SnowEx23 Oct22 IOP Snow Depth Profiles, Version 1 Technical Reference

1 INTRODUCTION

1.1 Data Set Overview

The data set contains boreal forest and tundra snow depth profile measurements in Northern Alaska, USA; data were collected during the October 2022 intensive observation period (IOP) as part of the NASA SnowEx 2023 field campaign. The purpose of the ground-based snow depth profiles is to provide detailed observations of the snow profile, which include observations of air gaps, generally caused by vegetation. Ground-based snow depth profile measurements were taken in the vicinity of snow pits distributed across five study areas in Northern Alaska. Three study areas represented boreal forest snow conditions near Fairbanks, AK: Farmers Loop Creamers Field (FLCF), Caribou Poker Creeks Research Watershed (CPCRW), and Bonanza Creek Experimental Forest (BCEF). Two study areas represented Arctic tundra snow conditions: Arctic Coastal Plain (ACP) and Upper Kuparuk Toolik (UKT). Detailed descriptions of study areas, snow plots, classifications, sampling design, and sampling protocols during are available in the NASA SnowEx 2023 experiment plan (Vuyovich et al., 2023). These data can be used as validation data for concurrent SnowEx 2023 ground-based snow depth measurements, as well as airborne lidar and radar observations. Snow depth profile measurements collected during the March 2023 and October 2023 IOPs are available as SnowEx23 Mar23 IOP Snow Depth Profiles, Version 1 and SnowEx23 Oct23 IOP Snow Depth Profiles, Version 1.

1.2 File Information

1.2.1 Format

These data are provided in a single comma-separated value (.csv) file.

1.2.2 Naming Convention

The data file is named `SNEX23_Oct22_Profiles_20221022_20221027_V01.0.csv`, where `SNEX23_Oct22` refers to the SnowEx 2023 October 2022 IOP field campaign, `Profiles` refers to snow depth profiles, `20221022_20221027` represents the data collection period, and `v01.0` represents Version 1.

1.3 Spatial Information

1.3.1 Coverage

Northernmost Latitude: 70.084378° N

Southernmost Latitude: 64.699253° N

Easternmost Longitude: 147.485758° W

Westernmost Longitude: 149.597226° W

1.3.2 Geolocation

This data set conforms to the WGS 84 / UTM zone 6N coordinate reference system (EPSG 32606).

1.4 Temporal Information

1.4.1 Coverage

11 October 2022 to 27 October 2022

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Snow depth profiles were measured coincident with standard snow depth measurements in order to document errors due to low-lying vegetation, air voids, ice crusts and penetration of the instrument into the ground. Particularly in areas with dense ground vegetation, the snow depth measured from the snow surface to the ground surface may not be representative of the actual depth of snow covering the ground. The vegetation can hold some of the snowpack and create air pockets underneath the surface with no snow (Figure 1). This could lead to a potential bias in estimates of snow depth collected from airborne lidar and stereophotogrammetry as well as from standard ground-based measurements. Furthermore, this could potentially create an error in estimates of SWE if the snowpack is assumed to be continuous from the surface to the ground based on these snow depth measurements. To help quantify the bias in snow depth measurements and better characterize the SWE at the SnowEx field sites we collected careful snow depth profile measurements at each SnowEx study plot.

Figure 1. Example air gap beneath the blanket of snow caused by grass supporting the snow above. Photo taken by A. Pinzer (UAF).

Snow depth profile measurements were made from October 22-27, 2022 as part of the NASA SnowEx 2023 October 2022 Intensive Observing Period. Ground-based snow depth profile measurements were taken in the vicinity of 187 snow pits distributed within five study areas across Northern Alaska. Three study areas represented boreal forest snow near Fairbanks, AK: Farmers Loop Creamers Field (FLCF), Caribou Poker Creeks Research Watershed (CPCRW), and Bonanza Creek Experimental Forest (BCEF). Two study areas represented Arctic tundra snow: Arctic Coastal Plain (ACP) and Upper Kuparuk Toolik (UKT).

Detailed descriptions of study areas, snow plots, classifications, sampling design, and sampling protocols during October 2022 IOP are available in the NASA SnowEx 2023 experiment plan (Vuyovich et al., 2023).

Every study plot visited within the SnowEx sites was assigned a Plot ID. Plot IDs were classified using one or two letters followed by a three-digit site number series (ex. EN900 or I800). In boreal forest sites the two letters reference the vegetation class and snow class. For the tundra sites the letter references the tundra snow class. Transects were identified with the code TRAN, followed by a one-digit number. The letter codes are described in the table below.

Table 1. Vegetation and Snow Class Codes

Letter Code	Description
Boreal Forest Plots	
D	Deciduous Forest
E	Evergreen Forest
W	Wetlands
S	Shrub scrub
C	Cultivated crop
B	Below average snow class
N	Neutral or average snow class
A	Above average snow class
TRAN	Transect
Arctic Tundra Plots	
N	Neutral or average (windward)
A	Above neutral (leeward slopes)
D	Snow drift
I	Ice cover (lake / river)

2.2 Acquisition

Snow depth profiles were measured with manual snow depth probes (foldable ruler, depth probe, or avalanche probe). At each study plot where snow pit measurements were collected, twenty manual snow depth profile measurements were collected along the edge of a 5x5m box surrounding the snow pit. At the boreal forest sites these measurements were taken at a 1 m spacing around the perimeter of the plot. At the north slope sites, 20 measurements were collected along one side of the perimeter box. Data and notes were recorded in the field books.

The geographical position of each manual snow depth profile measurement is in reference to the south-east corner of the study plot. The geographical position of the south-east corner was measured with navigation grade GPS. The distances and directions of each snow depth data profile were written in the field books. A detailed description of snow depth data acquisition methods, sampling patterns, instruments, and accuracy is provided in Stuefer et al., (2025).

The protocol consisted of first inserting the probe or ruler to collect and record a standard snow depth measurement. Then the snow in front of where the probe or ruler was located was carefully excavated down to the ground surface. If the probe penetrated the ground surface it was raised to align exactly with the ground surface before recording the height of the snow at the surface as the snow depth profile measurement. This ensured no overprobe measurements were recorded due to soft, spongy ground cover in the depth profile data. Any air pockets were noted by entering the

heights of each snow layer into the field book. At the boreal forest sites, observers noted any canopy impacts and added additional comments to the field book. Codes for canopy impacts are given in Table 2. Arctic tundra plots have low growing vegetation (shrubs, tussocks, mosses, lichens, graminoids) which was covered by snow at the majority of the plots visited during October 2022. Vegetations codes listed in Table 2 were not used in tundra plots.

Table 2. Vegetation Codes for boreal forest study plot snow depth profile measurements

Letter Code	Description
C	Overhead canopy that influences snow on the ground
TW	Measurement is located within a Tree Well
DF	Presence of Deadfall that affects snow measurement
ES	Elevated snow, held above the rest of the snowpack by a branch or shrub
NC	No Calibration, observer was not able to excavate to the ground surface

Figure 2. Excavated snow depth profile showing depth probe sinking into soft organic layer underneath the snowpack (example from Boreal Forest, FLCF study area). The depth profile data was adjusted to remove this overprobe error.

2.3 Processing

Snow depth profile data was processed using the following steps:

1. Transcribe field notes with snow depth profile measurements to electronic data sheets
2. Extract snow depth layer heights, directions, and distances from snow depth profile book sheets
3. Calculate “total snow” depth Calculate positioning based on GPS coordinates of the south-east corner and distance from that corner in specified direction
4. Calculate latitude and longitude in decimal degrees and UTM 6N
5. Plot data and check for positioning in respect to snow pit data set
6. Export data to a single .csv file

“Total snow” represents our best estimate of true snow depth based on measurements from the excavated profiles. Total snow depth excludes air gaps, vegetation (elevated snow), and organic layer (overprobing) unintentionally incorporated into the original snow depth measurement. “HS top” corresponds to the snow surface recorded in the traditional manual snow depth measurement.

Once all data were exported to the .csv file, the dataset was sorted based on study area and plot ID.

2.4 Quality, Errors, and Limitations

2.4.1 Location errors

GPS systems of various accuracies were used to geolocate the measurements. The accuracy of the handheld GPS units, used to mark the location of the southeast corner of the study plot, varies between 3-15 m depending on canopy conditions.

2.4.2 Depth errors

Snow depth profile measurements were taken to help quantify the measurement error in other methods. However, there were still challenges involved in excavating the snow profile that may impact the measurement accuracy. This step was done as carefully as possible to avoid snow falling into air gaps and under vegetation.

2.4.3 Snow depth profile summary figure

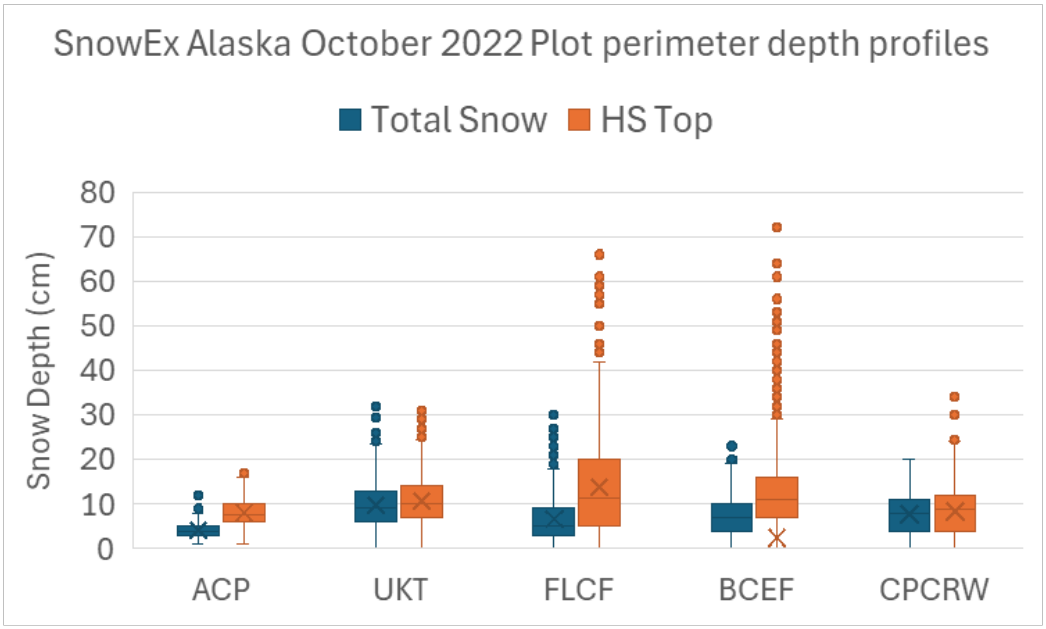

Figure 3. Boxplots show the median and interquartile range for Total snow (blue), and HS top (orange), for each of the five sites in Alaska.

3 REFERENCES

Stuefer, S.L., Hale, K., May, L.D., Mason, M., Vuyovich, C., Marshall, H.P., Vas, D., and Elder, K. 2025. *Snow depth measurements from Arctic tundra and boreal forest collected during NASA SnowEx Alaska campaign*. Scientific Data 12, 919 (2025). https://doi.org/10.1038/s41597-025-05170-x.

Vuyovich, C., Stuefer, S., Durand, M., Marshall, H. P., Osmanoglu, B., Elder, K., Vas, D., Gelvin, A., Larsen, C., Pedersen, S., Hodkinson, D., Deeb, E., Mason, M., & Youcha, E. 2023. *NASA SnowEx 2023 Experiment Plan*. https://snow.nasa.gov/sites/default/files/users/user354/SNEX-Campaigns/2023/NASA_SnowEx_Experiment_Plan_2023_draft_20June2024.pdf