



SnowEx23 CRREL Ground Penetrating Radar, Version 1

USER GUIDE

How to Cite These Data

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

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FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/SNEX23_CRREL_GPR



National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

This data set contains the results of 1 GHz ground-penetrating radar surveys conducted at the Upper Kuparuk/Toolik (UKT) site in northern Alaska, USA as part of the NASA SnowEx 2023. Data include two-way travel (TWT) time, calculated snow depth, and calculated snow water equivalent (SWE).

1.2 File Information

1.2.1 Format

The data is organized into 81 individual comma-separated value (.csv) files. Each file represents a single GPR track collected on a single day.

1.2.2 File Contents

Each .csv file contains the following 12 columns.

Table 1. Data Parameters

Name	Description	Unit/Format
DayTime	Date and time using nine digits representing month, day, and year for date; and nine digits representing the hour, minute, and seconds within the day	[dd-mmm-yyyy HH:MM:SS.SSS]
Longitude	Longitude	decimal degrees
Latitude	Latitude	decimal degrees
ElevationWGS84	Elevation using World Geodetic System 1984 (WGS84) as a global datum	m
Easting	Easting	m
Northing	Northing	m
ElevationEGM96	Elevation measured using GeoidEGM96 as a datum	m
UTMzone	Universal Transverse Mercator zone	N/A
GeoidEGM96	The difference in elevation between the WGS84 Ellipsoid and the EGM96 Geoid model	m
TWT	Two-way travel time (through snow)	ns
Snow Depth[cm]	Snow depth	cm
SWE[mm]	Snow water equivalent	mm

A subsection of the .csv files which contain the word “ice” in the file name have two additional columns, which are described in Table 2 below. For further information regarding these parameters, see Section 2.2.

Table 2. Data Parameters

Name	Description	Unit/Format
IceTWT	Two-way travel time (through ice)	ns
Ice Thickness [cm]	Ice thickness	cm

1.2.3 Naming Convention

The data files are named according to the following conventions, and as described in Table 3.

SNEX23_CRREL_GPR_UKT_TWT-[nn]_[configuration]_[YYYYMMDD]_v01.0.[csv]

SNEX23_CRREL_GPR_UKT_iceTWT-[nn]_[configuration]_[YYYYMMDD]_v01.0.[csv]

Table 3. Final naming convention

Variable	Description
SNEX23	SnowEx2023 field campaign
CRREL	Cold Regions Research and Engineering Laboratory
GPR	Ground-Penetrating Radar surveys
UKT	Site code: Upper Kuparuk Toolik
TWT	Two-way travel time collected over snow
iceTWT	Two-way travel time collected over ice
[nn]	Two-digit GPR line number; can be used to correlate each file to a snow pit or SWESARR track (see Appendix A)
[configuration]	Geometric configuration of GPR track (Trench, Spiral, Transect)
[YYYYMMDD]	Date acquisition date (4-digit year, 2-digit month, and 2-digit day)
v01.0	Data set version

1.3 Spatial Information

1.3.1 Coverage

Northernmost Latitude: 68.6400° N

Southernmost Latitude: 68.5257° N

Eastermost Longitude: 149.2186° W

Westernmost Longitude: 149.5680° W

1.3.2 Resolution

Point measurements.

1.3.3 Geolocation

The following table provides information for geolocating this data set.

Table 4. Geolocation Details

Geographic Coordinate System	WGS 84
Projected Coordinate System	Transverse Mercator
Longitude of True Origin	N/A
Latitude of True Origin	0°
Scale factor at longitude of true origin	0.9996
Datum	World Geodetic System 1984
Ellipsoid/spheroid	WGS 84
Units	degree
False Easting	500000
False Northing	0
EPSG code	32606
PROJ4 string	+proj=utm +zone=6 +datum=WGS84 +units=m +no_defs +type=crs
Reference	https://epsg.io/32606

1.4 Temporal Information

1.4.1 Coverage

08 Mar 2023 to 15 Mar 2023

1.4.2 Resolution

Data was collected once per sampling site.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

This data set contains the results of ground-penetrating radar surveys conducted in the North Slope region of the northern Alaska coastal plain (Upper Kuparuk Toolik) during the SnowEx2023 field campaign. Data were collected between 08 Mar 2023 to 15 Mar 2023, spatially coinciding with snow pit locations and along transects between snow pits. Raw GPR data are available as [SnowEx23 CRREL Ground Penetrating Radar Raw, Version 1](#).

2.2 Acquisition

These data were collected using a snow machine-mounted 1 GHz multipolarization Ground Penetrating Radar (GPR), which records imagery simultaneously on co- and cross-polarized antennas. The antennas were suspended approximately 50 cm above the snow surface and positioned to record undisturbed snow. Measurements were collected in three spatial configurations: 1) trench, 2) spiral, or 3) transect. Trench data was collected along a straight line approximately 5 m from the snow pit, traveling from the southwest corner to the northwest corner of each pit. Spiral data was collected by continuing in a clockwise direction, spiraling outward from the pit site. Transects were collected as the snow machine traveled between pit sites or along the SWESARR flight lines, with repeat snow machine passes to cover the swath width. In particular, data collected on 13 March 2023 were targeted along the SWESARR flight lines which coincided with Adirondack tube SWE measurements taken every kilometer along the transect (see [SnowEx23 Snow Water Equivalent, Version 1](#)).

Note, a subset of the data files includes additional parameters (IceTWT and Ice Thickness), which represent GPR sampling sites where ice was also present (i.e. frozen lakes or creeks).

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 (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). Unprocessed raw data can be found in [SnowEx23 CRREL Ground Penetrating Radar Raw, Version 1](#).

The snow surface reflection was chosen using the Modified Energy Ratio automatic picking algorithm. The snow/ground reflection was then automatically picked using the maximum coherence between the co- and cross-polarized GPR channels for each radar trace (Neidell & Taner, 1971). 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). For data collected over ice, the ice/ground reflection was selected by first using the coherence method, then refining the selections by manual picking/inspection. All picks were carefully reviewed and manually corrected where necessary.

Electromagnetic (EM) 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

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/m³. 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

Data were collected using a Sensors & Software pulseEKKO PRO ground penetrating radar (GPR) system and a 1 GHz antenna.

3 VERSION HISTORY

Table 5. Version History Summary

Version	Date Implemented	Impacted Temporal Coverage	Description of Changes
v01.0	September 2024	08 Mar 2023 to 15 Mar 2023	Initial release

4 RELATED DATA SETS

[SnowEx at NSIDC | Data Sets](#)

[SnowEx23 CRREL Ground Penetrating Radar Raw, Version 1](#)

[SnowEx23 University of Wyoming Ground Penetrating Radar](#)

[SnowEx23 Mar22 IOP Snow Depth Measurements](#)

[SnowEx23 Mar23 IOP Community Snow Depth Measurements](#)

[SnowEx23 Snow Water Equivalent](#)

5 RELATED WEBSITES

[SnowEx at NSIDC | Overview](#)

[SnowEx at NASA](#)

6 REFERENCES

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7 DOCUMENT INFORMATION

7.1 Publication Date

September 2024

7.2 Date Last Updated

September 2024

APPENDIX A – GPR TRACK IDENTIFICATION

The following table correlates GPR tracks with snow pit and SWESARR flight line locations. The information provided in the Date, Identifier, and Sampling Configuration fields can be matched with the data set files names (see Section 1.2.3.).

Date (MMDDYY)	Identifier	Sampling Configuration	Related Snow Pits	Additional Description
030823	Line 1	Trench	N667	
030823	Line 2	Spiral	A664	
030823	Line 3	Transect	A664, N667	Data collected on transit from A664 to N667
030823	Line 4	Transect	N667, N657	Data collected on transit from A664 to N667
030823	Line 5	Spiral	N657	
030823	Line 6	Transect	N657, N659	Data collected on transit from A664 to N667
030823	Line 7	Transect	N659	Data collected on transit from N659 to Toolik Field Station
030923	Line 1	Trench	A784	
030923	Line 2	Spiral	A784	
030923	Line 3	Transect	A784, N787	Data collected on transit from A784 to N787
030923	Line 4	Trench	N787	
030923	Line 5	Spiral	N787	
030923	Line 6	Transect	N787, N789	Data collected on transit from N787 to N789
030923	Line 7	Trench	N789	
030923	Line 8	Spiral	N789	
030923	Line 9	Transect	N789, N790	Data collected on transit from N789 to N790 to Toolik Field Station
031023	Line 1	Trench	A766	
031023	Line 2	Spiral	A766	

Date (MMDDYY)	Identifier	Sampling Configuration	Related Snow Pits	Additional Description
031023	Line 3	Transect	A766, N762	Data collected on transit from A766 to N762
031023	Line 4	Trench	N762	
031023	Line 5	Spiral	N762	
031023	Line 6	Transect	N762, A760	Data collected on transit from N762 to A760
031023	Line 7	Trench	A7760	
031023	Line 8	Spiral	A760	
031023	Line 9	Transect	A760	Data collected on transit from A760 to Toolik Field Station
031123	Line 1	Trench	N730	
031123	Line 2	Spiral	N730	
031123	Line 3	Transect	N730, A739	Data collected on transit from N730 to Snotel to A739
031123	Line 4	Trench	A739	
031123	Line 5	Spiral	A739	
031123	Line 6	Transect	A739, N746	Data collected on transit from A739 to N746
031123	Line 7	Spiral	N746	
031123	Line 8	Trench	N746	
031123	Line 9	Transect	N746	Data collected on transit from N746 to Toolik Field Station
031223	Line 1	Trench	A665	
031223	Line 2	Spiral	A665	
031223	Line 3	Transect	A665, A652	Data collected on transit from A665 to A652
031223	Line 4	Trench	A652	
031223	Line 5	Spiral	A652	
031223	Line 6	Transect	A652, I775	Data collected on transit from A652 to I775

Date (MMDDYY)	Identifier	Sampling Configuration	Related Snow Pits	Additional Description
031223	Line 7	Spiral	I775	
031223	Line 8	Transect	I775, I668	Data collected on transit from I775 to I668
031223	Line 9	Trench	I668	
031223	Line 10	Spiral	I668	
031323	Line 1	Transect	-	Data collected between UKE1 to UKE10 (UKE SWESARR Line W to E)
031323	Line 2	Transect	-	Data collected between UKE10 to UKE9 (E to W)
031323	Line 3	Transect	-	Data collected between UKE9 to UKE8
031323	Line 4	Transect	-	Data collected between UKE8 to UKE7
031323	Line 5	Transect	-	Data collected between UK7 to UKE9.5
031323	Line 6	Transect	-	Data collected between UKE9.5 to UKE7
031323	Line 7	Transect	-	Data collected between UKE7 to UKE1
031323	Line 8	Transect	-	Data collected between UKE1 to Toolik Field Station
031423	Line 1	Transect	I679	Data collected on transit from Toolik Field Station to 1679
031423	Line 2	Trench	I679	Antenna Height to Snow (36 cm, 43) lh (73,89) Snow depth (37, 46) (i.e., SW Corner, NW Corner)
031423	Line 3	Spiral	I679	
031423	Line 4	Trench	I679	Data collected on ice surface
031423	Line 5	Trench	I679	Data collected on ice trench
031423	Line 6	Transect	I679, I775	Data collected on transit from 1679 to I775
031423	Line 7	Transect	I775, I784	Data collected on transit from I775 to I784
031423	Line 8	Transect, Spiral	I668, D764	Data collected on transit from I668 to D764, then in spiral around D763
031423	Line 9	Transect	D764, I784	Data collected on transit from D764 to I784

Date (MMDDYY)	Identifier	Sampling Configuration	Related Snow Pits	Additional Description
031423	Line 10	Spiral	I784	
031423	Line 11	Transect	I784	Data collected on transit from I784 to Toolik Field Station
031523	Line 1	Transect	D698	Data collected on transit from USK Line to D698
031523	Line 2	Transect	D698	Data collected on transit from D698 to Grid
031523	Line 3	Trench	D698	
031523	Line 4	Transect	D698	D689 on UKS