IceBridge BedMachine Greenland, Version 2

USER GUIDE

How to Cite These Data

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

Morlighem, M., E. Rignot, J. Mouginot, H. Seroussi, and E. Larour. 2015. *IceBridge BedMachine Greenland, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: https://doi.org/10.5067/AD7B0HQNSJ29. [Date Accessed].

Literature Citation

As a condition of using these data, we request that you acknowledge the author(s) of this data set by referencing the following peer-reviewed publication.

> Morlighem, M., E. Rignot, J. Mouginot, H. Seroussi, and E. Larour. 2015. Deeply Incised Submarine Glacial Valleys Beneath the Greenland Ice Sheet, *Nature Geoscience*. 7. 418-422. https://doi.org/10.1038/ngeo2167

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/IDBMG4

National Snow and Ice Data Center

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1 DETAILED DATA DESCRIPTION

1.1 Format

The data are in netCDF 1.6 file format.

1.2 File and Directory Structure

Data file, `MCdataset-2015-04-27.nc`, is on the HTTPS site,
`https://daacdata.apps.nsidc.org/DATASETS/IDBMG4_BedMachineGr/`.

In the file name, "MC" refers to Mass Conservation, "nc" indicates netCDF file format, and 2015-04-27 indicates date of data file creation.

1.3 Spatial Coverage

Spatial coverage for the data set currently includes Greenland and the Arctic.

Greenland / Arctic:
Southernmost Latitude: 60° N
Northernmost Latitude: 90° N
Westernmost Longitude: 80° W
Easternmost Longitude: 10° E

1.3.1 Spatial Resolution

The output product is generated at 150 m resolution. The true resolution of the ice thickness data is 400 m.

1.3.2 Projection and Grid Description

The following table provides details about the coordinate system for this data set.

Table 1. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84 / NSIDC Sea Ice Polar Stereographic North
Longitude of true origin	-45° E

Latitude of true origin	70° N
Scale factor at longitude of true origin	1
Datum	WGS 84
Ellipsoid/spheroid	WGS 84
Units	meters
False easting	0
False northing	0
EPSG code	3413
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
Reference	https://epsg.io/3413

1.4 Temporal Information

1.4.1 Temporal Coverage

Ice thickness data were collected between 1993 and 2014. The nominal date of this data set is 2007.

1.5 Parameter or Variable

1.5.1 Parameter Description

The BedMachine data file contains parameters as described in Table 2.

Table 2. File Parameters and Units

Parameter Name	Description	Units
bed	Bedrock altitude	Meters
errbed	Bed topography/ice thickness error	Meters
geoid	Geoid height above WGS84 Ellipsoid	Meters
surface	Ice surface elevation	Meters
thickness	Ice thickness	Meters
mask	Ice/ocean/land mask	none
Source	Mass Conservation/kriging	none

1.5.2 Sample Data Record

Figure 1 illustrates Greenland bedrock altitude and ice thickness.

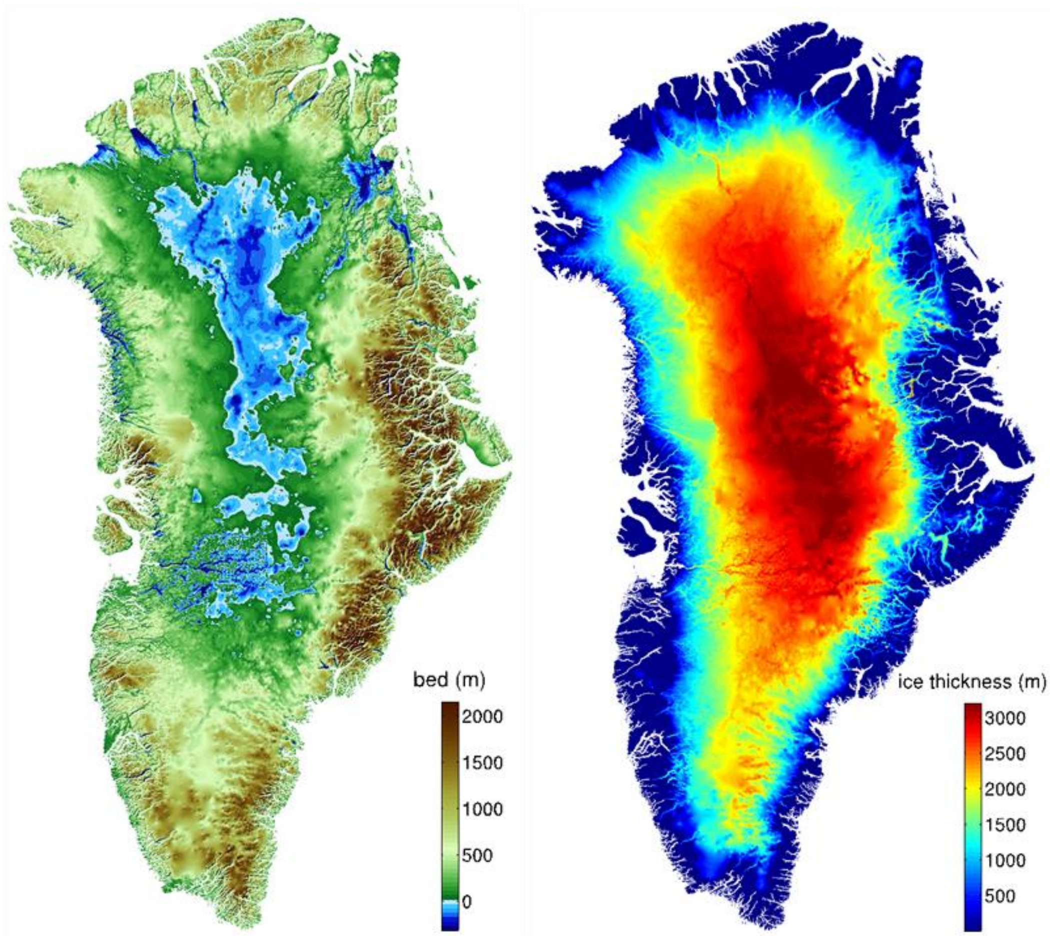

Figure 1. Greenland Bedrock Altitude and Ice Thickness

2 SOFTWARE AND TOOLS

2.1 Software and Tools

See the NetCDF Resources at NSIDC page for tools to work with netCDF files.

The netCDF data file is compatible with HDF5 libraries, and can be read by HDF readers such as HDFView. If the netCDF file reader you are using does not read the data, seehttp://www.unidata.ucar.edu/software/netcdf/ and http://nsidc.org/data/netcdf/tools.html for information on updating the reader.

2.2 Quality Assessment

An error estimate of the bed elevation and ice thickness is provided in the data set, illustrated in Figure 2.

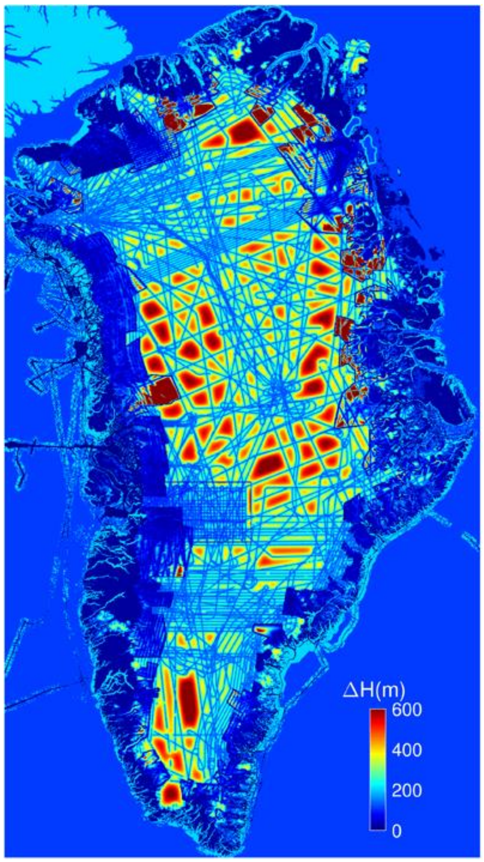

Figure 2. Error Estimate of Greenland Bed Elevation and Ice Thickness

3 DATA ACQUISITION AND PROCESSING

3.1 Data Acquisition Methods

Source data used in deriving this product include:

- Operation IceBridge radar-derived thickness data, posted at 15 m, with a vertical precision of 30 m, collected by the MCoRDS radar (https://nsidc.org/data/irmcr2/versions/1/documentation).

- Ice thickness data from the Doppler focused radar of the Technical University of Denmark (DTU) for the region of 79 North (Thomsen et al., 1997; Christensen et al., 2000) and Russell (Lindbäck et al., 2014).
- Ice velocity measurements derived from satellite radar data collected during 2008-2009, posted at 150 m, with errors of 10 m yr-1 in speed and 1.5Â° in flow direction (Rignot et al., 2012):
  - Japanese Advanced Land Observing System (ALOS) PALSAR
  - Canadian RADARSAT-1 SAR
  - German TerraSAR-X
  - European Envisat Advanced SAR (ASAR)

Ancillary products used include:

- Surface Mass Balance (SMB) averaged for the years 1961 to 1990 at 11 km posting with a precision between 7 percent and and 20 percent in the ablation zone (Ettema et al., 2009; data set available on request to the authors).
- Ice thickening rates combining satellite and airborne altimetry for the years 2003 to 2008, at a 0.1 degree posting, with a precision of 20 cm $yr^{-1.}$ (Schenk & Csatho, 2012).
- Surface elevation from the Greenland Mapping Project (GIMP) Digital Elevation Model (Howat et al., 2014; http://bpcrc.osu.edu/gdg/data/gimpdem).
- Ice and Ocean mask from the Greenland Mapping Project (GIMP) Digital Elevation Model (Howat et al., 2014; http://bpcrc.osu.edu/gdg/data/icemask).
- The International Bathymetric Chart of the Arctic Ocean (IBCAO) Version 3.0 (Jakobsson et al., 2012; http://www.ibcao.org/).

3.2 Derivation Techniques and Algorithms

Sparse, airborne, radar sounding-derived ice thickness data are combined with comprehensive, high-resolution, ice motion derived from satellite interferometric synthetic-aperture radar to calculate ice thickness based on Mass Conservation (MC). The MC method solves the mass conservation equation to derive ice thickness, while at the same time minimizing departure from the original radar-derived ice thickness data. The algorithm conserves mass fluxes while minimizing the departure from the original radar-derived ice thickness data. Ice surface motion provides a physical basis for extrapolating sparse ice thickness data to larger areas with few or no data. The method works best in areas of fast flow, where errors in flow direction are small and the glaciers slide on the bed. In the interior regions, where errors in flow direction are larger, kriging is used to interpolate ice thickness (Morlighem et al., 2014).

The algorithm neglects ice motion by internal shear, which is an excellent approximation for fast-flowing glaciers (>100 m yr-1) (Morlighem et al., 2014).

The bed topography is derived by subtracting the ice thickness from the Greenland Mapping Project (GIMP) Digital Elevation Model (http://bpcrc.osu.edu/gdg/data/gimpdem).

3.2.1 Version History

On May 19, 2015, the IceBridge BedMachine Greenland data were replaced by Version 2. Version 2 includes improved processing of some basins and adds some Operation IceBridge 2014 data. Heights are now provided with respect to mean sea level, instead of the WGS84 ellipsoid. The geoid is included in an additional field in the data.

3.2.2 Errors and Limitations

Sources of error include error in ice velocity direction and magnitude, error in surface mass balance and ice thinning rates.

In a trial setting with unusually dense radar sounding coverage, we report errors in the MC-inferred thickness of 36 m, only slightly higher than that of the original data. In areas less well constrained by radar-derived thickness data, or constrained by only one track of data, for example, in south Greenland, errors may exceed 50 m (Morlighem et al., 2013).

3.3 Sensor or Instrument Description

3.3.1 CReSIS Radar

The Center for Remote Sensing of Ice Sheets (CReSIS) Multichannel Coherent Radar Depth Sounder (MCoRDS) operates over a 180 to 210 MHz frequency range with multiple receivers developed for airborne sounding and imaging of ice sheets. See IceBridge MCoRDS L2 Ice Thickness for further information on the MCoRDS radar and the Level-2 data.

4 REFERENCES AND RELATED PUBLICATIONS

Christensen, E. L., et al. 2000. A low-cost glacier-mapping system, Journal of Glaciology, 46:531.

Ettema, J. et al. 2009. Higher surface mass balance of the Greenland Ice Sheet revealed by high-resolution climate modeling. Geophysical Research Letters, 36:1–5.

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.

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Schenk, T. and B. A. Csatho, B. 2012. A new methodology for detecting ice sheet surface elevation changes from laser altimetry data. IEEE Transactions on Geoscience and Remote Sensing, 50:3302–3316.

Thomsen, H., et al. 1997. The Nioghalvfjerdsfjorden glacier project, north-east Greenland: a study of ice sheet response to climatic change, Geology of Greenland Survey Bulletin, 179:95.

4.1 Related Data Collections

- IceBridge MCoRDS L2 Ice Thickness

4.2 Related Websites

- Ice Sheet Modeling Group, Department of Earth System Science, University of California Irvine (http://sites.uci.edu/morlighem/)
- Rignot Research Group, Department of Earth System Science, University of California Irvine (http://www.ess.uci.edu/group/erignot/projects/)

5 CONTACTS AND ACKNOWLEDGMENTS

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6 DOCUMENT INFORMATION

6.1 Publication Date