IceBridge HiCARS 2 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., Kempf, S. D., Young, D. A., Richter, T. G., Schroeder, D. M., Ng, G., Greenbaum, J. S., van Ommen, T., Warner, R. C., Roberts, J. L., Young, N. W., Lemeur, E., & Siegert, M. J. (2012, updated 2017). *IceBridge HiCARS 2 L2 Geolocated Ice Thickness* (IR2HI2, Version 1). [Data set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/9EBR2T0VXUDG [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/IR2HI2

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Summary

This data set contains ice thickness, surface and bed elevation, and echo strength measurements taken over Antarctica using the Hi-Capability Airborne Radar Sounder (HiCARS) 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 space-delimited ASCII text 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:

IR2HI2_2012337_ICP5_JKB2h_F15T01a_icethk.txt
IR2HI2_2012337_ICP5_JKB2h_F15T01a_icethk.txt.xml

IR2HI2_YYYYDOY_AAAA_JKB2x_XXXX_icethk.xxx

Where:

Table 1. File Naming Convention

Variable	Description
IR2HI2	Short name for IceBridge HiCARS 2 L2 Geolocated Ice Thickness
YYYY	Four-digit year of survey
DOY	Day of year of survey
AAAA	Geographic area
JKB2x	Host platform
XXXX	Geographic track line
icethk	Ice thickness data
xxx	File type: ASCII text (.txt), or XML (.xml)

1.4 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.

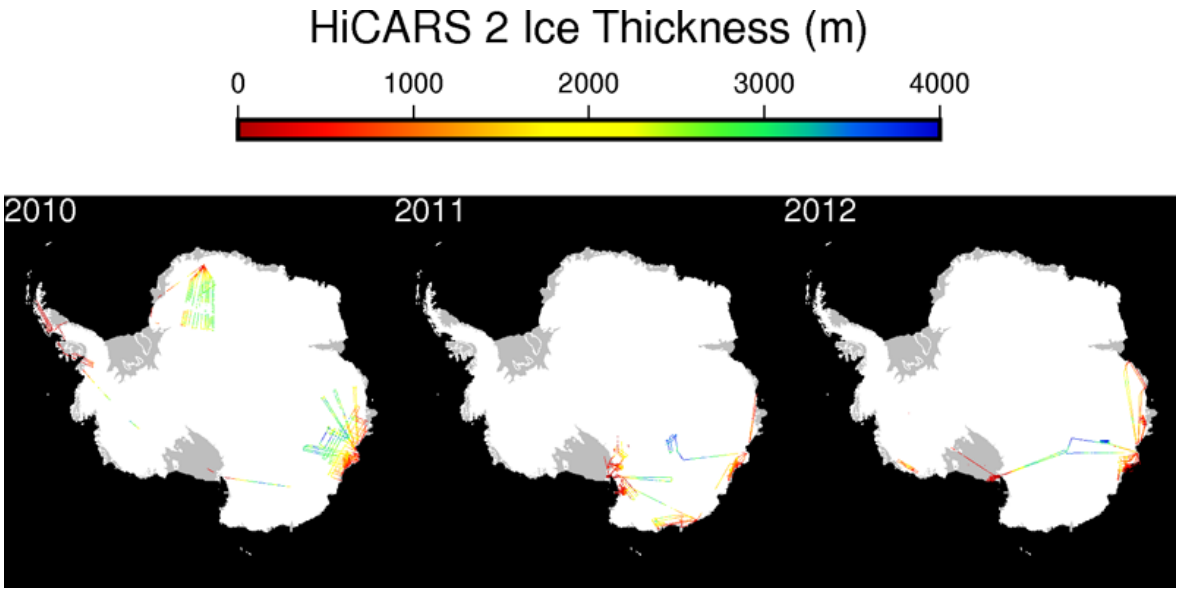

Figure 1. Coverage in the Wilkes Land Sector of Antarctica

ICECAP coverage is focused in the Wilkes Land Sector of Antarctica. In 2010-11, joint work was conducted as part of the ICEGRAV project in Dronning Maud Land (Project TRL) and the Antarctic Peninsula (project ICG1). Data along the coast of West Antarctica was collected in 2013 as part of the GIMBLE project (project MBL) and included here.

1.4.1 Spatial Resolution

Profile data sampled at 4 Hz (~23 m) along track. Due to the limited processing for this 'pik1' product, the horizontal resolution is typically 400 m. Vertical resolution is 8 m. (See the 2.2.2 section below for description of 'pik1'.)

1.4.2 Projection and Grid Description

Referenced to WGS-84 Ellipsoid, ITRF-2008.

1.5 Temporal Coverage

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

Temporal coverage for the entire data set is 5 December 2010 to 20 January 2013.

1.5.1 Temporal Resolution

ICECAP HiCARS 2 campaigns operated between October and February from 2010 to 2012, with some 2012 campaigns extending into early 2013. Typically three 7-hour flights were flown per week.

1.6 Parameter or Variable

1.6.1 Parameter Description

The HiCARS 2 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 1.78 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

Missing values have been replaced by "nan".

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 elevation products is recommended.

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.

1.6.2 Sample Data Record

Shown below are the first ten data records from data file: IR2HI2_2012337_ICP5_JKB2h_F15T01a_icethk.txt.

```
# YEAR DOY SOD LON LAT THK SRF_RNG BED_ELEVATION SURFACE_ELEVATION PARTIAL_BED_REFLECT SRF_REFLECT AIRCRAFT_ROLL
2012 337 12189.0872 111.138185 -66.481631 nan 649.61 nan 587.82 nan nan 1.01
2012 337 12189.3432 111.138489 -66.481787 nan 649.38 nan 588.01 nan nan 0.91
2012 337 12189.5992 111.138793 -66.481943 nan 649.15 nan 588.20 nan nan 0.76
2012 337 12189.8552 111.139097 -66.482099 nan 648.95 nan 588.36 nan nan 0.53
2012 337 12190.1162 111.139407 -66.482258 nan 648.72 nan 588.55 nan nan 0.16
2012 337 12190.3721 111.139710 -66.482414 nan 648.51 nan 588.70 nan nan -0.19
2012 337 12190.6282 111.140015 -66.482570 nan 648.28 nan 588.87 nan nan -0.53
2012 337 12190.8842 111.140319 -66.482725 nan 647.98 nan 589.07 nan nan -0.78
2012 337 12191.1451 111.140629 -66.482884 nan 647.70 nan 589.25 nan nan -0.95
2012 337 12191.4011 111.140934 -66.483040 nan 647.32 nan 589.53 nan nan -1.14
```

2 DATA ACQUISITION AND PROCESSING

2.1 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

2.2 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 1.78 as the dielectric constant for ice and no firn correction.

2.2.1 Trajectory and Attitude Data

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

2.2.2 Processing Steps

The radar data were processed using the 'pik1' processor. No focusing or range migration was performed. The original pulse repetition frequency was 6250 Hz. Echoes were summed onboard to a rate of 195 Hz (one in 192 stacks are not transmitted due to hardware limitations). Post collection, traces were coherently summed by a factor of 10. 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. A monochromatic local oscillator signal was filtered out at this stage. The result was converted to amplitude. The data were then incoherent averaged to 4 Hz, yielding 1 trace every 20 meters at typical aircraft speeds. The data were 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, in order to preserve the validity of statistics for the bed returns between cross overs.

2.2.3 Version History

Version 1.1. On 09 July 2013, the 2010 and 2011 Antarctica data were replaced with V1.1. In V1.1, new data fields were added: bed reflection coefficient, surface reflection coefficient, and aircraft roll; and some data fields were re-ordered.

Version 1.2. On 08 March 2017, the entire IR2HI2 data set was replaced with V01.2 data. V01.2 data files include extensive header information, including field descriptions, campaign information, and data processing notes. XML metadata files were also added to the V01.2 data set. XML files contain file level metadata and location, platform, and campaign information.

2.2.4 Error Sources

HiCARS 2 bed data takes 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 up to 700 m. Generally nadir ice thicknesses will be biased low in the data, and actual ice thicknesses based on the first return biased high.

2.3 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 to 67.5 MHz. HiCARS allows for phase coherent recording of radar returns for processing. The system uses two flat plate dipoles 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 UTIG. Digitizers, timing and signal generation are provided by National Instruments 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., 2015).

3 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.

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 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

March 2017

5.2 Date Last Updated

July 2025