# IceBridge HiCARS 1 L1B Time-Tagged Echo Strength Profiles, 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 QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/IR1HI1B

National Snow and Ice Data Center

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# 1 DETAILED DATA DESCRIPTION

## 1.1 Format

The data files are in NetCDF (.nc) format.

Each data file is paired with an associated XML file (.xml).

Browse files are provided in PDF format (.pdf).

## 1.2 File Naming Convention

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

File name examples:

IR1HI1B_2010342_WSB_JKB1a_GL0143a_003.nc
IR1HI1B_2010342_WSB_JKB1a_GL0143a_003.nc.xml
IR1HI1B_2010342_WSB_JKB1a_GL0143a_003.nc.browse.pdf

IR1HI1B_YYYYDOY_AAAA_JKB2x_TTTT_nnn.xxx

Where:

Table 1. File Naming Convention

| Variable | Description |
|---|---|
| IR1HI1B | Short name for IceBridge HiCARS 1 L1B Time-Tagged Echo Strength Profiles |
| YYYY | Four-digit year of survey |
| DOY | Three digit day of year of survey |
| AAAA | Geographic area |
| JKB2x | Host platform name |
| TTTT | Geographic track line, transect name within project |
| nnn | Granule within line |
| .xxx | File type: NetCDF (.nc), XML (.nc.xml), or PDF browse (.nc.browse.pdf) |

## 1.3 File Size

The NetCDF data files range from approximately 595 KB to 98 MB.

The XML data files range from approximately 4 KB to 34 KB.

The PDF browse files range from approximately 36 KB to 2 MB.

## 1.4 Volume

The full data set is approximately 112 GB.

## 1.5 Spatial Coverage

The target region for this data is Antarctica. Please see XML metadata files for targets for each granule.

<u>Antarctica:</u>
Southernmost Latitude: 90° S
Northernmost Latitude: 53° S
Westernmost Longitude: 180° W
Easternmost Longitude: 180° E

Figure 1 illustrates specific locations for this data set.

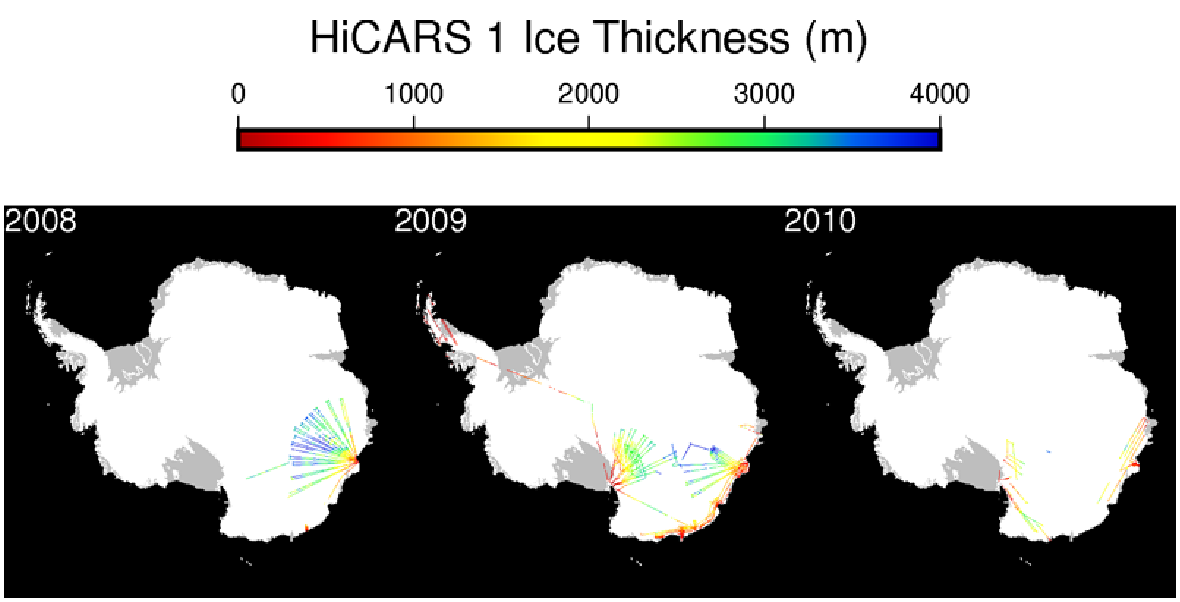



Figure 1. Coverage in the Wilkes Land Sector of East Antarctica

### 1.5.1 Spatial Resolution

Processed radar soundings are given every 4 Hz (250 milliseconds) which is roughly 20 m apart depending on platform velocity. Vertical samples (fast time) are given at 50 MHz (20 ns fast time). This is approximately 3 meters in air and 1.7 meters in ice.

### 1.5.2 Projection and Grid Description

Latitude, longitude, and altitude are provided using the WGS84 reference, ITRF-2008. Flight tracks are generally straight lines in the polar stereographic projection using a true scale latitude of 71 degrees south.

## 1.6 Temporal Coverage

These data were collected as part of Investigating the Cryospheric Evolution of the Central Antarctic Plate (ICECAP), National Science Foundation (NSF), National Environmental Research Council (NERC), and Operation IceBridge funded campaigns from 02 January 2009 to 29 December 2010.

### 1.6.1 Temporal Resolution

ICECAP campaigns were conducted on an annual basis. East Antarctic campaigns for this data set typically extend from November to early January.

## 1.7 Parameter or Variable

### 1.7.1 Parameter Description

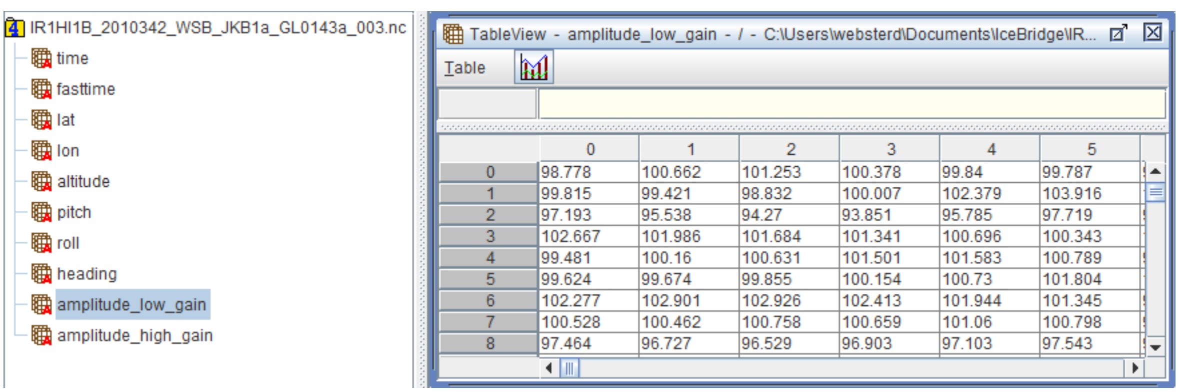
The HiCARS 1 L1B Time-Tagged Echo Strength Profiles data files contain fields as described in Table 2.

Table 2. File Parameter Description

| Parameter | Description | Units |
|---|---|---|
| time | Time of day, seconds since 2009-01-02 00:00:00 | UTC |
| fasttime | 2-way travel time | Microseconds |
| lat | Latitude of sample | Decimal degrees North, WGS-84 |
| lon | Longitude of sample | Decimal degrees East, WGS-84 |
| altitude | Altitude of antenna above nominal sea level (WGS84) | Meters |
| pitch | Pitch of the JKB platform. Positive is nose up. Zero is horizontal. | Degrees |
| roll | Roll of the JKB platform. Positive is right wing up. Zero is horizontal. | Degrees |
| heading | Heading of the JKB platform. Positive is clockwise from above. Zero is true north. | Degrees |
| amplitude_low_gain | Amplitude of low gain radar reflection after processing | Counts in dBV |
| ampltude_high_gain | Amplitude of high gain radar reflection after processing | Counts in dBV |

## 1.7.2 Sample Data Record

Below are amplitude values from a sample of the IR1HI1B_2010342_WSB_JKB1a_GL0143a_003.nc data file as displayed in the HDFView tool.




| | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 0 | 98.778 | 100.662 | 101.253 | 100.378 | 99.84 | 99.787 |
| 1 | 99.815 | 99.421 | 98.832 | 100.007 | 102.379 | 103.916 |
| 2 | 97.193 | 95.538 | 94.27 | 93.851 | 95.785 | 97.719 |
| 3 | 102.667 | 101.986 | 101.684 | 101.341 | 100.696 | 100.343 |
| 4 | 99.481 | 100.16 | 100.631 | 101.501 | 101.583 | 100.789 |
| 5 | 99.624 | 99.674 | 99.855 | 100.154 | 100.73 | 101.804 |
| 6 | 102.277 | 102.901 | 102.926 | 102.413 | 101.944 | 101.345 |
| 7 | 100.528 | 100.462 | 100.758 | 100.659 | 101.06 | 100.798 |
| 8 | 97.464 | 96.727 | 96.529 | 96.903 | 97.103 | 97.543 |

Figure 2. Sample Data showing amplitude values

# 2 SOFTWARE AND TOOLS

The following links provide access to software for reading and viewing NetCDF data files. Please be sure to review instructions on installing and running the programs.

- See the NetCDF Resources at NSIDC page for tools to work with NetCDF files.
- HDFView: Visual tool for browsing and editing HDF4, HDF5 and NetCDF files.

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

PDF browse files can be displayed by any software capable of reading PDF format.

# 3 DATA ACQUISITION AND PROCESSING

## 3.1 Theory of Measurements

Ice is nearly transparent at Very High Frequency (VHF) radio frequencies (Dowdeswell and Evans, 2004). Radar operates by transmitting a radio frequency signal and receiving the power, phase, and time delay of the returning echo. For airborne sounding of ice, antennas direct energy to nadir, and through repeated pulses and motion of the aircraft, a radargram (a profile of power in time delay versus transmit time coordinates) can be mapped out. From the time delay between transmission and reception, and knowledge of the refractive index of ice, range to the bed can be estimated. The phase history of a given point can be used to focus the along track position of a specific point, or filter out off-nadir scattering that can obscure the bed. The power of reflection relates to the dielectric contrasts between media and the roughness of the interface.

## 3.2 Data Acquisition Methods

A 1-μsec transmitted chirp was used for both surface and bed. Two 12-bit digitizer channels with offset receiver gain were used to record returned echoes over 64 μsec, accommodating 120 dB of dynamic range, including the surface and the bed.

Bandwidth: 52.5-67.5 MHz

Tx power: 5700 W

Waveform: 1 μsec FM chirp generation, analog down-conversion to 10 MHz center

Sampling: 12-bit ADC at 50 MHz sampling

Record window: 64 μsec

Acquisition: two gain channels separated by 39 dB (28 dB for 2009-10)

Dynamic Range: 120 dB

Monostatic Rx/Tx

Data rate: 2.2 MB/sec

Maximum Doppler frequency: 36 Hz

Pulse Repetition Frequency: 6400 Hz

Onboard stacking: 32x

## 3.3 Derivation Techniques and Algorithms

### 3.3.1 Trajectory and Attitude Data

Please see the IceBridge GPS/IMU L1B Primary Position and Attitude Solution (IPUTG1B) data set for information on positioning.

### 3.3.2 Processing Steps

Unfocussed Synthetic Aperture r=Radar (SAR) processing was done (internally referred to as pik1). This is a quick form of processing with no dependencies on other instruments. The first 10 recorded stacks are coherently summed resulting in a 20 Hz sample rate. Then, a narrow band notch filter is applied at 10 MHz to remove local oscillator (LO) leakage. The pulse is compressed using frequency domain convolution of over-scaled synthetic chirp waveform. This results in gains of 83 dB from overscaled chirp, 11.7 dB from range compression, and -3 dB from Hanning window. These are converted to magnitude and five of these stacks are incoherently summed resulting in the final 4 Hz sample rate.

### 3.3.3 Error Sources

For this Level 1B product, errors in power may be due to transmitter or receiver malfunctions. Elevated background noise may occur with areas of strong surface scattering (for example crevasses) or Radio Frequency (RF) noise from anthropogenic sources (for example radio calls from the aircraft or other radar systems).

In Antarctica 2009 toward the end of the season (during the NWZ and ICG1 projects), the radar developed timing instabilities consistent with an overloaded CPU.

In Antarctica 2009 during the NWZ, MZG, and ALG2 projects and part of the ASB project, the radar was co-operated with the 2 MHZ JPL WISE radar. As the two systems were not synchronized, elevated noise floors are apparent in both systems.

In Antarctica 2010, HiCARS 1 suffered a catastrophic transmitter failure on 1CP3/F15 (J322/2010, 18 November 2010) which was not repaired until ICP3/F18 (J329/2010, 25 November 2010).

HiCARS 1 bed data take the range to the bed echo and converts that to an apparent nadir ice thickness. However, the first unfocused echo may actually arrive from up to 700 m around the nadir spot, depending on ice thickness, aircraft height above the ice, and bed roughness. For extreme cases, this could result in errors in actual ice thickness of 70 meters, and a horizontal error of 700 m. Generally, nadir ice thicknesses will be biased low in pik1 data, and actual ice thicknesses based on the first return biased high.

## 3.4 Sensor or Instrument Description

The High Capability Radar Sounder (HiCARS) is a VHF ice-penetrating radar that operates in frequency-chirped mode from 52.5 to 67.5 MHz. HiCARS allows for phase coherent recording of radar returns for advanced processing. For antennas, the system uses twin flat dipoles, one mounted under each aircraft wing providing approximately 10 dB of antenna gain. The antennas are mounted 19 meters apart horizontally (Peters et al. 2005; Peters et al. 2007; Young et al. 2015).

The HiCARS 1 3-stage transmitter was constructed by the Technical University of Denmark in 1975 for the joint NSF-SPRI-TUD (Scott Polar Research Institute - Technical University of Denmark) aerogeophysics program (Drewry et al., 1978; Skou and Søndergaard, 1976). A 25 W preamp fed a 500 W Primary Pulsed Amplifier (PPA) which supplied a 5700 W High Power Pulsed Amplifier (HPPA). Power was transmitted through a TUD passive Transmit-Receive switch. For the 2009 season onward, the preamp/PPA was replaced by a 1000 W Tomco Technologies BT1000-Gamma4T.

The HiCARS 1 receivers and signal generators were built by the Jet Propulsion Laboratory as part of a Europa test bed program (Moussessian et al., 2001). For the same program, the University of Kansas developed digitizers and the acquisition computer.

The HiCARS components were integrated and configured for Antarctic operations during the 2001 Antarctic field season (Peters et al. 2005; Peters et al. 2007).

In Antarctica 2010, HiCARS 1 was replaced with the lighter, off the shelf HiCARS 2 radar system (See IceBridge HiCARS 2 L2 Geolocated Ice Thickness (IR2HI2)). HiCARS 1 was retired after flight ICP3/F36 (J363/2010, 29 December 2010).

### 3.4.1 Processing Method

During acquisition, the 12-bit samples at the same time delay are added together 32 times.

# 4 REFERENCES AND RELATED PUBLICATIONS

Dowdeswell, J. A. and S. Evans. 2004. Investigations of the form and flow of ice sheets and glaciers using radio-echo sounding. Reports on Progress in Physics 67(10):1821-1861.

Drewry, D. J. and D. T. Meldrum. 1978. Antarctic airborne radio echo sounding, 1977–78. Polar Record 19:267–273. doi:http://dx.doi.org/10.1017/S0032247400018271.

Moussessian, A., Rolando L. Jordan, E. Rodriguez, Ali Safaeinili, Torry Akins, W. N. Edelstein, Y. Kim, and Prasad Gogineni. 2000. A New Coherent Radar For Ice Sounding In Greenland, IEEE International Geoscience and Remote Sensing Symposium (IGARSS) 484–486.

Peters, M. E., D. D. Blankenship, and D. L. Morse. 2005. Analysis techniques for coherent airborne radar sounding: Application to West Antarctic ice streams. Journal of Geophysical Research 110(B06303). doi:http://dx.doi.org/10.1029/2004JB003222.

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N. Skou and F. Søndergaard. 1976. Radioglaciology: A 60 MHz ice sounder system. Technical Report R169, Technical University of Denmark.

Young, D. A., D. M. Schroeder, D. D. Blankenship, S. D. Kempf, and E. Quartini. 2016. The distribution of basal water between Antarctic subglacial lakes from radar sounding. Philosophical Transactions Of The Royal Society A 374(2059):1–21. doi:http://dx.doi.org/10.1098/rsta.2014.0297.

## 4.1 Related Data Collections

- IceBridge HiCARS 2 L1B Time-Tagged Echo Strength Profiles
- IceBridge HiCARS 1 L0 Raw Return Energy Amplitudes
- IceBridge HiCARS 2 L0 Raw Return Energy Amplitudes
- IceBridge HiCARS 1 L2 Geolocated Ice Thickness
- IceBridge HiCARS 2 L2 Geolocated Ice Thickness

## 4.2 Related Websites

- IceBridge Product Web Site
- IceBridge Web site at NASA
- ICESat/GLAS Web site at NASA Wallops Flight Facility
- ICESat/GLAS Web site at NSIDC

- University of Texas Institute for Geophysics Web site

# 5 CONTACTS AND ACKNOWLEDGMENTS

**Blankenship, Donald D., Duncan A. Young, Scott D. Kempf, Thomas G. Richter, Jamin S. Greenbaum and John. W. Holt**

University of Texas at Austin

Institute for Geophysics

Austin, TX, 78759-8500

**Dustin M. Schroeder**

Stanford University

450 Serra Mall

Stanford, CA 94305

**Martin J. Siegert**

Grantham Institute, and Department of Earth Sciences and Engineering

Imperial College London

South Kensington

London SW7 2AZ, UK

**Jason L. Roberts, Roland C. Warner, Neal W. Young and Tas van Ommen**

Australian Antarctic Division

Kingston, Tasmania, Australia

Antarctic Climate and Ecosystems Cooperative Research Centre

University of Tasmania

Hobart, Tasmania, Australia

**Emmanuel LeMeur**

University of Grenoble Alpes

LGGE

Grenoble, France

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# 6 DOCUMENT INFORMATION

## 6.1 Publication Date

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## 6.2 Date Last Updated

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