IceBridge Radar L3 Tomographic Ice Thickness, Version 2

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Wu, X. 2019. *IceBridge Radar L3 Tomographic Ice Thickness, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/5NSX14QW4U4J. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/IRTIT3

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

This data set contains five data files, all of which provide tomographic ice thickness measurements and ice thickness errors (Table 1). Two of the files, IRTIT3_20110413_Russell.nc and IRTIT3_20130420_Humboldt.nc, additionally provide bed elevation measurements.

Table 1. File Parameter Description

Parameter	Description	Units
`ice_thickness`	Tomographic ice thickness	meters
`thickness_err`	Tomographic ice thickness error	meters
`bed_elevation`	Bed elevation; only contained in `IRTIT3_20110413_Russell.nc` and `IRTIT3_20130420_Humboldt.nc`	meters

1.2 File Information

1.2.1 Format

The data files are in HDF5 (.h5) format. Each data file is paired with an associated XML (.xml) file, which contains additional metadata.

1.2.2 File Contents

Figure 1 shows ice thickness of the Umanaq Glacier in Greenland. The image was created with Panoply (see Section 3).

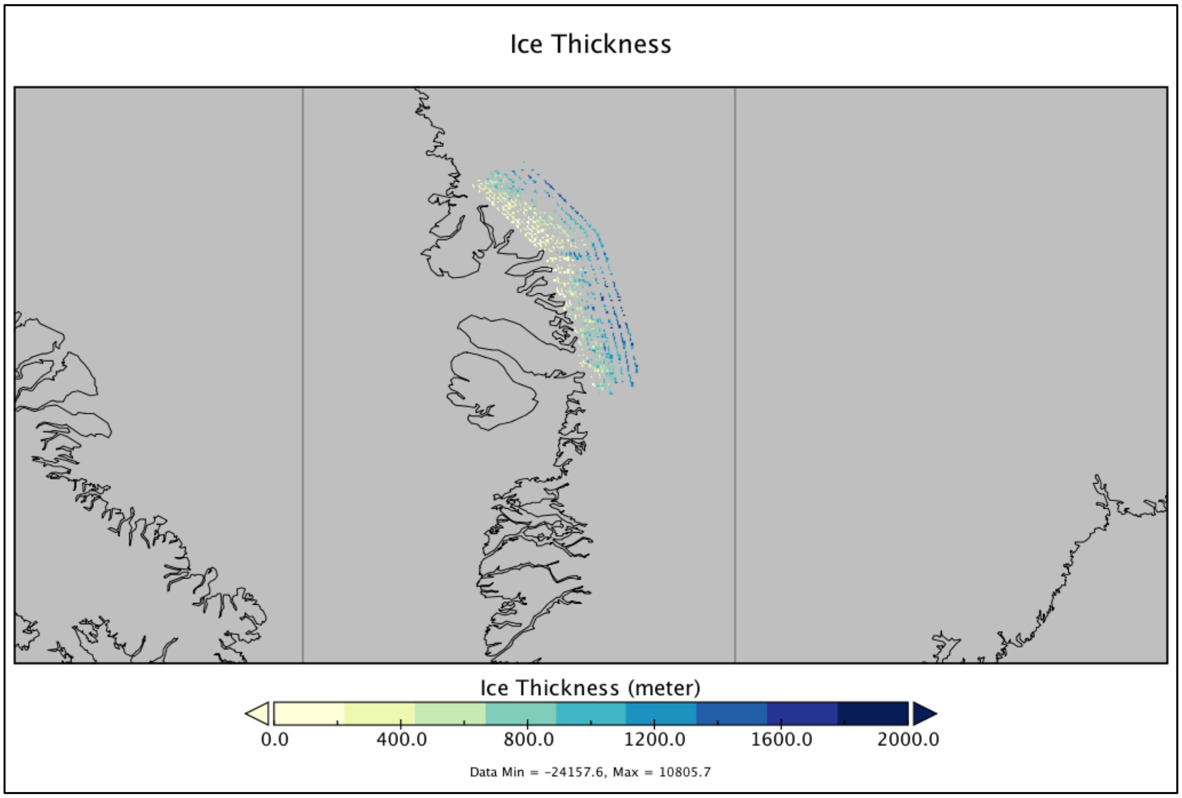

Figure 1. Ice thickness (in m) from file IRTIT3_20110407_Umanaq.nc.

1.2.3 Naming Convention

The five files contained in this data set are the following:

IRTIT3_20101120_PineIsland.nc

IRTIT3_20110407_Umanaq.nc

IRTIT3_20110413_Russell.nc

IRTIT3_20120421_Jakobshavn.nc

IRTIT3_20130420_Humboldt.nc

They are organized in chronological order and named according to the following convention (Table 2):

IRTIT3_YYYYMMDD_location.ext

Table 2. File Naming Convention

Variable	Description
IRTIT3	Short name for IceBridge Radar L3 Tomographic Ice Thickness
YYYYMMDD	Year, month, and day of survey
location	Campaign identifier / name of location: PineIsland, Umanaq, Russell, Humboldt, Jakobshavn

`.ext`	Indicates file type: `.nc` = netCDF4 data file `.nc.xml` = XML metadata file

1.3 Spatial Information

1.3.1 Coverage

Spatial coverage varies by campaign flight. Spatial coverage for the source data includes Antarctica and Greenland.

Antarctica:
Southernmost Latitude: 90° S
Northernmost Latitude: 63° S
Westernmost Longitude: 180° W
Easternmost Longitude: 180° E

Greenland:
Southernmost Latitude: 59° N
Northernmost Latitude: 83° N
Westernmost Longitude: 74° W
Easternmost Longitude: 12° W

1.3.2 Resolution

25 meters

1.3.3 Geolocation

The following table provides the geolocation details for this data set.

Table 3. Geolocation Details

	Arctic/Greenland	**Antarctica**
Geographic coordinate system	WGS 84	WGS 84
Projected coordinate system	WGS 84 / NSIDC Sea Ice Polar Stereographic North	WGS 84 / Antarctic Polar Stereographic
Longitude of true origin	-45° E	0°
Latitude of true origin	70° N	71° S

	Arctic/Greenland	Antarctica
Scale factor at longitude of true origin	1	1
Datum	WGS 84	WGS 84
Ellipsoid/spheroid	WGS 84	WGS 84
Units	meters	meters
False easting	0	0
False northing	0	0
EPSG code	3413	3031
PROJ4 string	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs	+proj=stere +lat_0=-90 +lat_ts=-71 +lon_0=0 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs
Reference	https://epsg.io/3413	https://epsg.io/3031

1.4 Temporal Information

1.4.1 Coverage

20 November 2010 to 20 April 2013

1.4.2 Resolution

Seasonal

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Conventional ice sheet sounding techniques only provide one-dimensional thickness measurements in the along-track direction of the radar sounder. The vertical resolution of the ice thickness is met by transmitting a high-bandwidth signal; the along-track resolution is obtained by forming a synthetic aperture. The cross-track direction, however, presents some difficulties: due to broad antenna elevation patterns, left and right targets from both the surface and the bottom of the ice can fall into the same range bin. To address this ambiguity, more measurements are needed in the cross-track direction. This can be achieved either by adding more antenna elements on the same platform, or by flying multiple tracks more closely together with only one antenna. All the IceBridge data collections were obtained by flying along a single track using multiple antenna elements.

2.2 Acquisition

The MCoRDS sounding radar system used to collect the data presented in this data set operated at frequencies between 180 MHz and 210 MHz. For Greenland missions, a NASA P-3B Orion aircraft was used. On these flights, the MCoRDS radar was operated at a center frequency of 195 MHz and a signal bandwidth of 30 MHz; it was equipped with 15 dipole antenna elements: seven elements were mounted under the fuselage of the aircraft and four elements were mounted under each wing. The seven antenna elements under the fuselage were used for both transmitting and receiving; the eight side elements were used for receiving only. Figure 2 shows the antenna layouts for the P-3B platform.

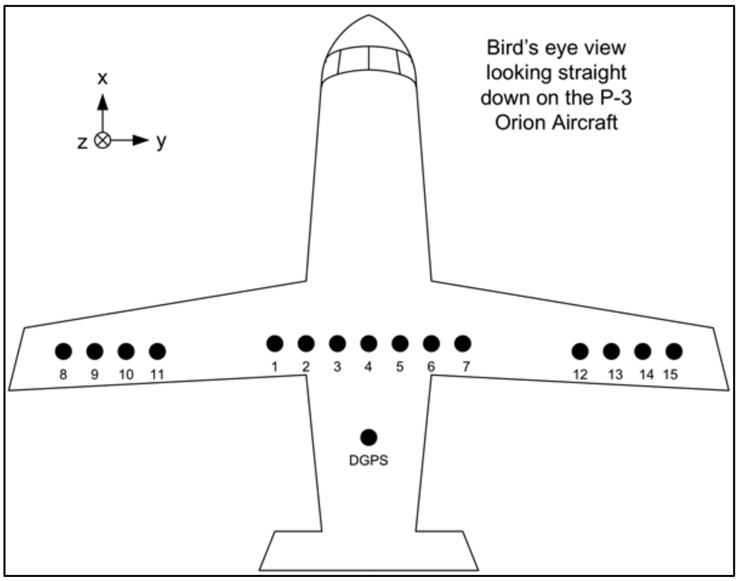

Figure 2. NASA P-3B Orion antenna layouts

For Antarctic missions, a NASA DC-8 aircraft was used. On these flights, the MCoRDS radar was operated at the same center frequency of 195 MHz, but with a signal bandwidth of 10 MHz. Only five antenna elements, mounted under the fuselage, were used. The DC-8 antenna layout is shown in Figure 3.

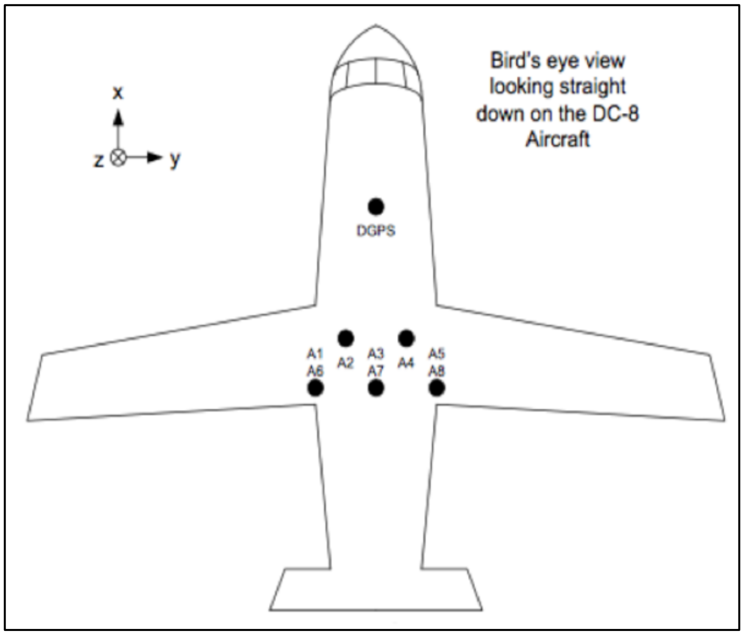

Figure 3. NASA DC-8 antenna layouts

2.3 Processing

Figure 4 highlights the principle of the tomographic radar sounding technique. After range and azimuth processing, the targets are resolved in the range and azimuth directions. Ambiguity only exists in the cross-track, or look-angle, direction. Assuming that there are only two interfaces, the air-ice interface and the ice-bottom interface, and that the internal ice backscattering can be ignored, then there are four targets for each range bin and each azimuth position in the case of no layovers. Theoretically, five or more measurements in the cross-track direction will enable these targets to be resolved. See Wu et al. (2011) for more details on the algorithm.

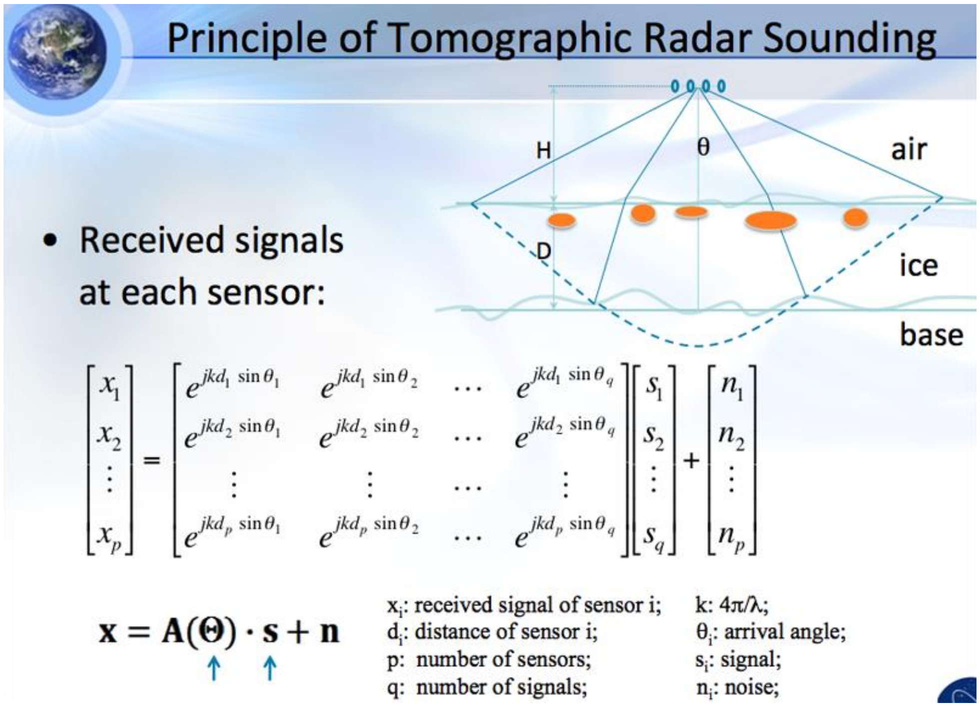

Figure 4. Principle of tomographic radar sounding

Figure 5 shows a processing flow diagram highlighting the detailed steps from the raw MCoRDS input data to the final bed map products provided in this data set.

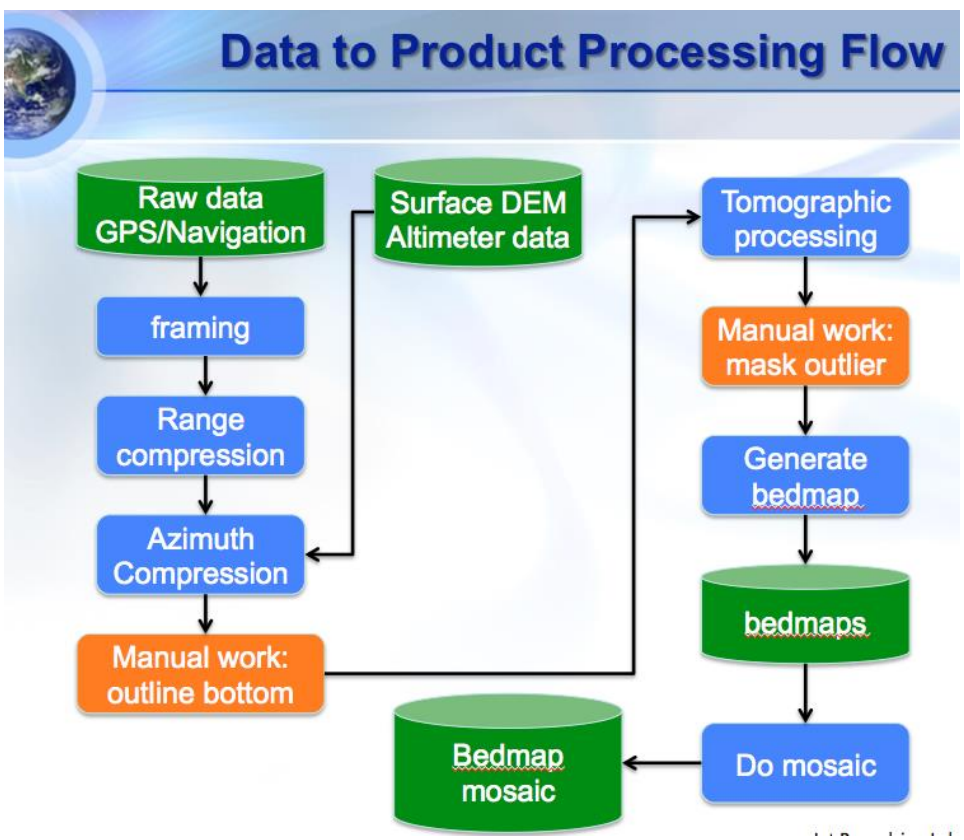

Figure 5. Data processing flow

2.4 Quality, Errors, and Limitations

2.4.1 Error Sources

Errors in the ice thickness measurements depend on the following factors: platform position and attitude accuracy, accuracy of the antenna layout, the surface clutter-to-noise ratio, the bottom echo signal-to-noise ratio, variations in the bottom topography, and the accuracy of the ice refraction index (a value of 1.8 is used for all the bed map products). The parameter thickness_err is an estimated value of the ice thickness error.

2.4.2 Quality Assessment

To evaluate the quality of the tomographic ice thickness produced by using the tomographic sounding technique, data from the Global Ice Sheet Mapping Orbiter (GISMO) project were used (see Figure 6). Since the MCoRDS radar and the radar used for the GIMSO project both operate at similar frequencies, have a similar number of antenna elements, and were flown at roughly the same altitude above the ice surface, their measurement qualities are comparable for the similar targets; thus, ice thickness data produced from the GISMO data lend themselves well to a quality assessment of the ice thickness products produced from the IceBridge MCoRDS data over some of the Greenland areas. Using the data collected in 2008 for GISMO campaign over the area of Jakobshavn, Greenland, we produced a 2D ice thickness map. A depth sounding radar made some 1D profile ice thickness measurements over the same area. These two independent radar measurements are compared in the following to help us assess the performance of the tomographic sounding technique.

The upper image in Figure 6 shows the ice thickness map produced from the 2008 GISMO data using the tomographic sounding technique. The tomographic sounding radar for GISMO operated at a center frequency of 150 MHz with a signal bandwidth of 20 to 30 MHz. This image also contains two flight tracks from the 2006 campaigns, which were flown with the same radar for GISMO but in depth-sounding mode, which can only measure a 1D ice thickness profile along the flight tracks.

The lower part of Figure 6 shows two plots comparing the ice thickness profile along two tracks: in red is the ice thickness profile produced from the 2008 data with the tomographic sounding technique and in blue is the ice thickness profile made from the 2006 data using the depth sounding technique. The standard deviation (RMS error) of the ice thickness measurements along these two tracks is 14 m and 18 m, respectively. Please refer to Wu et al. (2011) for more details on the validation of the tomographic sounding.

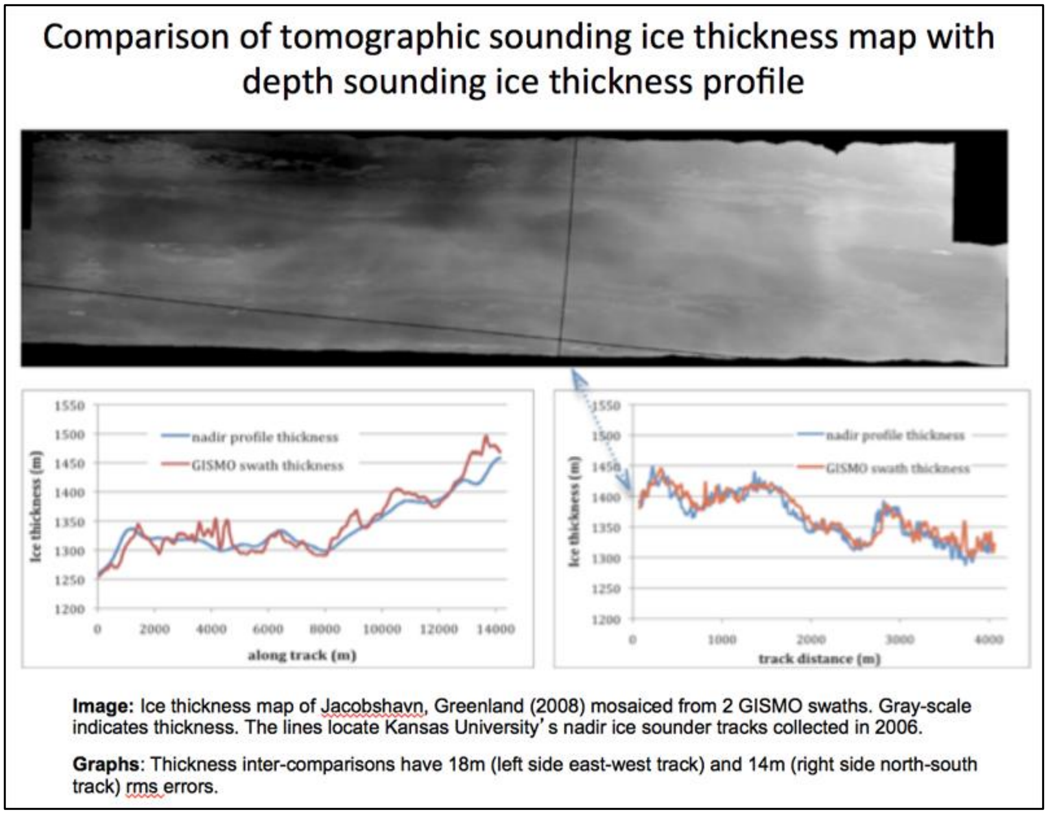

Figure 6. Comparison of ice thickness derived from two different techniques: tomographic sounding and depth sounding.

Figure 7 highlights another example of comparing tomographic ice thickness with the depth sounding profile. The upper image shows the color-coded tomographic ice thickness map. The lower plot shows the difference between the tomographic ice thickness and the official depth sounding profile. For the most part, the two results closely agree. In areas where the bed topography varies a lot, the difference can be up is 200 m; in such cases, the tomographic sounding yields better results.

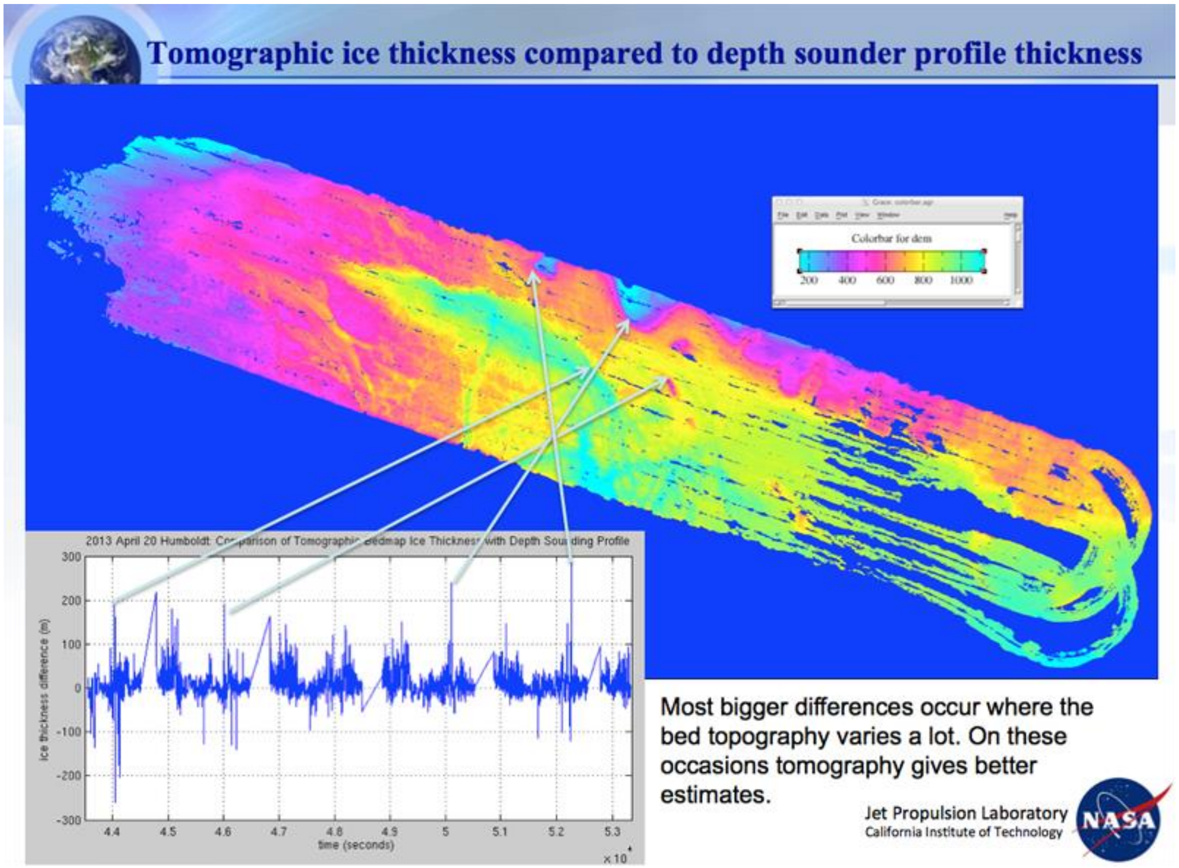

Figure 7. Comparison of tomographic ice thickness with the depth sounding profile.

Figure 8 shows the tracks from Figure 7, with values corresponding to the difference in ice thickness between the radar sounder along-track profile and the swath measurements using the tomographic technique (-100 m to 100 m). The lower plot shows the corresponding histogram of thickness differences. Since the depth sounder produces one continuous measurement along the track, only the locations along the track have values while the rest of the plot is void. The tomographic technique on the other hand produces a swath measurement and thus yields a 2-D map instead of a line.

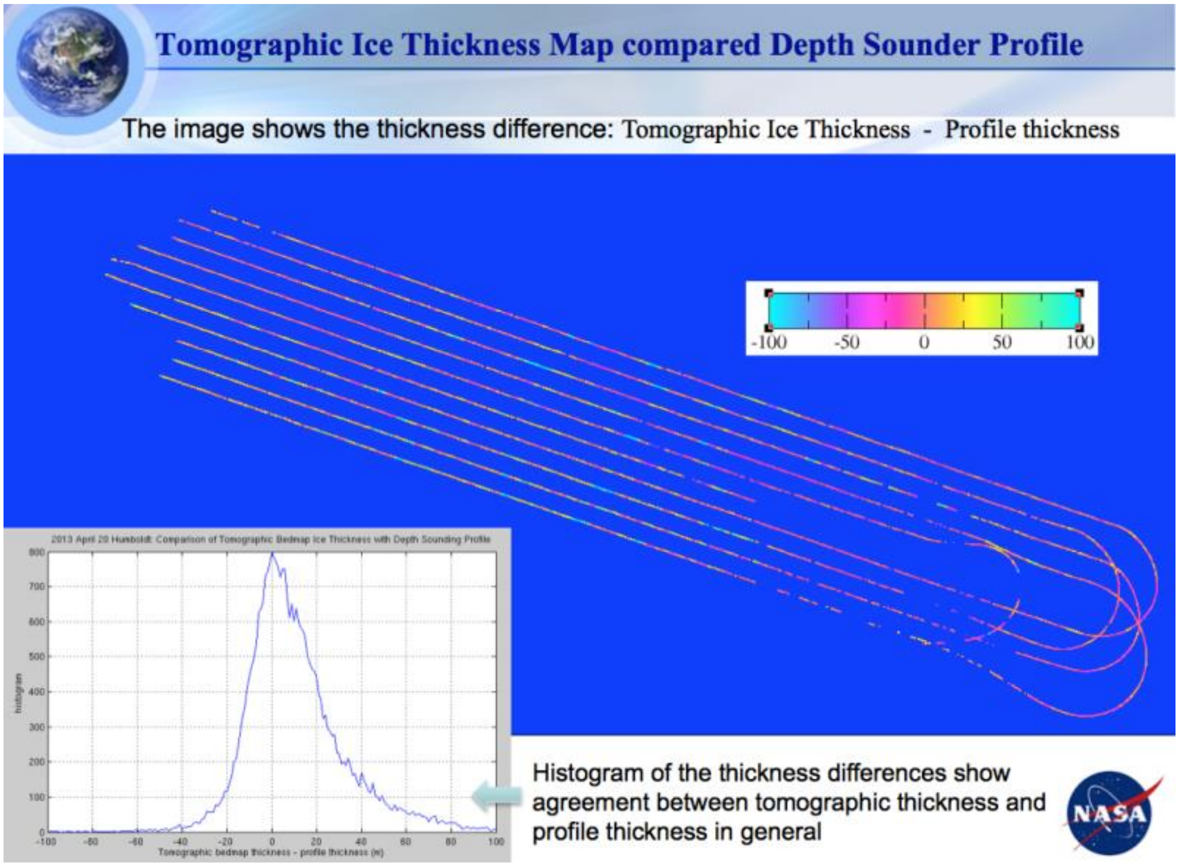

Figure 8. Difference between the tomographic ice thickness and the depth sounder profile, with corresponding histogram.

2.5 Instrumentation

The Multichannel Coherent Radar Depth Sounder operates over a 180 to 210 MHz frequency range with multiple receivers developed for airborne sounding and imaging of ice sheets. Measurements are made over two frequency ranges: 189.15 to 198.65 MHz, and 180 to 210 MHz. The radar bandwidth is adjustable from 0 to 30 MHz. Multiple receivers permit digital beam-steering for suppressing cross-track surface clutter that can mask weak ice-bed echoes and strip-map SAR images of the ice-bed interface. These radars are flown on twin engine and long-range aircraft including NASA P-3, Twin Otter (TO), and DC-8.

The details of the JPL tomographic processor are described in Wu et al. (2011). The processor produced the ice thickness map. For some areas the bed elevation maps were also produced using the existing Greenland or Antarctic surface DEMs. The Greenland DEM used for the calculation is described in Howat et al. (2014). See also: Byrd Polar Research Center Greenland Mapping Project (GIMP) Digital Elevation Model.

3 SOFTWARE AND TOOLS

The following external links provide access to software for reading and viewing HDF5 data files. Please be sure to review instructions on installing and running the programs.

HDFView: Visual tool for browsing and editing HDF4 and HDF5 files.

Panoply netCDF, HDF and GRIB Data Viewer: Cross-platform application. Plots geo-gridded arrays from netCDF, HDF and GRIB data sets.

For additional tools, see the HDF-EOS Tools and Information Center.

4 VERSION HISTORY

The Version 1 data covered the same time period but were in HDF5 format and only included ice thickness measurements.

For Version 2 of this data set, the following changes were made:

1. Converted data files from HDF5 to netCDF4 format, with the following data structure revisions:
    - Renamed the parameter dataset0 to ice_thickness.
    - Added the parameter thickness_err.
    - Added the parameter bed_elevation to the files IRTIT3_20110413_Russell.nc and IRTIT3_20130420_Humboldt.nc.
    - Added the following CF1.7-compliant geolocation variables/attributes for improved usability: polar_stereographic (grid mapping variable); x and y (coordinates of projection). Enables automatic geolocation in software such as QGIS.
2. Changed the no-data flag value from -10000 to NaN.

5 RELATED DATA SETS

IceBridge MCoRDS L1B Geolocated Radar Echo Strength Profiles
IceBridge MCoRDS L2 Ice Thickness

6 RELATED WEBSITES

CReSIS website
CReSIS Sensors web page
IceBridge data website at NSIDC
IceBridge website at NASA
Global Ice Sheet Mapping Orbiter (GISMO)

7 CONTACTS AND ACKNOWLEDGMENTS

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8 REFERENCES

Howat, I. M., A. Negrete, and B. E. Smith. 2014. The Greenland Ice Mapping Project (GIMP) land classification and surface elevation data sets, *The Cryosphere*, 8(4): 1509–1518. doi: 10.5194/tc-8-1509-2014.

Wu, X. 2011. Global Ice Sheet Mapping Observatory: Russell Glacier Bed Mapping Using IceBridge Mission Data Final Report, NASA Report, November 23, 2011.

Wu, X., K. Jezek, E. Rodriguez, S. Gogineni, F. Rodriguez-Morales, and A. Freeman. 2011. Ice Sheet Bed Mapping with Airborne SAR Tomography, *IEEE Transactions on Geoscience and Remote Sensing*, 49(10): 3791-3802. doi: 10.1109/TGRS.2011.2132802.

9 DOCUMENT INFORMATION

9.1 Publication Date

25 January 2019

9.2 Date Last Updated

22 January 2025