



IceBridge Gravimeter L4 Bathymetry, Version 1

USER GUIDE

How to Cite These Data

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

Tinto, K., Bell, R. E., & Cochran, J. R. (2014). *IceBridge Gravimeter L4 Bathymetry* (IGBTH4, Version 1) [Data set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. <https://doi.org/10.5067/DQVUVQCRYAM4> [Date Accessed].

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FOR CURRENT INFORMATION, VISIT <https://nsidc.org/data/IGBTH4>

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1 DATA DESCRIPTION

1.1 Summary

This data set contains bathymetry of Arctic fjords and Antarctic ice shelves based on measurements from IceBridge Sander AIRGrav L1B Geolocated Free Air Gravity Anomalies (IGGRV1B) and IceBridge LDEO Gravimeter Suite L1B Geolocated Free Air Gravity Anomalies (IGLGS1B). The data were collected as part of Operation IceBridge funded aircraft survey campaigns.

1.2 File Contents

1.2.1 Format

The data files are in CSV format.

1.2.2 File Naming Convention

The data files have the naming convention shown below. File name variables are described in Table 1.

IGBTH4_[region]_[YYYYMMDD]_v1.csv

Examples:

IGBTH4_Abbot_20141008_v1.csv

IGBTH4_Venable_20241127_v1.csv

Table 1. Bathymetry Profile Data File Naming Convention

Variable	Description
IGBTH4	IceBridge Gravimeter L4 Bathymetry data product
region	Study region
YYYYMMDD	Four-digit year, two-digit month, and two-digit day of data production date
v1	Version 1

1.3 Spatial Information

1.3.1 Spatial Coverage

Spatial coverage includes the Arctic and Antarctic areas listed below.

Arctic:

Northernmost Latitude: 83° N

Southernmost Latitude: 61° N

Westernmost Longitude: 70° W

Easternmost Longitude: 17° W

Antarctic:

Northernmost Latitude: 65° S

Southernmost Latitude: 75° S

Westernmost Longitude: 135° W

Easternmost Longitude: 155° E

1.3.2 Spatial Resolution

For Greenland data, fjords are commonly represented by a single profile with points at 500 m intervals. The along-track resolution of inverted gravity is ~4.4 km, corresponding to the 70 s filter and average survey speed of 125 m/s. Shorter wavelength features are from the radar-derived bed used to constrain the model. Profile lines approximate the fjord axis, but in parts were flown to the side of the midline and show shallower bathymetry corresponding to the fjord edges. Users are cautioned to check the flight track of profile data in order not to misinterpret this shallow bathymetry as an axial sill.

The northwest Greenland grid was flown at 5 km line spacing, with an average speed of 125 m/s giving an along-track resolution of 4.4 km. Data were gridded at 500 m cell size for inversion and then resampled along the flight lines.

The survey over Abbot Ice Shelf was flown as a series of nearly north-south parallel lines, 30 to 54 km apart (mean of 39.2 km), across the ice shelf and a single, nearly east-west line along the ice shelf axis. Free-air anomalies were filtered with a 70 s full wavelength filter, resulting in approximately 4.9 km half-wavelength resolution for a typical flying speed of 140 m/s (Cochran et al. 2014).

The survey over the Cook Ice Shelf and Ninnis Glacier Tongue was flown as a series of four east-west trending parallel lines ~10–50 km apart across the ice shelf and glacier tongue and six north-south trending parallel tie lies ~10–30 km along Cook Ice Shelf. Free-air anomalies were collected on an iMAR iNAV-RQH-0018-GUG IMU strapdown gravimeter, providing half-wavelength resolutions of ~5 km or more. The Cook Ice Shelf and Ninnis Glacier Tongue gridding has 1 km spacing.

The survey over the Venable Ice Shelf (and eastern Abbot Ice Shelf) was flown as a series of six east-west trending parallel lines ~10 km apart across the ice shelf and two north-south trending parallel tie lines ~20 km along the eastern portion of the Abbot Ice Shelf. Free-air anomalies were filtered with a 70-second full wavelength filter, providing a ~5 km half-wavelength resolution at typical aircraft operating speeds (~140 m/s) (Cochran et al., 2014). The Venable gridding has 500 m spacing.

1.3.3 Geolocation

X/Y coordinates: WGS 84 / Antarctic Polar Stereographic (EPSG 3031)

X/Y coordinates: WGS 84 / NSIDC Sea Ice Polar Stereographic North (EPSG 3413)

LAT/LON: WGS 84 (EPSG 4326)

Temporal Information

1.4.1 Temporal Coverage

The data collection spans 1 January 2010 to 19 November 2019 (see Table A – 1).

1.4.2 Temporal Resolution

IceBridge campaigns were conducted annually. Arctic and Greenland campaigns were conducted during March, April, and May; and Antarctic campaigns were conducted during October and November.

1.5 Parameters

The data set contains profile lines, location in Polar Stereographic easting and northing, and bathymetry measured positively downwards. The bathymetry profile data file contains fields as described in Table 2.

Table 2. Parameter Descriptions and Units

Column	Name	Description
1	#LINE	Line numbers of individual profiles; the format differs by data production date (see Table A - 1) as follows: Greenland (Production 7 Feb 2014) Format: XX.YYZ, where XX = Individual Glacier ID, YY = Year of flight, and Z = Repeat tracks (see Figure 1 and Table 3) Abbot (Production 8 Oct 2014) Format: abbotXX, where XX = line number

Column	Name	Description
		<p>Greenland (Production 26 Jan 2015) Values: 1-6</p> <p>Getz (Production 16 Mar 2018) Format: lineXXX, where XXX is numeric or alphanumeric (e.g., lineC3, line51)</p> <p>George VI (Production 21 Aug 2020) Format: crossing_profile_X, ITGC_X, or Tie_line, where X is the survey line number</p> <p>Cook and Ninnis (Production 15 Jun 2023) Format: Profile_XX, where XX is the survey line ID (A-G2) or Tie line number (T1-T6)</p> <p>Venable (Production 27 Nov 2024) Format: DX or TX, where DX is survey line number or TX = Tie line number</p>
2	FAG070_mGal	Observed free air gravity anomaly (mGal)
3	FAG_calc_mGal	Calculated free air gravity anomaly (mGal)
4	LON	Longitude on WGS84 ellipsoid (degrees)
5	LAT	Latitude on WGS84 ellipsoid (degrees)
6	X	EPSG 3413 X Coordinate (meters)
7	Y	EPSG 3413 Y Coordinate (meters)
8	BATHY_m	Modeled bathymetry from gravity inversion: positive down, with respect to WGS-84 ellipsoid (meters)

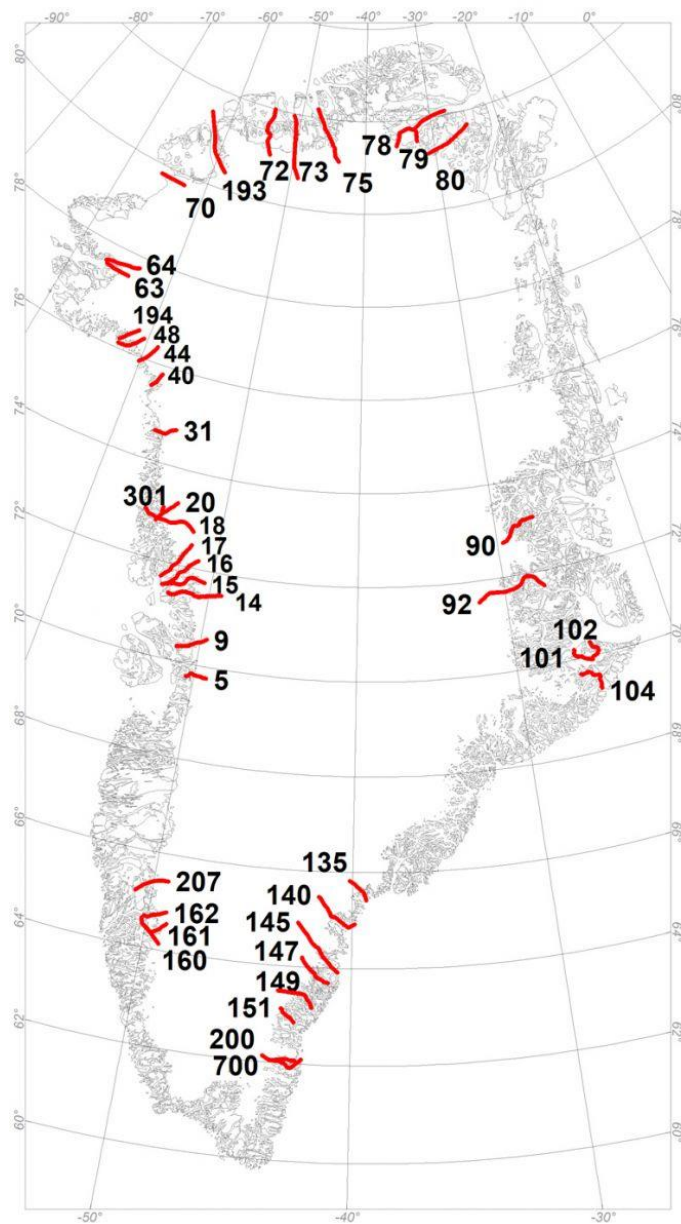


Figure 1. Greenland Glacier IDs

Table 3 lists the profiled Glacier IDs and names.

Table 3. Glacier IDs and Names

ID	Name	ID	Name
5	Eqip Sermia	90	Morell Gletscher
9	Store Gletscher	92	Daugaard-Jensen
14	Kangerlussuup Sermersua	101	Sydbrae
15	Rink Isbrae	102	Bredegletscher
16	Umiammakku Isbrae	104	Dendritgletscher
17	Inngia Isbrae	135	Ikertivaq N

ID	Name	ID	Name
18	Upernavik isstrom S	140	Koge Bugt C
20	Unnamed near Upernavik	145	Graulv
31	Alison Glacier	147	A.P. Bernstorff Gletscher
40	Sverdrup Glacier	149	Skinfaxe
44	Kong Oscar Glacier	151	Heimdal Gletscher
48	Rink Gletscher	160	Kangiata Nunaata Sermia
63	Heilprin Gletscher	161	Akullersuup Sermia
64	Tracy Gletscher	162	Narsap Sermia
70	Humboldt Glacier	193	Petermann Gletscher
72	Steensby Gletscher	194	Docker Smith Gl. W
73	Ryder Gletscher	200	Puisortoq N
75	C. H. Ostenfeld Gletscher	207	Nordenskiaeld Gletscher
78	Marie Sophie Gletscher	301	Unnamed near Upernavik
79	Academy Gletscher	700	Puisortoq S
80	Hagen brae		—

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Much of the global bathymetry used by the science community is a gravity-based bathymetric model. The IceBridge gravity data, along with the other data, provide a basis for building new bathymetry and sub-ice topography models. Notably, these data can recover water depth in fjords or under floating ice where radar cannot penetrate.

2.2 Instrument Description

2.2.1 AIRGrav

Sander AIRGrav is designed for airborne applications. The AIRGrav system consists of a three-axis gyro-stabilized, Schuler-tuned inertial platform on which three orthogonal accelerometers are mounted. The primary gravity sensor is the vertical accelerometer that is held within 10 arc-seconds (0.0028 degree) of the local vertical by the inertial platform, monitored through the complex interaction of gyroscopes and two horizontal accelerometers (Sander et al., 2004).

An advantage of the AIRGrav system over other airborne gravimeters is that it has been shown to be capable of collecting high-quality data during draped flights (Studinger et al., 2008). The gravimeter records accelerations arising from variations in the Earth's gravity field and

accelerations experienced by the airplane. These accelerations are recorded at 128 Hz. Aircraft accelerations are obtained utilizing differential GPS measurements.

2.2.2 LGS

The Lamont-Doherty Earth Observatory (LDEO) Gravimeter Suite (LGS) includes two complementary systems that are deployable separately or together. The first system is a two-axis stabilized, thermally-controlled, force feedback gravimeter by Dynamic Gravity Systems, a next-generation version of the Lacoste & Romberg airborne meter. The second system is a strap-down gravimeter by iMAR, capable of recovering free-air gravity anomalies during draped and turbulent flight conditions.

2.3 Theory of Measurements

The gravity signal is extracted from an inertially based system in which a small mass is suspended within a magnetic field. Tiny variations in the acceleration of the gravimeter produce small electrical signals in the sensor as the mass moves within the magnetic field. The processed data from the instrument data consists of two data types: gravity and aircraft attitude.

2.4 Acquisition

The gravimeter is located as near the airplane center of mass as possible. Simultaneously acquired gravimeter output GPS data are recorded on hard disks on the plane. Following the flight, this data is downloaded onto a PC for processing.

2.5 Processing

For all bathymetry data:

1. The gravimeter data were filtered and decimated to 10 Hz to match the GPS data.
2. GPS-derived accelerations were subtracted from the data.
3. The gravity was corrected for the Eötvös effect.
4. The expected gravity at the measurement latitude was subtracted.
5. The resulting anomalies were decimated to 2 Hz and low-pass filtered to suppress noise.
6. The free-air correction was applied.
7. After evaluating the noise level with different filter lengths, a 70 s filter was used. The filter half-wavelength is approximately 5 km at the average flight speed of 275 knots (142 m/s). Features narrower than ~ 5 km can be resolved but have an attenuated amplitude.
8. Horizontal accelerations associated with turns and other vigorous maneuvers disturb gravity measurements. A routine that examines horizontal accelerations was used to divide each flight into lines that are free of these perturbations.

For the Greenland Fjord (Boghosian et al., 2015), Abbot Ice Shelf (Cochran et al., 2014), Cook and Ninnis (Constantino and Tinto, 2023), and Venable data (Locke et al., 2025):

1. Ice surface and ice base were taken from the NASA Airborne Topographic Mapper (ATM) and the CReSIS Multichannel Coherent Radar Depth Sounder (MCoRDS). A forward model of gravity using Geosoft GMSys was generated with ice density of 0.915 g/cc, water density of 1.028 g/cc, and rock density of 2.67 g/cc.
2. The model was pinned at a point where ice was grounded and nearby gravity variations were due only to variations in topography of the ice/rock interface. This establishes a direct current (DC) shift to relate the anomalies calculated for the model space to the anomalies measured on Earth. Where multiple lines were flown along approximately the same track, the same DC shift was applied.
3. A gravity inversion was performed on the water/rock interface under floating ice in two dimensions along individual flight lines using Geosoft GMSys. The software performs iterative forward modeling using the technique of Talwani et al. (1959), producing a model of the sub-ice shelf bathymetry responsible for the gravity anomaly.

For the Northwest Greenland data:

1. Data from survey lines were gridded by minimum curvature gridding with cell size of 500 m.
2. Gravity data were upward continued from survey elevation to a constant elevation of 2000 m above the ellipsoid.
3. A forward gravity model was built based on gridded data sets of surface, bed topography, and seafloor bathymetry (Bamber et al., 2013). A DC shift was established to match gravity values calculated within the model space to observed values. The value of the DC shift was established from the mean misfit between calculated and observed gravity over large islands and peninsulas along the coast.
4. The observed gravity was inverted for bathymetry in the software GMSys-3D, with algorithms based on Parker (1972).

2.6 Quality, Errors, and Limitations

Errors range from ± 50 m to ± 200 m in the Greenland data sets. The variability in uncertainty is largely due to profile length, with uncertainty increasing with distance from the pinning point usually near the grounding line. The main sources of error are from short-wavelength features, which are not modelled at full amplitude, and from the presence of either local variations in geology or long-wavelength regional geological variations. These have been accounted for in some cases, notably Petermann Glacier, where a regional correction to the observed gravity was applied to fit known bathymetric constraints at the end of the fjord. Elsewhere, bathymetry inversion is not performed on gravity recovered from parts of fjords where magnetic anomalies indicate a significant change in rock type compared to the material at the point to which the model is pinned.

Errors are approximated as ± 70 m for the Abbot and Venable data sets, incorporating errors in gravity measurement, radar ice thickness, ATM surface elevation, 2-D model pinning point and

some allowance for geological structures. Variations in bed density were incorporated utilizing rock outcrops as a guide. The model assumes the absence of sea floor sediments. If sea floor sediments are present, then the true bathymetry will be less deep than the model.

For the Cook and Ninnis data, the total uncertainty ranges from ± 69 to ± 123 m. The uncertainty due to the gravimeter accuracy is estimated by calculating the standard error of the differences between gravity measurements at the crossover points between lines within the survey. The uncertainty from variations in geology is estimated by the Root Mean Square Error (RMSE) of the gravity residuals where topography is known from radar.

3 VERSION HISTORY

Table 4. Version History Summary

Version	Date	Description of Changes
1.1	30 Mar 2026	Added data for Venable Ice Shelf, Cook Ice Shelf, and Ninnis Glacier Tongue. Changed data set title from "IceBridge Sander AIRGrav L4 Bathymetry" to "IceBridge Gravimeter L4 Bathymetry".
1.1	11 Feb 2015	Version 1 was replaced by Version 1.1. The precision for latitude and longitude values in data file IGBTH4_20140207.csv was increased to six decimal places.
1.0	22 Oct 2014	Initial release

4 RELATED DATA SETS

IceBridge Gravimeter L3 Bathymetry (IGBTH3)

IceBridge Sander AIRGrav L1B Geolocated Free Air Gravity Anomalies (IGGRV1B)

IceBridge LDEO Gravimeter Suite L1B Geolocated Free Air Gravity Anomalies (IGLGS1B)

5 REFERENCES

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Boghosian, A., Tinto, K., Cochran, J. R., Porter, D., Elieff, S., Burton, B. L., & Bell, R. E. (2015). Resolving bathymetry from airborne gravity along Greenland fjords. *JGR Solid Earth*, 120(12), 8516–8533. <https://doi.org/10.1002/2015JB012129>

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Cochran, J. R., Tinto, K. J., & Bell, R. E. (2020). Detailed Bathymetry of the Continental Shelf Beneath the Getz Ice Shelf, West Antarctica. *JGR Earth Surface*, 125(10).

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Constantino, R. R., & Tinto, K. J. (2023). Cook Ice Shelf and Ninnis Glacier Tongue Bathymetry From Inversion of Operation Ice Bridge Airborne Gravity Data. *Geophysical Research Letters*, 50(11). <https://doi.org/10.1029/2023GL103815>

Constantino, R. R., Tinto, K. J., Bell, R. E., Porter, D. F., & Jordan, T. A. (2020). Seafloor Depth of George VI Sound, Antarctic Peninsula, From Inversion of Aerogravity Data. *Geophysical Research Letters*, 47(21). <https://doi.org/10.1029/2020GL088654>

Locke, C. D., Tinto, K. J., Porter, D. F., & Constantino, R. R. (2025). Novel Record of Intermittent Grounding of the Venable Ice Shelf Since 1935 From Operation IceBridge Airborne-Gravity-Derived Bathymetry and Landsat Imagery. *Geophysical Research Letters*, 52(9).

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Tinto, K. J., Bell, R. E., Cochran, J. R., & Münchow, A. (2015). Bathymetry in Petermann fjord from Operation IceBridge aerogravity. *Earth and Planetary Science Letters*, 422, 58–66.

<https://doi.org/10.1016/j.epsl.2015.04.009>

6 DOCUMENT INFORMATION

6.1 Publication Date

October 2014

6.2 Date Last Updated

March 2026

APPENDIX A – COLLECTION DETAILS

Table A - 1. Region, Production Date, Flights, Temporal Coverage, Source Gravity Data, and Associated Publication for Each Data Collection

Region	Production Date	Data Collection (Flight Dates)	Temporal Coverage	Source Gravity Data	Publication
Greenland	7 Feb 2014	2010/03/24 2010/03/30 2010/04/02 2010/05/08 2010/05/13 2010/05/17 2010/05/19 2010/05/20 2010/05/21 2010/05/25 2010/05/26 2011/03/29 2011/03/31 2011/04/08 2011/04/11 2011/04/19 2011/04/25 2011/04/26 2011/05/02 2011/05/07 2011/05/09 2011/05/11 2011/05/13 2011/05/16 2012/03/27 2012/04/11 2012/04/12 2012/04/17 2012/04/21 2012/04/28 2012/05/03 2012/05/10 2012/05/11 2012/05/15 2012/05/14	Mar 2010 – May 2012	IGGRV1B	Boghosian et al. (2015)
Antarctica (Abbot)	8 Oct 2014	2009/11/09 2009/11/12 2014/11/05	Nov 2009 – Nov 2014	IGGRV1B	Cochran et al. (2014)
Greenland	26 Jan 2015	2010/05/20 2010/05/21 2012/05/09	May 2010 – May 2012	IGGRV1B	Tinto et al. (2015)
Antarctica (Getz)	16 Mar 2018	2009/10/16 2010/11/05 2011/10/17 2011/11/03 2012/10/27 2016/10/20 2016/10/20 2016/11/05	Oct 2009 – Nov 2016	IGGRV1B	Cochran et al. (2020)

Region	Production Date	Data Collection (Flight Dates)	Temporal Coverage	Source Gravity Data	Publication
Antarctica (George VI)	21 Aug 2020	2011/10/24 2011/11/16 2011/11/19 2016/10/14 2019/02/07 ¹	Oct 2011 – Oct 2016 (Operation IceBridge) Oct 2019 (ITGC)	IGGRV1B and BAS processed line aerogravity data over the Thwaites Glacier region (2018/19 season)	Constantino et al. (2020)
Antarctica (Cook, Ninnis)	14 Jun 2023	2019/11/04 2019/11/05 2019/11/07 2019/11/19	Nov 2019	IGLGS1B	Constantino and Tinto (2023)
Antarctica (Venable)	27 Nov 2024	2017/11/16 2017/11/25	Nov 2017	IGGRV1B	Locke et al. (2025)

¹ 2019 flight is from the International Thwaites Glacier Collaboration (ITGC) aerogeophysical survey.