IceBridge BedMachine Greenland, Version 6

USER GUIDE

How to Cite These Data

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

Morlighem, M., Williams, C., Rignot, E., An, L., Arndt, J. E., Bamber, J., Catania, G., Chauché, N., Dowdeswell, J. A., Dorschel, B., Fenty, I., Hogan, K., Howat, I., Hubbard, A., Jakobsson, M., Jordan, T. M., Kjeldsen, K. K., Millan, R., Mayer, L., Mouginot, J., Noël, B., O'Cofaigh, C., Palmer, S. J., Rysgaard, S., Seroussi, H., Siegert, M. J., Slabon, P., Straneo, F., van den Broeke, M. R., Weinrebe, W., Wood, M., & Zinglersen, K. (2025). *IceBridge BedMachine Greenland* (IDBMG4, Version 6) [Data set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/6B6B225B8V2D [Date Accessed].

Literature Citation

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

Morlighem, M., Williams, C., Rignot, E., An, L., Arndt, J. E., Bamber, J., Catania, G., Chauché, N., Dowdeswell, J. A., Dorschel, B., Fenty, I., Hogan, K., Howat, I., Hubbard, A., Jakobsson, M., Jordan, T. M., Kjeldsen, K. K., Millan, R., Mayer, L., Mouginot, J., Noël, B., O'Cofaigh, C., Palmer, S. J., Rysgaard, S., Seroussi, H., Siegert, M. J., Slabon, P., Straneo, F., van den Broeke, M. R., Weinrebe, W., Wood, M., & Zinglersen, K. (2017). BedMachine v3: Complete bed topography and ocean bathymetry mapping of Greenland from multi-beam echo sounding combined with mass conservation. *Geophysical Research Letters*, *44*. https://doi.org/10.1002/2017GL074954

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

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

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1 DATA DESCRIPTION

1.1 Summary

This data set contains a bed topography and bathymetry map of Greenland based on mass conservation, multi-beam data, and other techniques. It also includes surface elevation and ice thickness data, as well as an ice/ocean/land mask.

1.2 File Information

1.2.1 Format

The data are provided as a single netCDF (`.nc`) file. The bed elevation parameter is also provided as a geoTIFF file (`.tif`).

1.2.2 File Contents

All parameters of the data set are detailed in Table 1.

Table 1. File Parameter Descriptions

Parameter	Description
`bed`	Bed elevation (bed topography) relative to the geoid (m)
`dataid`	Input data source ID: 1 = gimpdem, 2 = radar, 7 = seismic bathymetry, 10 = multibeam bathymetry
`errbed`	Bed topography/ice thickness error (m)
`geoid`	Height difference between the EIGEN-6C4 Geoid and WGS84 Ellipsoid (m)
`mapping`	WGS 84 / NSIDC Sea Ice Polar Stereographic North
`mask`	Mask: 0 = ocean; 1 = ice-free land; 2 = grounded ice; 3 = floating ice
`rgi`	Randolph Glacier Inventory (RGI) mask v7.0; 1 = inside RGI and 0 = outside RGI
`source`	Output data source ID: 0 = none; 1 = gimpdem; 2 = mass conservation; 3 = synthetic; 4 = interpolation; 5 = hydrostatic equilibrium; 6 = kriging; 7 = RTOPO-2; 8 = gravity inversion; 9 = IceBoost; 10+ = bathymetry data
`surface`	Ice surface elevation relative to the geoid (m)
`thickness`	Ice thickness (m)
`x`	Projection x coordinate (m)
`y`	Projection y coordinate (m)

1.2.3 Naming Convention

The netCDF data file is named `BedMachineGreenland-v6.nc` where "v6" refers to the version of the data set. The geoTIFF file is named `BedMachineGreenland_bed-v6.tif`.

1.2.4 Final Map Images

Figure 1 illustrates Greenland bed topography (m) with respect to mean sea level (left) and ice thickness (m) (right).

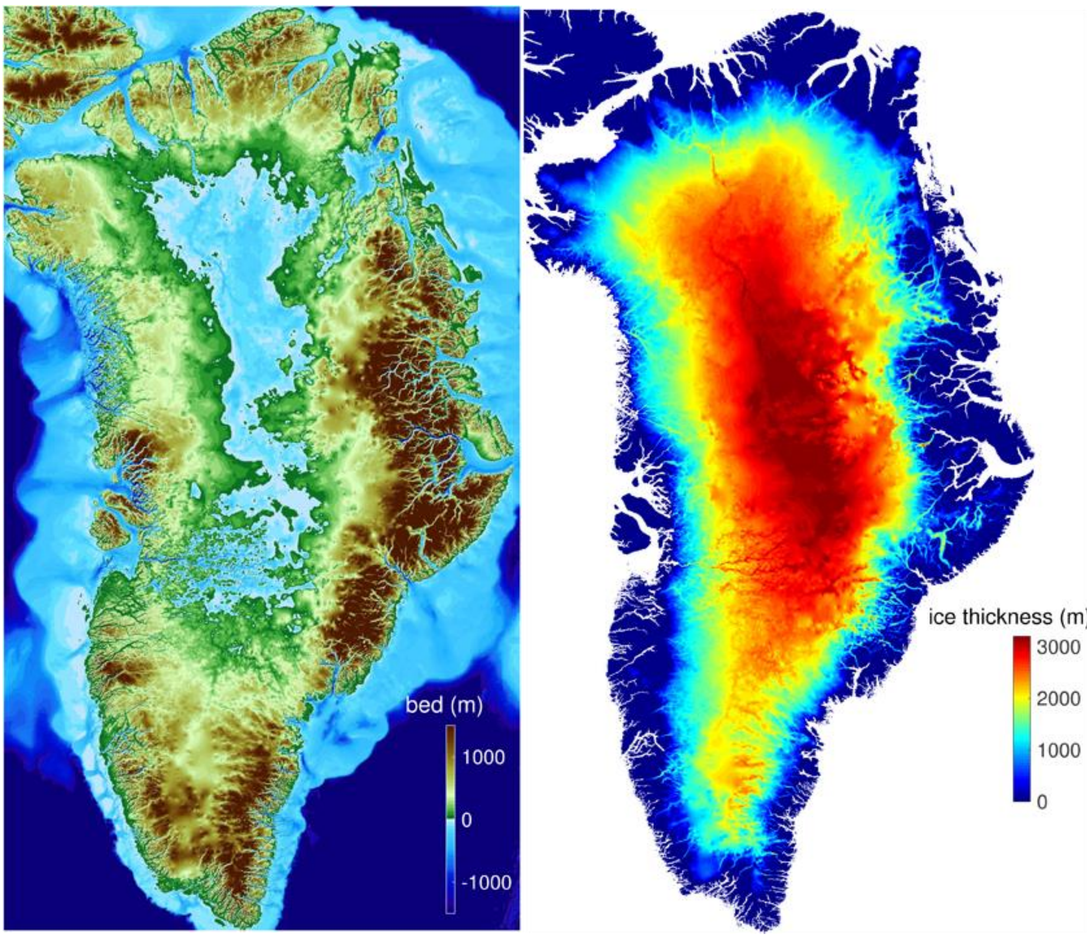

Figure 1. Greenland bed topography and ice thickness

1.3 Spatial Information

1.3.1 Coverage

Spatial coverage for this data set includes Greenland and portions of the Arctic.

Southernmost Latitude: 59° N

Northernmost Latitude: 84° N

Westernmost Longitude: 90° W

Easternmost Longitude: 9° E

1.3.2 Resolution

The output product is generated at a 150 m resolution. The true resolution varies between 150 m and 5 km.

1.3.3 Geolocation

WGS84 / NSIDC Sea Ice Polar Stereographic North (EPSG 3413)

1.4 Temporal Information

1.4.1 Coverage

The data were collected between 1 January 1993 and 31 December 2021. The nominal year of this data set is 2007.

1.4.2 Resolution

Not specified

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Bed topography and seafloor bathymetry regulate ice dynamics and water flow around Greenland, which impact glacier undercutting, calving, and movement. High-resolution mapping of subglacial features can improve understanding of ice-ocean interactions and ice sheet changes. Bed topography and ice thickness data are primarily collected by airborne radar sounders; however, the data quality is insufficient along coastal margins. Using multiple data sources and methods, along with the radar-derived ice thickness, optimizes mapping to provide a comprehensive bed topography and fjord bathymetry map of Greenland.

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, Version 1 for further information on the MCoRDS radar and the Level-2 data.

2.2 Acquisition

Source data used in deriving this product are listed below.

Table 2. Source Data

Type	Source
Ice thickness data	Operation IceBridge radar-derived, posted at 30–60 m, with a vertical precision of 30 m, collected by the MCoRDS radar (IceBridge MCoRDS L2 Ice Thickness)
	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)
	High CApability Radar Sounder (HiCARS; Peters et al., 2005; Peters et al., 2007) operated by the University of Texas, Institute for Geophysics
	Pathfinder Advanced Radar Ice Sounder (PARIS; Raney, 2010)
	Alfred Wegener Institute (AWI; Nixdorf et al., 1999)
	Uppsala University (UU; Lindbäck et al., 2014), collected in the vicinity of Russell Gletscher
	Millan et al. (2022) for ice caps
	IceBoost for periphery glaciers (Maffezzoli et al., 2025)
Sounding data	Multibeam echo sounding data from Oceans Melting Greenland (OMG 2016, 2017, and 2020 Missions) along the coast of West and Southeast Greenland
Bathymetry data	Oceans Melting Greenland (OMG 2021 Mission)
	Slabon et al. (2016) along the Northwest coast
	Weinrebe et al. (2009) in Torssukataq and Uummannaq Fjords
	O'Cofaigh et al. (2013) in Uummannaq Fjord
	Dowdeswell et al. (2014), Rignot et al. (2015), Fried et al. (2015), and Rignot et al. (2016) in Uummannaq Fjord
	Schumann et al. (2012), Holland et al. (2008) and Straneo et al. (2012) in Illulisat Icefjord
	Mix et al. (2015) in front of Petermann Fjord and the adjacent Hall Basin
	Sutherland et al. (2014) near Kangerdlussuaq
	Dowdeswell et al. (2016) in Nordvestfjord
	Chauché et al. (2014) near Lille Gletscher
	Straneo et al. (2016) in Sermilik fjord
	Motyka et al. (2017) in Godthåbsfjord
	Stevens et al. (2016) in Sarqardleq fjord

	Kjeldsen et al. (2017) in Timmiarmiut Fjord, Heimdal Glacier and Skjoldungen Fjord
	Rysgaard et al. (2003) in Young Sound fjord
	Bendtsen et al. (2017) near Flade Isblink Ice Cap
	Sutherland and Pickart (2008) on the continental shelf along the Southeast coast (single beam)
	Single-beam Olex and crowd sourced data from fishing and recreational vessels (MaxSea)
	An et al. (2019) along the Northwest Greenland coast
	Millan et al. (2018) and An et al. (2019) in Southeast Greenland
	An et al. (2021) in Northeast Greenland
	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, in front of the Northeast Ice Stream
	Danish Hydrographic Office
Radar data	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 1.5° in flow direction (Mouginot et al., 2017): • Japanese Advanced Land Observing System (ALOS) PALSAR • Canadian RADARSAT-1 SAR • German TerraSAR-X • European Envisat Advanced SAR (ASAR)
	Center for Remote Sensing of Ice Sheets (CReSIS) (2017)
	Hiawatha thickness (Kjaer et al., 2018)
	Programme for Monitoring of the Greenland Ice Sheet (PROMICE) (Søren et al., 2019)
	East Greenland Ice Core Project (EGRIP) thickness (Franke et al., 2020)
	Northeast Greenland Ice Stream (NEGIS) thickness (Jansen et al., 2020)
Ancillary data	Surface Mass Balance (SMB) averaged for the years 1961 to 1990 downscaled to 1 km with a precision between 7 percent and 20 percent in the ablation zone (Noël et al., 2016; data set available from the authors upon request)
	Ice thickening rates from altimetry data differencing between the years 2003 and 2006 (Khan et al., 2014)
	Surface elevation from the Greenland Mapping Project (GIMP) Digital Elevation Model (Howat et al., 2014)
	Ice and Ocean mask from the Greenland Mapping Project (GIMP) Digital Elevation Model (Howat et al., 2014)
	RTopo-2 (Schaffer et al., 2016)

2.3 Processing

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. The mass conservation method solves the mass conservation equation to derive ice thickness 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 the flow direction are small and glaciers slide on the bed. In the interior regions, where errors in the flow direction are larger, kriging is used to interpolate ice thickness for the 1993–2016 data (Morlighem et al., 2014). Beginning with the 2017 data, streamline diffusion was used in the interior regions instead of kriging.

Ocean bathymetry is mapped by combining sparse bathymetry measurements from single and multibeam measurements and casts and RTopo-2 (Schaffer et al., 2016).

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.

2.4 Quality, 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, errors in the mass-conservation-inferred thickness were 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).

No or very little data were available for some fjords, and uncertainty may be high (>500 m).

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

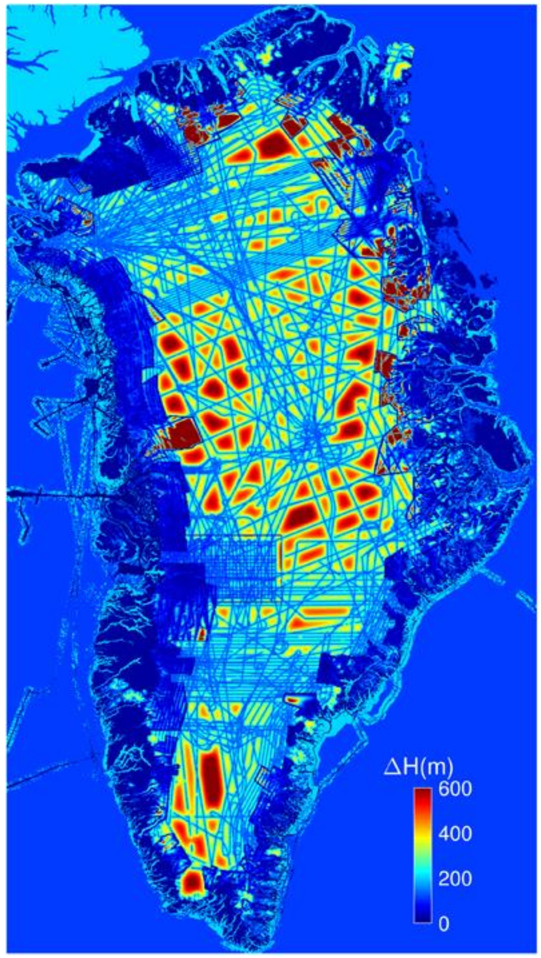

Figure 2. Error Estimate of Greenland Bed Elevation and Ice Thickness

3 VERSION HISTORY

Table 3. Version History Summary

Version	Date	Description of Changes
6.0	11 Dec 2025	• Generated ensemble of bed topography maps using ICESat-2 time series and used the median depth instead of a single estimate for some glaciers • Used ice thickness estimates from IceBoost for periphery glaciers (Maffezzoli et al., 2025) • Added a new field 'RGI' that indicates which pixel belongs to a glacier in the Randolph Glacier Inventory • Added bathymetry data from the Danish Hydrographic Office • Updated bathymetry of Petermann based on Ciraci et al. (2023) gravity inversion
5.0	6 Sep 2022	Added bathymetry measurements from the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, in front of the Northeast Ice Stream, ice thickness for ice caps from Millan et al. (2022), and bathymetry data from the 2021 OMG campaign. A geoTIFF file of bed elevation was also added.
4.0	13 May 2021	Incorporated updated radar data to better constrain the ice thickness inland. Multibeam data for ocean bathymetry were updated to include data from 2017 and 2020 OMG campaigns. Bathymetry data were added from new gravity inversions. The format of surface, bed, and thickness was changed to “single”. Streamline diffusion was implemented in the interior regions instead of kriging beginning January 2017.
3.0	25 Sep 2017	Added ocean bathymetry all around Greenland based on data from NASA’s Ocean Melting Greenland (OMG) and other campaigns of bathymetry measurements. The subglacial bed topography was also updated by including more ice thickness data and constraining the ice thickness at the ice/ocean interface based on bathymetry data when available.
2.0	19 May 2015	Improved processing of some basins and added Operation IceBridge 2014 data. Heights were provided with respect to mean sea level, instead of the WGS84 ellipsoid. The geoid was included in an additional field in the data.
1.0	13 Jan 2015	Initial release

4 ACKNOWLEDGMENTS

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6 DOCUMENT INFORMATION

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6.2 Date Last Updated

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