2023 CUES Snow Pit Data Report

Alex Michell

Beginning in December, 2022, snow pits were dug regularly on the northeast corner of the Cold Regions Research and Engineering Laboratory (CRREL) and University of California Santa Barbara (UCSB) Energy Site (CUES) plot located east and uphill of McCoy Station on Mammoth Mountain, at an elevation of 2940 m. The depth, density, snow water equivalent (SWE) and temperature of the snowpack were measured at each sampling. Following the snow season, these data were compared with the corresponding measurements collected at the CUES weather station as well as with the snow reports created by the National Snow and Ice Data Center for the entire western US. Summaries of the collected metrics and subsequent comparisons are provided below.

The CUES instrument-recorded depth data used to compose the plots below were collected by the laser depth meter located on the north side of the weather station. The CUES SWE (and back-calculated density) data were recorded by the snow pillow belonging to the California Department of Water Resources located on the CUES plot to the south-southeast of the pit locations.

Periodically throughout water year 2023 (see Table 1 for specific dates), a single snow pit was dug north-northwest of the weather station along the transect indicated in red in the Google Maps satellite image below (Figure 1). The locations of the CUES weather station and CDWR snow pillow are also indicated in the satellite photo; specific site information can be found at the CUES website; site photographs and instrument labels as of 2021 are provided here.

Water year 2023 was unprecedented with regards to the size and longevity of the snowpack. This massive snow year imposed unprecedented challenges to regular data sampling and to the automatic recording instruments. Due to labor and time constraints, fewer pits were dug than in previous years, and multiple instrument malfunctions occurred.

Table 1. Data collected from hand-dug snow pits during the 2023 water year.

Date	Depth (cm)	Avg density (kg/m^3)	SWE (cm)
12/6/22	111	262	29.082
12/13/22	141	279	39.339
1/3/23	216	318	68.688

1/12/23	351	329	115.479
4/5/23	530	421	223.13

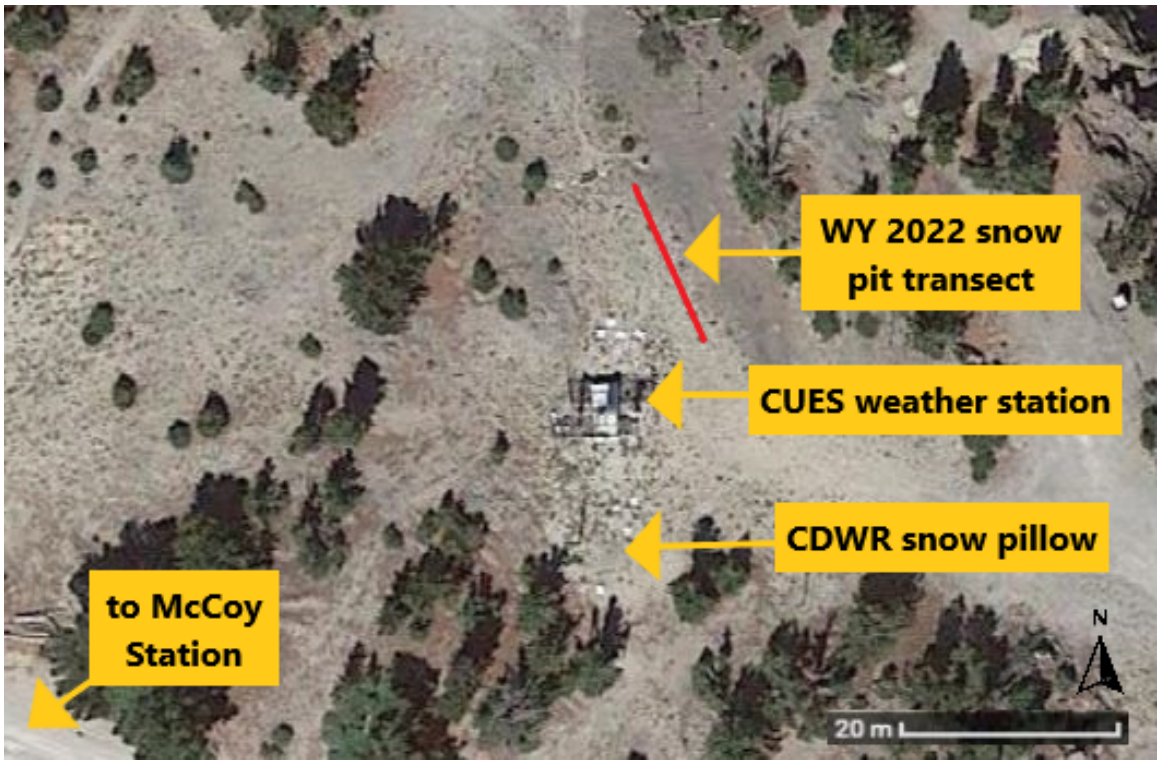

Figure 1. Site of the CUES weather station, CDWR snow pillow and snow pit transect (red) northeast of McCoy Station on Mammoth Mountain.

In the following text, detailed comparisons of the pit-measured snow depth, snow density and SWE with the corresponding data measured by instruments at the CUES weather site are conducted; graphs depicting these comparisons are shown in Figures 2, 3, and 4, respectively.

A comparison between the snow depths measured at each pit sampling and those continuously measured by the Lufft SHM31 laser mounted at the CUES weather station is shown in Figure 2 below.

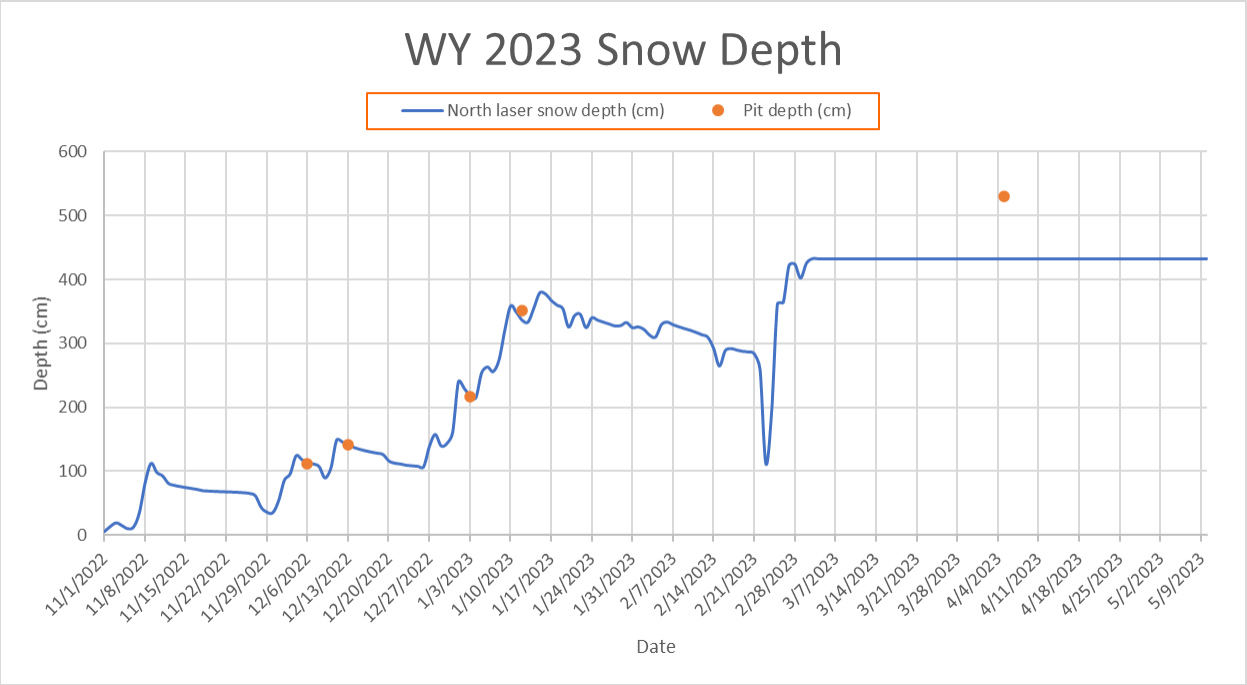

Figure 2. Depth series from the north Lufft SHM31 laser (blue line) and snow pit depths (orange dots).

The north laser is the closest depth-measuring instrument to the snow pit transect. The snow pit depth data reflect the trend shown in the laser-measured series well, and the small depth differences can be attributed to the varying temporal resolutions of the data series and to topographic differences arising due to the pit transect being located approximately 10 meters northeast of the mounted laser. Due to the low grazing angle, the north laser has been recording a constant depth of 433 cm since 3/3/2023, though the pit measured on 4/5/2023 was 530 cm deep; the laser-measured depth data can thus be assumed to be quite underestimated from early March onwards.

Figure 3, below, provides a comparison between the pit-averaged snow densities measured in each snow pit and those continuously measured by the CDWR snow pillow. As the snow pillow does not output density but instead outputs SWE values, the corresponding snow density values of the snowpack over the snow pillow were back-calculated using the following formula (Eq. 1):

$$Density\left(\frac{kg}{m^3}\right) = \frac{1000 \cdot SWE\ (cm)}{Depth\ (cm)}$$

Eq. 1

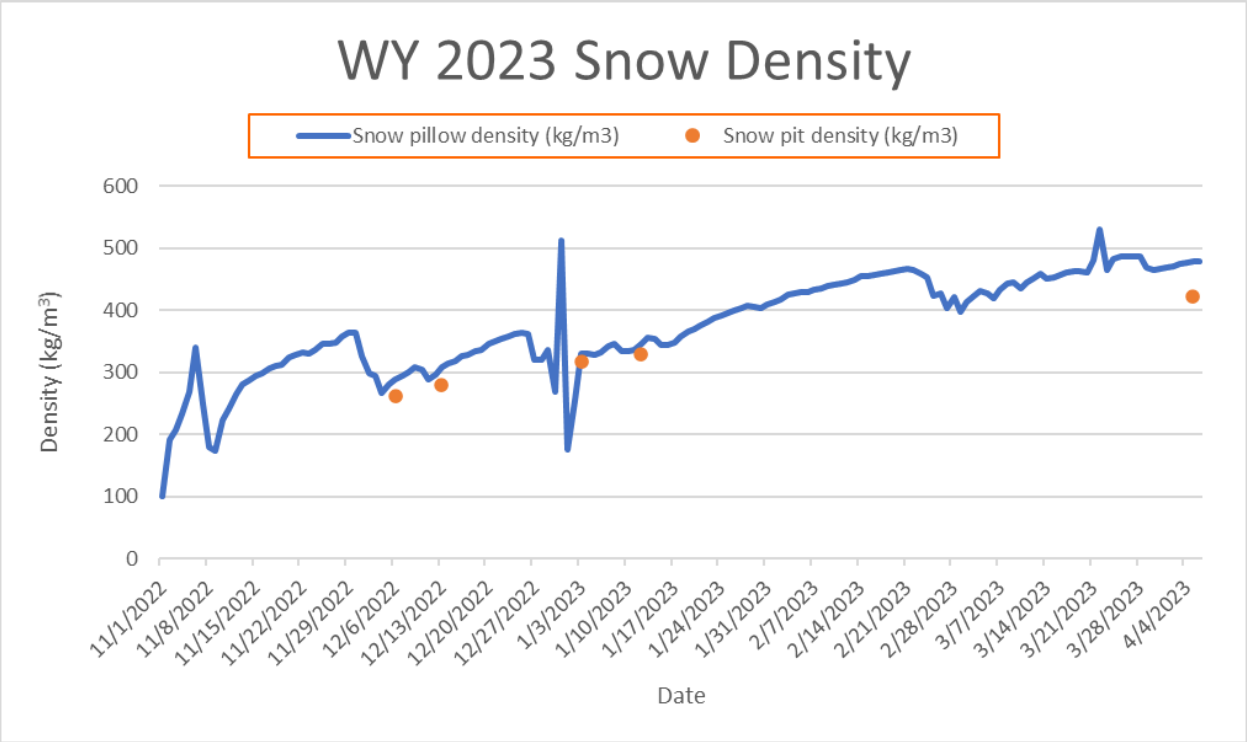

Figure 3. Density series from the CDWR snow pillow (blue line) and average column density from snow pits (orange dots).

Because the remote boom that measures the snow depth began malfunctioning on April 7, 2023, the graph shows the data series spanning from 11/1/2022 to 4/6/2023. The pit-measured and snow pillow-recorded densities match well during this period.

The SWE values obtained from the snow pits and those continuously measured by the CDW snow pillow are compared in Figure 4 below. As only snow density and snow depth were measured from the snow pits, the pit SWE values were calculated using the following obtained by rearranging Eq. 1 above (Eq. 2):

$$SWE\ (cm) = Depth\ (cm) \cdot \frac{Density\ \left(\frac{kg}{m^3}\right)}{1000}$$

Eq. 2

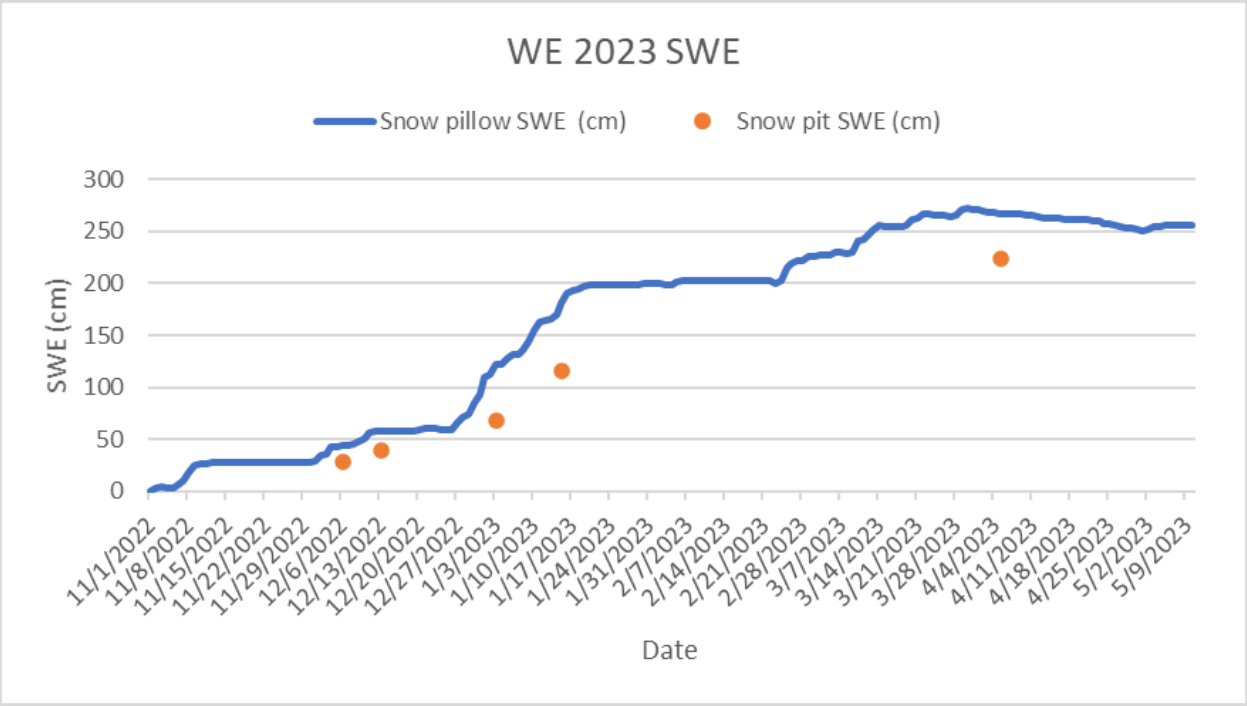

Figure 4. Daily average SWE series from the CDWR snow pillow (blue line) and recorded in snow pits (orange dots).

The pit data reflect consistently low SWE values compared to the snow pillow-collected series. The snow pillow is located slightly (approx. 20 meters) south of the snow pit course and is relatively sheltered by white pine trees. Despite this offset, the trends of the two data series are consistent.

References

CUES site: https://snow.ucsb.edu/

CUES instrument list (labeled photos):
https://snow.ucsb.edu/wp-content/uploads/2021/11/CUES-instruments-2021.pdf