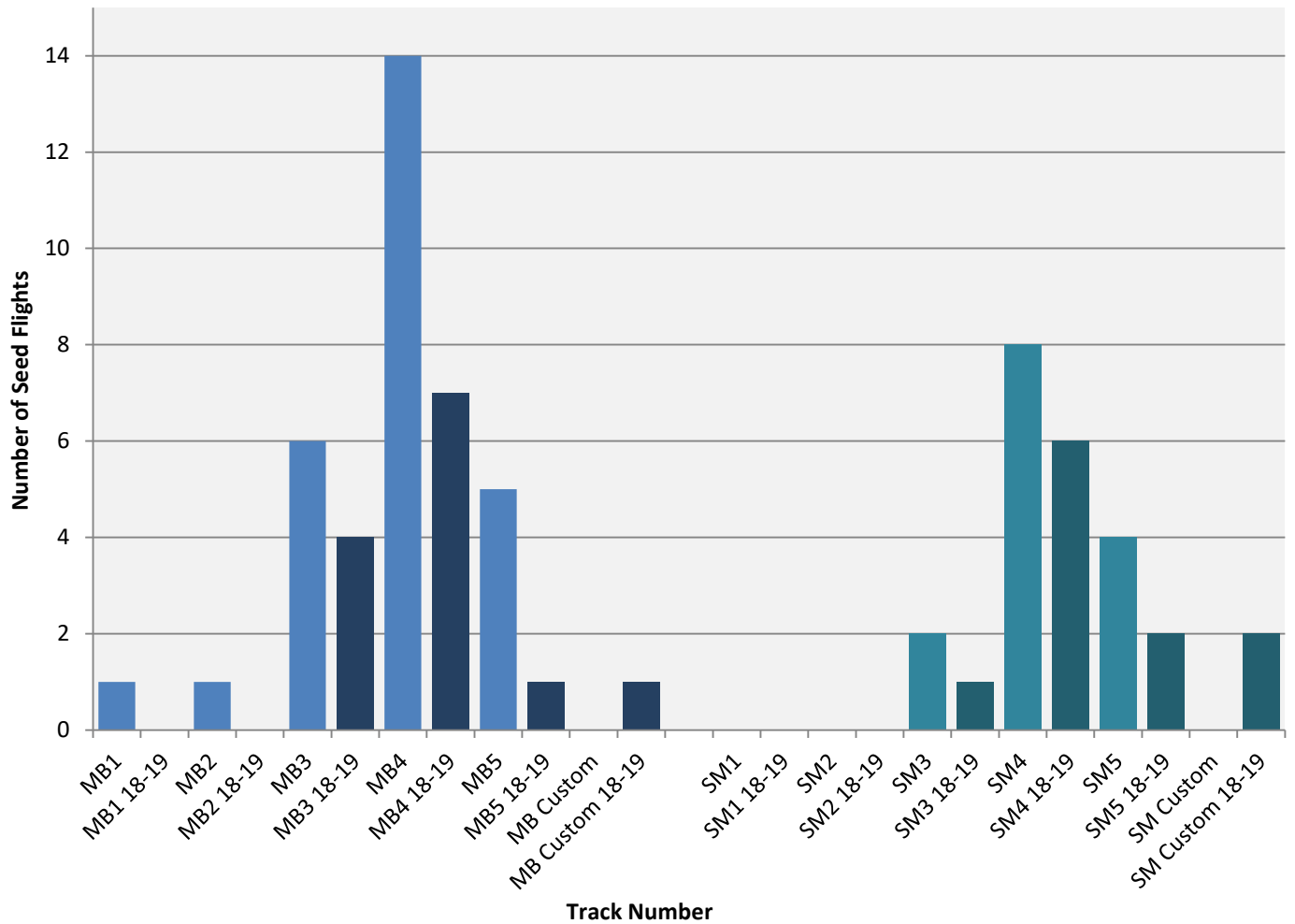


Figure 31. Number of seeding flights per track in the Medicine Bow and Sierra Madre Mountain Ranges, WY in 2018-2019 vs. 2019-2020. For each range, the lighter color is the number of missions flown this season, and the darker, in 2018-2019. Not graphed is the Laramie Range, as 2019-2020 was the first season that this target area was included in the WY program, and only a single mission was flown.



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WINTER AERIAL OPERATIONS 2019-2020

Percentage of Seeding Flights per Month
All Target Areas 2019-2020

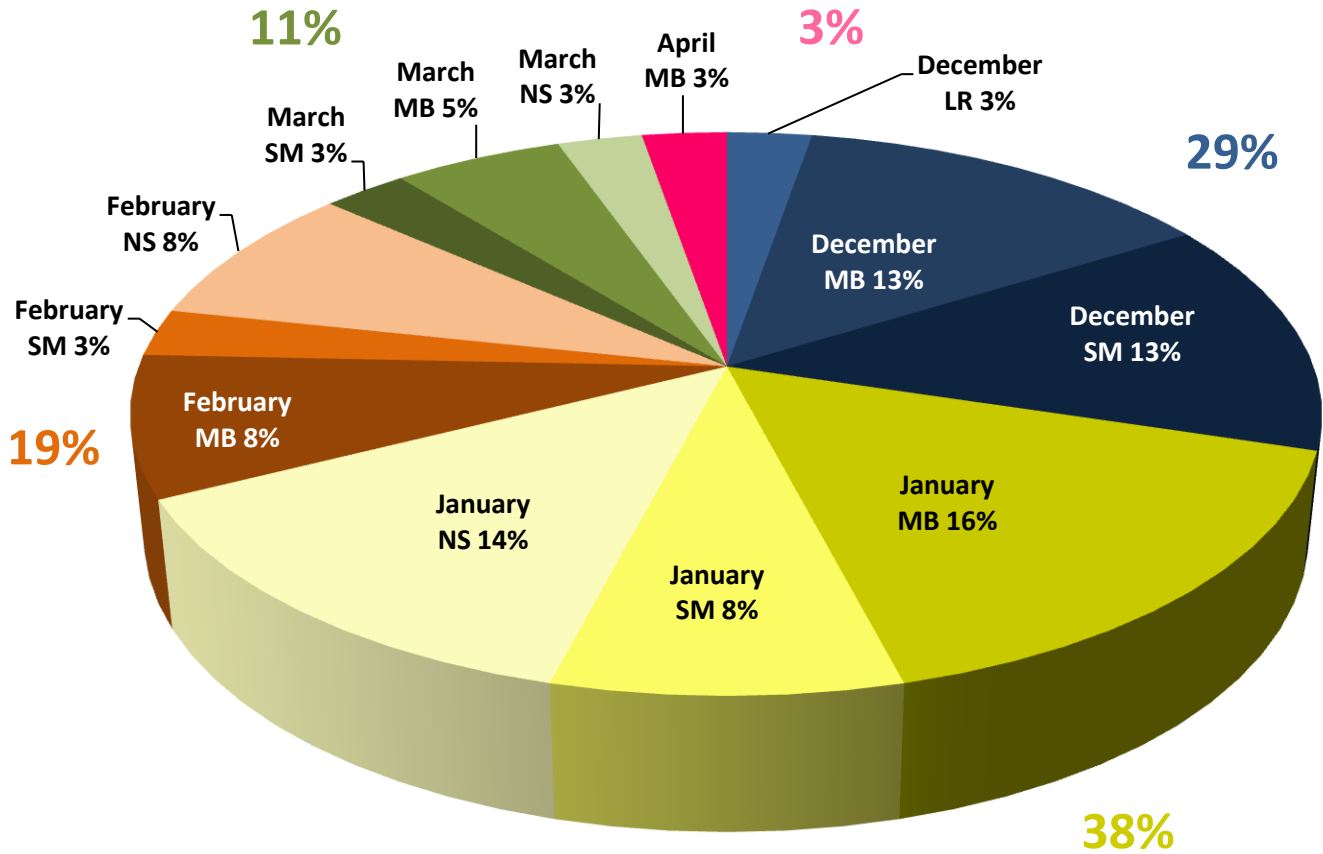


Figure 32. Number of seeding flights by month and per target area for the 2019-2020 winter season.



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WINTER AERIAL OPERATIONS 2019-2020

7 CONTRACTOR'S FINAL REMARKS

The 2019-2020 winter season was Weather Modification International's second winter season providing operational aerial cloud seeding and meteorological services for the Medicine Bow and Sierra Madre Mountain Ranges of Wyoming and the Never Summer Mountain Range in Colorado. It was the first season that included the Laramie Range in Wyoming. The target ranges provided ample suitable seeding targets, and the terrain, base of operations, and Air Traffic Control limitations allowed safe, effective operations. This season WMI provided a King Air B200 due to aircraft availability. The King Air B200 aircraft provided excellent endurance for extended seeding flights, many of which lasted for five hours or more due to increased fuel capacity. Airframe icing was also less of a factor due to the increased performance of the B200. The satellite communications system onboard the aircraft allowed for real-time coordination between pilots and meteorologists, which optimized the use of project resources and helped keep the crew safe during the ever-changing weather conditions. The use of ejectable flares

was a critical component of the program's success, and should be continued in subsequent seasons.



Figure 33. The sun rises between cloud layers during a mission over the Never Summer Mountain Range target area on 3 January 2020. Photo by Kirk Hamilton.

Annual snowpack for the region was near normal to slightly above normal. This suggests that the number of seeding opportunities observed this season loosely represents what can be expected in a typical season.

During the 2019-2020 season, meteorology and pilot staff focused efforts on utilizing project resources to target the most promising clouds in order to maximize the benefits of the program.

WMI invites comments from the WWDO and JCWCD regarding this winter's program. For more information regarding Weather Modification International please visit our website: www.weathermodification.com