SnowEx20 Time Series Snow Pit Measurements, Version 2

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Mason, M., H. P. Marshall, M. McCormick, D. Craaybeek, K. Hale, K. Elder, C. Vuyovich, and the Time Series Site Leads and Field Teams. 2024. *SnowEx20 Time Series Snow Pit Measurements, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/KZ43HVLZV6G4. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SNEX20_TS_SP

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

The data set is an updated version of a time-series of snow pit measurements obtained by the SnowEx community during the 2020 campaign. Between October 2019 and May 2020, data were collected from 454 snow pits at 12 regional locations throughout California, Colorado, Idaho, New Mexico, and Utah, USA. At each location, between one and 11 sites covering a range of conditions (terrains, snow depths, etc.) were chosen for weekly snow pit observations. Most time-series sites were visited once a week, and snow pits were dug approximately one meter from the previous week's snow pit. The median number of snow pits dug at each site is nine. Available measured parameters are:

- Snow depth
- Snow temperature
- Snow density
- Stratigraphy
- Grain size
- Wetness
- Liquid water content (LWC)
- Snow water equivalent (SWE)
- Environmental conditions

Also available are photos of the field notes and snow pits. Table 1 describes the available File Information

1.1.1 Format

Data can be sorted into four categories: snow pit sheets, individual parameter data, site photographs, and summary data. Snow pit sheets are provided as Microsoft Excel (.xlsx) and comma-separated value (.csv) files. Individual parameter (density, LWC, perimeter depths, site details, stratigraphy, and temperature) are provided as separate .csv files for each snow pit. Snow pit site photographs are provided in Joint Photographic Experts Group (.jpg) format. Summary (SWE and environment) data are provided as comma-separated value (.csv) files.

1.1.2 File Contents

1.1.2.1 File Granules

Two multi-file data granules are available for each snow pit: a data granule and a photo granule. The data granule includes the pit sheet and individual parameter (density, LWC, perimeter depths, site details, stratigraphy, and temperature) files. These file types and their content descriptions are

summarized in Table 1. The photo granule contains photos of the pit sheet and the site (if available); site photos might include pictures of the snow pit wall, the site from the 4 cardinal directions; and the overhead canopy conditions.

Table 1. Description of File Types

File Type	Content description
Snow pit sheet	File contains all data from the snow pits in multiple formats
Site details	Location, site and pit ID, date/time, UTM coordinates, latitude, longitude, slope, aspect, air temperature, total height of snow (HS), observers, weather, environment conditions, comments, and any associated data flags
Density	Density (kg/m^3) profiles at 10 cm intervals (e.g. 96-86, 86-76, ... 26-26, 16-6).
gapFilled_Density	Extrapolated and interpolated density (kg/m^3) profiles; used to compute SWE in summary file
LWC	Dielectric constant and calculated LWC profiles centered on 10 cm density intervals (e.g. 91, 81, 71, ... 21, 11)
Temperature	Temperature (°C) at surface and 10 cm intervals on even 10s (e.g. 96, 90, 80, … 10, 0)
Stratigraphy	Layer thickness, grain size, grain type, manual wetness, hand hardness, and comments
Perimeter depths	Probed snow depths surrounding pit location, starting in NW corner and moving clockwise. There are no associated geospatial data.

Note: If data were not recorded in the field then they appear as blanks in the snow pit sheets, and are shown as -9999 in the individual parameter csv files.

1.1.2.2 Summary Data Set Files

Two summary files are available as separate granules: SNEX20_TS_SP_Summary_SWE_v01.csv and SNEX20_TS_SP_Summary_Environment_v01.csv.

Note: Although the summary files apply to all snow pits, metadata constraints require the designation of a point coordinate for the data granules. The two summary files have been geographically assigned to a point in the study area with the most snow pits (East River, Colorado: 38.959 º N, 107.108 º W).

The Summary SWE file contains snow water equivalents for all snow pits at each timestamp. Each row contains the site and snow pit ID, date/time, UTM coordinates, latitude, longitude, density A mean (kg/m^3), density B mean (kg/m^3), mean density (kg/m^3), SWE A (mm), SWE B (mm), mean SWE (mm), and snow depth (cm, same as height of snow (HS) from the pit sheet).

The Summary Environment file contains qualitative environmental observations about each study site. Each row contains qualitative observations about potentially impactful environmental conditions, such as precipitation, cloud cover, wind, and ground cover.

1.1.2.3 Technical References

Five supporting files are available to download from the Technical References section of the data set landing page.

The Parameter Summary Graphs file (SNEX20_TS_SP_Summary_Graphs.pdf) presents bulk density, snow depth, and SWE data for all snow pits, organized by site region. Also available are graphs showing density profile values, A2 WISe sensor permittivity values, and A2 WISe sensor liquid water content by volume.

The Snow Pit Sheet Template Explanations file (Snow-Pit-Sheet-Template-Explanation.xlsx) includes descriptions of each parameter in the snow pit sheet template.

The Snow Pit Mean Locations file (SNEX20_TS_SP_Mean_Locations.xlsx) contains geographic information for each time-series site, including state, latitude and longitude, easting and northing, number of pits, as well as full time-series site name and pit ID.

The Time Series Pit Revisions file (SNEX20-TimeSeries-Pits-Revisions.xlsx) documents any changes that were made to correct or standardize the pit sheet for consistency across all measurement sites. For example, when a positive temperature value was recorded in the field, it was changed to 0°C as positive snow temperatures are unrealistic, but within the error of the instrument. Use the revision file to see precise edits that are not accounted for in the broad list of corrections and standardization methods listed in Section 2.3.

The Comprehensive Data Set Summary file (Comprehensive-DataSet-Summary.csv) can be used to determine what data are available for each time-series site and for all timestamps. All parameters are listed with a yes/no option to identify which measurements are included in each snow pit/timestamp data granule. Any associated data flags are denoted in a separate column. The flags are coded with descriptions and recommended amendments for data users in Table 10. The last column in the spreadsheet lists which of eight standard photos are included in the photo package. In a few cases, additional photos are supplied and given a descriptive name.

A suite of individual parameter files was generated for each snow pit. If a parameter was not measured at the site during the visit (e.g. instrument unusable/unavailable, or group did not adhere to all standard protocol observations), the parameter file will be populated with -9999. Use the Comprehensive Data Set Summary file and Table 2 to know how many pit visits have the parameter of interest.

Table 2. Total Snow Pit Profiles Available by Parameter

Parameter	Obs. Count
H.S (Height of Snow)	454

Parameter	Obs. Count
Density Profiles	451
Temperature Profiles	450
Liquid Water Content Profiles	142
Stratigraphy Profile	446

1.1.3 File Naming Convention

1.1.3.1 Snow Pit Sheet File Naming Convention

Snow pit sheets are named according to the following convention and as described in Table 3:

`SNEX20_TS_SP_<yyyymmdd>_<hhmm>_<ssssss>_data_pitSheet_ v<nn>.ext`

Table 3. Snow Pit Sheet File Naming Convention

Variable	Description
`SNEX20_TS_SP`	Short for SnowEx20 2020 Time Series Snow Pit Measurements
`<yyyymmdd_hhmm>`	Date and time of data collection, in year-month-day hour-minute format
`<ssssss>`	6-letter site code composed of a 2-letter state code, 2-letter location, and 2-letter study site. (See section 2.1.1 for snow pit site naming details)
`v<nn>`	Indicates version number of the data set
`.ext`	File extension: • .xlsx = Microsoft Excel file • .csv = comma-separated value file

A complete list of snow pit sheets from a single timestamp and time-series site (2020-01-16 at 13:45 for IDBRBU) are shown below:

- SNEX20_TS_SP_20200116_1345_IDBRBU_data_pitSheet_v01.xlsx
- SNEX20_TS_SP_20200116_1345_IDBRBU_data_pitSheet_v01.csv

1.1.3.2 Individual Parameter File Naming Convention

Individual parameter files are named according to the following convention and as described in Table 4:

`SNEX20_TS_SP_<yyyymmdd>_<hhmm>_<ssssss>_data_<param>_v<nn>.csv`

Table 4. Individual Parameter File Naming Convention

Variable	Description
SNEX20_TS_SP	Short for SnowEx20 2020 Time Series Snow Pit Measurements
<yyyymmdd_hhmm>	8-digit date and time of data collection, in year-month-day hour-minute format
<ssssss>	6-letter site code composed of a 2-letter state code, 2-letter location, and 2-letter study site. (see section 2.1.1 for snow pit site naming details)
<param>	Parameter contained within the file (see Table 1 for a description of each parameter): • density • LWC • perimeterDepths • siteDetails • stratigraphy • temperature
V<nn>	Indicates version number of the data set
.csv	File extension for comma-separated value file

A complete list of parameter data files from a single timestamp and time-series site (2020-01-16 at 13:45 for IDBRBU) are shown below:

- SNEX20_TS_SP_20200116_1345_IDBRBU_data_density_v01.csv
- SNEX20_TS_SP_20200116_1345_IDBRBU_data_LWC_v01.csv
- SNEX20_TS_SP_20200116_1345_IDBRBU_data_perimeterDepths_v01.csv
- SNEX20_TS_SP_20200116_1345_IDBRBU_data_siteDetails_v01.csv
- SNEX20_TS_SP_20200116_1345_IDBRBU_data_stratigraphy_v01.csv
- SNEX20_TS_SP_20200116_1345_IDBRBU_data_temperature_v01.csv

1.1.3.3 Site Photograph Naming Convention

Site photographs are named according to the following convention and as described in Table 5:

SNEX20_TS_SP_yyyymmdd_<hhmm>_<ssssss>_photo_<content>_v<nn>.jpg

Table 5. Site Photograph File Naming Convention

Variable	Description
SNEX20_TS_SP	Short for SnowEx20 Time Series Snow Pit Measurements
<yyyymmdd_hhmm>	8-digit date and time of data collection, in year-month-day hour-minute format

Variable	Description
<ssssss>	6-letter site code composed of a 2-letter state code, 2-letter location, and 2-letter study site. (See section 2.1.1 for snow pit site naming details)
<content>	Contents of the image: • _book1 / _book2 = image of the field book in which snow pit data were documented • north = picture taken looking north of the snow pit • south = picture taken looking south of the snow pit • east = picture taken looking east of the snow pit • west = picture taken looking west of the snow pit • pit = picture of the snow pit wall • up = picture of the overhead conditions above the snow pit
v<nn>	Indicates version number of the data set
.jpg	File extension for compression mode of digital photograph

A complete list of site photographs from a single timestamp and time-series site (2020-01-16 at 13:45 for IDBRBU) are shown below:

- SNEX20_TS_SP_20200116_1345_IDBRBU_photo_book1_v01.jpg
- SNEX20_TS_SP_20200116_1345_IDBRBU_ photo_book2_v01.jpg
- SNEX20_TS_SP_20200116_1345_IDBRBU_ photo_north_v01.jpg
- SNEX20_TS_SP_20200116_1345_IDBRBU_ photo_east_v01.jpg
- SNEX20_TS_SP_20200116_1345_IDBRBU_ photo_south_v01.jpg
- SNEX20_TS_SP_20200116_1345_IDBRBU_ photo_west_v01.jpg
- SNEX20_TS_SP_20200116_1345_IDBRBU_ photo_pit_v01.jpg
- SNEX20_TS_SP_20200116_1345_IDBRBU_ photo_up_v01.jpg

As a general rule, snow pit sheets consisted of two hand-written pages and were photographed as two separate images (_book1 and _book2). Several snow pits were deep enough to require a third pit sheet page. These images are named _book3.

Data granules that are missing the _book2 image fall into one of three categories. 1) both pages of the pit sheet were captured in a single photograph, 2) page two of the pit sheet was not photographed and is missing, or 3) data was not recorded on a physical pit sheet (e.g. snow pit measurements were taken on a smart phone). If no photos of a physical pit sheet were available, a filler photo named _book1 is provided.

1.2 Spatial Information

1.2.1 Coverage

Northernmost Latitude: 44.305º N
Southernmost Latitude: 35.859º N
Easternmost Longitude: 105.546° W
Westernmost Longitude: 120.042° W

1.2.2 Resolution

These data are point observations.

This data set contains measurements from 47 unique time-series sites across 12 regional locations throughout CA, CO, ID, NM, and UT (see Table 7 for more details). The time-series campaign aimed to visit all sites weekly to overlap with scheduled airborne activities. Each site was visited a median number of nine times throughout the campaign, with a unique snow pit dug at each visit, resulting in a total of 454 snow pit observations. Each site has a general zone of interest (i.e. protected study plot) and at each site visit, a new snow pit was dug roughly one meter from the previous pit. For most snow pits, GPS coordinates were collected weekly, while at other sites a single coordinate pair was collected at the start of the campaign and used to represent each weekly snow pit location. In a handful of sites, the pit varied spatially due to forest interference or the observer's decision to migrate around the general zone of interest.

1.2.3 Geolocation

Table 6 provides information for geolocating this data set. Depending on the location of a certain snow pit, the coordinate reference system (CRS) is WGS 84 / UTM zone 10N, 11N, 12N, or 13N. The twelve time-series sites where snow pit observations were conducted are presented in Table 7 with Lower Left and Upper Right boundary box coordinate pairs, along with the location lead, number of unique sites, and total pit count at each location. The CRS for an individual snow pit is noted in the corresponding siteDetails file and an averaged center point for each unique site is provided in Table 8.

Table 6. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84 UTM zone 10N / 11N / 12N / 13N
Longitude of true origin	-123 / -117 / -111/ -105
Latitude of true origin	0

Scale factor at longitude of true origin	0.9996
Datum	WGS_1984
Ellipsoid/spheroid	WGS 84
Units	meters
False easting	500000
False northing	0
EPSG code	32610 / 32611 / 32612 / 32613
PROJ4 string	+proj=utm +zone=XX +datum=WGS84 +units=m +no_defs where XX has to be replaced by 10, 11, 12, or 13 depending on the UTM zone.
Reference	http://epsg.io/32610 / http://epsg.io/32611 / http://epsg.io/32612 / http://epsg.io/32613

1.3 Temporal Information

1.3.1 Coverage

24 October 2019 to 20 May 2020

Note: Most locations ended their measurements in mid-March 2020 due to the onset of the novel coronavirus outbreak. Two of the twelve regional locations (Grand Mesa and East River) continued to deploy field observers weekly well into the melt season as they were already on site and conducting fieldwork separate from this NASA-funded campaign. The bulk of observations occurred between January and mid-March 2020.

1.3.2 Resolution

Weekly

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Snow pit data collected during the SnowEx 2020 Time Series campaign can be used to validate snow remote sensing data. The regional locations and time-series sites cover a range of terrain, environmental conditions, and snow classes. The regional locations of the field experiments were chosen based on existing ground-based infrastructure, previous remote sensing experiments, and availability of local experienced observers. Each regional location is listed below along with the site

lead, bounding box coordinates, and the number of time-series sites and snow pits dug at each location.

Table 7. SnowEx 2020 Time Series Locations with Snow Pit Measurements

State	Location	Site Lead	LL (lat, lon)	UR (lat, lon)	No. of Sites	Pit Count
CA	American River Basin	Peter Hartsough	38.71024, -120.04190	38.71034, -120.04182	1	7
CA	Mammoth Lakes	Ned Bair	37.61959, -119.02910	37.64329, -119.00027	2	15
CA	Sagehen Creek	Anne Nolin	39.42216, -120.29898	39.43041, -120.23981	3	20
CO	Cameron Pass	Dan McGrath	40.51857, -105.89350	40.52412, -105.89188	2	16
CO	East River	Jeff Deems, Mark Raleigh	38.88812, -107.10796	38.95931, -106.97094	11	111
CO	Fraser Experimental Forest	Kelly Elder	39.90550, -105.88286	39.90705, -105.87783	4	51
CO	Grand Mesa	Jewell Lund	39.03044, -108.21480	39.05107, -108.03187	6	77
CO	Niwot Ridge	Kate Hale, Mark Raleigh	40.03148, -105.59065	40.05497, -105.54613	6	67
CO	Senator Beck	Andy Gleason	37.90702, -107.72630	37.90717, -107.71118	2	13
ID	Boise River Basin	Hans-Peter Marshall	43.73630, -116.12188	44.30464, -115.23450	6	47
NM	Jemez River	Ryan Webb	35.85789, -106.53190	35.88862, -106.52136	2	16
UT	Little Cottonwood Canyon	McKenzie Skiles	40.57210, -111.63759	40.59125, -111.62997	2	14
				Total	**47**	**454**

This SnowEx campaign aimed to visit all time-series sites weekly. The majority of field crews were able to deploy weekly and capture coincident measurements with the airborne platforms that were part of the broader SnowEx 2020 mission. Sites with smaller pit counts (see Table 7 and 8) may not have obtained consistent weekly measurements, but the snow pit data are still valuable and supply baseline data for other coincident remote sensing data sets and modeling efforts.

Weekly visits to each time-series site involved digging a new snow pit 1m ahead of the prior snow pit wall. The pit locations are not fixed in space but succeed one another across the weeks of observation. Each time-series site has a 6-letter pit ID (Table 8) which, when combined with the

observation date and time, provides a unique alphanumerical code for each snow pit observation. The coordinates found in Table 8 are an average location for each snow pit in a given time series to represent the zone of interest. UTM Coordinates in the parameter and summary files have been manually adjusted to best represent the sampling design (~1 m spacing with the known sampling progression). This was done in close communication with the site lead and observers. Raw UTM coordinates can be found in the photographs of the handwritten pit sheet observations (_book1.jpg), and are estimated to have a ± 15 m GPS accuracy. Note, some raw UTM coordinates have known errors and are noted in the Revisions file.

2.1.1 Snow Pit Naming Convention

Snow pit IDs consist of a 6-letter code composed of a 2-letter state code, 2-letter location code, and 2-letter study site code. For example, IDBRBS stands for Idaho (ID), Boise River Basin (BR) Banner Snotel (BS). Table 8 lists all IDs with their corresponding state, regional, and time-series place names and the total number of snow pits dug per site. A complete table with mean locations of each snow pit site (SNEX20_TS_SP_Mean_Locations.xlsx) can be downloaded from the technical references on the dataset landing page.

Table 8. SnowEx 2020 Mean Location for Snow Pit Sites

State	Regional Location	Time-Series Site	Pit ID	Pit Count
CA	American River Basin	Caples Lake	CAAMCL	7
CA	Mammoth Lakes	CUES	CAMLCP	9
CA	Mammoth Lakes	Panorama Dome	CAMLPD	6
CA	Sagehen Creek	Forest	CASHFO	7
CA	Sagehen Creek	Open	CASHOP	7
CA	Sagehen Creek	Tower 4	CASHT4	6
CO	Cameron Pass	Joe Wright	COCPJW	8
CO	Cameron Pass	Michigan River	COCPMR	8
CO	East River	Forest 12	COER12	12
CO	East River	Forest 13	COER13	9
CO	East River	Forest 14	COER14	12
CO	East River	Aspen	COERAP	9
CO	East River	Gothic	COERGT	9
CO	East River	Irwin Barn	COERIB	13
CO	East River	Open 2	COERO2	9
CO	East River	Open 4	COERO4	12
CO	East River	Open 6	COERO6	9
CO	East River	Trench 13	COERTR	5

State	Regional Location	Time-Series Site	Pit ID	Pit Count
CO	East River	Upper	COERUP	12
CO	Fraser Experimental Forest	SNB 1	COFEB1	8
CO	Fraser Experimental Forest	SNB 2	COFEB2	6
CO	Fraser Experimental Forest	JPL 1	COFEJ1	21
CO	Fraser Experimental Forest	JPL 2	COFEJ2	16
CO	Grand Mesa	County Line Open	COGMCO	12
CO	Grand Mesa	County Line Tree	COGMCT	10
CO	Grand Mesa	Skyway Open	COGMSO	20
CO	Grand Mesa	Skyway Tree	COGMST	18
CO	Grand Mesa	Mesa West Open	COGMWO	10
CO	Grand Mesa	Mesa West Trees	COGMWT	7
CO	Niwot Ridge	C1	CONWC1	9
CO	Niwot Ridge	Forest Flat	CONWFF	12
CO	Niwot Ridge	Forest North	CONWFN	11
CO	Niwot Ridge	Forest South	CONWFS	13
CO	Niwot Ridge	Open Flat	CONWOF	15
CO	Niwot Ridge	Saddle	CONWSA	7
CO	Senator Beck	Swamp Angel	COSBSA	8
CO	Senator Beck	Senator Beck	COSBSB	5
ID	Boise River Basin	Banner Open	IDBRBO	10
ID	Boise River Basin	Banner Snotel	IDBRBS	10
ID	Boise River Basin	Bogus Upper	IDBRBU	11
ID	Boise River Basin	LDP Open	IDBRLO	7
ID	Boise River Basin	LDP Tree	IDBRLT	7
ID	Boise River Basin	Mores Creek Summit	IDBRMC	2
NM	Jemez River	BA Flux Tower	NMJRBA	8
NM	Jemez River	HQ Met Station	NMJRHQ	8
UT	Little Cottonwood Canyon	Alta Collins	UTLCAC	7
UT	Little Cottonwood Canyon	Atwater	UTLCAW	7

Refer to SnowEx 2020 Experimental Plan in section 8 for additional details specific to each time-series site.

2.2 Acquisition

Measurements were made using a standard snow pit kit, which included 250 and 1000 cc Snowmetrics wedge-type density cutters, a digital scale, pocket microscope and 2mm gridded crystal cards for manual grain size, and digital thermometers. The dielectric constant was measured using a A2 Photonic WISe LWC sensor. In most cases, sensor serial numbers were recorded in the site details file. LWC was calculated using the below formula taken from the WISe LWC user manual.

$$\varepsilon = 1 + 1.202 * (D - W_v) + 0.983 * (D - W_v)^2 + 21.3 * W_v$$

Where ε is the permittivity of snow measured by the WISe sensor; D is the snow density (g/cm^3), averaged over all measurements taken at that layer; and W_v is the volumetric liquid water content. In practice, the following iteration was used to compute W_v:

Start with $W_v = 0$ and repeat 5 times $D_s = D - W_v$

$$W_v = (\varepsilon - 1 - 1.202 * D_s - 0.983 * {D_s}^2)/21.3$$

For each layer, an average density was computed from the observations and used with each permittivity measured at that layer to compute LWC. For more information on the snow pit protocol, measurement details, and in-field instructions refer to the SnowEx 2020 Experimental Plan or the Instructions tab of the Snow Pit Sheet Template Explanations file.

All measurements were made within the snow pit with the exception of the perimeter snow depths and new snow measurements. The perimeter depths are a series of probed snow heights around the study sites. There are four to nine probed snow depth observations per snow pit. Observers were asked to begin measurements at the NW corner and moved clockwise around the pit. New snow measurements were collected at the majority of sites using interval (or storm) boards. Raw data can be found in the photographs of the handwritten snow pit sheets (_book2.jpg) and will be published separately from this data set. A comprehensive list of instruments is given in Table 9.

2.3 Processing

Measurements and observations were recorded in handwritten snow pit sheets before being transcribed to electronic sheets. After all records in the data set were verified, transcription errors were manually corrected. Corrections broadly fall into categories of:

- Fixing general transcription errors.
- Making nomenclature consistent with field protocol.
- If blank, filling in Height of Snow (HS) field using the density profile snow height.

- Correcting formatting errors that may interfere with automated scripts.
- Incorporating all handwritten comments on data sheets.
- Adding precipitation type to weather comments because it was missed when the electronic pit sheet was generated.
- Converting field times to Standard Time to best overlap with airborne instrumentation methods. This means that any pit after March 8th, 2020 became minus 1-hour from the recorded field time.

The data were then visually inspected for completeness and validity of data values. The majority of the quality control process was dedicated to reviewing the snow pit stratigraphy categories. See the Revisions file for a complete list of all edits/corrections.

2.4 Instrumentation

Table 9 lists all instruments used to record measurements for this data set.

Table 9. Instrument Specifications

Instrument	Brand	Measurement	Specs
Global Positioning System (GPS) field unit	Garmin rhino 755T and/or personal cell phones	Latitude, Longitude / Easting, Northing, UTM zone	horizontal error ±3 m in open, ±10 m in trees
Digital thermometer	Copper-Atkins model DFP450W	snow temperature profiles	accuracy ±1°C, resolution 0.1°C, 121 mm stem
Snow Liquid Water Content (LWC) sensor	A2 Photonics WISe	LWC profiles	±1%
Digital scale	AD-3000	Snow sample mass for density profiles	3100 g capacity, 1 g resolution, 1 g repeatability
Snow Density sampler, 1000 cc capacity	Snowmetrics RIP 1 – 1000 cc capacity	Snow density profiles	± <1% volume, 10 x 10 x 20 cm wedge-shaped cutter
Snow Density sampler, 250 cc capacity	Snowmetrics RIP 2 – 250 cc capacity	Snow density profiles	±<1% volume, 5 x 10 x 10 cm wedge-shaped cutter
Macroscope	RF Interscience Macroscope 25A	snow crystal type identification and size quantification	30x magnification, 8 mm field of view, graduated reticle with 0.1 mm resolution

Instrument	Brand	Measurement	Specs
Folding ruler	Wiha Tools USA	for measure snow height (HS), stratigraphic boundary heights, layer thickness,	2 m fiberglass folding rule, mm graduations

2.5 Quality, Errors, and Limitations

The SnowEx 2020 Time Series campaign was a community led effort. The same protocol was distributed to all site leads and observer crews. Even with a standard protocol in place, human variability is a factor, especially when considering some of the more subjective snow property measurements. The large variety in snow climates and local terrain means subjective decisions could be different across sites. The data set authors acknowledge that human variability is a limitation in collecting manual snow measurements, but efforts were made to ensure consistency in data collection methods between sites.

Data flags were assigned to some pits where close inspection of the raw data (available in .jpg files _book1 and _book2) is recommended before analysis. Flags note when there were deviations from the protocol or when observer comments are particularly useful for interpreting data. Flag codes are listed in the comments portion of the electronic pit sheets and included in the header information of each parameter file. The flag code is also a column in the Comprehensive Data Set Summary file and can be used to filter snow pits. Table 10 outlines the flag codes, flag descriptions, and recommended amendments before analysis.

Table 10. Data Usage and Flag Information

Flag Code	Flag Description	Recommended Amendments
Density		
TDG	Top density gap: Density profile starts at least 3 cm below recorded HS and has no further comments to explain the measurement gap.	Look at the corresponding stratigraphic layers and decide if the available density measurements are applicable or not depending on the layer hardness and grain size.
MDG	Middle density gap: Density measurement has a gap within the profile.	Use comments to inform as to why measurement intervals were not continuous.
BDG	Bottom density gap: Density profile ends above 10 cm, and SWE has been calculated using a density value from 10 cm or above.	Evaluate if the SWE interpolation to the ground with the given density is valid for your analyses.

Stratigraphy		
STCom	Stratigraphy Comments: There is additional significant information in the comments column that could contribute to better understanding of the snow profile.	It is advised you look closely at the comments section.
STLay	Stratigraphy Layer: A layer was recorded in the field notes, but could not be added to the profile because no thickness was specified. See comments column for description of snow properties.	It is advised you look closely at the comments section, and evaluate whether or not the described feature(s) would show up in remote sensing/be relevant to your analyses.
MW	Manual Wetness: Examine/evaluate manual wetness values	Compare manual wetness values observed in the field to other snow properties (temperature, density) and assess whether or not the reported MW is reasonable for your purposes.
General		
AD	Additional Data: On this date at this site, additional data (outside of standard pit protocol) were collected.	Review the pit book photos (.jpgs) or contact the site PI for additional information. In some cases, the data may be in a separately published dataset available at NSIDC. Note this flag is not used to mark ALL occurrences of coincident field observations with unique instruments, but denotes any that have handwritten notes in the pit book images.

3 SOFTWARE AND TOOLS

CSV files can be accessed using software that reads ASCII text.

4 VERSION HISTORY

Table 11. Version History Summary

Version	Date Implemented	Impacted Temporal Coverage	Description of Changes
v01.0	April 2023	24 October 2019 to 20 May 2020	Initial release

v02.0	June 2024	24 October 2019 to 20 May 2020	• SWE values were recalculated using an updated algorithm to correct minor errors • Snow pit coordinates were updated • Data files were updated to correct transcription errors • A new technical reference showing summary graphs was added

5 RELATED DATA SETS

SnowEx at NSIDC | Data sets
SnowEx20 Grand Mesa Intensive Observation Period Snow Pit Measurements
SnowEx21 Time Series Snow Pits

6 RELATED WEBSITES

NASA SnowEx
NSIDC SnowEx | Overview

7 ACKNOWLEDGMENTS

This data set would not be possible without all the work of the time series leads and the observation crews. The authors are extremely grateful for everyone who participated at all the time series sites. Thank you for the time spent traveling to and from sites, taking snow pit measurements, entering data, and responding to reviewers' questions.

An immense effort was taken to standardize the snow pit data to create this legacy validation/calibration ground-based data set to study a wide variety of snow properties through time. This was a collaborative QA/QC review effort shared amongst the following people: Megan Mason, Maeve McCormick, Dylan Craaybeek, Kate Hale, and Kelly Elder. This group spent a lot of hours manually comparing and deciphering raw data sheets and matching them to the electronic pit sheets submitted by observation crews or generating electronic pit sheets if they were added post-campaign work. In several cases methods needed to be verified with site leads and repeat observers to ensure accurate interpretation of data collection and local terminology used between a variety of field observers with various backgrounds and prior snow science experience.

8 REFERENCES

NASA SnowEx 2020 Experimental Plan

9 DOCUMENT INFORMATION

9.1 Publication Date

June 2024

9.2 Date Last Updated

June 2024