



IceBridge Accumulation Radar L1B Geolocated Radar Echo Strength Profiles, Version 1

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. 2011, updated 2012. *IceBridge Accumulation Radar L1B Geolocated Radar Echo Strength Profiles, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. <https://doi.org/10.5067/AOLNV74W1O4K>. [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.

Note: Currently IRACC1B data for 2009 through 2012 are in MATLAB and binary format stored separately as IRACC1B V01. Beginning with the 2013 Arctic campaign, all data are provided in netCDF format. In the near future, data from all campaigns prior to Spring 2013 will be replaced with netCDF data and added to V02. For details on the Version 02 data, see the Version 2 documentation.

1.1 Format

Binary files contain a vector stream of record data. Each record includes seven header values and a Fast Fourier Transform (FFT) window of snow radar data. The FFT window has dimensions N-number of range bins.

Digital image files are JPEG and PNG files. The 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 from 0 meters to 60 or 80 meters for the land ice, and 0 meters to 4 meters for sea ice.

MATLAB files are binary files produced and readable by the proprietary Matlab software or other tools such as the Octave high-level language.

KML files are flight line browse images for each segment. There is an entry for the location of the first record for each data frame.

The most convenient way to browse the imagery quickly is through the JPEG files. The quickest way to plot the data set is to look at the KML browse files for the entire season.

1.2 File and Directory Structure

Data are available on the following HTTPS site:

https://daacdata.apps.nsidc.org/pub/DATASETS/ICEBRIDGE/IRACC1B_AccumXyEcho_v01/

The data are divided into segments. A segment is a contiguous data set where the radar settings do not change. A day is divided into segments if the radar settings were changed, hard drives were switched, or other operational constraints required that the radar recording be turned off and on. All data from a particular segment are stored in a directory with the following nomenclature YYYYMMDD_SS where YYYY is the year, MM is the month, DD is the day, and SS is the segment. Segments are always sorted in the order in which the data was collected.

1.3 File Naming Convention

1.3.1 Binary Files

The binary files are named according to the following convention and as described in Table 1:

Binary file name example: accum.20100507A.1.1_50.dat

accum.YYYYMMDDM.N.n_nn.dat

Where:

Table 1. Binary File Naming Convention

Variable	Description
accum	Accumulation radar file
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
M	Multiple flights were flown some days, first flight of the day is A, second flight B, and so on.
N	Indicates subsection during data processing
n_nn	Indicates raw file numbers combined during data processing, for example 1_50, 51_100.
.dat	Indicates a binary data file

1.3.2 MATLAB Files

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

Example: Data_20110329_01_034.mat

Data_YYYYMMDD_SS_FFF.mat

Where:

Table 2. MATLAB File Naming Convention

Variable	Description
Data	Indicates data file
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
SS	Day segment
FFF	Frame number
.mat	Indicates a MATLAB file

1.3.3 JPEG and PNG Files

For each data frame, there is a flight path file (0map) and an echogram file (1echo). The file naming conventions are shown below and as described in Table 3.

Examples:

20110329_01_034_037_113431_0maps.jpg

20110329_01_034_037_113431_1echo.jpg

YYYYMMDD_SS_ff_FFF_HHmms_0maps.jpg

YYYYMMDD_SS_ff_FFF_HHmms_1echo.jpg

Where:

Table 3. Flight Path and Echogram File Naming Variables

Variable	Description
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
SS	Segment number
fff_FFF	Frame numbers
HHmmss	GPS time stamp for the first range line in the image where HH is 00-23 hours, mm is 00-59 minutes, and ss is 00-59 seconds.
0maps	Flight path file
1echo	Echogram file
.jpg or .png	Indicates JPEG or PNG image file

1.3.4 KML Files

The KML browse image files, for 2011 Greenland and 2011 Antarctica only, are named according to the following convention and as described in Table 4.

Example: Browse_Data_20110329_01.kml

Browse_Data_YYYYMMDD_SS.kml

Where:

Table 4. KML Browse Image File Naming Convention

Variable	Description
Browse_Data	Indicates browse data file
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
SS	Day segment
.kml	Indicates KML file

1.3.5 GPS MATLAB and Applanix Output Files - 2010 Only

The GPS MATLAB files are named according to the following convention and as described in Table 5.

Example: GPS15MAY2010.mat

GPSDDMMYYYY.mat

Where:

Table 5. GPS MATLAB File Naming Convention

Variable	Description
GPS	Indicates GPS file
DD	Two-digit day
MMM	Month
YYYY	Four-digit year
.mat	Indicates MATLAB file

The Applanix output files are named according to the following convention and as described in Table 6.

Example: BD960_15May10_PPPK.out

BD960_DDMMYY_PPPK.out

Where:

Table 6. Applanix Output File Naming Convention

Variable	Description
BD960	Trimble BD960 GNSS receiver
DD	Two-digit day
MM	Month
YY	Two-digit year
PPPK	Post-Processed Kinematic
.out	Indicates Applanix output file

1.4 File Size

The binary files range from approximately 61 MB to 203 MB.

The MATLAB files are approximately 3 MB to 8 MB.

The JPEG files are approximately 78 KB to 161 KB.

The PNG files are approximately 372 KB to 693 KB.

The KML files are approximately 3 KB to 216 KB.

The GPS Applanix .mat output files are approximately 139 MB to 235 MB.

The GPS Applanix .out output files are approximately 485 MB to 820 MB.

1.5 Volume

The entire data set is approximately 150 GB.

1.6 Spatial Coverage

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

Arctic / Greenland:

Southernmost Latitude: 60° N

Northernmost Latitude: 90° N

Westernmost Longitude: 180° W

Easternmost Longitude: 180° E

1.6.1 Spatial Resolution

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

1.6.2 Projection and Grid Description

Referenced to WGS-84 Ellipsoid.

1.7 Temporal Coverage

06 May 2010 to 07 May 2012

1.7.1 Temporal Resolution

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

1.8 Parameter or Variable

This data set contains elevation and surface measurements.

1.8.1 Parameter Description

The Accumulation Radar MATLAB files contain fields as described in Table 7.

Table 7. MATLAB File Parameter Description

Parameter	Description	Units
Data	Radar echogram data	Relative linear power
Time	Fast time (zero time is the beginning of the transmit event calibrated to within one range resolution cell).	Seconds
Depth	Range axis assuming a vacuum ($\text{Depth} = \text{Time} * c/2$)	Meters
GPS_Time	GPS time when data were collected.	Seconds since January 1, 1970
Latitude	Latitude where data were collected (potentially modified by motion compensation).	Degrees
Longitude	Longitude where data were collected (potentially modified by motion compensation).	Degrees
Elevation	Elevation where data were collected (potentially modified by motion compensation).	Meters referenced to WGS-84 ellipsoid
Surface	Estimated two way propagation time to the surface from the collection platform. Uses the same frame of reference as the Time variable. Used to automatically adjust the y-limits of the output PNG files.	Seconds
param	Radar and processing settings	n/a

2 SOFTWARE AND TOOLS

MATLAB files may be opened using the NSIDC [MATLAB reader](#), or the Octave high-level language.

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

KML files are read by GIS software packages and earth browsers such as Google Earth or Google Maps.

3 DATA ACQUISITION AND PROCESSING

3.1 Data Acquisition Methods

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

3.2 Derivation Techniques and Algorithms

The MATLAB code below shows how to compensate for elevation so the echogram data mimics constant elevation flight at the maximum elevation in each data frame.

```
% Example shows snow radar data
load Data_20110323_03_028.mat

% Plot Data without elevation compensation
figure(1); clf;
imagesc(lp(Data)); colormap(1-gray(256)); ylim([5750 6000]);
xlabel('Range line');
ylabel('Range bin');

% Plot Elevation without elevation compensation
figure(2); clf;
plot(Elevation);
xlabel('Range line');
ylabel('Elevation (m)');

% Elevation compensate data
c = 2.997924580003452e+08;
dt = Time(2)-Time(1);
dr = dt*c/2;
max_elev = max(Elevation);
% This routine only compensates with range bin resolution accuracy
for rline = 1:size(Data,2)
    Data(:,rline) = circshift(Data(:,rline),round((max_elev-
    Elevation(rline))/dr));
end
Elevation(:) = max_elev;

% Plot Data with elevation compensation
figure(3); clf;
imagesc(lp(Data)); colormap(1-gray(256)); ylim([5750 6000]);
xlabel('Range line');
ylabel('Range bin');

% Plot Elevation after elevation compensation
figure(4); clf;
plot(Elevation);
xlabel('Range line');
ylabel('Elevation (m)');

return;
```

Figure 1 illustrates an echogram without elevation compensation and with elevation compensation.

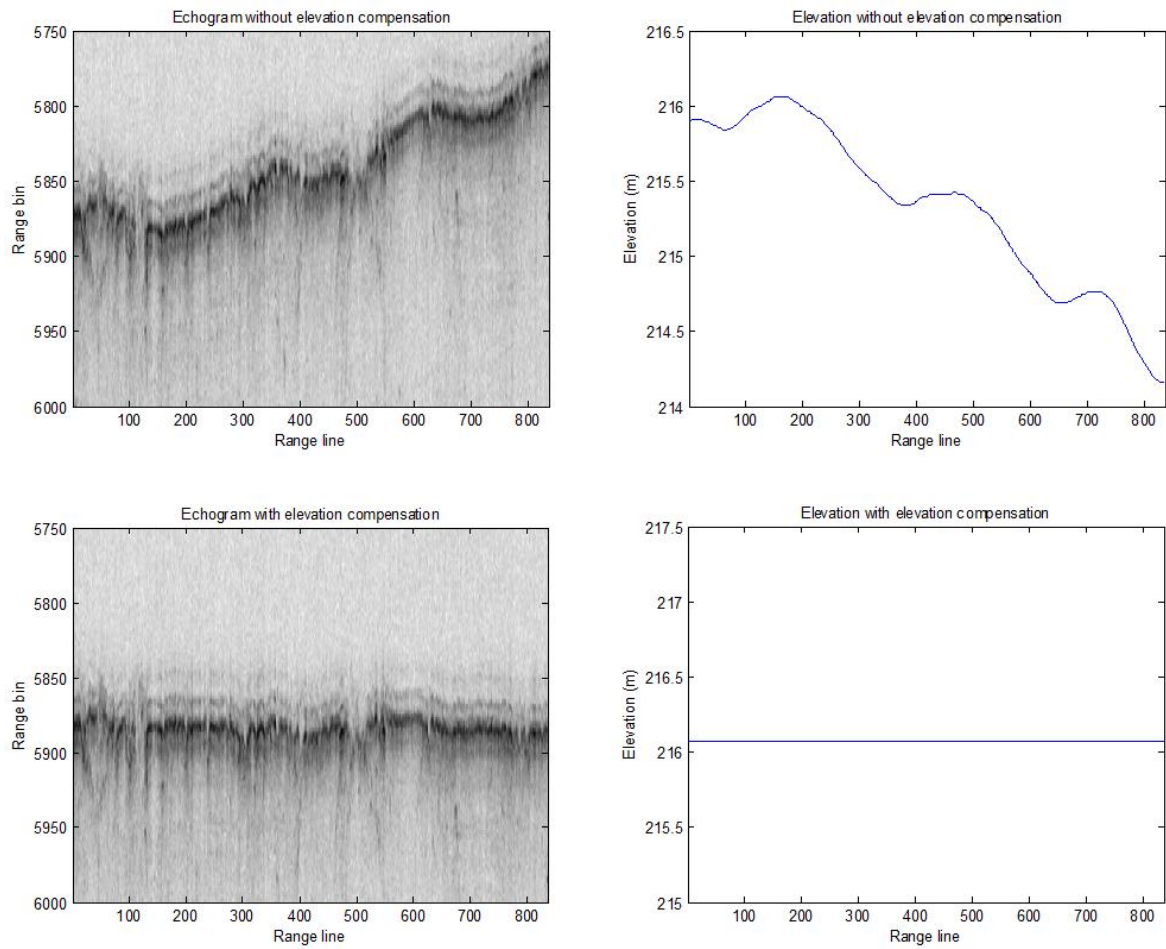


Figure 1. Elevation Compensation Echogram

3.2.1 Flat Surface Range Resolution

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

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

(Equation 1)

Where:

Table 8. Flat Surface Range Resolution

Variable	Description
k_t	$k_t = 1.6$ 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 9.

Table 9. 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 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.

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

Where:

Table 10. 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.

$$D = \sqrt{2H\lambda_c} \tag{Equation 3}$$

Where:

Table 11. Fresnel Zone

Variable	Description
D	Diameter
H	Height above ground. For $H = 500$ m, the diameter is 20 m.
λ_c	Wavelength. $\lambda_c = 0.4$ 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.

$$\sigma_{y, \text{pulse-limited}} = 2\sqrt{\frac{Hck_t}{B}} \tag{Equation 4}$$

Where:

Table 12. 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 was from a basic GPS receiver. Lever arm and attitude compensation has not been applied to the data.

3.2.4 Processing Steps

The following processing steps are performed by the data provider.

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).

3.2.5 Version History

IRACC1B Version 1: Currently Version 1 IRACC1B data for 2009 through 2012 are in MATLAB and binary format. In the near future, data from all V1 campaigns will be replaced with netCDF data and added to Version 2. For details on the V2 data, see the Version 2 documentation.

3.2.6 Error Sources

The CReSIS ku-band, accumulation, and snow 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 kuband radars which have independent GPS receivers. A comparison to geographic features and between ocean surface radar return and GPS elevation is also made to ensure GPS synchronization. GPS time corrections are given in the vector worksheet of the parameter spreadsheet.

3.3 Sensor or Instrument Description

As described on the [CReSIS Sensors Development Radar](#) website, 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, it 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

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6.2 Date Last Updated

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