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:


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

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

<table>
<thead>
<tr>
<th>File Type/Variable</th>
<th>Contents/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow pit sheet</td>
<td>File contains all data from the snow pits in multiple formats</td>
</tr>
<tr>
<td>Site photos</td>
<td>Photos taken of pit sheets, snow pit wall, and the site in 4 cardinal directions plus directly up towards the sky</td>
</tr>
<tr>
<td>Site Details</td>
<td>Location, site and Pit ID, date/time, UTM coordinates, slope, total depth, new snow depth, new snow SWE, weather, comments.</td>
</tr>
<tr>
<td>Density</td>
<td>Density (kg/m$^3$) profiles at 10 cm intervals</td>
</tr>
<tr>
<td>LWC</td>
<td>Dielectric constant and calculated liquid water content profiles at 10 cm intervals</td>
</tr>
<tr>
<td>Stratigraphy</td>
<td>Layer thickness, grain size, grain type, manual wetness and hand hardness</td>
</tr>
<tr>
<td>Temperature</td>
<td>Temperature (°C) at surface and 10 cm intervals on even 10s (e.g. 96, 90, 80, ... 10, 0.)</td>
</tr>
<tr>
<td>Snow Water Equivalent</td>
<td>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).</td>
</tr>
<tr>
<td>Environment</td>
<td>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.</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
</table>
| .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_yyymmdd_<pitID>_ <param>_<v>nn>.csv

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SnowEx20_SnowPits</td>
<td>Short for SnowEx20 2020 Snow Pit Measurements</td>
</tr>
<tr>
<td>GMIOP</td>
<td>Indicates the data were collected during the Grand Mesa Intensive Observation Period</td>
</tr>
<tr>
<td>yyymmdd</td>
<td>Date of data collection, in year-month-day format</td>
</tr>
<tr>
<td>&lt;pitID&gt;</td>
<td>Snow Pit ID (See Section 2.1 for more details)</td>
</tr>
</tbody>
</table>
| <param> | Parameter contained within the file (see Table 1 for a description of each parameter):  
  - siteDetails  
  - density  
  - LWC  
  - temperature  
  - stratigraphy |
| v<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>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SnowEx20_SnowPits</td>
<td>Short for SnowEx20 2020 Snow Pit Measurements</td>
</tr>
<tr>
<td>GMIOP</td>
<td>Indicates the data were collected during the Grand Mesa Intensive Observation Period</td>
</tr>
<tr>
<td>yyyymmdd</td>
<td>Date of data collection, in year-month-day format</td>
</tr>
<tr>
<td>&lt;pitID&gt;</td>
<td>Snow Pit ID (See section 2.1 for more details)</td>
</tr>
<tr>
<td>&lt;content&gt;</td>
<td>Contents of the image:</td>
</tr>
<tr>
<td></td>
<td>• book1 / book2 = image of the field book</td>
</tr>
<tr>
<td></td>
<td>• north = picture taken looking north of the snow pit</td>
</tr>
<tr>
<td></td>
<td>• south = picture taken looking south of the snow pit</td>
</tr>
<tr>
<td></td>
<td>• east = picture taken looking east of the snow pit</td>
</tr>
<tr>
<td></td>
<td>• west = picture taken looking west of the snow pit</td>
</tr>
<tr>
<td></td>
<td>• pit1 = picture of the snow pit wall</td>
</tr>
<tr>
<td></td>
<td>• up = picture of the sky above the snow pit</td>
</tr>
<tr>
<td>v&lt;nn&gt;</td>
<td>Indicates version number of the data set</td>
</tr>
<tr>
<td>.jpg</td>
<td>File extension for compression mode of digital photograph</td>
</tr>
</tbody>
</table>

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

Both summary files are available to download as a separate data granule.

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
Note: These two files were previously listed under the technical references tab on the data set landing page. To make the files more accessible they are now part of the main data set.

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: 108.11º W
Westernmost Longitude: 108.23º W

1.3.2 Resolution

Point observations

1.3.3 Geolocation

Table 5 provides information for geolocating this data set

<table>
<thead>
<tr>
<th>Geographic coordinate system</th>
<th>WGS 84</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projected coordinate system</td>
<td>WGS 84 / UTM zone 12N</td>
</tr>
<tr>
<td>Longitude of true origin</td>
<td>-111</td>
</tr>
<tr>
<td>Latitude of true origin</td>
<td>0</td>
</tr>
<tr>
<td>Scale factor at longitude of true origin</td>
<td>0.9996</td>
</tr>
<tr>
<td>Datum</td>
<td>WGS_1984</td>
</tr>
<tr>
<td>Ellipsoid/spheroid</td>
<td>WGS 84</td>
</tr>
<tr>
<td>Units</td>
<td>meters</td>
</tr>
<tr>
<td>False easting</td>
<td>500000</td>
</tr>
<tr>
<td>False northing</td>
<td>0</td>
</tr>
<tr>
<td>EPSG code</td>
<td>32612</td>
</tr>
<tr>
<td>PROJ4 string</td>
<td>+proj=utm +zone=12 +datum=WGS84 +units=m +no_defs</td>
</tr>
</tbody>
</table>
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

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

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.

\[ \varepsilon = 1 + 1.202 \times (D - W_v) + 0.983 \times (D - W_v)^2 + 21.3 \times W_v \]

Where \( \varepsilon \) 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 \( D_s = D - W_v \)

\[ W_v = (\varepsilon - 1 - 1.202 \times D_s - 0.983 \times D_s^2) / 21.3 \]

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>
<thead>
<tr>
<th>Instrument</th>
<th>Brand</th>
<th>Measurement</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Positioning System (GPS) field unit</td>
<td>Garmin rhino 755T</td>
<td>Latitude, longitude, elevation</td>
<td>horizontal error +/- 3 m in open, +/- 10 m in trees</td>
</tr>
<tr>
<td>Instrument</td>
<td>Brand</td>
<td>Measurement</td>
<td>Specifications</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------------</td>
<td>--------------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>Digital Thermometer</td>
<td>Copper-Atkins model DFP450W</td>
<td>snow temperature profiles</td>
<td>accuracy +/-1°C, resolution 0.1°C, 121 mm stem</td>
</tr>
<tr>
<td>Snow Liquid Water Content (LWC) Sensor</td>
<td>A2 Photonics WISe</td>
<td>LWC profiles</td>
<td>+/-1%</td>
</tr>
<tr>
<td>Digital Scale</td>
<td>AD-3000</td>
<td>snow sample mass for density profiles</td>
<td>3100 g capacity, 1 g resolution, 1 g repeatability</td>
</tr>
<tr>
<td>Snow Density sampler, 1000 cc capacity</td>
<td>Snowmetrics RIP 1 – 1000 cc capacity</td>
<td>Snow density profiles</td>
<td>+/- &lt;1% volume, 10 x 10 x 20 cm wedge-shaped cutter</td>
</tr>
<tr>
<td>Snow Density sampler, 250 cc capacity</td>
<td>Snowmetrics RIP 2 – 250 cc capacity</td>
<td>Snow density profiles</td>
<td>+/- &lt;1% volume, 5 x 10 x 10 cm wedge-shaped cutter</td>
</tr>
<tr>
<td>Pocket microscope</td>
<td>RF Insterscience Macroscope 25A</td>
<td>snow crystal type identification and size quantification</td>
<td>2 magnification, 8 mm field of view, graduated reticule with 0.1 mm resolution</td>
</tr>
<tr>
<td>Folding ruler</td>
<td></td>
<td>for measure snow height (HS), stratigraphic boundary heights, layer thickness,</td>
<td>2 m fiberglass folding rule, mm graduations</td>
</tr>
</tbody>
</table>

### 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

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**National Snow and Ice Data Center**

nsidc.org
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

12 January 2021

9.2 Date Last Updated

23 June 2021