# IceBridge Radar L3 Tomographic Ice Thickness, Version 1

## USER GUIDE

**How to Cite These Data**

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

Wu, X. 2014. *IceBridge Radar L3 Tomographic Ice Thickness, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/92SUAOLU6AP1. [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 DETAILED DATA DESCRIPTION

## 1.1 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 File Naming Convention

Example file name:

IRTIT3_20130420_100000_Humboldt_Thickness.h5

The files are named according to the following convention, which is described detail in Table 1:

IRTIT3_YYYYMMDD_hhmmss_location_Thickness.ext

Table 1. File Naming Convention

| Variable | Description |
|---|---|
| `IRTIT3` | Data set ID |
| `YYYYMMDD` | Four-digit year, two-digit month, and two-digit day |
| `hhmmss` | Starting time of the day in hours, minutes, seconds |
| `location` | Campaign identifier name of location. For example: Pineisland, Umanaq, Russell, Humboldt, Jacobshavn |
| `Thickness` | Indicates data content: thickness |
| `.ext` | Indicates file type:<br>`.h5` = HDF5 data file<br>`.h5.xml` = XML metadata file |

## 1.3 Spatial Coverage

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

<u>Antarctica:</u>

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

### 1.3.1 Spatial Resolution

50 meters

### 1.3.2 Projection and Grid Description

The bed elevation given is with respect to the WGS 84 ellipsoid. The map projection is polar stereo projection with latitude of true scale of 70.0 degrees and reference longitude of -45.0 degrees for Greenland. For Antarctica, the latitude of true scale is -70 degrees and the reference longitude is zero.

## 1.4 Temporal Coverage

20 November 2010 to 20 April 2013

### 1.4.1 Temporal Resolution

Seasonal

## 1.5 Parameter or Variable

Tomographic ice thickness

### 1.5.1 Parameter Description

The IceBridge Radar L3 Tomographic Ice Thickness HDF5 data files contain one field, as described in Table 2.

Table 2. File Parameter Description

| Parameter | Description | Units |
| --- | --- | --- |
| `dataset0` | Tomographic ice thickness | Meters |

### 1.5.2 Sample Data Record

Figure 1 shows an image of Russell Glacier, Greenland ice thickness with color scale in meters. The color images and the color bars in Figures 1 and 2 were created using the JPL MDX viewing tool.

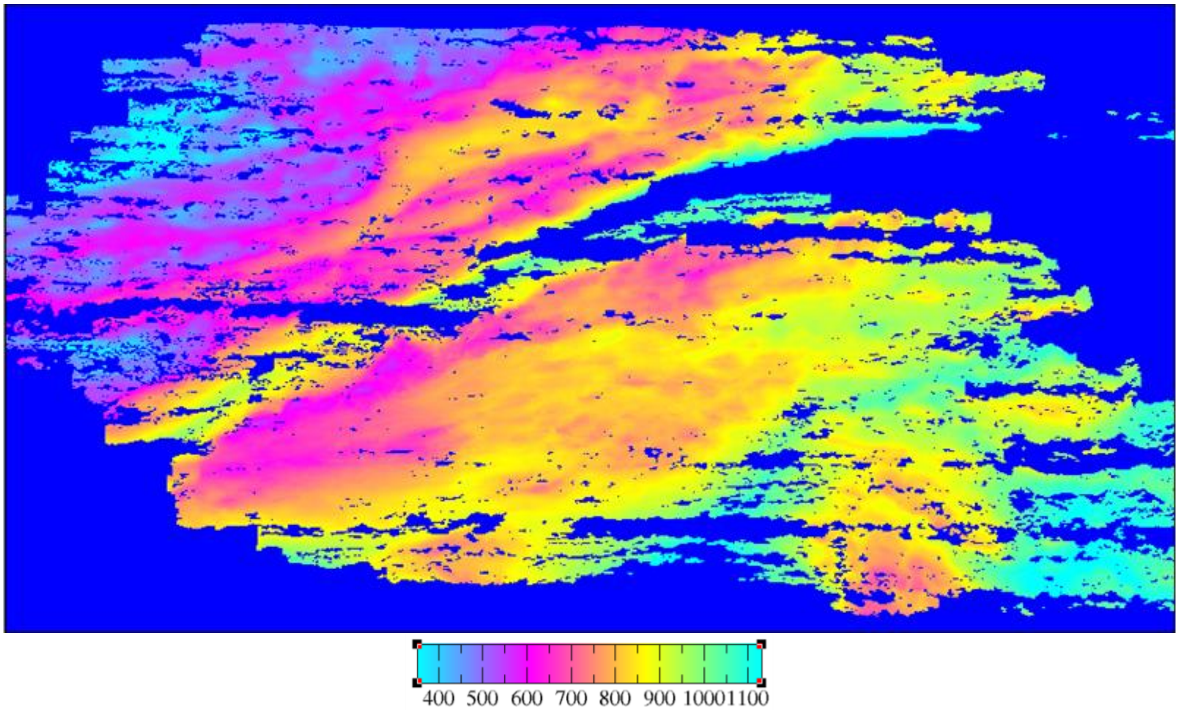


Figure 1. Russell Glacier Ice Thickness

The content of the map header file is shown below.

The header file was integrated into the .h5 file by using the hdf5 utility command h5jam as follows: h5jam −u basename.hdr −I basename.h5 −o final_basename.h5. The output file is final_basename.h5.

projection_name = PS

datum_name = WGS 84

hemisphere = North

latitude_of_true_scale = 70.0

reference_longitude = -45.0

nrows = 911

ncols = 1700

UL_x = -208600.000

UL_y = -2483700.00

row_spacing = 20.000000

col_spacing = 20.000000

nodata_value = -10000.000000

Figure 2 shows the error map of the measurement of Russell Glacier.

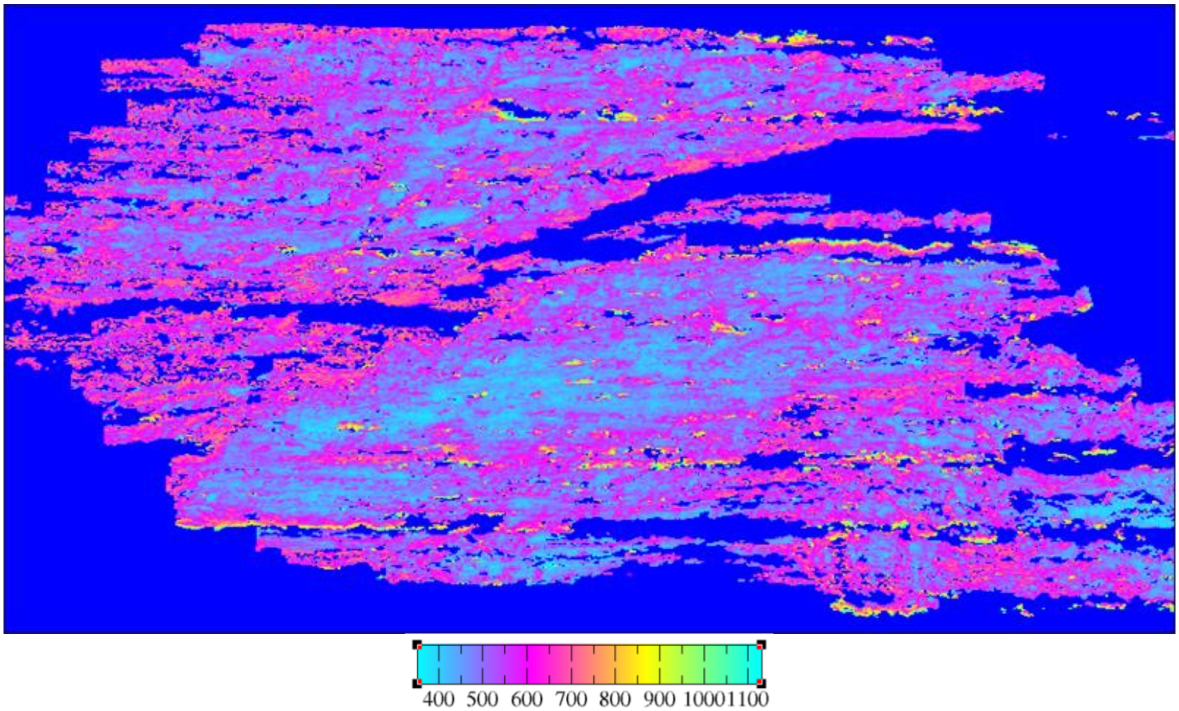


Figure 2. Russell Glacier Error Map

# 2 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.

# 3 QUALITY ASSESSMENT

To evaluate the product quality, we select several test sites where multiple data collections have been made through the past three years over four different glaciers outlets. By processing these data sets we have better visibility into product quality and the best ways to process data, and archive and distribute the results.

The method for assessing the quality of tomographic ice thickness products is derived from 2008 Global Ice Sheet Mapping Orbiter (GISMO) data, as shown in Figure 3. The top image shows the ice thickness map produced using the 2008 data collection and the tomographic technique. The sounding radar used to collect the GISMO data was built by the same institution: Center for Remote Sensing of Ice Sheets of University of Kansas. The sounding radar operated at a similar center frequency of 150 MHz with signal bandwidth between 20 MHZ and 30 MHz. The number of antenna elements was 10 for 2008 data collection. The same tomographic sounding technique as used for IceBridge bedmapping was used to produce the ice thickness maps.

On the same image there are two flight tracks, which were flown in 2006 with an ice depth radar sounder on board. The radar flown in 2006 for depth mode data collection was the same radar used for 2008 GISMO data collection but with fewer antenna elements. The bottom part of the figure shows two plots, which correspond to the ice thickness profile comparison along the two tracks. The standard deviation of ice thickness measurements using tomography against the depth sounder profile measurement is 14 m and 18 m, respectively.

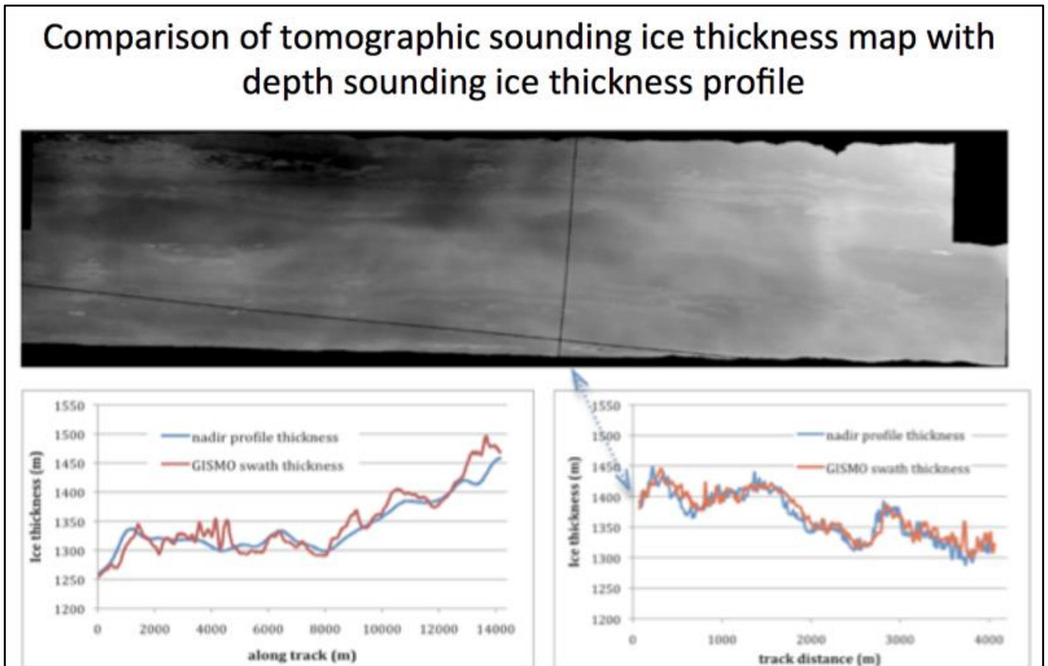


**Image:** Ice thickness map of Jacobshavn, Greenland (2008) mosaiced from 2 GISMO swaths. Gray-scale indicates thickness. The lines locate Kansas University's nadir ice sounder tracks collected in 2006.

**Graphs**: Thickness inter-comparisons have 18m (left side east-west track) and 14m (right side north-south track) rms errors.

Figure 3. Quality Assessment of the Tomographic Ice Thickness

Another example is the comparison of the tomographic ice thickness with the depth sounding profile picked by CReSIS. The top image in Figure 4 shows the color coded tomographic ice thickness map. The lower left plot in this figure shows the difference of the tomographic thickness minus the official depth sounding profile. These two results closely agree in most part of the areas.

They differ by as much as 200 meters where the base has big tomograph variations as indicated in the image.

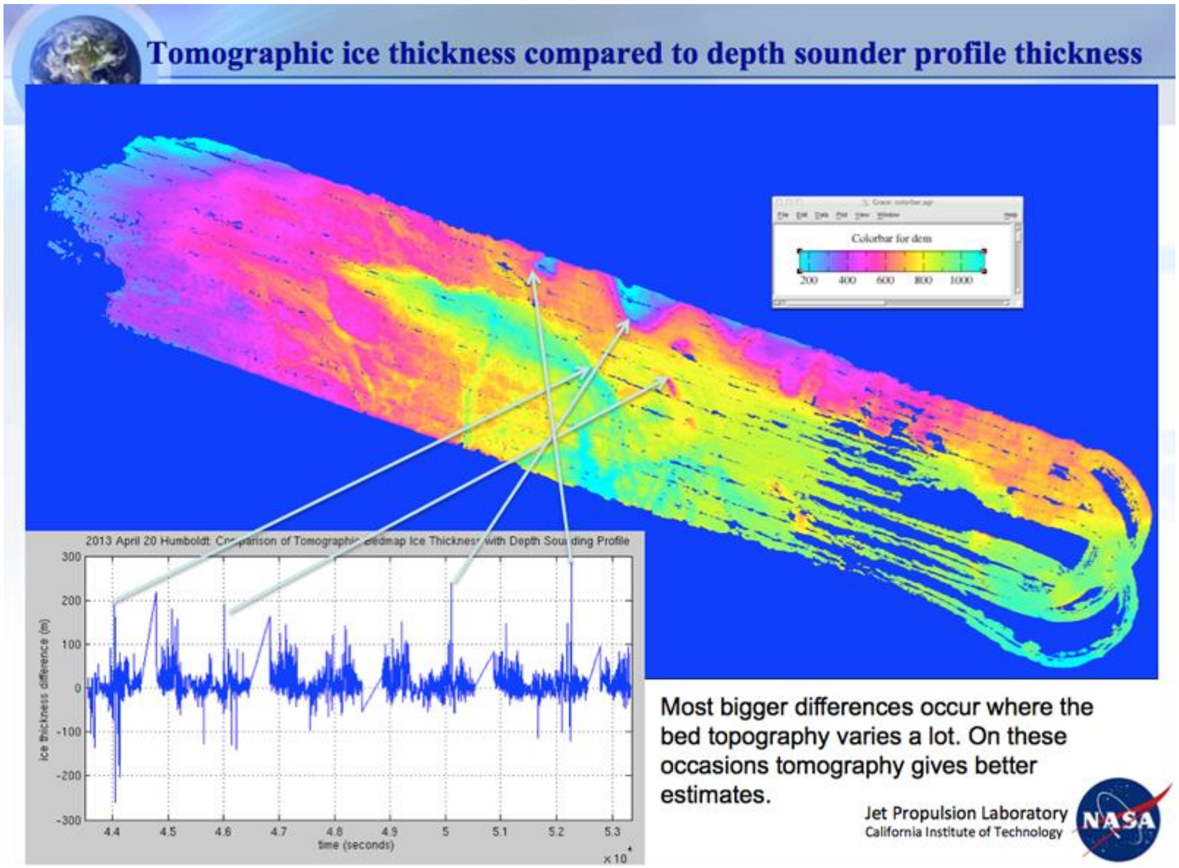


Figure 4. Tomographic Ice Thickness Compared to Depth Sounder Profile Thickness

Figure 5 shows the tracks from Figure 4, with values corresponding to ice thickness differences between the radar sounder along-track profile and the swath measurements from the tomographic technique (-100 m to 100 m). The left lower plot shows a histogram of thickness differences. The depth sounder produces only one measurement along the track. Therefore, only the locations along the track have values and anywhere else is void, shown as blue. The tomographic technique produces swath measurement and thus gives us a 2D map instead of a one-dimensional line.

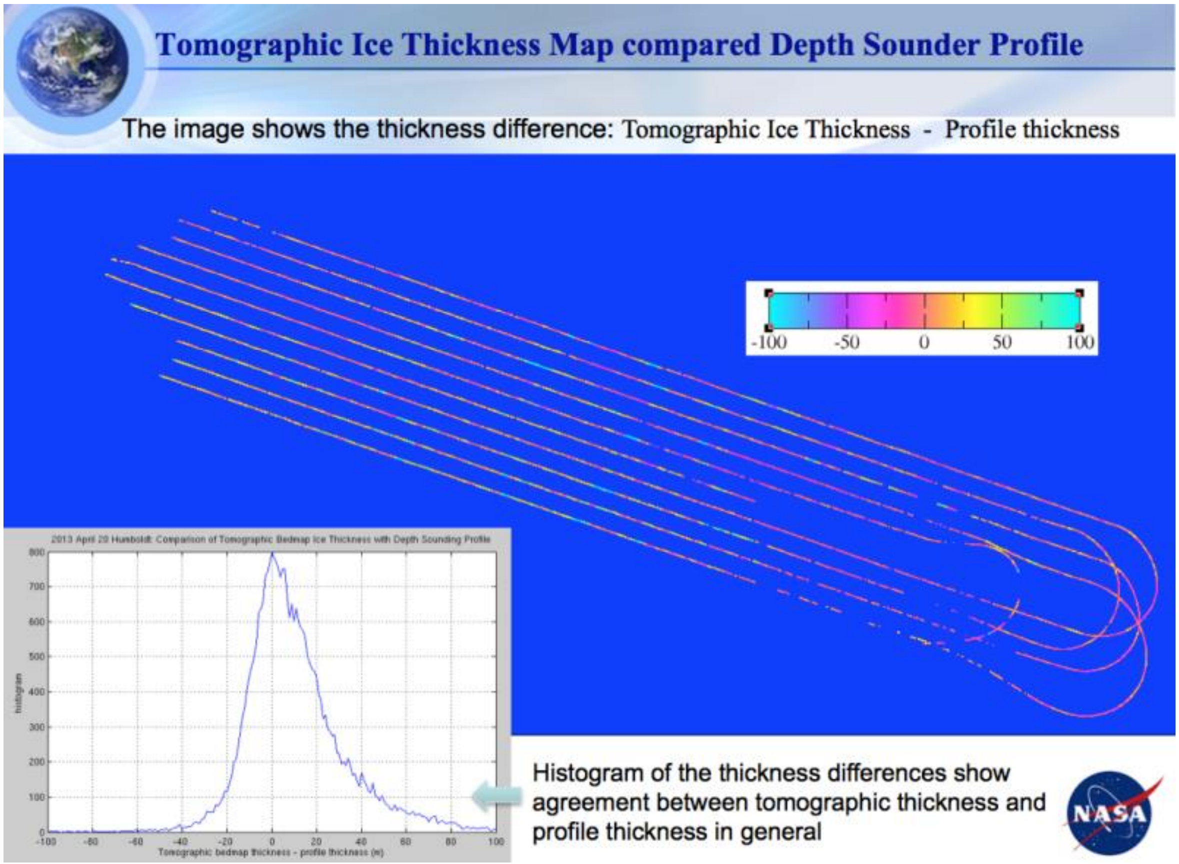


Figure 5. Tomographic Ice Thickness Map Compared to Depth Sounder Profile

# 4 DATA ACQUISITION AND PROCESSING

## 4.1 Theory of Measurements

Conventional ice sounding provides one dimensional thickness measurements of the ice sheets along the flight lines of the radar sounder. The vertical resolution of the thickness is met by transmitting high bandwidth signal and the along track resolution is obtained by forming a synthetic aperture. There are, however, ambiguities in the cross-track direction due to broad antenna elevation pattern, where left and right targets from both surface and bottom fall in the same range bin. In order to resolve the ambiguity, more measurements are needed in the cross-track direction. The multiple cross track measurements can be made by either more antenna elements on the same platform or closely spaced multiple tracks with one antenna. All the data collections in IceBridge missions were made with single track multiple antenna elements.

## 4.2 Data Acquisition Methods

The MCoRDS sounding radar system operated at a center frequency of 195 MHz with a signal bandwidth of 30 MHz. For Greenland missions on the platform of NASA P-3B Orion aircraft, the radar 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 middle seven antenna elements are used for both transmitting and receiving. The eight side elements are used for receiving only. Figure 6 shows the antenna layouts for the P-3B platform.

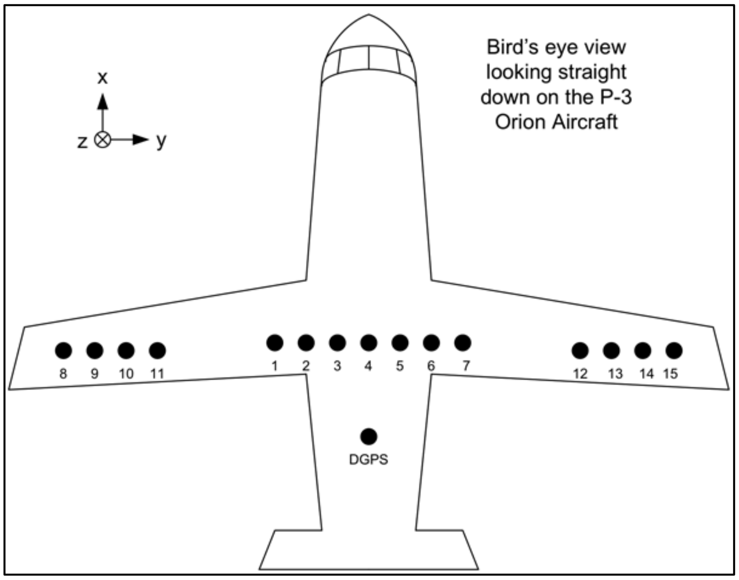


Figure 6. NASA P-3B Orion Antenna Layouts

For Antarctic missions, a NASA DC-8 aircraft was used. The MCoRDS sounding radar operated at the same center frequency 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 7.

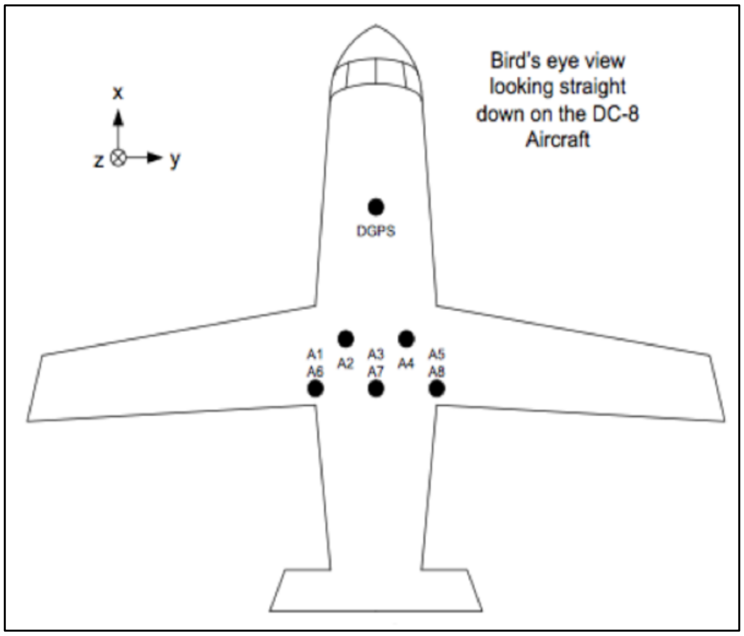


Figure 7. NASA DC-8 Antenna Layouts

## 4.3 Derivation Techniques and Algorithms

Figure 8 shows the principle of the tomographic sounding technique. After range and azimuth processing, the targets are resolved in azimuth and range directions. Ambiguity is only in cross track direction or look angle direction. If there are only two interfaces of air-ice and ice-bottom interfaces and if we can ignore the internal ice back-scattering, there are four targets for each range bin and each azimuth position in the case of no layovers. Theoretically five or more measurements in cross track direction will enable us to resolve these targets. The detailed algorithm is described in Wu et al. (2011).

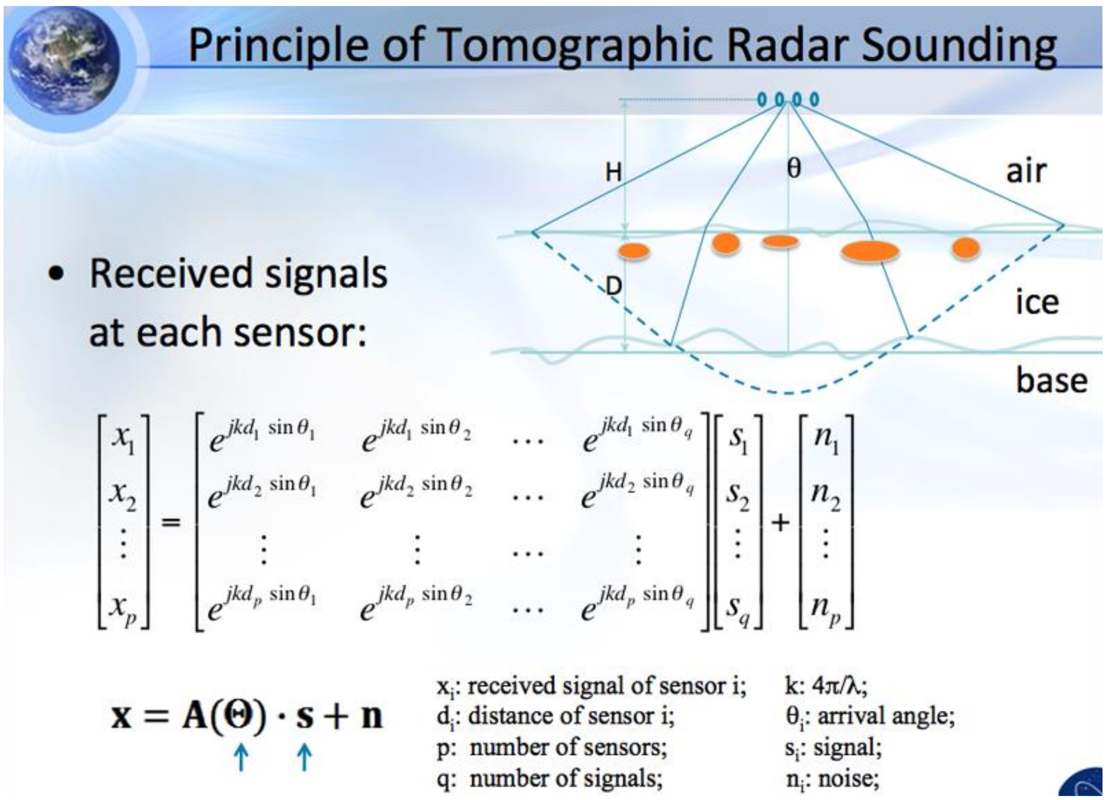


Figure 8. Principle of Tomographic Radar Sounding

### 4.3.1 Processing Steps

Figure 9 shows the processing flow diagram and the detailed steps from the raw data to the final bedmap products.

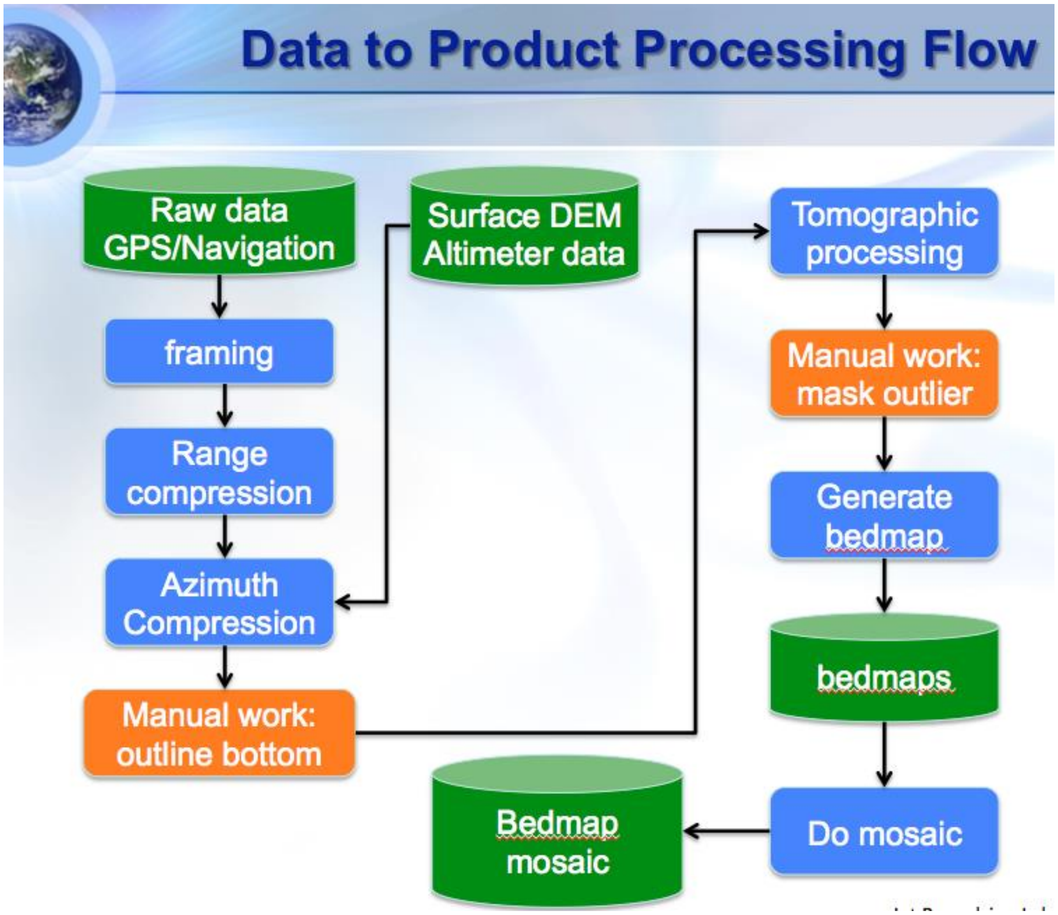


Figure 9. Data Processing Flow

### 4.3.2 Errors Sources

The error of the derived ice thickness depends on platform position accuracy, platform attitude accuracy, accuracy of the knowledge of the antenna layout, surface clutter to noise ratio, bottom echo Signal to Noise Ratio (SNR), local bottom topographic variations, and accuracy of the used ice refraction index (1.8 is used for all the bedmap products).

## 4.4 Sensor or Instrument Description

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.

# 5 REFERENCES AND RELATED PUBLICATIONS

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

Wu, Xiaoqing. 2014. Global Ice Sheet Mapping Observatory: IceBridge Tomographic Bedmapping Final Report, *NASA Report, June*, 2014.

Wu, Xiaoqing, K. Jezek, E. Rodriguez, S. Gogineni, F. Rodriguez-Morales, and A. Freeman. 2011. IceSheet Bed Mapping with airborne SAR tomography, *IEEE Trans. on Geoscience and Remote Sensing* 49(10).

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

## 5.1 Related Data Collections

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

## 5.2 Related Websites

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

# 6 CONTACTS AND ACKNOWLEDGMENTS

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# 7 DOCUMENT INFORMATION

## 7.1 Publication Date

September 2014

## 7.2 Date Last Updated

May 2019