IceBridge HiCARS 2 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:

Blankenship, D. D., S. D. Kempf, D. A. Young, T. G. Richter, D. M. Schroeder, G. Ng, J. S. Greenbaum, T. van Ommen, R. C. Warner, J. L. Roberts, N. W. Young, E. Lemeur, and M. J. Siegert. 2017. *IceBridge HiCARS 2 L1B Time-Tagged 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/10.5067/0I7PFBVQOGO5. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/IR2HI1B

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DATA DESCRIPTION

1.1 Summary

This data set contains Antarctica radar sounder echo strength profiles from the Hi-Capability Radar Sounder (HiCARS) Version 2 instrument. The data were collected by scientists working on the Investigating the Cryospheric Evolution of the Central Antarctic Plate (ICECAP) project, which was funded by the National Science Foundation (NSF) and the Natural Environment Research Council (NERC) with additional support from NASA Operation IceBridge.

1.2 Format

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

1.3 File Naming Convention

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

File name examples:

```
IR2HI1B_2013025_ICP5_JKB2h_RIGGS1b_006.nc
IR2HI1B_2013025_ICP5_JKB2h_RIGGS1b_006.nc.xml
IR2HI1B_2013025_ICP5_JKB2h_RIGGS1b_006.nc.brow.pdf

IR2HI1B_YYYYDOY_AAAA_JKB2x_TTTT_nnn.xxx
```

Table 1. File Naming Convention

Variable	Description
IR2HI1B	Short name for IceBridge HiCARS 2 L1B Time-Tagged Echo Strength Profiles
YYYY	Four-digit year of survey
DOY	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.brow.pdf)

1.4 Spatial Coverage

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

Antarctica:
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.

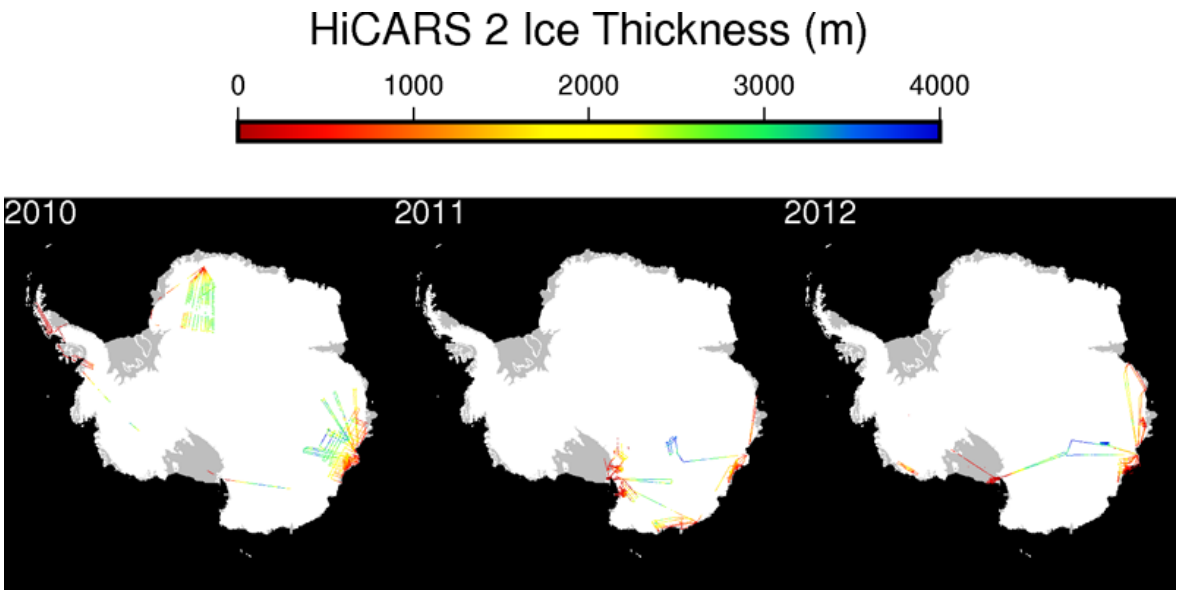

Figure 1. Coverage in the Wilkes Land Sector of Antarctica

1.4.1 Spatial Resolution

This data set has over 110,000 line km of coverage. 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.

1.4.2 Projection and Grid Description

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

1.5 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 28 October 2010 to 25 January 2013.

1.5.1 Temporal Resolution

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

1.6 Parameter or Variable

1.6.1 Parameter Description

The High Capability Radar Sounder (HiCARS) 2 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 2013-01-25 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 platform. Positive is nose up. Zero is horizontal.	Degrees
roll	Roll of the platform. Positive is right wing up. Zero is horizontal.	Degrees
heading	Heading of the 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

2 DATA ACQUISITION AND PROCESSING

2.1 Theory of Measurements

Ice is nearly transparent at Very High Frequency (VHF) radio frequencies (Dowdeswell and Evans, 2004). Radar operated 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.

2.2 Data Acquisition Methods

A 1-µsec transmitted chirp was used for both surface and bed. Two 14-bit digitizer channels with offset receiver gain were used to record returned echoes over 64 µsec, accommodating 120 dB of dynamic range, including accurate representations of power of the surface and bed echoes.

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: 64.74 µsec
Acquisition: two gain channels separated by 47 dB
Dynamic Range: 120 dB
Monostatic Rx/Tx
Data rate: 2.2 MB/sec
Maximum Doppler frequency: 36 Hz
Pulse Repetition Frequency: 6250 Hz
Onboard stacking: 32x

2.3 Derivation Techniques and Algorithms

2.3.1 Trajectory and Attitude Data

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

2.3.2 Processing Steps

Unfocussed Synthetic aperture 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.

2.3.3 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). For flights between 2011-11-14 and 2011-11-21, a splitter combiner connector to the antennas failed – the radar records are presented for completeness.

2.4 Sensor or Instrument Description

The High Capability Airborne Radar Sounder (HiCARS) 2 is a VHF ice-penetrating radar which operates in a pulsed, frequency-chirped mode from 52.5 MHz to 67.5 MHz. HiCARS allows for phase coherent recording of radar returns for processing. The system uses two flat plate dipole antennas, 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 2 transmitter was in part 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). An intermediate Tomco Technologies BT1000-Gamma4T drives the input of a 5700 W High Power Pulsed Amplifier (HPPA); the output of this amplifier was transmitted through a TUD passive Transmit-Receive switch and a high power Wilkinson divider/combiner to both antennas.

The HiCARS 2 receivers were developed at University of Texas Institute for Geophysics (UTIG). Digitizers, timing, and signal generation are provided by National Instruments PCI eXtensions for Instrumentation (PXI) hardware, and the acquisition software is implemented in National Instruments LabView Real Time.

HiCARS 2 components were integrated and configured for Antarctic operations during the 2010 Antarctic field season (Young et al., 2016).

2.4.1 Processing Method

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

3 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:10.1017/S0032247400018271.

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:10.1029/2004JB003222.

Peters, M. E., D. D. Blankenship, S. P. Carter, D. A. Young, S. D. Kempf, and J. W. Holt. 2007. Along-track Focusing of Airborne Radar Sounding Data From West Antarctica for Improving Basal Reflection Analysis and Layer Detection. IEEE Transactions On Geoscience And Remote Sensing 45(9):2725–2736. doi:10.1109/TGRS.2007.897416.

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:10.1098/rsta.2014.0297.

4 ACKNOWLEDGMENTS

Funding: The collection of this data was funded by a variety of sources, including NASA's Operation Ice Bridge (grants NNX09AR52G, NNG10HP06C and NNX11AD33G) and National Science Foundation grant PLR-0733025 to the University of Texas at Austin, the United Kingdom's National Environmental Research Council grant NE/F016646/1, and Australia's Antarctic Climate and Ecosystems Collaborative Research Center. Logistical support was provided by the United States Antarctic Program, the Australian Antarctic Program (through projects 3103 and 4077), the French Polar Institute, and Italy's Programma Nazionale Di Ricerche In Antartide. Full funding information for each granule can be found in the file header.

Development of HiCARS 2 was supported by the Jackson School of Geosciences, the G. Unger Vetlesen Foundation, and a NSF Graduate Fellowship.

5 DOCUMENT INFORMATION

5.1 Publication Date

June 2017

5.2 Date Last Updated

July 2025