SnowEx20 Grand Mesa IOP Computed Tomography Snow Microstructure, Version 1

USER GUIDE

How to Cite These Data

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

Courville, Z., L. Farnsworth, and H. Wittmann. 2023. *SnowEx20 Grand Mesa IOP Computed Tomography Snow Microstructure, Version 1* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/SO0GIXLAK2SG. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SNEX20_GM_CTSM

National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data set characterizes snow microstructure for 6 snow pits from the SnowEx 2020 Grand Mesa Intensive Observation Period (February 2020) using microcomputed tomography (micro-CT). Included with this data set are two- and three-dimensional microstructural analysis of DMP/DEP casted and un-casted snow samples, available as .xlsx and .txt files, and visual representations of the three-dimensional snow structure, available is .bmp image files. Containers of snow were collected at 6 snow pits in approximately 17 cm intervals. There were approximately 5-8 discrete containers per pit and each container had an ~2 cm overlap with the sample below. A 6-cm section of snow was dissected from each container of snow, which were analyzed in ~2 cm sub-samples. Each sub-sample was scanned in three intervals using a micro-CT instrument. The three interval scans comprise multiple slices, and were combined into the reconstructed final scan used for calculating the snow microstructural data. Figure 1 below presents a schematic diagram demonstrating the relationship between the following descriptors used throughout this document: (1) snow pit, (2) container of snow, (3) sub-sample, (4) interval scan, (5) final scan, and (6) slice.

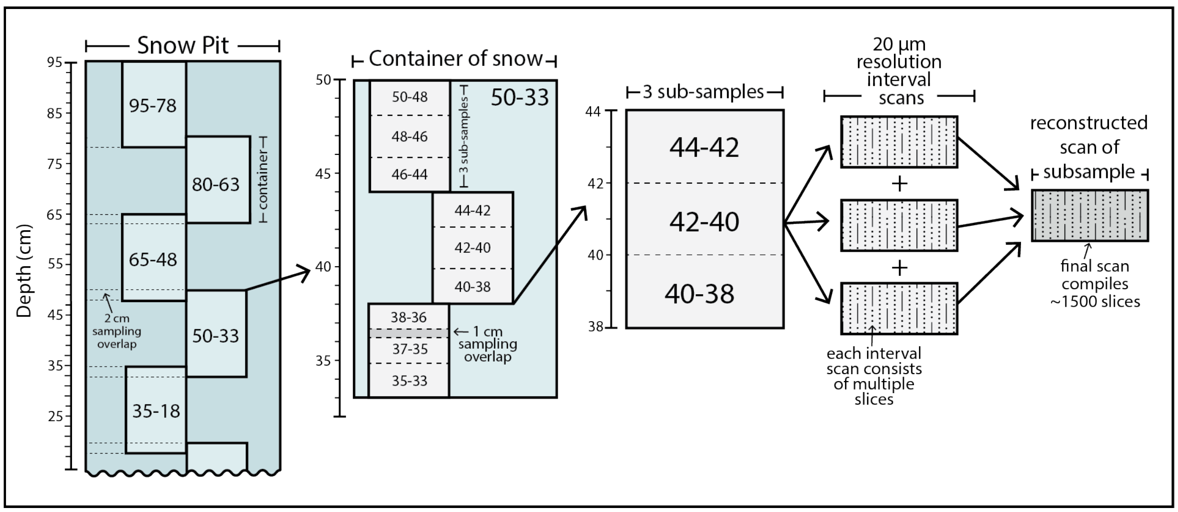

Figure 1. Overview of snow sampling strategy for snow pit 1s17.

1.1 Parameters

This data set presents snow microstructural data, which encompasses multiple variables. The following two-dimensional variables are available for each interval:

- Object area
- Percent object area
- Total ROI perimeter
- Object perimeter / area ratio
- Average object area
- Average object area-equivalent circle diameter
- Surface convexity index
- Euler number
- Number of closed pores

- Area of closed pores
- Perimeter of closed pores
- Closed porosity (percent)
- Area of open pore space
- Total area of pore space
- Open porosity (percent)
- Total porosity (percent)
- Centroid(x)
- Centroid (y)
- Moment of inertia (x)
- Moment of inertia (y)
- Polar moment of inertia
- Radius of gyration (x)
- Radius of gyration (y)
- Polar radius of gyration
- Product of inertia (xy),
- Principal moment of inertia (max)
- Principal moment of inertia (min)
- Total orientation (phi)
- Eccentricity Structure thickness (plate model)
- Structure separation (plate model)
- Structure linear density (plate model)
- Fractal dimension
- Intersection perimeter

The following three-dimensional (morphometry) variables are available for each sub-sample:

- Total VOI volume
- Object volume
- Percent object volume
- Total VOI surface
- Object surface
- Intersection surface
- Object surface / volume ratio
- Object surface density
- Surface convexity index,
- Centroid (x)
- Centroid (y)
- Centroid (z)
- Moment of inertia (x)
- Moment of inertia (y)
- Moment of inertia (z)
- Polar moment of inertia
- Radius of gyration (x)
- Radius of gyration (y)
- Radius of gyration (z)
- Polar radius of gyration
- Product of inertia (xy)
- Product of inertia (xz)
- Product of inertia (yz)
- Total orientation (theta)
- Total orientation (phi)
- Structure model index
- Structure thickness
- Structure linear density
- Structure separation
- Fractal dimension
- Number of objects
- Number of closed pores
- Volume of closed pores
- Surface of closed pores
- Closed porosity (percent)
- Volume of open pore space
- Open porosity (percent)
- Total volume of pore space
- Total porosity (percent)
- Euler number
- Connectivity
- Connectivity density
- Degree of anisotropy
- Eigenvalue 1
- Eigenvalue 2
- Eigenvalue 3
- SSA

1.2 File Information

1.2.1 Format

Data are provided as .xlsx files, .bmp files, and .txt files.

1.2.2 File Contents

This data set is organized into six granules, each representing a single snow pit. Included within each granule are three types of files: (1) a summary Excel spreadsheet (.xlsx), which compiles micro-CT derived analysis for each snow pit, including separate sheets for the data outputs for each 2 cm sub-sample and the morphometry analysis for the entire container of snow; (2) a .txt file for each 2 cm sub-sample containing data outputs from micro-CT post-processing; and (3) a .bmp image file for each 2 cm sub-sample showing a 3D representation of the sub-sample.

1.2.3 Naming Convention

File naming conventions vary by file content, as described below. Note, all granules and file names begin with the NSIDC data set ID: `SNEX20_GM_CTSM`. Additional variables used in the file naming conventions can be found in Table 1.

Each .xlsx file conforms to the following naming convention:

```
[pitID]_analysis.xlsx
```

The .xlsx files also contain multiple named sheets, which conform to either of the following naming conventions:

```
[pitID]_morphometry_results
[pitID]_[XX-XX]_[YY-YY]cm
```

Each .txt and .bmp file conform to the following naming convention:

```
[pitID]_[XX-XX]_[YY-YY]cm_20um_rec_voi_.[ext]
```

Table 1. File Naming Variable Descriptions

Variable	Description
`pitID`	Snow pit ID (`1s17, 2n13, 2s16, 2s7, 9c16, 1s2`)
`XX-XX`	Depth range of snow pit container of snow in cm
`YY-YY`	Depth range of 2 cm sub-sample
`20um_rec_voi`	20 µm resolution reconstruction of the volume-of-interest

.[ext]	File extension, including: `.bmp` (image files), and `.batman.txt` or `.ctan.txt` (text files exported by the Bruker CTAn analysis software)

1.3 Spatial Information

1.3.1 Coverage

Northernmost Latitude: 39.065321 N

Southernmost Latitude: 39.005111 N

Westernmost Latitude: 108.228389 W

Easternmost Latitude: 108.110485 W

1.3.2 Resolution

N/A

1.3.3 Geolocation

The following tables provide information for geolocating this data set

Table 2. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84 / UTM zone 12 N
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	32610
PROJ4 string	+proj=utm +zone=12 +datum=WGS84 +units=m +no_defs +type=crs
Reference	https://epsg.io/32612

1.4 Temporal Information

1.4.1 Coverage

03 February 2020 to 08 February 2020

1.4.2 Resolution

N/A

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Quantitative snow microstructural data provides essential insight into the process of microwave radiation transfer within a snowpack, and is integral for interpreting data collected by remote sensing instruments, such as NASA's SWE Synthetic Aperture Radar and Radiometer (SWESARR). Microcomputed tomography (micro-CT) provides a non-destructive means of analyzing the two- and three-dimensional microstructure of snow samples. This data set presents microstructural data from 6 snow samples extracted from six snow pits dug during the SnowEx Grand Mesa Intensive Observation Period (IOP) between February 3-8, 2020. More information about the Grand Mesa IOP, including study location details, snow pit sampling strategy, and other core observations can be found in the NASA SnowEX 2020 Experiment Plan.

2.2 Acquisition

Samples (referred to throughout as "containers of snow") were collected in the field by extracting rectangular sections of snow from a single face of a snow pit wall. Each section measured ~17 cm long and was extracted in an alternating pattern beginning at the snow surface, such that the collection height of each overlapped ~2 cm. Between 5 and 8 containers of snow were collected per snow pit. Collection heights ranged between 2 cm (from the base of the snow pit) to 139 cm (height of the snow surface in the deepest pit). Please refer to the included technical reference SnowEx_IOP_2020.pdf for additional details regarding the sample extraction process.

Following extraction, each container of snow was filled with either the cold casting agent diethyl phthalate (DEP) or dimethyl phthalate (DMP), which replaces the air space in the snow sample, preserving the three-dimensional geometry of the snow sample. Containers of snow were packed in dry ice for transport to a laboratory cold room (14 °F). In the cold room, an ~6 cm section was cut from each container of snow for analysis, which was scanned at 2-cm intervals (i.e., sub-samples).

Each sub-sample was scanned three times using a cold-hardened Skyscan1173 Bruker Micro-CT scanner at the instrument settings described in Table 3. Approximately 1500+ scanned images were produced for each sub-sample, each which represent a single two-dimensional (2D) “slice” or cross-section through the sub-sample.

Table 3. Instrument Settings

Scan resolution	20 µm
Scan duration	0.6 µm
Step rotation	330 ms
Exposure	40 kV
Voltage	200 µA
Filter	None

2.3 Processing

A software tool (NRecon) was used to reconstruct a three-dimensional (3D) model of each snow sub-sample by stacking the 2D scans. The software tool CTAn was used to conduct statistical analysis of the scans, producing the following data for the 2D (per cross-sectional slice) and 3D (per total volume of the sample) scans:

- Total porosity
- Close porosity
- Open porosity
- Surface to volume ratio (S/V)
- Mean grain size per sample volume
- Mean grain size over the height of the sample
- Anisotropy.

From the S/V data, specific surface area (SSA) of each snow sample can then be calculated. A third software tool (CTVox) was used to create the 3D visualizations of the scans included with this data set. Note, all software tools described here are proprietary programs included with the Bruker Skyscan1173 Micro-CT instrument. Further discussion of the micro-CT analysis methods used in the collection of this data set can be found in Heggli et al., 2017.

2.4 Quality, Errors, and Limitations

Quantitative error analysis is not provided for this data set.

2.5 Instrumentation

All analyses were performed using a Bruker Skyscan1173 Micro-CT instrument.

3 VERSION HISTORY

Table 4. Version History Summary

Version	Release Date	Description of Changes
1	June 2023	Initial release

4 RELATED DATA SETS

SnowEx at NSIDC | Data Sets

5 RELATED WEBSITES

Snow Ex at NSIDC | Overview

Snow Ex at NASA

6 REFERENCES

Heggli, M., Köchle, B., Matzl, M., Pinzer, B., Riche, F., Steiner, S., Steinfeld, D., and Schneebeli, M. (2011). Measuring snow in 3-D using X-ray tomography: Assessment of visualization techniques. Annals of Glaciology, 52(58), 231-236. doi:10.3189/172756411797252202

7 DOCUMENT INFORMATION

7.1 Publication Date

June 2023

7.2 Date Last Updated

June 2023