IceBridge Accumulation Radar L1B Geolocated Radar Echo Strength Profiles, Version 2

USER GUIDE

How to Cite These Data

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

Paden, J., J. Li, C. Leuschen, F. Rodriguez-Morales, and R. Hale. 2014, updated 2021. *IceBridge Accumulation Radar L1B Geolocated Radar Echo Strength Profiles, Version 2.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/0ZY1XYHNIQNY. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/IRACC1B

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

Operation IceBridge products may include test flight data that are not useful for research and scientific analysis. Test flights usually occur at the beginning of campaigns. Users should read flight reports for the flights that collected any of the data they intend to use. Check IceBridge campaign Flight Reports for dates and information about test flights.

The data set includes measurements for echograms, time, latitude, longitude, elevation, and surface, as well as flight path charts and echograms images. The background images in the flight path files are Landsat-7 natural color imagery in polar stereographic format where 70 degrees true scale latitude and -45 degrees longitude is center for Greenland/Canada, and -71 degrees true scale latitude and 0 degrees longitude is center for Antarctica.

1.1 Format

The data files are in netCDF format. The echogram and flight path image files are JPEG files.

Each data file is paired with an associated XML file, which contains additional metadata.

The `Echogram.jpg` files contain depth echograms. The echograms are useful for tracking internal layers and shallow ice thickness.

The `Map.jpg` files show campaign flight locations and flight lines.

The left y-axis in the JPEG files shows depth relative to a range around the surface. The surface is in the center of the y-axis and the y-axis is set to a fixed range, usually 0-60 m or 0-80 m for land ice, and 0-4 m for sea ice. The left y-axis in the JPEG files shows surface elevation referenced to WGS-84 ellipsoid. The right y-axis shows the two-way propagation delays between the radar and ice medium.

Currently, IceBridge Accumulation Radar L1B Geolocated Radar Echo Strength Profiles (IRACC1B) data for 2009 through 2012 are in MATLAB and binary format stored separately as IRACC1B Version 1. In the near future, data from all campaigns prior to Spring 2013 will be replaced with netCDF data and added to Version 2. For details on the IRACC1B Version 1 data, see the Version 1 documentation.

1.2 File Naming Convention

1.2.1 Data Files

Data files are named according to the following conventions and as described in Table 1.

Example:

IRACC1B_20130321_01_123.nc

IRACC1B_YYYYMMDD_xx_xxx.NNN

Table 1. File Naming Convention

Variable	Description
IRACC1B	Short name for IceBridge Accumulation Radar L1B Geolocated Radar Echo Strength Profiles
YYYY	Four-digit year of survey
MM	Two-digit month of survey
DD	Two-digit day of survey
xx	Segment number
xxx	Frame number
NNN	Indicates file type. For example: netCDF (.nc), or XML (.xml)

1.2.2 JPEG Files

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

Example:

IRACC1B_20130321_01_123_Echogram.jpg

IRACC1B_YYYYMMDD_xx_xxx_aaa.NNN

Table 2. JPEG File Naming Convention

Variable	Description
IRACC1B	Short name for IceBridge Accumulation Radar L1B Geolocated Radar Echo Strength Profiles
YYYY	Four-digit year of survey
MM	Two-digit month of survey
DD	Two-digit day of survey
xx	Segment number
xxx	Frame number

aaa	Image type. Examples: Echogram, Map
NNN	Indicates file type. For example: JPEG (.jpg)

1.3 Spatial Coverage

Spatial coverage for the IceBridge accumulation radar campaigns includes Greenland and Antarctica and surrounding ocean areas.

Arctic / Greenland:
Southernmost Latitude 60° N
Northernmost Latitude: 90° N
Westernmost Longitude: 180° W
Easternmost Longitude: 180° E

Antarctica:
Southernmost Latitude: 90° S
Northernmost Latitude: 53° S
Westernmost Longitude: 180° W
Easternmost Longitude: 180° E

1.3.1 Spatial Resolution

Spatial Resolution varies dependent on along-track, cross-track, and aircraft height characteristics.

1.3.2 Projection and Grid Description

Referenced to WGS-84 Ellipsoid.

1.4 Temporal Coverage

21 March 2013 to 01 May 2018

1.4.1 Temporal Resolution

IceBridge campaigns are conducted on an annual repeating basis. Arctic and Greenland campaigns are conducted during March, April, and May, and Antarctic campaigns are conducted during October and November.

1.5 Parameter or Variable

The Accumulation Radar L1B Geolocated Radar Echo Strength Profiles data set contains elevation and surface measurements.

1.5.1 Parameter Description

The Accumulation Radar netCDF files contain fields as described in Table 3.

Table 3.File Parameter Description

Parameter	Description	Units
heading	Platform heading attitude. Zero is north, positive to east. Dimension is time.	Degrees
pitch	Platform pitch attitude. Zero is level flight, positive is up. Dimension is time.	Degrees
roll	Platform roll attitude. Zero is level flight, positive is right wing tip down. Dimension is time.	Degrees
surface	Estimated two way propagation time to the surface from the collection platform. This uses the same frame of reference as the fasttime variable. This information is sometimes used during truncation to determine the range bins that can be truncated. Dimension is time.	Seconds
altitude	WGS-84 geodetic elevation coordinate of the measurement's phase center. Dimension is time.	Meters
amplitude	Power detected radar echogram data matrix. The first dimension is fasttime and time is the second dimension. In very few cases for pre-2017 campaigns, power is relative to the current range line only. Range line may contain different biases and so power comparisons between range lines may not be possible.	Relative power (log scale)
fasttime	Fast time. Zero time is the time at which the transmit waveform begins to radiate from the transmit antenna.	Microseconds
lat	WGS-84 geodetic latitude coordinate where data were collected, potentially modified by motion compensation. Always referenced to North. Represents the location of the origin of the trajectory data which is generally not the radar's phase center, but some other point on the aircraft, for example the GPS antenna or the INS.	Degrees
lon	WGS-84 geodetic longitude coordinate where data were collected, potentially modified by motion compensation. Always referenced to East. Represents the location of the origin of the trajectory data which is generally not the radar's phase center, but some other point on the aircraft, for example the GPS antenna or the INS.	Degrees

Parameter	Description	Units
time	UTC time of day. This is also known as the slow time dimension. The parameter "units" attribute contains a string of the form "seconds since YYYY-MM-DD 00:00:00" which indicates the day related to this time parameter. This pertains to data sets that wrap over a UTC day boundary which will cause this parameter to be outside the range [0,86400].	Seconds
file_type	File type describing contents (string 'qlook').	N/A
file_version	Internal CReSIS file version (double with value 1)	N/A
radiometric_corr/ radiometric_corr_dB	Radiometric corrections applied to data	dB
param_qlook	Structure with fields controlling data loading and quick look processing	N/A
param_records	Structure with fields controlling records or metadata generation prior to data processing	N/A

2 SOFTWARE AND TOOLS

See the NetCDF Resources at NSIDC page for tools to work with netCDF files.

CReSIS netCDF files are compatible with HDF5 libraries, and can be read by HDF readers such as HDFView. If the netCDF file reader you are using does not read the data, see http://www.unidata.ucar.edu/software/netcdf/ and http://nsidc.org/data/netcdf/tools.html for information on updating the reader.

CReSIS MATLAB readers are available for loading, plotting, and elevation compensation for CReSIS Level-1B radar products. These tools are provided by the Principal Investigator as-is as a service to the user community in the hope that they will be useful. Please note that support for these tools is limited. Bug reports, comments, and suggestions for improvement are welcome; please send to nsidc@nsidc.org.

JPEG files may be opened using any image viewing program that recognizes the JPEG file format.

XML files can be read with browsers such as Firefox and Internet Explorer.

3 DATA ACQUISITION AND PROCESSING

3.1 Data Acquisition Methods

The radar architecture before the 2012 Greenland P-3 aircraft campaign is a combined stepped-chirped system. The complete bandwidth from 565 MHz to 885 MHz is divided into 16 overlapping subbands 550-600, 570-620,...850-900. Data is recorded on each subband. In post processing, the subbands are combined into a single frequency band.

The radar architecture from 2012 Greenland P-3 aircraft campaign and later uses a single wideband chirp. The digital acquisition system was replaced to enable this. The chirp is 600 to 900 MHz and is directly sampled using a 1 GigaSample-Per-Second (GSPS) Analog to Digital Converter (ADC).

The accumulation radar is only installed on the P-3 aircraft using an antenna installed in the bomb bay.

3.2 Derivation Techniques and Algorithms

3.2.1 Flat Surface Range Resolution

For a flat surface the range resolution is expressed by Equation 1.

$$\frac{k_t c}{2Bn}$$

Where:

Table 4.Flat Surface Range Resolution

Variable	Description
kt	kt = 1.6 due to the application of a Hanning time-domain window to reduce the range sidelobes of the chirped transmit waveform
c	Speed of light in a vacuum
B	Bandwidth, nominally 320 MHz (565 to 885 MHz range)
n	Index of refraction for the medium

Range resolution for several indices of refraction are given in Table 5.

Table 5.Flat Surface Range Resolution Examples

Index of Refraction	Range Resolution (m)	Medium
1	0.75	Air
1.3	0.58	Snow
sqrt(3.51)	0.42	Solid Ice

3.2.2 Footprint

The antenna installed in the bomb bay of the P-3 aircraft is a two by four element antenna array where each element is an elliptical dipole and the array is aligned so that there are two elements in the along-track direction and four elements in the cross-track direction. The dipoles are aligned with the fuselage so that the E-plane is along-track. The element spacing is 26 cm in cross-track and 37 cm in along-track. The approximate beamwidths are 21 degrees in along-track and 18 degrees in cross-track. The footprint is a function of range as shown in Equation 2.

$$\sigma = 2H \tan\left(\frac{\beta}{2}\right)$$

Where:

Table 6. Footprint

Variable	Description
H	Height above ground level. For H = 500 m, the footprint is 185 m in along-track and 158 m in cross-track.
β	Beamwidth in radians

For a smooth target, for example internal layers, the primary response is from the first Fresnel zone which is considerably smaller than the antenna footprint. The first Fresnel zone is a circle with diameter given in Equation 3.

$$D = \sqrt{2H\lambda_c}$$

(Equation 3)

Where:

Table 7.Fresnel Zone

Variable	Description
D	Diameter
H	Height above ground. For H = 500 m, the diameter is 20 m.
λc	Wavelength. λc = 0.4 m is the wavelength at the center frequency.

For a rough surface with no appreciable layover, the cross-track resolution will be constrained by the pulse-limited footprint, which is approximately as shown in Equation 4.

$$\sigma_{y,\text{pulse-limited}} = 2\sqrt{\frac{Hck_t}{B}}$$

(Equation 4)

Where:

Table 8.Pulse-Limited Footprint

Variable	Description
H	Height above the air/ice interface. For H = 500 m, the cross-track resolution is 54.8 m.
c	Speed of light in a vacuum
kt	kt = 1.6 due to the application of a Hanning time-domain window to reduce the range sidelobes of the chirped transmit waveform
B	Bandwidth

In the along-track dimension, data are coherently averaged 160 times which includes both hardware and software averaging, and decimated by this same amount so that the along-track spacing between records with a platform speed of 140 m/s is 7.2 m. A 1 range-bin by 10 along-track-range-line boxcar filter is applied to the power detected data and then decimated in the along-track by 5 so the data product has an along-track resolution of 35.8 m.

3.2.3 Trajectory and Attitude Data

The trajectory data used for this data release are from a basic GPS receiver. Lever arm and attitude compensation has not been applied to the data.

3.2.4 Processing Steps

Before 2012 Greenland, the steps for the stepped-frequency radar system are:

1. Conversion from quantization to voltage at the 50 ohm antenna.
2. Removal of DC-bias.
3. Channel compensation between each of the 16 subbands. This includes amplitude mismatches only.
4. Pulse compression with time domain window which matches transmitted time domain window and an additional frequency domain window.
5. Sixteen subbands are combined into a single band.
6. The quick look output is generated using presumming or unfocused SAR processing for a total of 160 coherent averages which includes hardware and software averages.
7. A 1 range-bin by 10 along-track-range-line boxcar filter is applied to the power detected data and then decimated in along-track by 5.
8. The quick look output is used to find the ice surface location (fully automated).

From 2012 Greenland and onward, the processing steps for the directly sampled radar system are:

1. Conversion from quantization to voltage at the 50 ohm antenna.
2. Removal of DC-bias.
3. The data are pulse compressed with a frequency domain window to reduce pulse compression side lobes.
4. The quick look output is generated using presumming or unfocused SAR processing for a total of 1280 coherent averages which includes hardware and software averages. As only a single subband needs to be captured, this is equivalent to 80 presums with the old system.
5. A 1 range-bin by 5 along-track-range-line boxcar filter is applied to the power detected data and then decimated in along-track by 5.
6. The quick look output is used to find the ice surface location (fully automated).

3.2.5 Version History

IRACC1B Version 1: Currently IRACC1B data for 2009 through 2012 are in MATLAB and binary format stored separately as IRACC1B V1. In the near future, data from all campaigns prior to Spring 2013 will be replaced with netCDF data and added to Version 2. For details on the Version 1 data, see the Version 1 documentation.

IRACC1B Version 2: Beginning with the 2013 Arctic campaign, data are provided in netCDF format.

IRACC1B Version 2.1: On 16 September 2014, Version 2 data were replaced by Version 2.1. A time stamp error was discovered in the 2013 Arctic campaign data. The latest leap second (July 1, 2012) was not accounted for in the GPS times for these campaigns. This error has been corrected in Version 2.1.

3.2.6 Error Sources

GPS Time Error:

The CReSIS accumulation, snow, MCoRDS, and kuband data acquisition systems have a known issue with radar data synchronization with GPS time. When the radar system is initially turned on, the radar system acquires Universal Time Coordinated (UTC) time from the GPS National Marine Electronics Association (NMEA) string. If this is done too soon after the GPS receiver has been turned on, the NMEA string sometimes returns GPS time rather than UTC time. GPS time is 15 seconds ahead of UTC time during this field season. The corrections for the whole day must include the offset -15 second correction. GPS corrections have been applied to all of the data using a comparison between the accumulation, snow, and ku-band radars which have independent GPS receivers. Comparisons to geographic features and between ocean surface radar return and GPS elevation are also made to ensure GPS synchronization. GPS time corrections are given in the vector worksheet of the parameter spreadsheet.

A time stamp error was discovered in the 2013 Arctic campaign data. The latest leap second (July 1, 2012) was not accounted for in the GPS times for these campaigns.

The error affects Version 2 of the Level 1B CReSIS data sets. Accumulation Radar data are affected for the time period: March 2013 - 2014. In the near future, the NSIDC DAAC will publish updated data files with a correction to the 'Time' field.

3.3 Sensor or Instrument Description

As described on the CReSIS Sensors Development Radar Web site, fine depth resolution profiling of the top 100 m of the ice column is achieved with the Accumulation Radar designed to map variations in the snow accumulation rate. When operated from aircraft, the Accumulation radar operates from 600 to 900 MHz providing 28 cm depth resolution in ice and when operated on the ground (500 MHz to 2 GHz) a 5.6-cm depth resolution in ice is achieved. This fine depth resolution enables extensive spatial mapping of the annual accumulation layers.

4 REFERENCES AND RELATED PUBLICATIONS

Lewis, C. 2010. *Airborne UHF Radar for Fine Resolution Mapping of Near Surface Accumulation Layers in Greenland and West Antarctica*, Department of Electrical Engineering and Computer Science: Master's Thesis, University of Kansas.

Lewis, C., A. Patel, H. Owen, F. Rodriguez-Morales, C. Leuschen, S. A. Seguin, J. Ledford, K. Player, and S. Gogineni. 2009. A Radar Suite for Ice Sheet Accumulation Measurements and Near-Surface Internal Layer Mapping, *Geoscience and Remote Sensing Symposium, IEEE International, IGARSS 2009*, pp.V-441 - V-444, doi: 10.1109/IGARSS.2009.5417635.

Rodriguez-Morales, F., P. Gogineni, C. Leuschen, C. T. Allen, C. Lewis, A. Patel, L. Shi, W. Blake, B. Panzer, K. Byers, R. Crowe, L. Smith, and C. Gifford. 2010. Development of a Multi-Frequency Airborne Radar Instrumentation Package for Ice Sheet Mapping and Imaging, *Proc. 2010 IEEE Int. Microwave Symp*., Anaheim, CA, May 2010, 157-160.

4.1 Related Data Collections

- IceBridge Ku-Band Radar L1B Geolocated Radar Echo Strength Profiles
- IceBridge MCoRDS L1B Geolocated Radar Echo Strength Profiles
- IceBridge MCoRDS L2 Ice Thickness

4.2 Related Websites

- CReSIS Sensors Development Radar website
- CReSIS website
- IceBridge data website at NSIDC
- IceBridge website at NASA
- ICESat/GLAS website at NASA Wallops Flight Facility
- ICESat/GLAS website at NSIDC

5 CONTACTS AND ACKNOWLEDGMENTS

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6 DOCUMENT INFORMATION

6.1 Publication Date

26 June 2014

6.2 Date Last Updated

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