SnowEx20 Grand Mesa Intensive Observation Period Snow Pit Measurements, Version 1

USER GUIDE

How to Cite These Data

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

Vuyovich, C., H.P. Marshall, K. Elder, C. Hiemstra, L. Brucker, and M. McCormick. 2021. *Data set title, SnowEx20 Grand Mesa Intensive Observation Period Snow Pit Measurements, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/DUD2VZEVBJ7S. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SNEX20_GM_SP

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DATA DESCRIPTION 2
1.1 Parameters 2
1.2 File Information 2
1.2.1 Format 2
1.2.2 File Contents 2
1.2.3 File Naming Convention 3
1.3 Spatial Information 6
1.3.1 Coverage 6
1.3.2 Resolution 6
1.3.3 Geolocation 6
1.4 Temporal Information 7
1.4.1 Coverage 7
1.4.2 Resolution 7
2 DATA ACQUISITION AND PROCESSING 7
2.1 Background 7
2.1.1 Snow Pit Naming Convention Examples 9
2.2 Acquisition 9
2.3 Processing 10
2.4 Instrumentation 10
2.5 Quality, Errors, and Limitations 11
3 SOFTWARE AND TOOLS 11
4 VERSION HISTORY 11
5 RELATED DATA SETS 11
6 RELATED WEBSITES 12
7 CONTACTS AND ACKNOWLEDGMENTS 12
7.1 Acknowledgements 12
8 REFERENCES 12
9 DOCUMENT INFORMATION 12
9.1 Publication Date 12
9.2 Date Last Updated 12

1 DATA DESCRIPTION

1.1 Parameters

The data set contains snow pit measurements obtained by the SnowEx community during the 2020 campaign from the Grand Mesa, Colorado, USA site, a snow-covered, forested area 40 miles east of Grand Junction. Available measured parameters are:

- Temperature
- Density
- Stratigraphy
- Grain size
- Wetness
- Depth
- Liquid water content (LWC)
- Snow water equivalent (SWE)

Also available are photos taken of the pit sheets and the site. Table 1 describes the available measured parameters in more detail.

1.2 File Information

1.2.1 Format

Data can be sorted into three categories: snow pit sheets, individual parameter data, and summary data. Snow pit sheets are provided as Microsoft Excel (.xlsx) and Portable Document Format (.pdf) files. Individual parameter and summary (SWE and environment) data are provided only as comma-separated value (.csv) files. Snow pit site photographs (.jpg) are also provided.

1.2.2 File Contents

Data were recorded for 154 snow pits at Grand Mesa (GM). For each pit the data package includes the full pit sheet and photos taken of the pit data sheets and the site. Density, LWC, stratigraphy, and temperature are provided in separate .csv files for each snow pit. The “Site Details” file for each snow pit contains site information such as location (UTM), elevation, time, LWC sensor serial number and comments. Snow water equivalents for all pits are stored in a master file. Qualitative environmental observations about each study site are also available. See the technical reference for the original data intake form, including descriptions of each parameter for this data set. The available file types, contents and variable descriptions are summarized in Table 1.

Table 1. File content

File Type/ Variable	Contents/ Description
Snow pit sheet	File contains all data from the snow pits in multiple formats
Site photos	Photos taken of pit sheets, snow pit wall, and the site in 4 cardinal directions plus directly up towards the sky
Site Details	Location, site and Pit ID, date/time, UTM coordinates, slope, total depth, new snow depth, new snow SWE, weather, comments.
Density	Density (kg/m^3) profiles at 10 cm intervals
LWC	Dielectric constant and calculated liquid water content profiles at 10 cm intervals
Stratigraphy	Layer thickness, grain size, grain type, manual wetness and hand hardness
Temperature	Temperature (°C) at surface and 10 cm intervals on even 10s (e.g. 96, 90, 80, … 10, 0.)
Snow Water Equivalent	One file for all snow pits on GM. Each row contains the site and snow pit ID, date/time, UTM coordinates, density A (kg/m^3), density B (kg/m^3), mean density (kg/m^3), SWE A (mm), SWE B (mm), mean SWE (mm), and snow depth (cm).
Environment	One file for all snow pits on GM which contains qualitative observations about potentially impactful environmental conditions, such as precipitation, cloud cover, wind, and ground cover.

1.2.3 File Naming Convention

1.2.3.1 Snow Pit Sheet File Naming Convention

Snow pit sheet files are named according to the following convention described in Table 2:

`SnowEx20_SnowPits_GMIOP_ yyyymmdd_<pitID>_ v<nn>.ext`

Table 2. Snow Pit Sheet File Naming Convention

Variable	Description
SnowEx20_SnowPits	Short for SnowEx20 2020 Snow Pit Measurements
GMIOP	Indicates the data were collected during the Grand Mesa Intensive Observation Period
yyyymmdd	Date of data collection, in year-month-day format
<pitID>	Snow Pit ID (See Section 2.1 for more details)
v<nn>	Indicates version number of the data set

Variable	Description
.ext	File extension: • .xlsx = Microsoft Excel file • .pdf = Portable Document Format file

A complete list of snow pit sheet files for an exemplary snow pit (9C16) are shown below:

- SnowEx20_SnowPits_GMIOP_20200205_9C16_v01.xlsx
- SnowEx20_SnowPits_GMIOP_20200205_9C16_v01.pdf

1.2.3.2 Individual Parameter File Naming Convention

Individual parameter files are named according to the following convention described in Table 3:

`SnowEx20_SnowPits_GMIOP_yyyymmdd_<pitID>_<param>_v<nn>.csv`

Table 3. Individual Parameter File Naming Convention

Variable	Description
SnowEx20_SnowPits	Short for SnowEx20 2020 Snow Pit Measurements
GMIOP	Indicates the data were collected during the Grand Mesa Intensive Observation Period
yyyymmdd	Date of data collection, in year-month-day format
<pitID>	Snow Pit ID (See Section 2.1 for more details)
<param>	Parameter contained within the file (see Table 1 for a description of each parameter): • siteDetails • density • LWC • temperature stratigraphy
v<nn>	Indicates version number of the data set
.csv	File extension for comma-separated value file

A complete list of parameter data files for an exemplary snow pit (9C16) are shown below:

- SnowEx20_SnowPits_GMIOP_20200205_9C16_siteDetails_v01.csv
- SnowEx20_SnowPits_GMIOP_20200205_9C16_density_v01.csv
- SnowEx20_SnowPits_GMIOP_20200205_9C16_LWC_v01.csv
- SnowEx20_SnowPits_GMIOP_20200205_9C16_temperature_v01.csv
- SnowEx20_SnowPits_GMIOP _20200205_9C16_stratigraphy_v01.csv

1.2.3.3 Site Photograph Naming Convention

Site photographs are named according to the following convention described in Table 4:

```
SnowEx20_SnowPits_GMIOP_yyyymmdd_<pitID>_<content>_v<nn>.jpg
```

Table 4. Site Photograph File Naming Convention

Variable	Description
SnowEx20_SnowPits	Short for SnowEx20 2020 Snow Pit Measurements
GMIOP	Indicates the data were collected during the Grand Mesa Intensive Observation Period
yyyymmdd	Date of data collection, in year-month-day format
<pitID>	Snow Pit ID (See section 2.1 for more details)
<content>	Contents of the image: • book1 / book2 = image of the field book • 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 • pit1 = picture of the snow pit wall up = picture of the sky 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 photograph files for an exemplary snow pit (9C16) are shown below:

- SnowEx20_SnowPits_GMIOP_20200205_9C16_book1_v01.jpg
- SnowEx20_SnowPits_GMIOP_20200205_9C16_book2_v01.jpg
- SnowEx20_SnowPits_GMIOP_20200205_9C16_north_v01.jpg
- SnowEx20_SnowPits_GMIOP_20200205_9C16_east_v01.jpg
- SnowEx20_SnowPits_GMIOP_20200205_9C16_south_v01.jpg
- SnowEx20_SnowPits_GMIOP_20200205_9C16_west_v01.jpg
- SnowEx20_SnowPits_GMIOP_20200205_9C16_pit1_v01.jpg

1.2.3.4 Summary File Naming Convention

All three summary files are available under the technical references tab on the data set landing page.

The SWE summary file is named:
SnowEx20_SnowPits_GMIOP_swe_2020_v01.csv

The environment summary file is named:
SnowEx20_SnowPits_GMIOP_environment_2020_v01.csv

A list of all corrections is given in 2020GM_snowpit_revisions_masterlist_edits_21Oct2020.csv. This file can be found under the Technical References tab on the data set landing page. See section 2.3 for more details on this file.

1.3 Spatial Information

1.3.1 Coverage

Northernmost Latitude: 39.06º N
Southernmost Latitude: 39.01º N
Easternmost Longitude: 108.11° W
Westernmost Longitude: 108.23° W

1.3.2 Resolution

Point observations

1.3.3 Geolocation

Table 5 provides information for geolocating this data set

Table 5. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84 / UTM zone 12N
Longitude of true origin	-111
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	32612
PROJ4 string	+proj=utm +zone=12 +datum=WGS84 +units=m +no_defs

Reference	http://epsg.io/32612

1.4 Temporal Information

1.4.1 Coverage

27 January 2020 to 12 February 2020

1.4.2 Resolution

Not applicable – snow pits were only sampled once during the campaign.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Snow pit data collected during the SnowEx 2020 Grand Mesa Intensive Observation Period (IOP) can be used to validate snow remote sensing on Grand Mesa. Snow pits were selected to cover the full range of conditions found on Grand Mesa, from meadows to dense forests and from shallow snow depths to deep snowpack.

To select 2020 snow pit locations, data from the SnowEx 2017 airborne lidar and optical imagery (Figure 1) were analyzed. Specifically, the Airborne Snow Observatory's 8 February 2017 lidar-derived snow depths (ASO L4 Lidar Snow Depth 3m UTM Grid, Version 1) were binned into three classes: shallow (<90 cm), intermediate (90-122 cm), and deep (>122 cm). A tree density map created from November 2010 WorldView-2 imagery was also binned into three classes based on the percentage of tree-class pixels within a 50 m radius: treeless (0%), sparse (1-30%), and dense (31-100%). The two factors were combined to form a nine-point snow and tree matrix (Figure 1). Within this matrix, values 1-3, 4-6, and 7-9 represent treeless, sparse, and dense tree areas, respectively. These three ranges can be further subdivided into three categories of snow depth classification: shallow (lowest number in a range, e.g. 1), intermediate, and deep (highest number in a range, e.g. 3). Treeless areas were not split into shrub or meadow cover types. Water bodies and missing lidar data remain unclassified (grey areas in Figure 1).

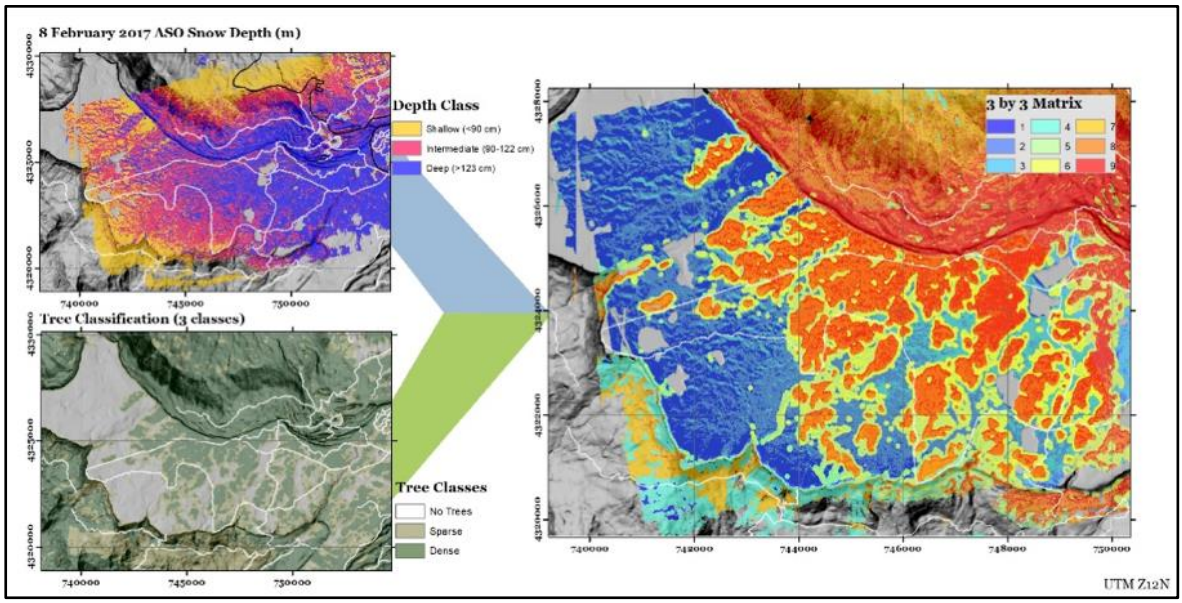

Figure 1. Separate vegetation and snow depth classifications for the Grand Mesa IOP study site are shown (left). These classifications were combined to form the final tree density and snow depth matrix used to describe snow pit locations (right). In all images, gray areas represent undefined regions (e.g. water bodies).

Finally, the Grand Mesa IOP study site was clipped into three flight lines (north, N; south, S; and cross, C) (Figure 2). These flight lines correspond to the scheduled IOP airborne observations. Within the flight lines, 150 snow pit locations (approximately three weeks of work) were proportionally divided by the nine matrix classes, then randomly distributed amongst the three flight lines for each matrix class (Figure 2). Matrix classes were not evenly represented and varied in frequency; for example, there are 3 Class 4 snow pits and 33 Class 2 snow pits. Snow pit names use the convention described in Table 6.

Table 6. Pit Naming Convention

Variable	Description
Matrix	Number describing the measurement site conditions. Each number contains information about the amount of vegetation around the snow pit: • 1/2/3 = treeless (0% tree cover) • 4/5/6 = sparse (1-30% tree cover) • 7/8/9 = dense (31-100% tree cover) and the relative, expected snow pit depth: • 1/4/7= shallow snowpack • 2/5/8= medium snowpack • 3/6/9= deep snowpack
[FlightLine]	Indicates on which flight line the snow pit resided: • N = North • S = South • C = Crossline

Variable	Description
##	Pit ID number. Numbers are lowest in the West and North and increase incrementally by whole numbers as you move further East or South along a particular flight line.

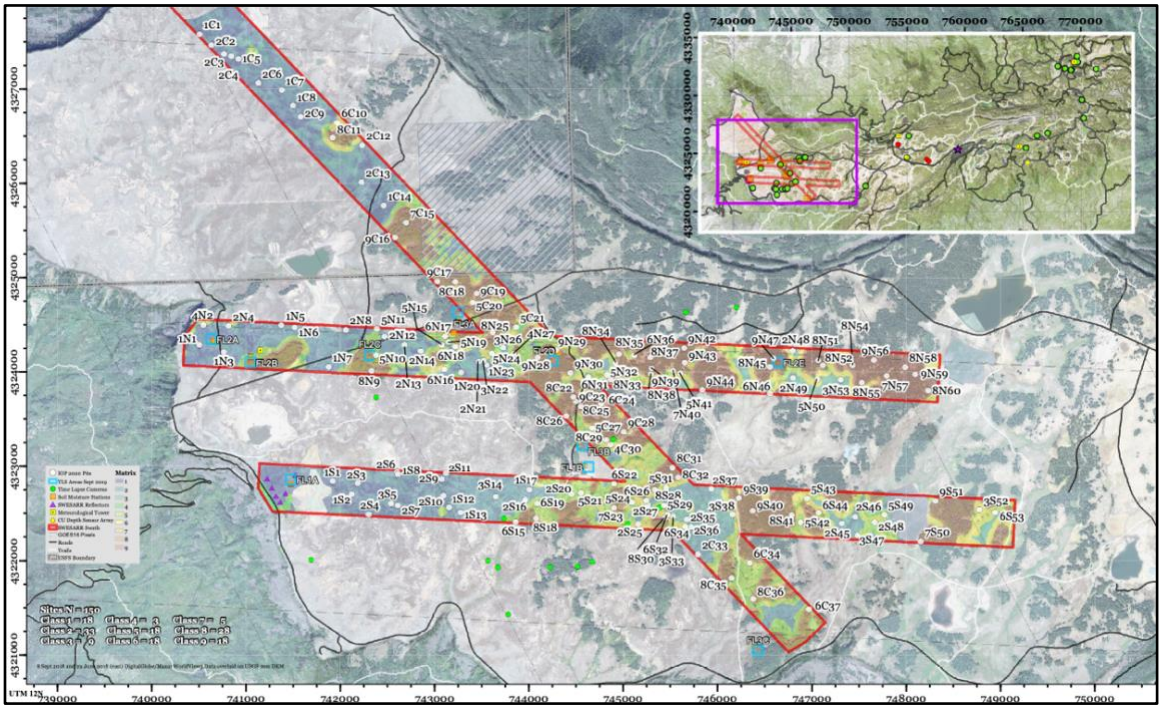

Figure 2. Location of the 150 Grand Mesa IOP snow pits. Snow pits were randomly spaced along the North (upper horizontal line), South (lower horizontal line), and Cross (diagonal line) flight lines, along which airborne measurements were collected. Snow pit naming conventions are described in Table 6. The inset in the top right shows the location of the IOP snow pits and flight lines relative to the rest of Grand Mesa and other SnowEx 2020 locations. Green dots show the location of time lapse cameras, red dots show the location of time series snow pits, yellow squares with black circles show the location of meteorological towers, and yellow circles show the location of snow depth sensors.

2.1.1 Snow Pit Naming Convention Examples

- Pit “9S40” denotes matrix class 9 (deep snow and dense trees), South flight line, and the 40th total pit on the South line from west to east.
- Pit “1C14” denotes matrix class 1 (shallow snow and no trees), Cross line, and the 14th pit along the Cross line from Northwest to Southeast.

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, macroscope and 2mm gridded crystal cards for manual grain size, and digital thermometers. Dielectric constant was measured using the

A2 Photonic WISe LWC sensor. Sensor serial numbers were recorded in the site details. 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. A comprehensive list of instruments is given in Table 7.

2.3 Processing

Measurements and observations were recorded in hand-written field notebooks 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
- If blank, filling in snow height (HS) field using the density profile snow height
- Fixing formatting errors that may interfere with automated scripts
- Making note of precipitation type

The data was then visually inspected for completeness and positional accuracy. Pit positions were adjusted based on GPS or differential GPS measurements, where necessary. See section 1.2.3.4 for a detailed description of the file containing a complete list of all corrections.

2.4 Instrumentation

Table 7 lists all instruments used to record measurements in this snow pit data set.

Table 7. Instrument Specifications

Instrument	Brand	Measurement	Specifications
Global Positioning System (GPS) field unit	Garmin rhino 755T	Latitude, longitude, elevation	horizontal error +/- 3 m in open, +/- 10 m in trees

Instrument	Brand	Measurement	Specifications
Digital Thermometer	Copper-Atkins model DFP450W	snow temperature profiles	accuracy +/-1oC, resolution 0.1oC, 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
Pocket microscope	RF Insterscience Macroscope 25A	snow crystal type identification and size quantification	2 magnification, 8 mm field of view, graduated reticule with 0.1 mm resolution
Folding ruler		for measure snow height (HS), stratigraphic boundary heights, layer thickness,	2 m fiberglass folding rule, mm graduations

2.5 Quality, Errors, and Limitations

See Table 7 for instrument uncertainties.

3 SOFTWARE AND TOOLS

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

4 VERSION HISTORY

Initial release

5 RELATED DATA SETS

SnowEx at NSIDC | Data sets

SnowEx 2017 Snow Pit Measurements

6 RELATED WEBSITES

NASA SnowEx

NSIDC SnowEx | Overview

7 CONTACTS AND ACKNOWLEDGMENTS

Carrie M. Vuyovich
NASA Goddard Space Flight Center

7.1 Acknowledgements

This data collection effort was supported by the NASA Terrestrial Hydrology Program (THP) and the THP Program Manager, Dr. Jared Entin. The authors would like to thank all participants of the 2020 SnowEx Grand Mesa IOP for their hard work in collecting these data.

8 REFERENCES

Snow Pit Sheet Template and Explanation

SnowEx 2020 GM IOP Data Corrections

9 DOCUMENT INFORMATION

9.1 Publication Date

January 2021

9.2 Date Last Updated

January 2021