United States Army Corps of Engineers
Cold Regions Research & Engineering Laboratory
Remote Sensing and GIS Center of Expertise
Hanover, NH

Boise, Idaho Airborne LiDAR Survey at Mores Creek Summit

2024-2025 Snow Season

Overview

Between 2021 and 2024, the Cold Regions Research and Engineering Laboratory (CRREL) completed 13 airborne LiDAR collections of a 30 km^2 domain in the headwaters of Mores Creek (Mores Creek Summit, or MCS), located in the Boise Mountains of southwest Idaho (*figure 1)*. These collections follow two surveys of the same domain completed by NV5 (formerly Quantum Spatial. Inc) as part of 2020-2021 NASA SnowEx. These data support several military and civilian snow projects, and data products are designed to allow time series analyses of snowpack properties and sub-seasonal to interannual changes of these properties. This report details collection efforts throughout the 2024-2025 winter, when 5 flights occurred.

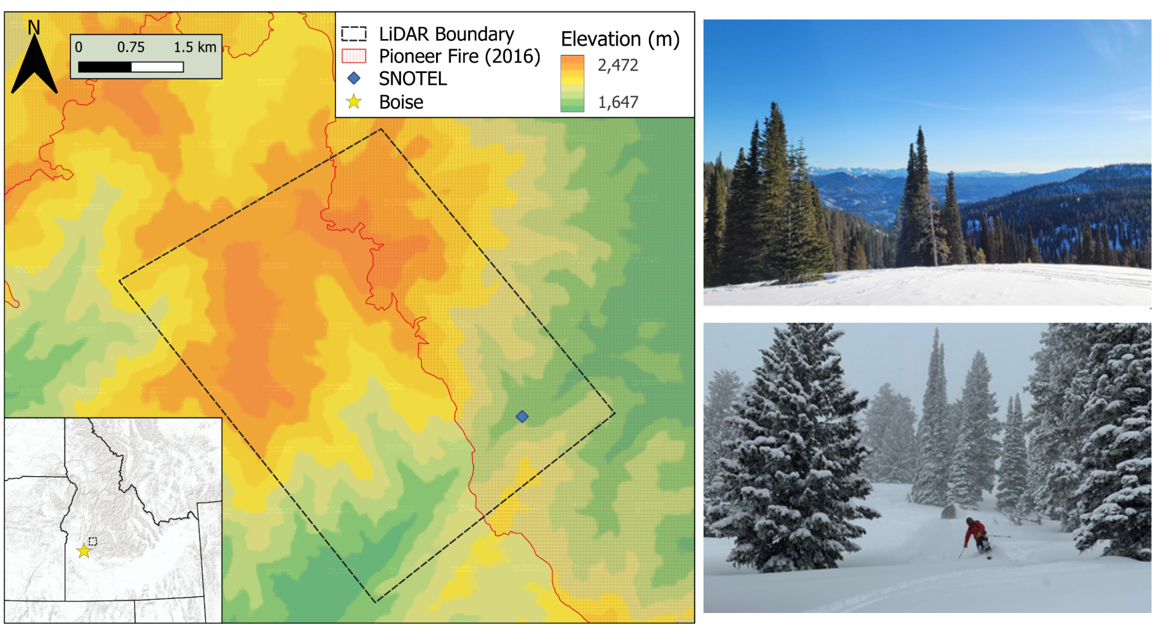

Figure 1- (Left) Mores Creek Summit is in the Boise Mountains of central Idaho. Elevations range from roughly 1,500-2,500 m a.s.l. and the MCS Snotel sits in the lower reaches of the domain. This domain was partially burned by the Pioneer fire of 2016. (Right) Canopy height at MCS averages 15 meters.

Topography at MCS is rugged and complex, with approximately 1000m of topographic relief. The site is characterized by moderate slopes (20-40 degrees), with deeply incised ravines between opposing slopes. The domain is primarily forested or burned (approximately 40% burned in the 2016 Pioneer Fire). Within the southeast quadrant of the domain, the Mores Creek Summit SNOTEL sits at 1,800 meters. The climate is characterized as Mediterranean-continental and is typically snow covered from November through May.

- Collection dates: January 13, 2025; January 29, 2025; March 30, 2025; April 4, 2025, May 1, 2025
- Sensors: CRREL RaLiPod (Radar-LiDAR Pod)
    - Riegl VQ-580ii Airborne Laser Scanner
    - Applanix AP60 Inertial Measurement Unit
    - Antcom G5ANT-42AT1 Antenna
- Point of contact: Siobhan Ciafone (siobhan.m.ciafone@erdc.dren.mil) & Shad O'Neel (shad.r.oneel@erdc.dren.mil)
- Aircraft: Robinson R66 Helicopter (Tail # N166FS)
- Spatial reference system: WGS84 / UTM Zone 11N (EPSG: 32611)
    - Height: WGS84 Ellipsoid
    - Units: meters

Contents

Mission description

As part of a multi-year effort to document seasonal snow distributions and enable new analysis methods, airborne LiDAR was collected throughout the 2024-2025 snow season over the 30 km² region of Mores Creek Headwaters in the Boise Mountains of central Idaho by the Remote Sensing and Geographic Information Systems Center of Expertise (RSGIS CX) at the Cold Regions Research and Engineering Laboratory (CRREL) and the Boise State University Geosciences Department, Cryosphere Geophysics and Remote Sensing Group (CryoGARS). The nose-mounted RaLiPod system (*figure 2*), mounted on a Robinson R66 helicopter, consisted of: REIGL VQ580ii laser scanner; Applanix AP60 Inertial Measurement Unit (IMU); Antcom G5ANT-42AT1 antenna, and TopoFlight flight management system (FMS) (Figure 2). The aircraft is owned and operated by Silverhawk Aviation, based out of Caldwell, Idaho.

A nominal mission consists of:

1. 5 minute ground-based initialization period
2. Boresight calibration over built environment, consisting of several passes in different directions over a neighborhood.
3. Main data acquisition over survey domain as weather and fuel allow
4. 5 minute ground-based static-alignment before aircraft shutdown.

Most missions are paired with ground-based calibration/validation data collection consisting of snow-depth probing and/or snow pits.

Figure 2 - CRREL's nose-mounted RaLiPod system installed on a Robinson R66 helicopter. All sensors are located inside the pod, with control systems located within the passenger compartment for in-flight operations.

Deliverables

The following deliverables are available for each survey:

- Point Clouds:
  - LAZ v 1.2, all unclassified returns
    - *MCS_YYYYMMDD_PC_#.laz*
- 0.5-Meter Rasters:
  - Digital terrain model: ground points
    - *MCS_YYYYMMDD_DTM.tif*
  - Digital surface model: surface points
    - *MCS_YYYYMMDD_DSM.tif*
  - Canopy height model: found by subtracting reference map from DSM
    - *MCS_YYYYMMDD_CHM.tif*
  - Snow depth: found by subtracting reference map from DTM
    - *MCS_YYYYMMDD_SNOWDEPTH.tif*

Raw data files are preserved at CRREL. Anyone interested in accessing raw data can contact POCs listed in Overview.

GNSS Control

Two semi-permanent GNSS base stations were used during trajectory processing (*figure 3)*. Pilot Peak and Treeline are semi-permanent stations installed in 2022 that consist of Septentrio PolaRx5 receivers and Trimble Zephyr 3 antennas. These stations are owned and maintained by the Boise State CryoGARS group. Positions for Pilot and Treenline stations were resolved by processing several 24-hour observation periods using the NOAA Online Positioning User Service (OPUS; https://geodesy.noaa.gov/OPUS/) and averaging solutions to obtain the positions given in Table 1. The standard deviation among daily solutions was less than 5 mm suggesting these mounts are stable enough to be used as reference data for these campaigns.

Table 1 - Permanent base station coordinates EPSG(32611).

Reference System: ITRF2014						
Station ID	**Latitude**	**Longitude**	**Ellipsoid Height (m)**	**Northing (m)**	**Easting (m)**	**Antenna Height (m)**
Pilot Peak	43 57 34.240834	115 41 10.211798	2449.604	4842269.634	659244.7581	3.12
Treeline	43 43 48.8307973	116 8 24.8128245	1601.180273	4868214.451	605408.5431	3.0

Figure 3 - A map of base stations relative to the airport (Silverhawk Aviation) and the survey domain (red polygon). The BSU Base Station was used in previous years when Treeline base was offline, but it was not needed in the 2024-2025 season.

Data collection summary

January Survey, 1

Table 2 - MCS airborne laser scanning survey parameters for January 13.

Collection Date	January 13, 2025
Target flight parameters	swath overlap: 50%, flight height: 750 m a.s.l., flight speed: 40 knots
Sensor parameters	Pulse repetition rate: 600 kHz; target point density: 15 points/m^2 before overlap
System Operator	Thomas Van Der Weide, Yasmin Wadhwani
Pilot	Bobby Hodgden
Base stations used	Pilot Peak, Treeline

January Survey, 2

Table 3 - MCS airborne laser scanning survey parameters for January 29.

Collection Date	January 29, 2025
Target flight parameters	overlap: 50%, flight height: 750 m a.s.l., flight speed: 40 knots
Sensor parameters	Pulse repetition rate: 600 kHz; target point density: 15 points/m^2 before overlap
System Operator	Thomas Van Der Weide, Yasmin Wadhwani
Pilot	Bobby Hodgden
Base stations used	Pilot Peak, Treeline

March Survey

Table 4 - MCS airborne laser scanning survey parameters for March 30. The scanner was accidentally pulsed at 2000 kHz rather than 600 kHz. The resultant data had high noise and required elevated data remediation. Therefore, this dataset will become available at a later date than other 2024-2025 surveys.

Collection Date	March 30, 2025
Target flight parameters	overlap: 50%, flight height: 750 m a.s.l., flight speed: 40 knots
Sensor parameters	Pulse repetition rate: 2000 kHz
System Operator	Karina Zikan, Chance Roberts
Pilot	Bobby Hodgden
Base stations used	Pilot Peak, Treeline

April Survey

Table 5 - MCS airborne laser scanning survey parameters for April 4.

Collection Date	April 4, 2025
Target flight parameters	overlap: 50%, flight height: 750 m a.s.l., flight speed: 40 knots
Sensor parameters	Pulse repetition rate: 600 kHz; target point density: 15 points/m^2 before overlap
System Operator	Thomas Van Der Weide, Yasmin Wadhwani
Pilot	Bobby Hodgden
Base stations used	Pilot Peak, Treeline

May Survey

Table 6 - MCS airborne laser scanning survey parameters for May 5. To reduce flight time, we experimented with a higher above-ground flight altitude. Unfortunately, this resulted in data gaps during post-processing point filtration.

Collection Date	May 5, 2025
Target flight parameters	overlap: 50%, flight height: 900 m a.s.l., flight speed: 40 knots
Sensor parameters	Pulse repetition rate: 600 kHz; target point density: 10 points/m^2 before overlap
System Operator	Thomas Van Der Weide, Yasmin Wadhwani
Pilot	Bobby Hodgden
Base stations used	Pilot Peak, Treeline

NV5 Geospatial Collection

NV5 Geospatial was contracted by Boise State University to collect LiDAR data as part of NASA's 2020-2021 SnowEx Program. Mores Creek Summit study area was surveyed with a Riegl VQ-1560ii sensor on September 17, 2021 as a part of this effort. The resulting 0.5-meter resolution bare-earth map serves as a reference DEM for all snow depth mapping. NV5 snow-on collections were completed on February 9, 2020 and March 15, 2021. NV5 bare earth, snow depth, and vegetation height products can be found here.

System Parameters

Table 7 - Specifications of the Riegl VQ-580ii laser scanner.

Riegl VQ-580ii Airborne Laser Scanner (serial number H2225798)	
Parameter	**Specification**
Laser Wavelength	1064 nm
Accuracy	20 mm
Precision	20 mm
Pulse Repetition Rate	150 kHz to 2000 kHz
Scan Angle	75°
Beam Divergence	0.25 mrad

Table 8 - Specifications of the Applanix AP60 inertial measurement unit.

Applanix AP60 Inertial Measurement Unit (serial number 19560)	
Parameter	**Specification**
Embedded GNSS	L1/L2, GPS, GLONASS, BeiDou, Galileo, QZSS, SBAS, L-Band
Weight	2.6 kg
Size	179mm x 126mm x 127mm
Output refreshing rate	200 Hz
Time tagging	PPS output
Heading accuracy (PPK)	Up to 0.005°
Roll and pitch accuracy (PPK)	Up to 0.0025°
Horizontal Accuracy (PPK)	Typically <0.05 m
Vertical Accuracy (PPK)	Typically <0.10 m

Processing Workflow

ALS Data

1. Download laser scanner data and GNSS/INS data from the scanning system
2. Download base station data from the GNSS receivers
3. Post-process the GNSS/INS trajectory against the base station receivables to determine a Smoothed Best Estimate of Trajectory (SBET)
    - Software/application: Applanix POSPac software
4. Post-process the laser scanner data against the SBET to create a point cloud
    - Software/application: Riegl RiPROCESS software suite
5. Using planar features in the boresight survey, iteratively adjust sensor orientation parameters (roll, pitch, yaw) to improve the alignment between overlapping data. The orientation solution found during boresight alignment is applied to all AOI records.
    - Software/application: Riegl RiPROCESS software suite
6. Minimize offsets between scan data overlap using a least squares solution
    - Software/application: Riegl RiPROCESS software suite
7. Export the point cloud from the post processing software into a deliverable file format for all collection records
    - Software/application: Riegl RiPROCESS software suite

Post-processing with ice-road-copters

The ice-road-copter suite (https://github.com/SnowEx/ice-road-copters) leverages Point Data Abstraction Library (PDAL) and NASA's Ames Stereo Pipeline (ASP) to create four DEM deliverables - (1) digital surface model (all surface points), (2) digital terrain model (all ground points), (3) snow depth model (the difference between the digital terrain model and reference DEM), and (4) a canopy height model (the difference between the digital surface model and reference DEM). A summary of point cloud processing via ice-road-copter can be found at the URL linked above.