IceBridge Snow 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 2019. *IceBridge Snow 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. doi: https://doi.org/10.5067/FAZTWP500V70. [Date Accessed].

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DATA DESCRIPTION

This data set includes measurements for surface, time, latitude, longitude, pitch, roll, and heading, as well as associated files with flight path charts and echogram images. The echogram images are useful for tracking internal layers and snow thickness on sea ice.

In addition to the campaigns flown over Greenland and Antarctica, airborne snow measurements were taken during 10 flights over Alaska mountains, ice fields, and glaciers between 20 and 30 May 2018. The data were collected by a compact CReSIS FMCW radar system installed on a Single Otter aircraft, operating from 2 GHz to 8 GHz. Seasonal snow depth was observed at elevations between approximately 1726 m to 3624 m and for depths around 0.3 m to 15 m. Snow accumulation layers were mapped to depths exceeding 85 m at high elevations, including the summits of Mountain Wrangell and Bona. The mapped snow depths and accumulation layers can be used in the cryospheric study of Alaskan regions.

1.1 File Information

1.1.1 Format

The data files are in netCDF format. The `XXX_Echogram.jpg` files show depth echograms and the `XXX_Map.jpg` files show campaign flight locations and flight lines. The y-axis in the echogram files shows depth relative to a range around the surface, which is located at the center of the axis. The y-axis is set to a fixed range; for land ice the range is either 0–60 m or 0–80 m, and for sea ice the range is 0–4 m. Each data file is paired with an associated XML file, which contains additional information.

1.1.2 Deconvolution Files and Supplement Files

On 10 February 2016, deconvolution files and supplement files were added to the 2009 to 2015 Greenland data captured over sea ice.

1.1.2.1 Deconvolution Files

Fast-time deconvolution filtering has been applied which affects the amplitude field in the data file. The deconvolution filter for each range line is constructed from nearby sea ice lead responses. The purpose of the deconvolution filter is to reduce sidelobes.

1.1.2.2 Supplement Files

Supplement files contain metadata information for the data segment (SS = segment; FFF = frame in the segment). There is one supplement file per data granule, containing a quality mask for each data frame. Supplement files contain the following seven classification masks:

1. supplement.coh_noise_removal_artifact: uint8 type, set to 0 for no substantial coherent noise removal artifacts and 1 if these artifacts do exist.
2. supplement.deconvolution_artifact: uint8 type, set to 0 for no substantial deconvolution artifacts and 1 if these artifacts do exist.
3. supplement.vertical_stripes_artifact: uint8 type, set to 0 for no substantial vertical striping artifacts and 1 if these artifacts do exist.
4. supplement.missing_data: uint8 type, set to 0 for no missing data and 1 if there is missing data (caused by the radar range gate truncating the radar return).
5. supplement.low_SNR: uint8 type, set to 0 for sufficient SNR and 1 if the SNR is low.
6. supplement.unclassified_artifact: uint8 type, set to 0 for no unclassified artifacts and 1 if these artifacts do exist.
7. supplement.land_ice: uint8 type, set to 0 for sea ice and 1 for land ice.

NOTE: uint8 = Unsigned (no negative sign) Integers only 8 bits of information – min value 0, max value 255.

1.1.3 Naming Convention

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

Examples:
IRSNO1B_20120402_01_001.nc
IRSNO1B_20120402_01_001.xml
IRSNO1B_YYYYMMDD_xx_xxx.NNN

IRSNO1B_20120402_01_001_uwb.nc
IRSNO1B_YYYYMMDD_xx_xxx_ttt.NNN

IRSNO1B_20120402_01_001_deconv.nc
IRSNO1B_20120402_01_001_supplement.nc
IRSNO1B_YYYYMMDD_xx_xxx.zzzzzz.NNN

IRSNO1B_20120402_01_001_Echogram.jpg
IRSNO1B_YYYYMMDD_xx_xxx_aaa.jpg

IRSNO1B_20120402_01_001_uwb_Echogram.jpg
IRSNO1B_YYYYMMDD_xx_xxx_ttt_aaa.jpg

Table 1. File Naming Convention

Variable	Description
IRSNO1B	Short name for IceBridge Snow Radar L1B Geolocated Radar Echo Strength Profiles
YYYY	Four-digit survey year
MM	Two-digit survey month
DD	Two-digit survey day
xx	Segment number
xxx	Frame number
zzzzzz	Ancillary file: deconv or supplement. Pertains only to data captured over sea ice.
aaa	Image type. Examples: Echogram, Map
ttt	Indicates files processed with an ultra-bandwidth of 2-18 GHz (uwb)
NNN	Indicates file type. For example: netCDF (.nc), XML (.xml), JPEG (.jpg)

1.1.4 File Size

NetCDF files range from approximately 386 KB to 535 MB. The total netCDF file volume is approximately 5.1 TB.

JPEG files range from approximately 41 KB to 378 KB. The total JPEG file volume is approximately 0.1 TB.

XML files range from approximately 4 KB to 5 KB. The total XML file volume is approximately 0.8 GB.

The entire data set is approximately 5.3 TB.

1.2 Spatial Information

1.2.1 Coverage

Spatial coverage includes the Arctic, Greenland, Antarctica, and surrounding ocean areas

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

Arctic / Greenland:

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

1.2.2 Resolution

Spatial resolution varies depending on along-track direction, cross-track direction, and aircraft height characteristics.

1.2.3 Projection and Grid Description

Referenced to the WGS-84 ellipsoid.

1.3 Temporal Information

1.3.1 Coverage

31 March 2009 to 30 May 2018

1.3.2 Resolution

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

1.4 Parameter or Variable

This data set contains radar backscatter measurements sensitive to snow thickness and internal layering, collected over land ice and sea ice.

1.4.1 Parameter Description

The netCDF files contain fields as described in Table 2.

Table 2. File Parameter Description

Parameter	Description	Units
alt	WGS-84 geodetic elevation coordinate of the measurement's phase center. Dimension is `time`.	Meters

Parameter	Description	Units
amplitude	Power detected radar echogram data matrix. The first dimension is `fasttime` and the second dimension is `time`. Power is relative to the current range line only. Each range line may contain a different bias and thus power comparisons between range lines may not be possible.	Relative power (log scale)
Elevation_Correction	Represents the number of zeros that were inserted during elevation compensation for each range line to simulate near-level flight. These zeros are not included in the truncation noise statistics. Only available when `amplitude` is truncated. Dimension is `time`.	Range bins
fasttime	Fast-time. Zero time is the time at which the transmit waveform begins to radiate from the transmit antenna.	Microseconds
heading	Platform heading attitude (zero is north, positive to east). Dimension is `time`.	Degrees
lat	WGS-84 geodetic latitude coordinate of the measurement phase center. Always referenced to North. Dimension is `time`.	Degrees
lon	WGS-84 geodetic longitude coordinate of the measurement phase center. Always referenced 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` parameter. This information is sometimes used during truncation to determine the range bins that can be truncated. Dimension is `time`.	Seconds
time	UTC time of day. This is also known as the slow-time dimension. The parameter's units attribute contains a string of the form "seconds since YYYY-MM-DD 00:00:00" which indicates the day relative to `time`. This pertains to data sets that wrap over a UTC day boundary which will cause `time` to be outside the range [0,86400].	Seconds
Truncate_Bins	Indices into the original (before truncation) fast-time vector for which the `amplitude` values are available. Only available when amplitude is truncated. Dimension is `time`.	n/a

Parameter	Description	Units
Truncate_Mean	Represents a mean of the noise power for the truncated range bins before the surface return. When no range bins were truncated before the surface return, the value is NaN. Only available when `amplitude` is truncated. Dimension is `time`.	n/a
Truncate_Median	Represents a median of the noise power for the truncated range bins before the surface return. When no range bins were truncated before the surface return, the value is NaN. Only available when `amplitude` is truncated. Dimension is `time`.	n/a
Truncate_Std_Dev	Represents a standard deviation of the noise power for the truncated range bins before the surface return. When no range bins were truncated before the surface return, the value is NaN. Only available when `amplitude` is truncated. Dimension is `time`.	
param	Multiple variables with a name containing the string "param." Contains radar and processing settings, and processing software version and time stamp information. Fields of structures are not static and may change from one version to the next.	

2 DATA ACQUISITION AND PROCESSING

2.1 Acquisition

The CReSIS Snow Radar uses a Frequency Modulated Continuous Wave (FMCW) architecture (Carrara et al., 1995). This is done to reduce the required sampling frequency of the Analog to Digital Converter (ADC) and is possible when the range gate is limited. Currently, the range gate is limited to low altitude flights. In the FMCW radars, an approximately 250 μs long chirp signal is generated which sweeps linearly from the start frequency to the stop frequency. This signal is transmitted and also fed to a mixer in the receiver to be used to demodulate the received signal. Signals outside the range gate are suppressed by the Intermediate Frequency (IF) filter and aliased by the system.

The dominant scattered signal is the specular or coherent reflection from the air-snow surface and shallow layers beneath the surface. A bistatic antenna configuration is used to provide isolation between the transmit and the receive paths. This is important because the FMCW system receives while transmitting and too little isolation means that the direct path from the transmitter to the receiver will be too strong and will saturate the receiver. The antennas are mounted such that the main beam is pointed in the nadir direction to capture the specular surface and layer reflections.

The Pulse Repetition Frequency (PRF), or along-track sampling rate, does not necessarily capture the full Doppler bandwidth for point scatterers without aliasing. However, since the target energy is mostly coherent, it occupies only a small portion of the Doppler spectrum so the undersampling in the along-track direction is not generally a problem. Since the coherent portion of the surface and layer scattering is the primary signal of interest, presumming is used to lower the data rate which effectively low-pass-filters and decimates the Doppler spectrum.

2.2 Derivation Techniques and Algorithms

The Echogram JPEG files include an altitude correction, but the netCDF files do not. In the case of the netCDF files, correction can be applied by shifting a record from bottom to top by the altitude correction value. To this end, altitude variations within a data file are removed by subtracting the minimum altitude from all values. The result is variation in meters from the minimum. These values are then converted to whole pixel values given the following radar parameters: sampling frequency, pulse duration, FFT length, and bandwidth. Sampling frequency before the 2009 Greenland campaign is 58.32 MHz, whereas after the Greenland campaign it was set to 62.5 MHz.

2.2.1 Resolution and Error Bounds

2.2.1.1 Flat Surface Range Resolution

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

$$r = \frac{k_t \cdot c}{2 \cdot B \cdot n}$$ **(Equation 1)**

Table 3. 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 4500 MHz (2 to 6.5 GHz range)
n	Index of refraction for the medium

Examples of range resolutions for several indices of refraction are shown in Table 4.

Table 4. Range Resolutions for Indices of Refraction

Index of Refraction	**Range Resolution (in cm)**	**Medium**
1	5.0	Air

sqrt(1.53)	4.0	Snow
sqrt(3.15)	2.8	Solid Ice

2.2.1.2 Index of Refraction

The index of refraction n can be approximated by Equation 2.

$$n = (1 + 0.51 \cdot \rho_{snow})^3$$ **(Equation 2)**

ρ_{snow} is the density of the snow in grams per cm^3. In the data, a dielectric constant of 1.53 is used, which corresponds to a snow density of 0.3 g/cm^3 (Warren, 1999).

2.2.1.3 Bandwidth

The bandwidth *B* for a particular segment can be determined by reading the `param_get_heights.radar.wfs` structure in the netCDF files or by looking at the parameter spreadsheet values `f0, f1`, and `fmult` and doing the calculation in Equation 3.

$$B = (param\_radar.f1 - param\_radar.f0) \cdot param\_radar.fmult$$ **(Equation 3)**

Table 5. Segment Bandwidth Variable Definitions

Variable	Name in netCDF file	Description
param_radar.f1	param_get_heights(1).radar(1).wfs(1).f1	Stop frequency of chirp out of Direct Digital Synthesis (DDS) and into Phase-Locked Loop (PLL)
param_radar.f0	param_get_heights(1).radar(1).wfs(1).f0	Start frequency of chirp out of DDS and into PLL
param_radar.fmult	param_get_heights(1).radar(1).wfs(1).fmult	PLL frequency multiplication factor

2.2.1.4 Along-Track Resolution

Before any hardware or software coherent averages have been applied, the resolution of the raw data in the along-track direction is derived in the same manner as in the cross-track direction. However, a basic form of focusing is applied called Unfocused Synthetic Aperture Radar (SAR) Processing, also known as stacking or coherent averaging. If all effects are accounted for, the data may be coherently averaged to the SAR aperture length *L*, defined by Equation 4.

$$L = \sqrt{\frac{H \cdot \lambda_c}{2}}$$ **(Equation 4)**

Table 6. SAR Aperture Length Variable Definitions

Variable	**Description**
H	Height above ground level
λ_c	Wavelength at the center frequency

For *H* = 500 m, the data are averaged to an aperture length *L* of 4.3 m. The resolution is approximately equal to this value, with the actual resolution approximation given in Equation 5. However, these data are only coherently averaged 16 times, which includes both hardware and software averaging, and decimated by the same amount. At a platform speed of 140 m/s, this corresponds to an aperture length of 1.12 m. The sample spacing is likewise 1.12 m. The approximation for the actual resolution, which is substantially less fine, is given in Equation 5.

$$\sigma_{x,SAR-qlook} = H \cdot \tan\left(\sin^{-1}\left(\frac{\lambda_c}{2 \cdot L}\right)\right)$$ **(Equation 5)**

Table 7. Actual Resolution Variable Definitions

Variable	**Description**
H	Height above ground level
λ_c	Wavelength at the center frequency
L	Aperture length

For *H* = 500 m, the along-track resolution is 16.7 m. A 1 range-bin by 5 along-track-range-line boxcar filter is applied to the power detected data and then decimated in the along-track direction by 5 so the data product has an along-track sample spacing of 5.6 m.

2.2.1.5 Fresnel Zone and Cross-Track Resolution

For a smooth or quasi-specular target, for example for internal layers, the primary response is from the first Fresnel zone. Therefore, the directivity of specular targets effectively creates the appearance of a cross-track resolution equal to this first Fresnel zone. The first Fresnel zone is a circle with a diameter given by Equation 6.

$$\sigma_{y,Fresnel-limited} = \sqrt{2 \cdot \lambda_c \cdot \left(H + \frac{T}{\sqrt{3.15}}\right)}$$ **(Equation 6)**

Table 8. First Fresnel Zone Diameter

Variable	**Description**
H	Height above the air/ice interface
T	Depth in ice
λ_c	Wavelength at the center frequency

Table 9 gives the cross-track resolution for this case.

Table 9. Cross-track Resolution Example

Center Frequency (MHz)	**Cross-track Resolution H = 500 m T = 0 m**
3500	8.7

For a rough surface with no discernible layover, the cross-track resolution will be constrained by the pulse-limited footprint, approximated in Equation 7.

$$\sigma_{y,pulse-limited} = 2 \cdot \sqrt{\frac{c \cdot k_t}{B} \cdot \left(H + \frac{T}{\sqrt{3.15}}\right)} \qquad \textbf{(Equation 7)}$$

Table 10. Pulse-Limited Footprint

Variable	**Description**
H	Height above the air/ice interface
T	Depth in ice
c	Speed of light in a vacuum
k_t	K_t = 1.5 due to the application of a hanning time-domain window to reduce the range sidelobes of the chirped transmit waveform
B	Bandwidth in radians

Table 11 gives the cross-track resolution with windowing.

Table 11. Cross-track Resolution with Windowing

Bandwidth (MHz)	**Cross-track Resolution H = 500 m T = 0 m**
4500	14.1

2.2.1.6 Footprint

The antenna installed in the bomb bay of the P-3 aircraft and in the wing roots of the DC-8 aircraft is an ETS Lindgren 3115. The E-plane of the antenna is aligned in the along-track direction for the P-3 aircraft and in the cross-track direction for the DC-8 aircraft. The approximate beamwidths are 45 degrees in the along-track direction and 45 degrees in the cross-track direction. The footprint is a function of range as shown in Equation 8.

$$\sigma = 2 \cdot H \cdot \tan\left(\frac{\beta}{2}\right)$$ **(Equation 8)**

Table 12. Footprint

Variable	Description
H	Height above ground level.
β	Beamwidth in radians

For H = 500 m, the footprint is 414 m in both the along-track and the cross-track directions.

2.2.2 Processing Steps

The following processing steps are performed by the data provider.

1. Set digital errors to zero. Error sequences are 4 samples in length and occur once every few thousand range lines.
2. Synchronization of GPS data with the radar data using the Universal Time Code (UTC) time stored in the radar data files.
3. Conversion from quantization to voltage at the ADC input.
4. Removal of DC-bias by subtracting the mean.
5. For 2013 Greenland P3 and later, a tracking and truncation function has been implemented in the hardware which reduces the recorded data volume. Each range line is tracked and truncated separately and a step is added here to undo the tracking and truncation step so that the data can be placed in a matrix with constant time bins. This requires zero padding and time shifting of the data to get each range line to line up.
6. The quick look output is generated using presumming or unfocused SAR processing for a total of 16 coherent averages which includes hardware and software averages. If the PRF is 2000 Hz, the new effective PRF is 125 Hz.
7. A fast-time FFT is applied with a Hanning window to convert the raw data into the range domain, analogous to pulse compression. The data are flipped around based on the Nyquist zone.
8. A high-pass filter is applied in the along-track direction to remove coherent noise.
9. A 1 range-bin by 5 along-track-range-line boxcar filter is applied to the power detected data and then decimated by 5 in the along-track direction.
10. The quick-look output is used to find the ice surface location, fully automated.

11. The output is elevation compensated to the nearest radar range bin and then truncated in fast time to reduce the data volume.

The purpose of the elevation compensation, when applied, is to remove the large platform elevation changes to make truncation more effective. The process is not designed to perform precision elevation compensation and is probably not sufficient for scientific analysis. The following steps are performed:

1. Let:
    a. Elevation_Orig be the 1 by N elevation vector before elevation compensation.
    b. Data_Orig be the M_orig by N data matrix before elevation compensation.
    c. Time_Orig be the M_orig by 1 fast-time time axis before elevation compensation.
    d. Elevation be the 1 by N vector from the data product file.
    e. Data be the matrix from the data product file.
    f. Time be the M by 1 fast-time time axis from the data product file maxElev = max(Elevation_Original).
2. dRange = maxElev − Elevation_Original
3. dt = Time_Orig(2) − Time_Orig (1)
    a. Sample spacing in fast-time (i.e. one range bin)
4. dBins = round(dRange / (c/2) / dt)
    a. This is a 1 by N vector of the number of range bins for each range line we will shift Data_Orig. In other words, this is the elevation compensation for each range line written in terms of range bins.
5. M = M_orig + max(dBins)
6. The original data matrix is zero padded to M and then each range line is shifted by the corresponding entry in dBins.
    a. Because of the round function for creating dBins, the elevation compensation is only done with range bin accuracy.
    b. The new Data matrix is similar to what would have been collected if the aircraft had flown at a constant elevation of maxElev.
7. The elevation matrix is modified according to the elevation compensation so that: Elevation_Orig = Elevation − dBins*dt*c/2. Once again, because of the round function, the Elevation vector will be nearly constant, but not quite; the quantization noise caused by the round function remains.
8. The Time_Orig vector is extended in length by the maximum bin shift to create the new Time vector.

2.2.3 Error and Limitations

As of 10 June 2011, all of the 2009 Greenland binary files were replaced. The GPS time written in the headers of the previously published binary files contained an error. The error was corrected in the replacement binary files.

GPS Time Error:

The CReSIS accumulation, snow, MCoRDS, and ku-band 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 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. 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.

A time stamp error was discovered in the 2012 Antarctica and 2013 Greenland data. The latest leap second (01 July 2012) was not accounted for in the GPS times for these campaigns. The error was corrected in Version 2.1.

In the 2012 Antarctica and 2013 Greenland campaigns, the wrong start day was used with most files due to a programming error. This caused an N*86400 second error in the field where N was some unknown integer. The time field was corrected in Version 2.2 for the 2013 Greenland campaigns. Note: In Version 2.2 the time field correction was not applied to the 2012 Antarctica campaign data.

For the data on 19 May 2016, the Snow Radar frequency band was set to a value between 2 GHz to 5 GHz, instead of the usual 2 GHz to 8 GHz. As these data were processed with the same settings as the previous data, the two-way propagation times for the ice or snow surface and the internal layers were incorrectly calculated. This error affected the calculation of the elevations of the internal layers, as well as the layer thicknesses. The data for 19 May 2016 have been reprocessed and replaced with the corrected data.

2.3 Instrumentation

2.3.1 Description

As described on the CReSIS Sensors Development Radar website, the ultra-wideband radar operates over the frequency range from 2 to 8 GHz to map near-surface internal layers in polar firn with fine vertical resolution. The radar also has been used to measure thickness of snow over sea ice. Information about snow thickness is essential to estimate sea ice thickness from ice freeboard measurements performed with satellite radar and laser altimeters. This radar has been successfully flown on both NASA P-3 and DC-8 aircraft.

2.3.2 Trajectory and Attitude

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 SOFTWARE AND TOOLS

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 the NetCDF Resources at NSIDC DAAC page or UCAR's Unidata NetCDF page for information on updating the reader.

CReSIS Level-1B 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 a service to the user community in the hopes 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 these to nsidc@nsidc.org.

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

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

4 VERSION HISTORY

Version 1 of the IRSNO1B data. All Version 1 data from 2009 to 2012 were provided in binary format. For details on the Version 1 data, see the Version 1 documentation.

Version 2 of the IRSNO1B data. Beginning with the 2012 Antarctica campaign, all subsequent data were provided in netCDF format.

Version 2.1 of the IRSNO1B data. On 17 September 2014, Version 2 data were replaced by Version 2.1. A time stamp error was discovered in the 2012 Antarctica and 2013 Greenland data. The latest leap second (01 July 2012) was not accounted for in the GPS times for these campaigns. This error was corrected in Version 2.1 and the data were redelivered.

Version 2.2 of the IRSNO1B data. On 10 February 2016, Version 2.1 data were replaced by Version 2.2, including the following changes:

- Time field correction for 2013 Greenland campaigns: The time field contains the seconds of the day relative to the start day of the flight. In the 2012 Antarctica and 2013 Greenland campaigns, the wrong start day was used with most files due to a programming error. This

caused an N*86400 second error in the field where N was some unknown integer. The time field was corrected.
    - **Note:** In Version 2.2 the time field correction was not applied to the 2012 Antarctica campaign data.
- Version 1 Greenland data moved to Version 2: Version 1 2009 to 2012 Greenland data, previously in binary format, were reformatted to netCDF and included with Version 2.2.
- On 01 September 2016, Version 1 2009 to 2011 Antarctica data, previously in binary format, were moved to ECS and included with Version 2.2. As of this date, IRSNO1B Greenland and Antarctica data, beginning with the 2009 Greenland campaign, are in netCDF format.

5 RELATED DATA SETS

- IceBridge Accumulation Radar L1B Geolocated Radar Echo Strength Profiles
- IceBridge Ku-Band Radar L1B Geolocated Radar Echo Strength Profiles
- IceBridge MCoRDS L1B Geolocated Radar Echo Strength Profiles

6 RELATED WEBSITES

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

7 CONTACTS AND ACKNOWLEDGMENTS

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Acknowledgments:

The radar systems and software were developed with funding from a variety of sources including NASA (NNX16AH54G), NSF (ACI-1443054), and the State of Kansas. The Operation IceBridge data were collected as part of the NASA Operation IceBridge project. The processing requires GPS and attitude data that are made available by various groups including the Airborne Topographic Mapper team, the Digital Mapping System team, and the Sanders Geophysics company. We also acknowledge all the personnel involved in supporting the field operations.

8 REFERENCES

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Warren, S., I. Rigor, and N. Untersteiner. 1999. Snow Depth on Arctic Sea Ice, *Journal of Climate*, 12(6): 1814–1829. doi: 10.1175/1520-0442(1999)012<1814:SDOASI>2.0.CO;2

9 DOCUMENT INFORMATION

9.1 Publication Date

July 2014

9.2 Date Last Updated

February 2023