IceBridge HiCARS 1 L2 Geolocated Ice Thickness, 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, J. S. Greenbaum, J. W. Holt, T. van Ommen, R. C. Warner, J. L. Roberts, N. W. Young, E. Lemeur, and M. J. Siegert. 2011, updated 2017. *IceBridge HiCARS 1 L2 Geolocated Ice Thickness, Version 1.* [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/F5FGUT9F5089. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/IR1HI2

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

1.1 Format

The data files are in space-delimited ASCII text format.

1.2 File and Directory Structure

Data are available in the https://n5eil01u.ecs.nsidc.org/ICEBRIDGE/IR2HI2.001/ directory. Within this directory, the folders are organized by date, for example /2009.11.09/. Folders contain ASCII (.txt) and XML (.xml) files. XML files contain file level metadata and location, platform, and campaign information.

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:

IR1HI2_2010355_ASB_JKB1a_Y11b_icethk.txt
IR1HI2_2010355_ASB_JKB1a_Y11b_icethk.txt.xml

IR1HI2_YYYYDOY_AAAA_JKB1a_XXXX_icethk.xxx

Where:

Table 1. Naming Convention

Variable	Description
IR1HI2	Short name for IceBridge HiCARS 1 L2 Geolocated Ice Thickness
YYYY	Four-digit year of survey
DOY	Day of year of survey
AAAA	Geographic area
JKB1a	Host platform
XXXX	Geographic track line
icethk	Ice thickness data
xxx	File type: ASCII text (.txt), or XML (.txt.xml)

1.4 File Size

File Size

The data files range from approximately 29 KB to 5 MB.

XML files range from approximately 4 KB to 42 KB.

1.5 Volume

The data set when downloaded in its entirety is approximately 436 MB.

1.6 Spatial Coverage

Spatial coverage for this data set is Antarctica, generally described in the coordinates below.

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.

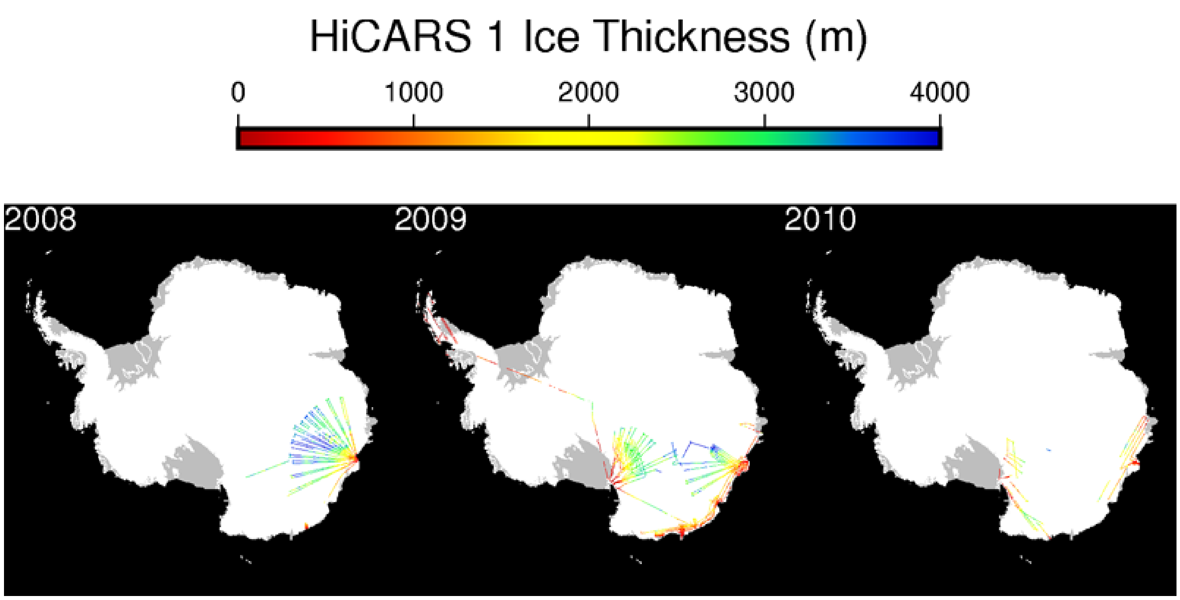

Figure 1. Coverage in the Wilkes Land Sector of East Antarctica

1.6.1 Spatial Resolution

Profile data in this product is sampled at 4 Hz (~23 m) along track. Due to the limited processing for this 'pik1' product, horizontal resolution is approximately 400 m, and vertical resolution is 8 m. (See the Processing Steps section below for description of 'pik1'.)

1.6.2 Projection and Grid Description

Referenced to WGS-84 Ellipsoid, ITRF-2008.

1.7 Temporal Coverage

These data were collected as part of the five-year international ICECAP program which included four Operation IceBridge funded campaigns.

Temporal coverage for the IR1HI2 data set is 02 January 2009 to 21 December 2010.

1.7.1 Temporal Resolution

ICECAP HiCARS 1 campaigns operated between October and February from 2008 to 2010. Typically three 7-hour flights were flown per week.

1.8 Parameter or Variable

1.8.1 Parameter Description

The HiCARS 1 L2 Geolocated Ice Thickness Antarctica files contain fields as described in Table 2.

Table 2. File Parameter Description

Parameter	Description	Units
YEAR	Year	UTC
DOY	Day Of Year	UTC
SOD	Second Of Day	UTC
LON	Longitude	Decimal degrees, WGS-84
LAT	Latitude	Decimal degrees, WGS-84
THK	Radar Derived Ice Thickness using dielectric of ice of 3.15 and no firn correction	Meters
SRF_RNG	Radar Derived Surface Range	Meters
BED_ELEVATION	Radar Derived Bed Elevation	Meters, WGS-84
SURFACE_ELEVATION	Radar Derived Surface Elevation	Meters, WGS-84
PARTIAL_BED_REFLECT	Bed reflection coefficient @ 60 MHz	Decibels with reference to perfect reflector; no ice loss accounting
SRF_REFLECT	Surface reflection coefficient @ 60 MHz	Decibels with reference to perfect reflector
AIRCRAFT_ROLL	Roll, right wing down positive	Degrees

Horizontal positions represent aircraft location at the time of the observation.

Radar Derived Surface Elevations should not be used for quantitative surface elevation analysis. Use of the laser-derived products is recommended for surface elevation analysis.

Do not directly sum or average records in Decibels. Convert Decibels to linear power (10(dB/10)) first.

Locations are indicated by a surface elevation with no corresponding surface reflectivity.

1.8.2 Sample Data Record

Shown below are the first eleven data records from data file: IR1HI2_2010351_ASB_JKB1a_R04Wb_icethk.txt.

```
# YEAR DOY SOD LON LAT THK SRF_RNG BED_ELEVATION SURFACE_ELEVATION PARTIAL_BED_REFLECT SRF_RELFECT AIRCRAFT_ROLL
2010 351 16067.1121 111.607408 -66.719499 nan 1011.89 nan 754.89 nan -14.68 0.59
2010 351 16067.3621 111.607767 -66.719613 nan 1011.33 nan 755.53 nan -14.87 0.57
2010 351 16067.6120 111.608127 -66.719727 nan 1011.28 nan 755.66 nan -14.62 0.54
2010 351 16067.8620 111.608486 -66.719840 565.72 1010.85 190.45 756.17 -58.33 -15.61 0.53
2010 351 16068.1118 111.608845 -66.719954 nan 1010.62 nan 756.48 nan -15.86 0.54
2010 351 16068.3618 111.609205 -66.720068 570.38 1009.61 187.18 757.56 -55.73 -16.65 0.55
2010 351 16068.6117 111.609564 -66.720182 570.31 1009.64 187.29 757.60 -57.66 -16.63 0.59
2010 351 16068.8617 111.609923 -66.720296 nan 1010.18 nan 757.14 nan -15.90 0.62
2010 351 16069.1115 111.610282 -66.720409 nan 1010.06 nan 757.33 nan -15.65 0.66
2010 351 16069.3614 111.610641 -66.720523 nan 1010.78 nan 756.68 nan -14.93 0.67
2010 351 16069.6114 111.611000 -66.720637 nan 1010.84 nan 756.69 nan -14.38 0.67
```

2 SOFTWARE AND TOOLS

The data files may be opened by any ASCII text reader.

3 DATA ACQUISITION AND PROCESSING

3.1 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

3.2 Derivation Techniques and Algorithms

Radar equation used (surface):

Surface reflectivity coefficienty =
Power[received]/(Power[transmitted]*Antenna_gain*wavelength[air]2)/(((4*pi)2)*(2*range)2).

Ice thicknesses were estimated from the two-way travel time between the surface and the bed using 3.15 as the dielectric constant for ice and no firn correction.

3.2.1 Trajectory and Attitude Data

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

3.2.2 Processing Steps

The radar data was processed using the 'pik1' processor. No focusing or range migration was performed. The original pulse repetition frequency was 6400 Hz. Echoes were summed onboard to a rate of 200 Hz. Post collection, traces were coherently summed by a factor of 10 to yield a short approximately 1 meter aperture. This short aperture suppressed surface clutter, while retaining subsurface energy.

The summed traces were pulse compressed using a 1-μsec, 15 MHz synthetic FM chirp windowed with a Hanning filter and a monochromatic local oscillator signal was filtered out at this stage. The result was converted to amplitude and was further incoherently averaged to 4 Hz, yielding 1 trace every 20 meters at typical aircraft speeds. The data was logarithmically scaled for interpretation.

The first bed and surface returns were manually bound and within each bound an algorithm detected the time delay of the brightest return for each trace. Bounds were not forced to match at cross over points, so as to preserve the validity of statistics for the bed returns between cross overs.

3.2.3 Version History

On July 23, 2012, Version 01 2009 Antarctica data were replaced by Version 01.1. The V01.1 2009 Antarctica data are re-organized, and include aircraft orientation and surface and bed reflection coefficient information not contained in the V01 data.

On 08 July 2013, the 2009 Antarctica data were replaced with V01.2. In V01.2, data fields are re-ordered and revised.

On 13 March 2017, the entire IR1HI2 data set was replaced with V01.3 data. V01.3 data files include extensive header information, including field descriptions, campaign information, and data processing notes. XML metadata files were also added to the V01.3 data set. XML files contain file level metadata and location, platform, and campaign information.

3.2.4 Error Sources

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.

3.3 Sensor or Instrument Description

The High Capability Radar Sounder (HiCARS) is a VHF ice-penetrating radar which 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).

4 REFERENCES AND RELATED PUBLICATIONS

Drewry, D. J. and Meldrum, D. T. 1978. Antarctic airborne radio echo sounding, 1977–78, Polar Record, 19:267–273, doi: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: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. 2015. The distribution of basal water between Antarctic subglacial lakes from radar sounding, Philosophical Transactions Of The Royal Society A, 374, 20140297:1–21, doi:10.1098/rsta.2014.0297.

4.1 Related Data Collections

- IceBridge HiCARS 1 L0 Raw Return Energy Amplitudes
- IceBridge HiCARS 2 L0 Raw Return Energy Amplitudes
- 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

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2008 campaign data were acquired pre-IceBridge.

6 DOCUMENT INFORMATION

6.1 Publication Date

14 March 2017

6.2 Date Last Updated

06 October 2020