SnowOp Field Campaign, Grand Mesa, Colorado

January 30-February 23, 2023

Grant from NASA JPL to Boise State

Final Report

H.P. Marshall and Kelly Elder

This report provides a brief summary of the field activities performed during two intensive surveys, aligned with JPL SnowOp airborne flights. The first survey took place January 30-February 2, 2023, and the second survey occurred February 21-23, 2023. Based on airborne flight plans, two survey lines were established on Grand Mesa, both oriented North-South, which were named “West” and “East”, shown in Figure 1. SWE is shown with colors in cm (colorbar to right), and the background is the vegetation height measured above the snow from the 2020 QSI lidar collected as part of SnowEx (scale to left, in meters).

A black and white image of a rock

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Figure : SWE measured in 35 snowpits between Jan 30 and Feb 2, 2023. Magenta diamonds show nearby weather stations, and red triangles show radar corner reflectors installed for SnowEx.

Between the two campaigns, Grand Mesa received approximately 5.5cm of SWE, however due to settlement there was little change in depth. A storm that occurred during the second campaign increased the depth at the Mesa Lakes SNOTEL site by 15cm, and an increase of SWE of 2cm, however this was spatially variable. This storm came with very high winds, preventing safe fieldwork on February 22. While there was a small but measurable increase in depth and SWE between February 21 and 23 at the SNOTEL site, note that the East line was surveyed on the 21st and the West line on the 23rd due to team size and weather, so this should be considered if comparing the two lines.

Figure 2 shows the time series of depth and SWE during the period of the two campaigns (left), along with notched boxplots for depth (middle top) and SWE (middle bottom) from the 35 snowpit locations. Note that there was a significant (5.5cm) increase in median SWE, but no significant change in depth due to settlement. Because of the dangerous weather conditions and smaller field team, the second survey used a combination of standard snowpit observations and Federal Sampler coring. The figures on the far right in Figure 2 show a comparison of the two approaches where they were coincident, showing no significant difference in median values. We therefore grouped the pit and federal sampler data together for Survey #2.

A graph of different shapes and sizes

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Figure : Depth and SWE time series from Mesa Lakes SNOTEL (left). Survey periods shown (gray). Boxplots are shown for each surveys for depth (middle top) and SWE (middle bottom). Changes in depth and SWE using the two approaches shown on right.

At a smaller scale, Fig 3 and Fig 4 show the measured SWE during Survey #1 (Fig 3) and Survey #2 (Fig 4). The average increase in SWE is apparent as both figures are on the same color scale, but changes are spatially variable and influenced by vegetation height. Figure 5 shows the change in SWE measured for those locations that were repeated on the two surveys (n=28). A total of 35 snowpits were measured during Survey #1, and 17 pits during Survey #2. SWE was measured at a total of 22 sites with the Federal Sampler.

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Figure : SWE measured in 35 snowpits during Survey #1

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Figure : SWE measured in 17 snowpits and 22 Federal Sampler cores during Survey #2.

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Figure : Change in SWE between Survey #1 and Survey #2.

During Survey #1, we also performed depth surveys with a manual depth probe, connected to a sub-meter GPS system. Note that snow depths were too great to use a MagnaProbe, therefore probing was more time consuming. During Survey #1 we collected 2,629 snow depth observations (in addition to the depth measured at the snowpits), and during Survey #2 we measured depth in 1,365 locations. These depth surveys confirm that there was very little change in snow depth, with a statistically significant decrease in median snow depth of 3 centimeters. Figure 6 shows histograms of snow depth from the two surveys (left) and notched boxplots on the right. Snow depths ranged from 75cm to 275cm on both surveys, with lower depths in forested areas, and higher depths in open areas. Both depth and SWE was greater on the East line compared to the West line, due to the gradient in snow depth and SWE that occurs in the East-West direction. If possible, future surveys might consider orienting in the East-West direction, however the North-South lines were required based on the geometry of the signal sources.

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Figure : Snow depth histograms and boxplots for the two surveys (n=2,629 for Survey #1, n=1,365 for Survey #2).

Figure 7 and Figure 8 show the measured snow depths from the two surveys. Probing was performed in spirals around the snowpits, as well as along transects. All depths were geolocated using sub-meter GPS receivers attached to the end of the probe, with typical horizontal accuracies on the order of 20cm. The snow was deeper on the East line compared to the West line.

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Figure : Snowdepth measurements [cm] during Survey #1

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Figure : Snow depth measurements [cm] during Survey #2

Figures 9, 10 and 11 below show zoomed in plots of snow depth, illustrating the impact of vegetation on depth, likely due to snow intercepted in the canopy.

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A screenshot of a survey

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All data has been QA/QC’d, and along with the MATLAB code used for this report, is located in the github repo at <https://github.com/hpmarshall/SnowOp2023field>. Please contact HP Marshall ([hpmarshall@boisestate.edu](mailto:hpmarshall@boisestate.edu)) and Kelly Elder ([elderrmrs@gmail.com](mailto:elderrmrs@gmail.com)) with any questions about this dataset and preliminary analysis. Note that other observations were also performed by the team, including snow stratigraphy, hardness, grain size/type, liquid water content, dielectric permittivity, SnowMicroPenetrometer profiles, and extensive ground-based radar. The QA/QC and processing of this data is currently underway and is available upon request, as it was not a deliverable for this project.