ASO Survey Report

Yampa & Elk Rivers, CO

Survey Date: March 21, 2026

Airborne Snow Observatories, Inc. is a public benefit corporation with a mission to provide high-quality, timely, and accurate snow measurement, modeling, and runoff forecasts to empower the world's water managers to make the best possible use of our planet's precious water.

Historical data and reports can be found at:
data.airbornesnowobservatories.com

Survey date: March 21, 2026
Survey # of Water Year 2026: 1
Report delivery date: March 28, 2026

Full domain SWE: 289 ± 11 TAF
Estimated snowline: 8120 ft

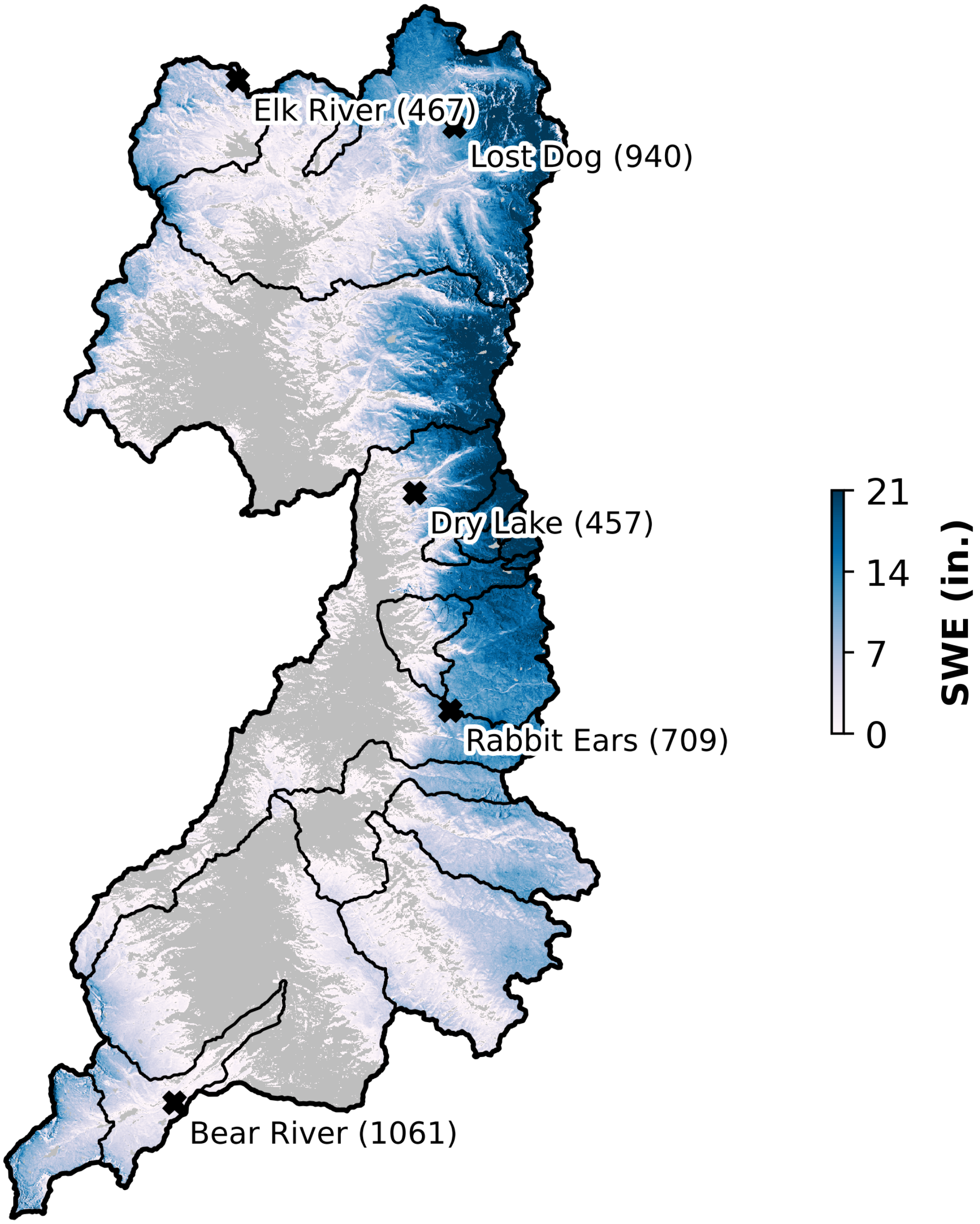
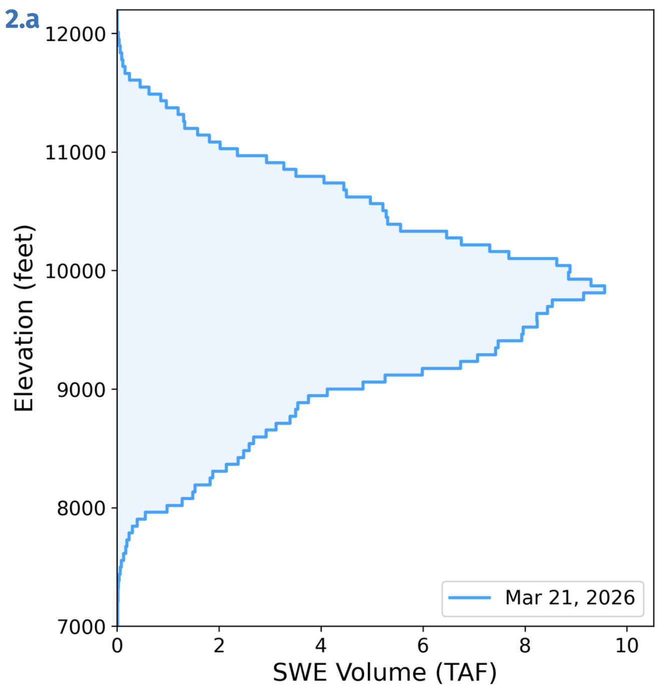


Figure 1. Spatial distribution of Snow Water Equivalent depth (in).

Table 1. Estimated SWE volume in Thousand Acre Feet (TAF) for the full Yampa and Elk Rivers and subbasins for the March 21 survey. Note: subbasins may overlap and/or not fully cover the survey domain, therefore TAF values may not add up to the full-domain SWE. We also do not report SWE values for subbasins that extend beyond the boundary of the survey domain.

Basin	Estimated SWE Volume (TAF)
Full domain	289
Uncertainty range	*278-300*
Yamcolo Inflow	9
Bear River below Yampa	14
Yampa above Stagecoach	22
Morrison Creek	15
Sarvis Creek	14
Yampa River above Catamount	55
Walton Creek Upper	26
Walton Creek Lower	29
South Fork Fish Creek	1
Middle Fork Fish Creek above Fish Creek Reservoir	2
Granite Creek	4
Middle Fork Fish Creek	8
North Fork Fish Creek	16
Yampa River below Soda Creek at Steamboat	138
Pearl Lake	0.9
Steamboat Lake	9
Upper Elk River	99
Elk River near Milner	151

2.a



2.b

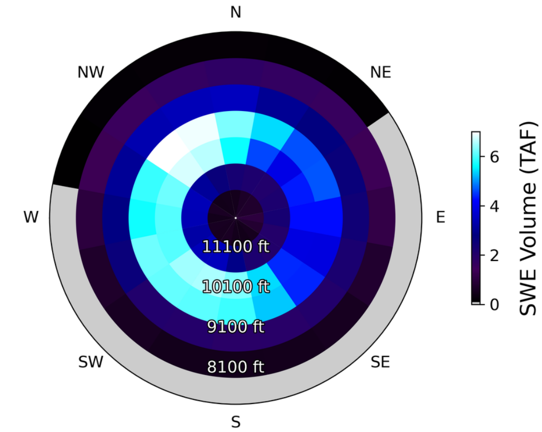


Figure 2.a. Distribution of SWE volume (TAF) by elevation. **2.b.** Distribution of SWE volume (TAF) by aspect and elevation for the March 21 survey. See **Figure 8** and **Figure 9** for additional descriptive plots.

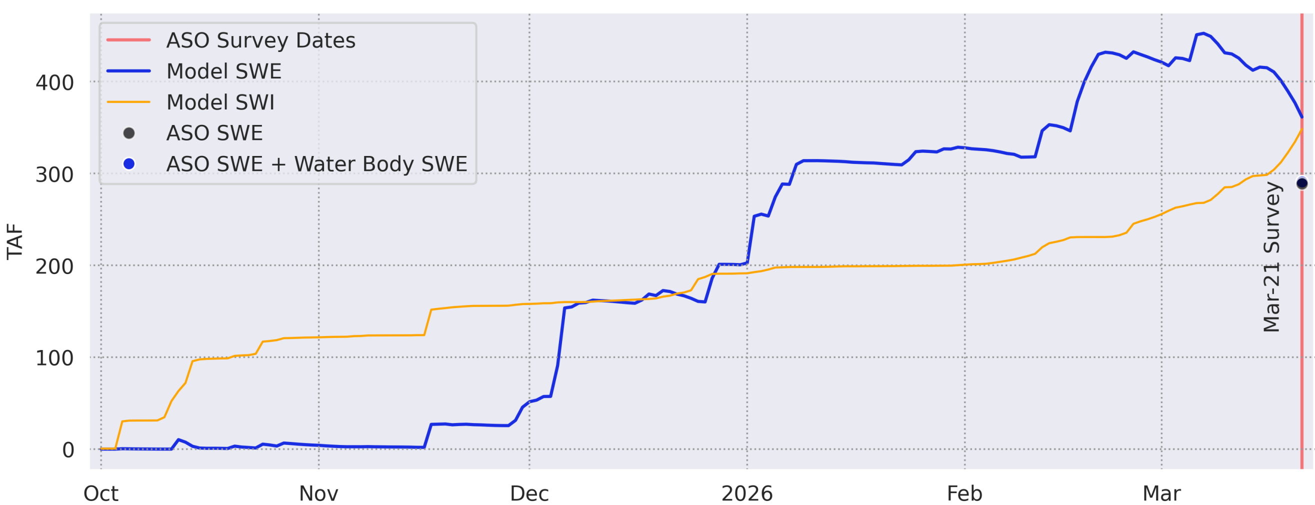


Figure 3. Daily timeseries of modeled SWE volume (TAF) and Surface Water Input (SWI) volume (TAF) for the Yampa and Elk Rivers. In this instance, the ASO SWE (black dot) and the ASO SWE + Water Body SWE (blue dot) are overlapping.

Summary of background conditions

The Yampa and Elk Rivers experienced a slow start to Water Year 2026, as reflected by snow station observations across the region. At the Dry Lake snow sensor (SNOTEL 457; elevation 8240 ft), little snow accumulation was recorded throughout November and into December. A large storm occurred in early December, after which a series of small storms continued through the winter.

Strong mid-to-late-February storm cycles bolstered the snowpack, but in the week leading up to the survey, SWE had begun to decrease at this site, marking the beginning of the ablation period. The ablation context of this survey and accompanying warming temperatures in the week leading up to the survey were considered during the density analysis.

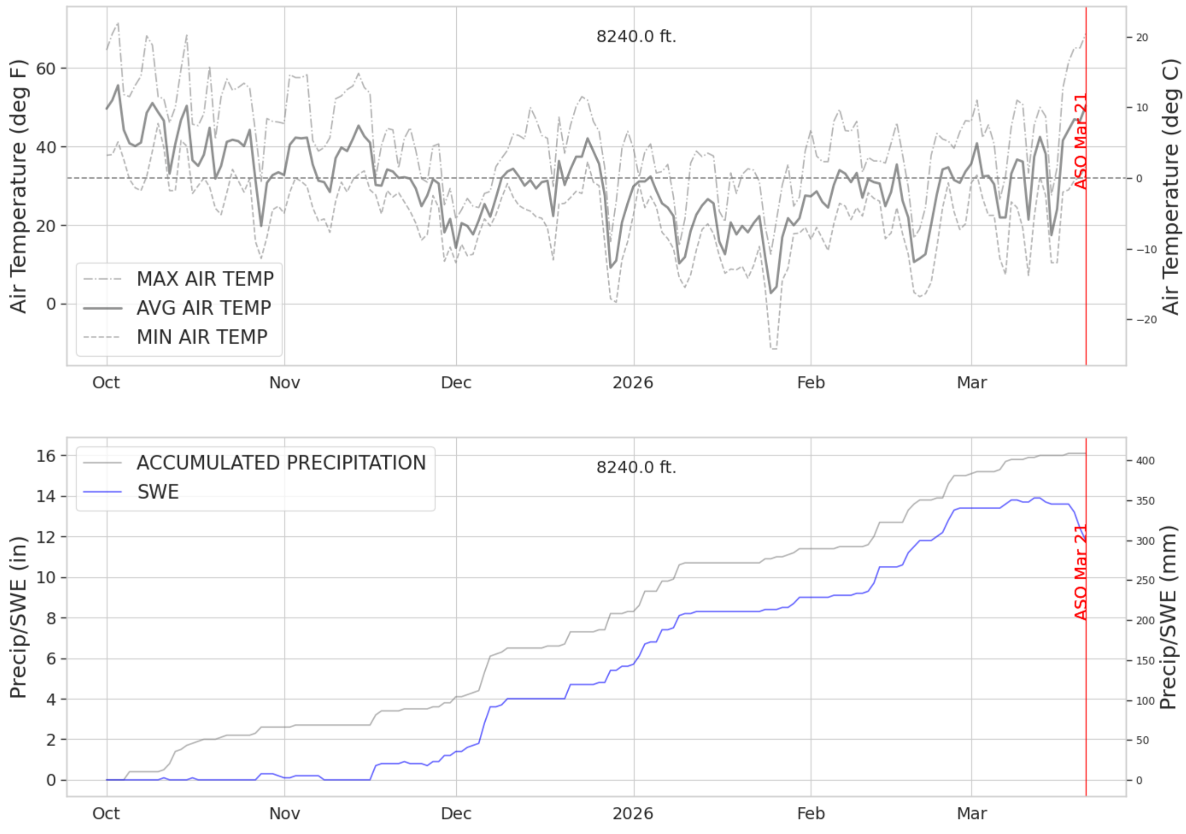


Figure 4. Daily meteorological conditions at Dry Lake (SNOTEL 457; elevation 8240 ft).
Note: the raw daily data shown have been downloaded directly from the Natural Resources Conservation Service (NRCS) and have not been quality checked for this report. Noise or incorrect data may be present. Precipitation data are shown only if the featured station records such data, and the air temperature plot shows daily maximum, mean, and minimum values. ASO surveys are marked with red vertical lines.

Evaluation of ASO snow depth measurements

Snow-free, planar surfaces, common between the snow-on and snow-off datasets, are used to co-register the elevation datasets. This relative registration process ensures that in areas without snow, we measure a snow depth of 0, and enforces snow depth accuracy throughout the survey area.

At 3 m resolution, the standard deviation of snow depth distribution at 50 locations was 1 cm, unbiased based on a rigorous bare surface evaluation. At 50 m resolution the snow depth uncertainty was less than 1 cm.

Point-to-point comparison of in-situ snow depths with ASO 3 m resolution snow depth is shown in Table 2.

These depth comparisons are typically performed at stations and/or field measurement locations for which we are confident in 1) the location and 2) the depth data being reported at the time of the ASO survey. Because we are directly comparing a point to a 3 m pixel in our data, we need to be certain that the station location is accurate to within 1.5 m. For reference, GPS data are usually only accurate to within 5 m, but we are often able to pinpoint locations using other means, thereby enabling these comparisons. For these reasons, specific sites might not be included in the comparison. Please contact the ASO team to converge on accurate and precise coordinates and/or investigate data quality issues for any sites of interest.

At these known and trusted station and field locations in the Yampa and Elk Rivers, the mean snow depth uncertainty was -2 cm. Stations that were excluded due to inaccurate locations or questionable or missing depth readings include: Lynx Pass.

Table 2. Comparison of ASO and high-quality snow station snow depths.
Note: the ASO long-term depth uncertainty is ±5 cm. All depths are rounded to the nearest whole number.

Site	Elevation (ft)	Date	ASO depth (cm)	Site depth (cm)	Depth difference (cm)
Elk River (467)	8710	3/21/2026	54	61	-7
Rabbit Ears (709)	9390	3/21/2026	76	81	-5
Tower (825)	10610	3/21/2026	172	165	7
Lost Dog (940)	9350	3/21/2026	76	82	-6
Bear River (1061)	9100	3/21/2026	50	48	2
Crosho (426)	8960	3/21/2026	18	23	-5
Columbine (408)	9710	3/21/2026	88	87	1
Buffalo Park (913)	9240	3/21/2026	62	61	1
Dry Lake (457)	8240	3/21/2026	61	69	-8
				Mean	-2

In-situ measurements

Note: "±" values represent standard deviation.

Supplemental field collections

- To better understand the current snow density conditions, the ASO field team conducted field work in the Yampa and Elk Rivers on March 18th, three days prior to this survey. The ongoing densification of the snowpack affected snow density between the collection window and the ASO survey. The densification rate was estimated at +5 $kg/m^3/day$ based on nearby in-situ sensors; this rate was used to time-adjust the snow density measurements that were taken prior to the ASO survey. Following the application of this densification rate, the mean snow density reported from two snow pits on Rabbit Ears Pass was 367 kg/m^3.
- NRCS staff also obtained snow tube measurements in the Yampa and Elk Rivers on March 20th, one day preceding this survey. The same densification rate discussed above (+5 $kg/m^3/day$) was applied to these measurements. Following the application of this densification rate, the mean snow density reported from two snow pits was 302 kg/m^3.

Sensor measurements

- The mean snow density reported on March 21st at 12 pillow locations in or near the Yampa and Elk Rivers was 375 ± 38 kg/m^3, with a range of 295-407 kg/m^3 (Columbine, Crosho, Dry Lake, Tower, Lost Dog, Lynx Pass, Rabbit Ears, Elkhead Divide, Zirkel, Buffalo Park, Elk River, and Bear River SNOTEL sites).

Snow course measurements

- The March snow course measurements from two locations, collected on February 23rd, were available from NRCS at the time of processing. However, these measurements were collected more than 14 days prior to the aerial survey; thus, all courses were omitted from our density analysis.
- Refer to Figure 5 for snow density changes that occurred since the March snow course measurement window.

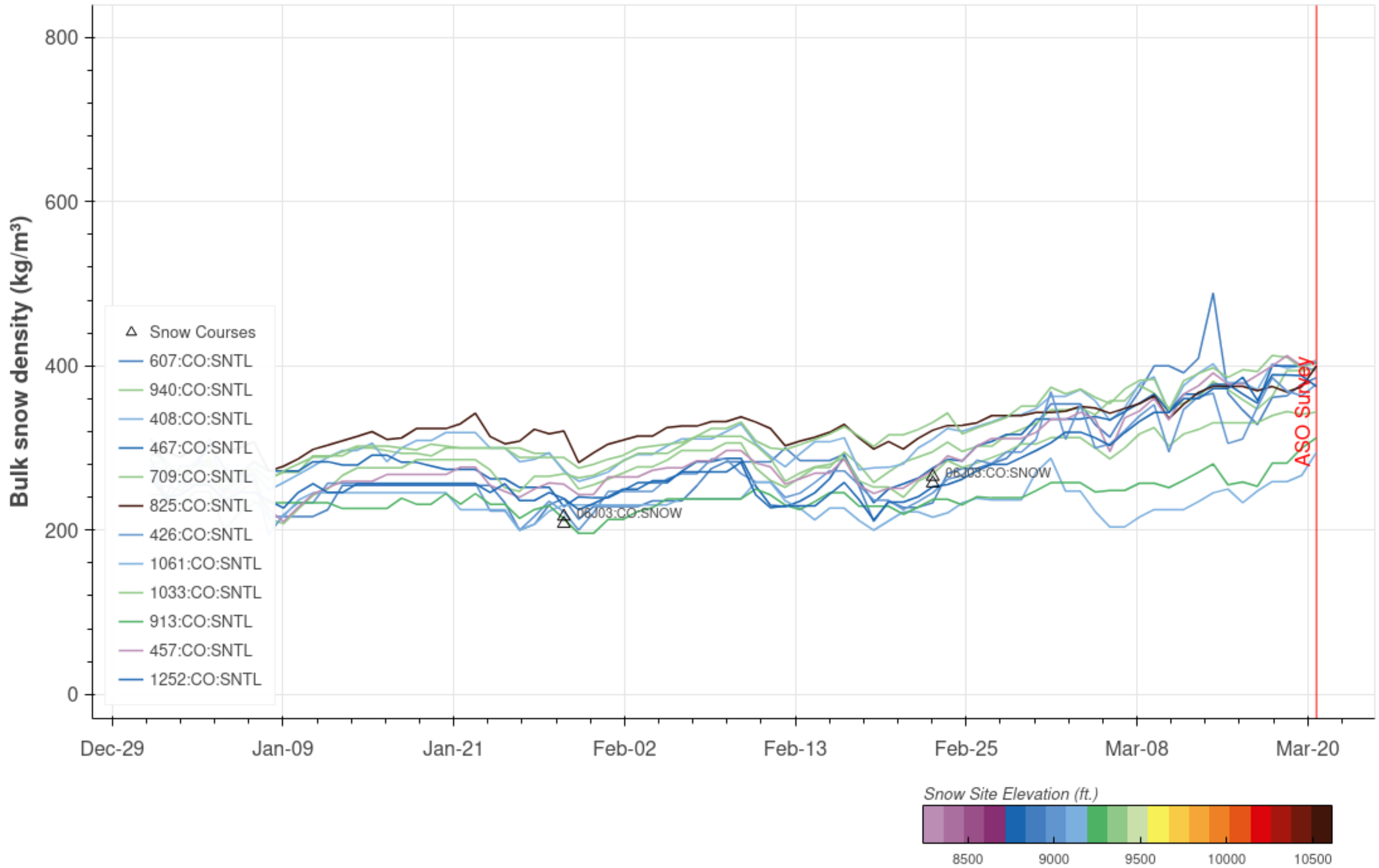


Figure 5. Snow density timeseries at automated sensor locations and snow courses in the Yampa and Elk Rivers (data source: NRCS).

Evaluation of snow density

Model evaluation

- As this is the first survey of the season in the Yampa and Elk Rivers, the iSnobal model is only now being updated with data from the March 21st airborne survey.
- A comparison of the measurements with the model was conducted accounting for model representation of vegetation type, canopy height, and canopy density. The direct and proximal grid cell comparison with the in-situ measurements at 9 locations revealed a mean difference of 25 kg/m^3 or 7%, and a mean absolute difference of 39 kg/m^3 or 10%.
- For more information on the iSnobal model evaluation, see iSnobal model state update on page 17.

Model adjustment

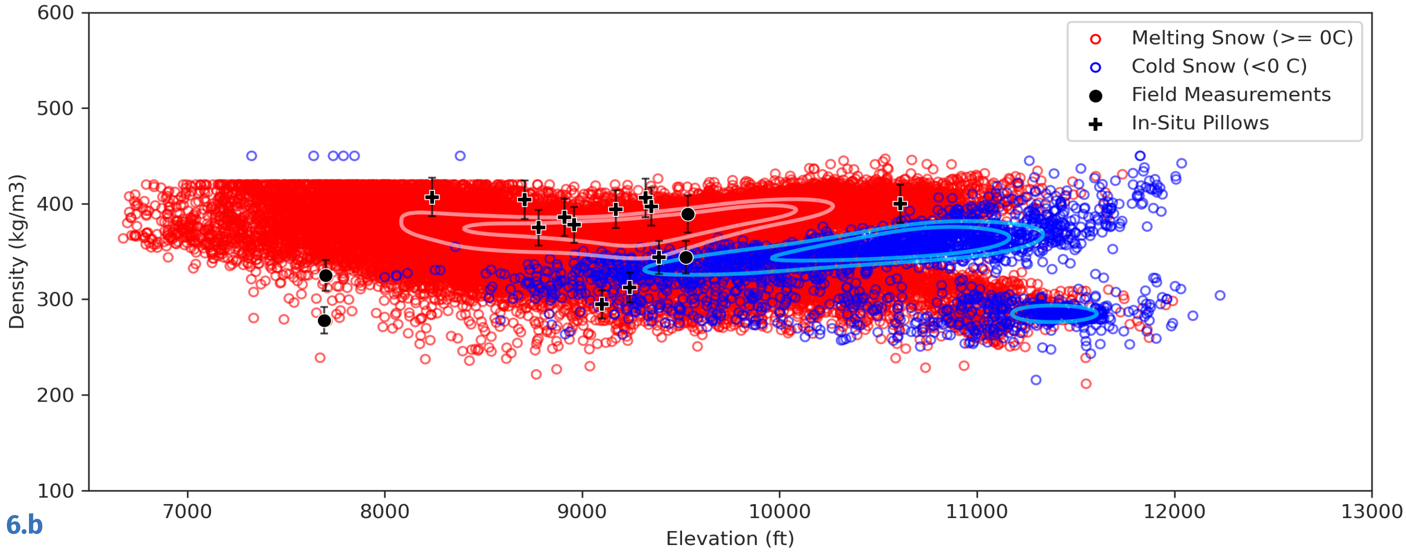
- When compared to the available in-situ measurements in the Yampa and Elk Rivers, the iSnobal model was overestimating melting-snow densities in shallow snow and underestimating melting-snow densities in deep snow. To account for these biases, melting-snow densities were adjusted using a depth-based polynomial equation.
- The model was generally underestimating cold-snow densities. The densities of cold snow were increased by 10%, in accordance with available in-situ guidance.
- The densities of shallow snow (<0.25 m) were capped at 420 kg/m^3.
- After adjustment, the direct and proximal grid cell comparison with in-situ measurements showed a mean difference of 0 kg/m^3 or 0%, and a mean absolute difference of 22 kg/m^3 or 6%. The spread of adjusted modeled densities is shown with snow depth and elevation in Figure 6 alongside considered in-situ values.

SWE sensitivity to snow density

- Using the open-loop model density and applying ASO snow depths, the full domain SWE was 281 TAF; after snow density adjustments were applied, the domain SWE estimate was 289 TAF. The snow density adjustments increased the domain SWE estimate by 2.8%.
- To encompass the full spread of the considered in-situ measurements, we generated two additional SWE scenarios: a low-density scenario (Scenario L) and a high-density scenario (Scenario H).

- For Scenario L, an additional snow density reduction of 6% was applied, while Scenario H saw an additional snow density increase of 6%, reflecting the variation in field and station density values.
- The resulting full-domain SWE outcomes for these scenarios were 272 TAF and 306 TAF, respectively. These scenarios span and exceed the full range of the in-situ measurements and thus should be interpreted more as possible snow density extremes rather than equally probable SWE outcomes.
- We have factored uncertainty based on these outcomes into the values reported on page 3 of this report.

6.a



6.b

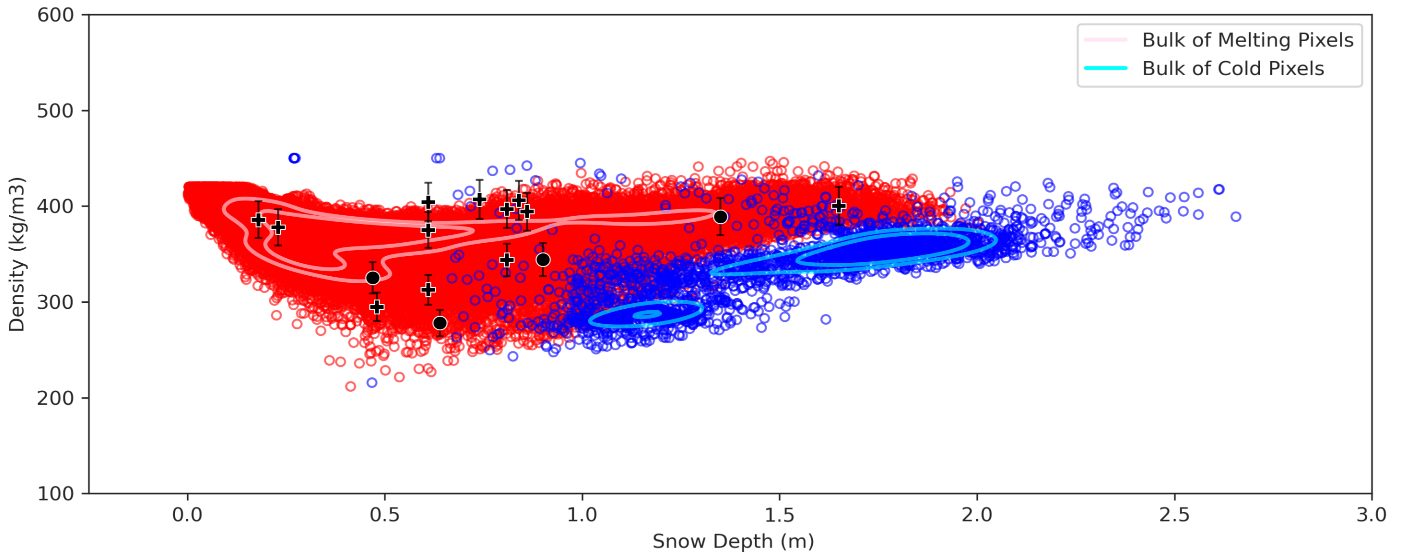
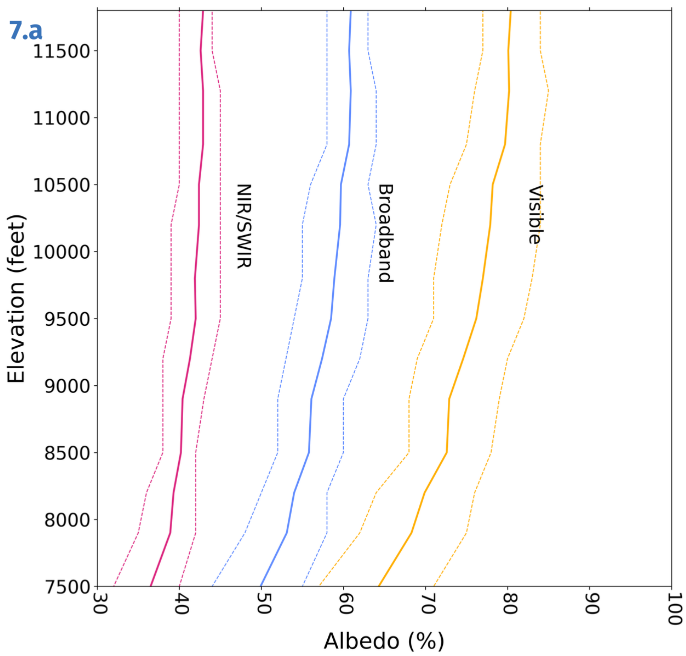


Figure 6. Observed and modeled bulk snow density (kg/m³) by **6.a.** elevation (ft) and **6.b.** depth (m). These plots show densities following the adjustment process.

Snow albedo

- Albedo traces by elevation show that the snowpack albedo decreases with decreasing elevation due to both increasing grain size and increasing impurity load.
- Reduced snow albedo values due to dust contamination on the snow surface were observed at all elevations.
- Note: snow albedo retrievals are only made over well-illuminated, non-shaded, and non-vegetated areas.
- There was high, thin cloud cover above the plane during our survey of the southern portion of the domain on the second flight of March 21st which affected the albedo retrieval. We have masked albedo retrievals from that portion of the survey.

7.a



7.b

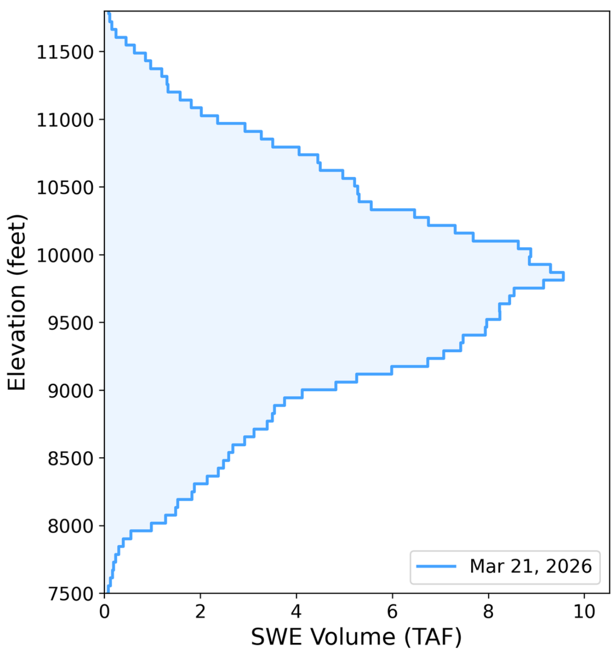


Figure 7.a. Snow albedo (%) by elevation (ft) on March 21 with mean (solid lines) and ± 1 quartile (dotted lines) for near and shortwave infrared (magenta), broadband (blue), and visible (gold) wavelengths. **7.b.** Distribution of SWE volume (TAF) by elevation on March 21. The SWE data displayed here match the elevation range for which we have albedo data; for the full distribution of SWE volume by elevation, see **Figure 9.a**.

Additional data and remarks

- The following additional data products are available in the product zip pack downloadable via the ASO, Inc. data portal:
    - SWE extractions for the River Forecast Center basins/polygons that were 100% covered by the ASO survey (*swe_RFC_aggregate.csv).
    - Full-resolution PDF versions of the images and figures in this report.
- Please refer to the text files included in the data package for SWE volume per elevation band and other summary statistics.

Additional figures

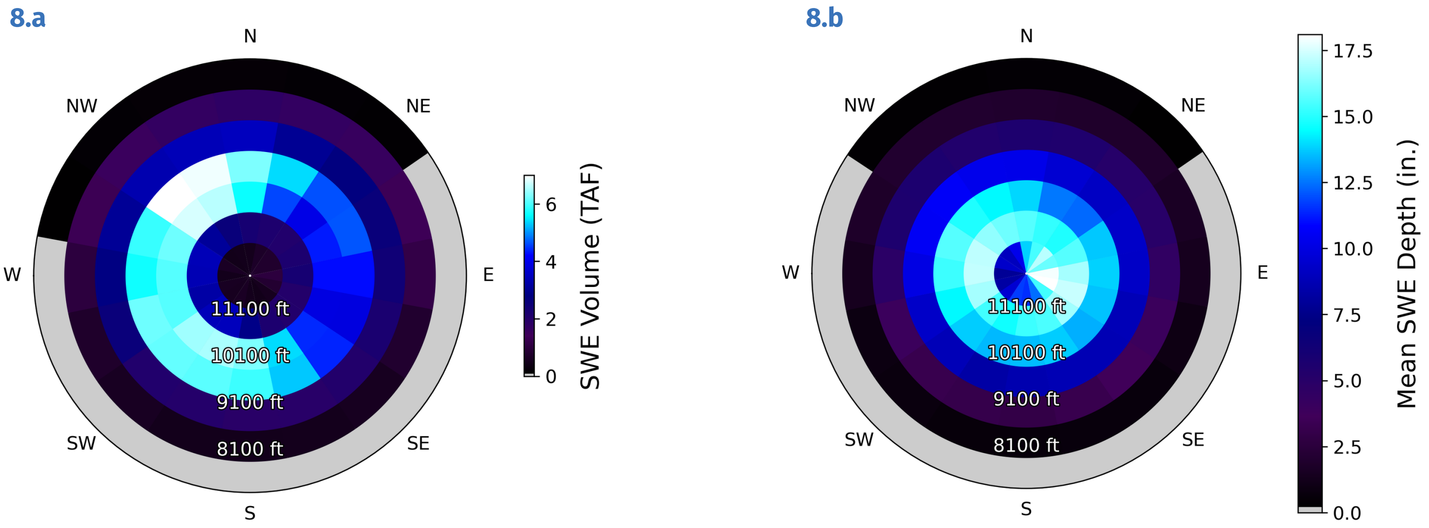


Figure 8. Aspect/elevation SWE plots **8.a.** SWE volume (TAF) and **8.b.** SWE depth (in) for the March 21 survey.

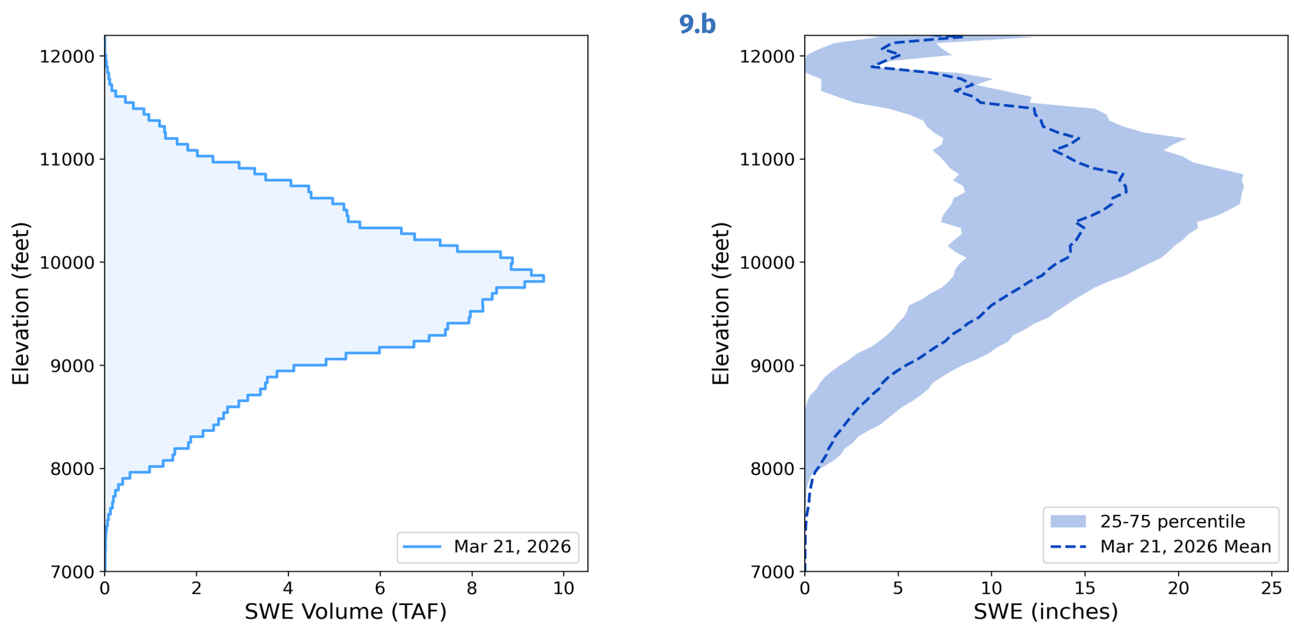


Figure 9. Plots of SWE volume (TAF) and depth (in) by elevation for the March 21 survey. **9.a.** Distribution of SWE volume (TAF) across elevations. **9.b.** Distribution of SWE depth (in) across elevations.

iSnobal model state update

In this section, we show the changes* to the iSnobal model following the ingestion of the ASO measured snow depth and adjusted snow density product from the March 21st survey.

Prior to ingesting the March 21st ASO survey data, the model showed a smaller snow-covered-area (SCA). The update increased the domain SCA from 62% to 70% coverage; however, due to reduced depths, the total domain SWE in the model decreased by 69 TAF.

Change in total SWE: -69 TAF
Change in mean SWE: -1.3 ± 3.2 in
*comparison of non-waterbody pixels

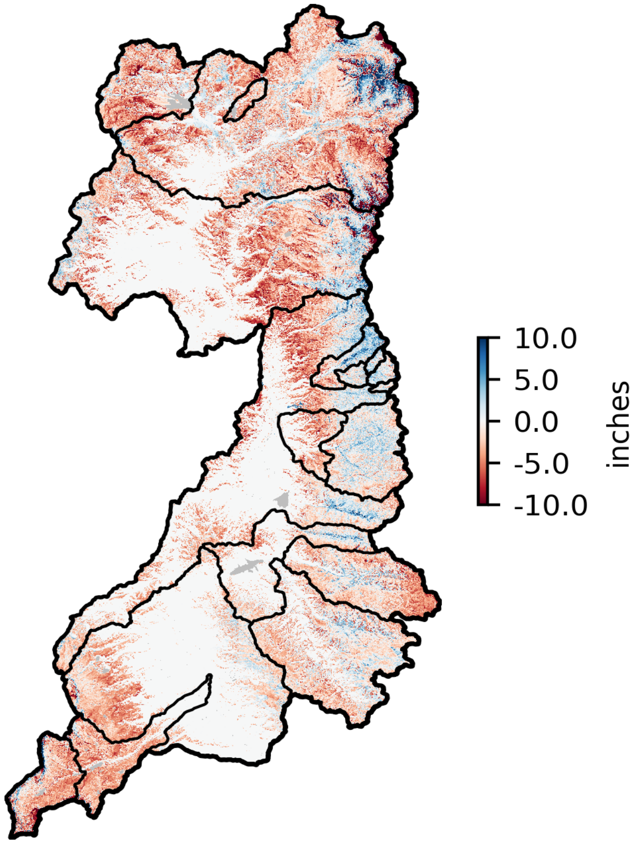


Figure 10. Change in iSnobal SWE depth (in) before and after ingestion of the March 21 ASO survey data. Blue represents areas in which modeled snow depths were lower than the depths measured during the ASO survey; red represents areas in which modeled snow depths were higher than the depths measured during the ASO survey. Darker colors represent a greater magnitude of change.

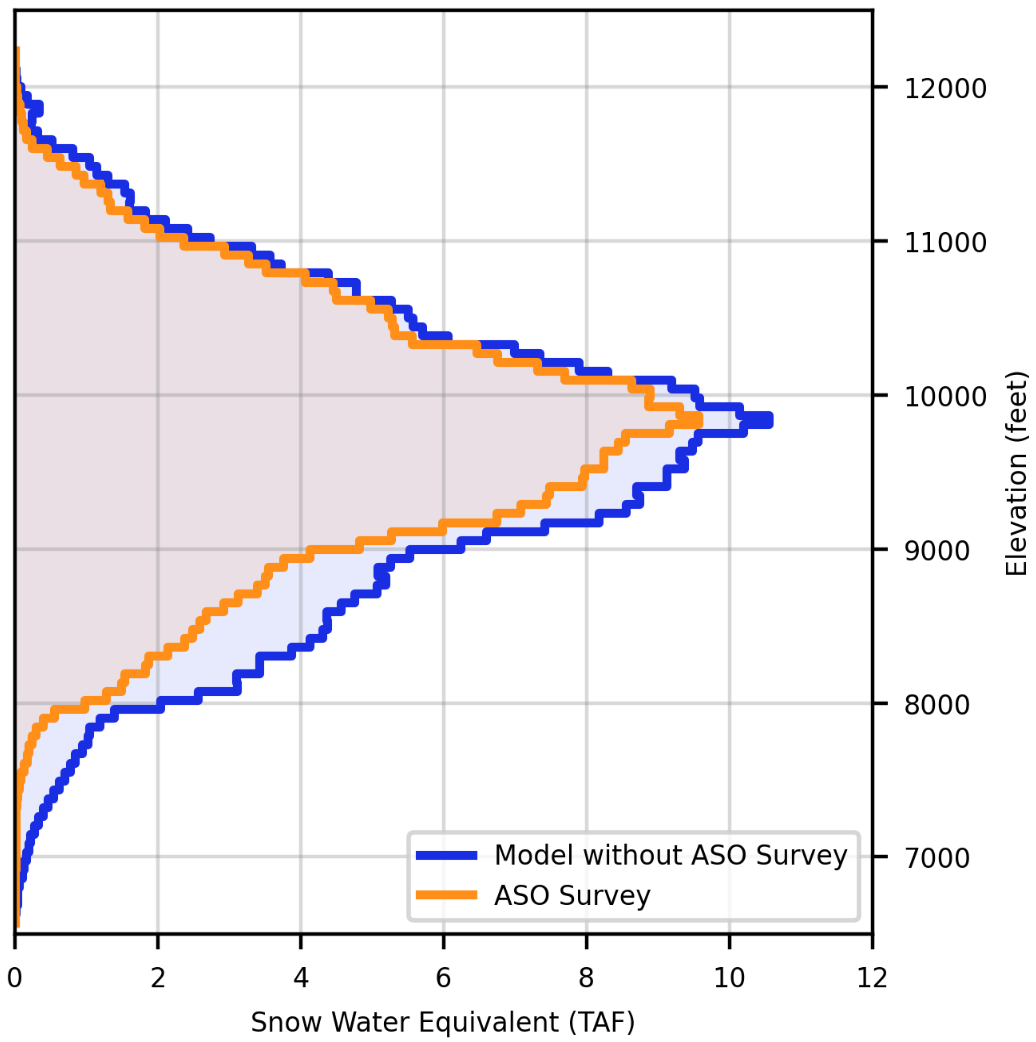


Figure 11. Distribution of iSnobal SWE volume (TAF) by elevation before and after ingestion of the March 21 ASO survey data. Blue represents the model state before the ASO survey, and orange represents the model state following the ASO survey.