SnowEx20 Grand Mesa IOP BSU 1 GHz Multi-polarization GPR, Version 1

USER GUIDE

How to Cite These Data

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

Meehan, T. G. 2021. *SnowEx20 Grand Mesa IOP BSU 1 GHz Multi-polarization GPR, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/Q2LFK0QSVGS2. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SNEX20_BSU_GPR

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

The main parameters for this data set are snow water equivalent (SWE), measured in millimeters (mm), and snow depth, measured in centimeters (cm). These parameters are derived from ground penetrating radar (GPR) two-way travel time (nanoseconds, ns).

1.2 File Information

1.2.1 Format

Data files are provided in comma-separated values (`.csv`) format.

1.2.2 File Contents

File contents are described in Table 1 and a sample of data is shown in Figure 1.

Table 1. Description of file contents

Column Header	Description	Units	Notes
Date	Month, day and year of data acquisition.	N/A	Provided in mmddyy format.
Time	Hour, minute, second and millisecond of data acquisition.	N/A	Provided in HHMMSS.sss format
Longitude		N/A	
Latitude		N/A	
Elevation	WGS84 elevation above ellipsoid	Meters (m)	Corrected for geoid and antenna height
Easting	UTM Easting (X) Coordinate	Meters (m)	N/A
Northing	UTM Northing (Y) Coordinate	Meters (m)	N/A
UTM Zone	UTM grid zone 12	N/A	See note in section 1.3.3
TWT	Radar two-way travel time from the snow surface	Nanoseconds (ns)	N/A
Depth	Snow depth	Centimeter (cm)	Estimated from TWT
SWE	Snow water equivalent	Millimeters (mm)	Estimated from Depth

Date	Time	Longitude	Latitude	ElevationWGS84	Easting	Northing	UTM_Zone	TWT	Depth	SWE
12820	161549.562	-108.1908894	39.03437438	3040.467636	743148.4242	4324346.715	12	8.30	101.0967355	275.994088
12820	161552.888	-108.1909109	39.03435432	3040.798289	743146.632	4324344.431	12	8.20	99.87870256	272.668858
12820	161556.205	-108.1909102	39.03431459	3041.117494	743146.8267	4324340.023	12	9.00	109.6229662	299.2706978
12820	161559.522	-108.1908934	39.03428544	3041.153496	743148.3826	4324336.832	12	8.70	105.9688674	289.2950079
12820	161602.838	-108.1908744	39.03424775	3041.343392	743150.1518	4324332.699	12	8.60	104.7508344	285.9697779
12820	161606.155	-108.1908393	39.03419067	3041.583402	743153.3858	4324326.457	12	8.80	107.1869003	292.6202379
12820	161609.48	-108.1907803	39.03413803	3041.916766	743158.6723	4324320.773	12	8.80	107.1869003	292.6202379
12820	161612.792	-108.190716	39.03407894	3042.188145	743164.4431	4324314.385	12	7.89	96.14919051	262.4872901
12820	161616.12	-108.1906748	39.03400874	3042.5026	743168.2514	4324306.704	12	6.40	77.95410932	212.8147184
12820	161619.438	-108.1907048	39.03393079	3042.706822	743165.9262	4324297.971	12	8.00	97.44263665	266.018398

Figure 1. The first ten lines of data from 28 January 2020.

1.2.3 Naming Convention

There are two files in this data set:

`SNEX20_BSU_GPR_pE_01282020_01292020_02042020.csv`

`SNEX20_BSU_GPR_pE_01282020_01292020_02042020_downsampled.csv`

They are named according to the following convention and as described in Table 2:

`SNEX20_BSU_GPR_pE_MMDDYYYY_MMDDYYYY_MMDDYYYY<_downsampled>.csv`

Table 2. Description of File Names

Variable	Description
SNEX20_BSU_GPR	Short for SnowEx20 Grand Mesa IOP BSU 1 GHz Multi-polarization GPR
pE	Short for pulseEKKO, the name of the GPR system
[MMDDYYYY]	Dates of all days of measurements in Day-Month-Year format
<_downsampled> (optional)	The downsampled file includes data in 10 m resolution compared to the other file that has a resolution of 10 cm.
.csv	File name extension indicating comma separated value files.

1.3 Spatial Information

1.3.1 Coverage

Northernmost Latitude: 39.038896° N
Southernmost Latitude: 39.002182° N
Easternmost Longitude: 108.159761° W
Westernmost Longitude: 108.206626° W

1.3.2 Resolution

The along-track resolution of the GPR instrument is approximately 10 cm, but the actual resolution in the data files depends on the speed at which the radar system was towed. The file with the file name extension "_downsampled" has a resolution of approximately 10 m.

Radar transects were acquired in a gridded survey pattern with an approximate grid resolution of 30 m.

1.3.3 Geolocation

All data falls within the project coordinate system WGS 84 / UTM Zone 12 North (corresponding to grid zone 12S, in the Northern Hemisphere; see note below), details of which are presented in Table 3.

Table 3. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84 / UTM Zone 12 North
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	50000
False northing	0
EPSG code	32612
PROJ4 string	+proj=utm +zone=12 +datum=WGS84 +units=m +no_Defs
Reference	https://epsg.io/32612

NOTE: The data files indicate that all geographic coordinates fall within UTM Grid Zone 12S. This designation corresponds to the intersection of longitudinal projection zone 12 and latitudinal projection zone S, as shown in Figure 2. Users should be aware that UTM Grid Zone 12S falls within the projected coordinate system WGS 84 / UTM Zone 12 North.

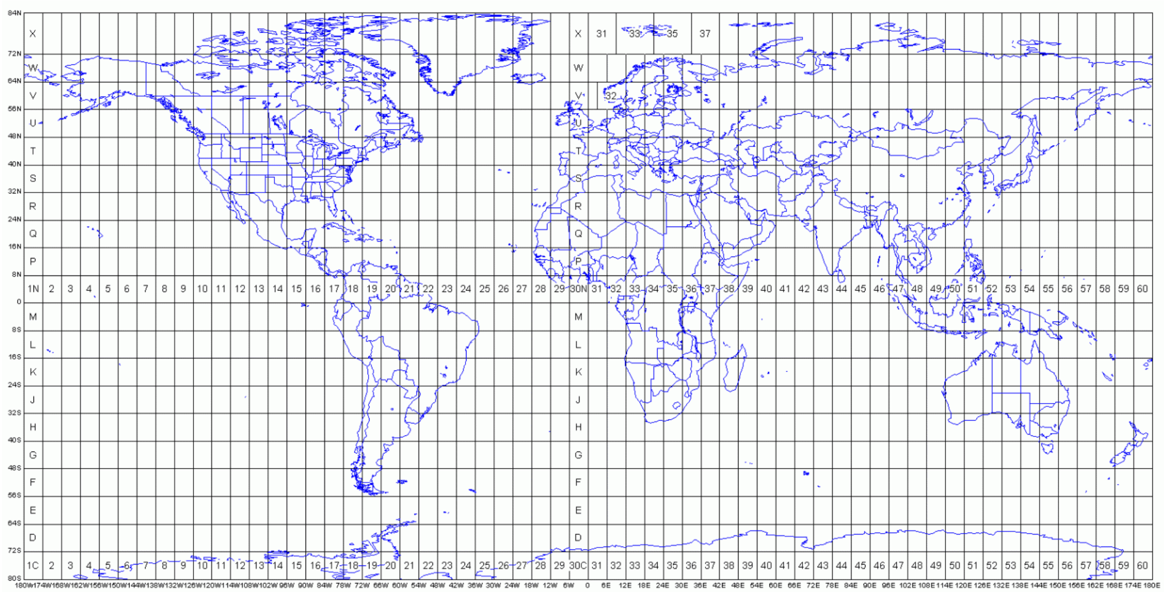

Figure 2. UTM Grid Zone map

1.4 Temporal Information

1.4.1 Coverage

28 January 2020 through 04 February 2020

1.4.2 Resolution

N/A, data were collected at each site only once.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

These data were collected as part of the SnowEx 2020 Intensive Observation Period (IOP) campaign in Grand Mesa, Colorado. They were collected in conjunction with the SnowEx20 Grand Mesa Intensive Observation Period Snow Pit Measurements.

2.2 Acquisition

Radar data were collected using the Sensors & Software pulseEKKO PRO 1 GHz ground penetrating radar (GPR) with a multi-channel adaptor. The multi-channel adaptor was configured to support one transmitting antenna (horizontal polarization) and two receiving antennas (horizontal and vertical polarization). Data were collected on two channels with the same 25 cm antenna separation but different polarizations: channel 1 was HH, channel 2 was HV.

The GPR was towed approximately 5 m behind a snowmobile and acquired data continuously. A Juniper Systems Geode antenna recorded the GPS position of the snowmobile. These positions were corrected to the antenna midpoint by assuming that the radar was pulled in a straight path behind the snowmobile. This assumption was valid, as only wide turns were made to keep the sled straight.

2.2.1 Other Input Data

Snow density was measured using two-three vertical profiles, which were continuously sampled in 10 cm intervals. The 2-3 samples at each 10 cm depth interval were averaged, then the column was averaged (see: SnowEx20 Grand Mesa Intensive Observation Period Snow Pit Measurements) to determine the average density used in this data set.

2.3 Processing

Raw GPR data were processed using conventional GPR filtering techniques, including a Butterworth band-pass filter (500 MHz – 2 GHz) (Selesnick & Burrus, 1998), time-zero correction using the Modified Energy Ratio for first break picks (Wong, Han, Bancroft & Stewart, 2009), background (i.e. coherent noise) removal using Median Subtraction (Kim, Cho & Yi, 2007), amplitude gain using t-squared scaling (Yilmaz, 2001), and random noise removal using the Kuwahara Filter (Kuwahara, Hachimura, Eiho & Kinoshita, 1976). After initial radar processing, the coherence between the HH and HV channels was calculated (Neidell & Taner, 1971). The maximum coherence of each radar trace was selected to automatically determine the two-way travel time, i.e. the time between when the signal was transmitted at the snow surface and when the signal was reflected from the ground surface. One nanosecond was subtracted from this maximum coherence / two-way travel time value to match the initial reflected energy of the transmitted wavelet (Booth, Clark & Murray, 2010). Two-way travel times were carefully reviewed and manually re-picked where necessary (very few were).

Electromagnetic velocity was calculated from the average snow pit density using the CRIM equation (Wharton, Hazen, Rau & Best, 1980). Velocities were then interpolated to GPR positions using inverse distance weighting (Shepard, 1968).

Snow depth (z_s) was estimated from the radar two-way travel time (t) and average EM velocity of the snow (v_s):

$$z_s = \frac{v_s t}{2} .$$

SWE was estimated from snow depth (z_s) and average snow density (ρ_s) that was normalized by the density of water (ρ_w):

$$SWE = z_s \frac{\rho_s}{\rho_w} .$$

2.4 Quality, Errors, and Limitations

2.4.1 Errors and Uncertainty

The horizontal positioning error is approximately 70 cm.

Travel time estimates have an error of approximately ±0.5 ns, and snow density estimates have an error of approximately ±10 kg/m^3.

Propagating the travel time and snow density errors forward, the uncertainty associated with snow depth and SWE estimates are approximately 3 cm and 9 mm, respectively.

2.5 Instrumentation

2.5.1 Description

Data were collected using a Sensors & Software pulseEKKO PRO 1 GHz ground penetrating radar (GPR) with a multi-channel adaptor.

3 SOFTWARE AND TOOLS

Users may find the tools and resources listed on the PI's GitHub useful:
https://github.com/tatemeehan/SnowEx2020_BSU_pE_GPR.
These tools are not supported by NSIDC.

4 VERSION HISTORY

Table 4. Version History Summary

Version	Release Date	Description of Changes
1	January 2021	Initial release

5 RELATED DATA SETS

SnowEx Data | Overview

SnowEx20 Grand Mesa IOP BSU 1 GHz Multi-polarization GPR Raw

SnowEx20 Grand Mesa Intensive Observation Period Snow Pit Measurements

6 RELATED WEBSITES

SnowEx Project at NASA

7 CONTACTS AND ACKNOWLEDGMENTS

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8 REFERENCES

Booth, A. D., Clark, R., & Murray, T. (2010). Semblance response to a ground-penetrating radar wavelet and resulting errors in velocity analysis. *Near Surface Geophysics*, *8*(3), 235–246. https://doi.org/10.3997/1873-0604.2010008

Kim, J. H., Cho, S. J., & Yi, M. J. (2007). Removal of ringing noise in GPR data by signal processing. *Geosciences Journal*, *11*(1), 75–81. https://doi.org/10.1007/BF02910382

Kuwahara, M., Hachimura, K., Eiho, S., & Kinoshita, M. (1976). Processing of RI-Angiocardiographic Images. In *Digital Processing of Biomedical Images* (pp. 187–202). Boston, MA: Springer US. https://doi.org/10.1007/978-1-4684-0769-3_13

McGrath, D., Webb, R., Shean, D., Bonnell, R., Marshall, H., Painter, T. H., Molotch, N. P., Elder, K., Hiemstra, C., & Brucker, L. (2019). Spatially extensive ground-penetrating radar snow depth observations during nasa's 2017 snowex campaign: Comparison with in situ, airborne, and satellite observations. *Water Resources Research*, *55*(11), 10026–10036. https://doi.org/10.1029/2019WR024907

Neidell, N. S., & Taner, M. T. (1971). Semblance and Other Coherency Measrues for Multichannel Data. *Geophysics*, *36*(3), 482–497. https://doi.org/10.1190/1.1440186

Selesnick, I. W., & Burrus, C. S. (1998). Generalized digital butterworth filter design. *IEEE Transactions on Signal Processing*, *46*(6), 1688–1694. https://doi.org/10.1109/78.678493

Shepard, D. (1968). A two-dimensional interpolation function for irregularly-spaced data. In *Proceedings of the 1968 23rd ACM national conference* (pp. 517–524).

Wharton, R. P., Hazen, G. A., Rau, R. N., & Best, D. L. (1980). Advancements In Electromagnetic Propagation Logging. In *SPE Rocky Mountain Regional Meeting*. Society of Petroleum Engineers. https://doi.org/10.2118/9041-MS

Wong, J., Han, L., Bancroft, J. C., & Stewart, R. R. (2009). Automatic time-picking of first arrivals on noisy microseismic data. *CREWS*, 1–6.

Yilmaz, Ö. (2001). *Seismic Data Analysis*. Society of Exploration Geophysicists. https://doi.org/10.1190/1.9781560801580

9 DOCUMENT INFORMATION

9.1 Publication Date

25 January 2021

9.2 Date Last Updated

25 January 2021