MEaSUREs ITS_LIVE Antarctic Grounded Ice Sheet Elevation Change, Version 1

USER GUIDE

How to Cite These Data

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

Nilsson, J., A.S. Gardner, and F.S. Paolo. 2023. *MEaSUREs ITS_LIVE Antarctic Grounded Ice Sheet Elevation Change, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/L3LSVDZS15ZV. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/NSIDC-0782

National Snow and Ice Data Center

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1 DATA DESCRIPTION

This data product contains monthly ice sheet elevation change data for Antarctica derived from five radar altimetry missions (Geosat, ERS-1 and -2, Envisat and CryoSat-2) and two laser altimetry missions (ICESat and ICESat-2). Each time step and grid node includes relative error estimates and a quality flag that can be used to filter the data in space and time. The product is also provided with an estimate of static topography in the form of a digital elevation model (DEM), which was used to estimate monthly ice sheet elevation change. With a temporal coverage of 17 April 1985 to 16 December 2020, this product can be used to determine changes in ice sheet mass balance over time.

1.1 Parameters

This product includes parameters for ice sheet height (static topography), monthly ice sheet height change, and root mean squared error of monthly ice sheet height change. Static topography comes from the European Space Agency Copernicus 30-meter global Digital Elevation Model (ESA COP DEM GLO30 DGED). This DEM product is used to estimate the primary parameter in the data set, the change in ice sheet elevation, which is provided on a monthly time step. The root mean squared error of ice sheet height change is also provided on a monthly time step.

1.2 File Information

1.2.1 Format

This data set is provided in Network Common Data (NetCDF4) (`.nc`) format using CF-1.6 conventions.

1.2.2 File Contents

The data set includes one NetCDF4 file, `ANT_G1920_GroundedIceHeight_v01.nc`, which contains the variables described in Table 1.

Table 1. Variable Names and Descriptions

Variable	Description	Units
glacier_basin	Ice sheet basin id, adapted from MEaSUREs Antarctic Boundaries for IPY 2007-2009 from Satellite Radar, Version 2	N/A
height	Estimate of static topography from ESA COP DEM GLO30 DGED from 2010-2015 filled with NASADEM data, resampled to the ITS_LIVE grid using a box filter	m
height_change	Change in ice sheet elevation since the nominal center reference date of 2013-12-16	m
height_change_rmse	Root mean squared error of ice sheet elevation change	m
mapping	Coordinate reference system details	N/A
quality_flag	Metric of data quality 0 - No data 1 - High quality data 2 - Low quality data 3 - Pole hole	N/A
time	Time in days since 1950-01-01	days
x	Cartesian x coordinate	m
y	Cartesian y coordinate	m

1.3 Spatial Information

1.3.1 Coverage

These data span the entire polar region southwards of 60 S.

1.3.2 Resolution

1920 m

1.3.3 Geolocation

Table 2 provides information for geolocating this data set.

Table 2. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84 / Antarctic Polar Stereographic
Longitude of true origin	0
Latitude of true origin	-71
Scale factor at longitude of true origin	1
Datum	WGS_1984
Ellipsoid/spheroid	WGS 84
Units	meter
False easting	0
False northing	0
EPSG code	3031
PROJ4 string	+proj=stere +lat_0=-90 +lat_ts=-71 +lon_0=0 +x_0 =0 +y_0=0 +datum=WGS84 +units=m +no_defs
Reference	https://epsg.io/3031

1.4 Temporal Information

1.4.1 Coverage

17 April 1985 to 16 December 2020

1.4.2 Resolution

Monthly

2 DATA ACQUISITION AND PROCESSING

2.1 Acquisition

Data was acquired from Geosat, ERS-1 and -2, Envisat, and CryoSat-2 radar altimetry missions and ICESat and ICESat-2 laser altimetry missions. For each mission, altimetry data was collected in the form of Level-2 (L2) geophysically corrected data, with the exception of CryoSat-2 which was collected at Level-1b (L1b) and processed to L2. The spatial and temporal coverage of each satellite altimetry mission is shown in Figure 1.

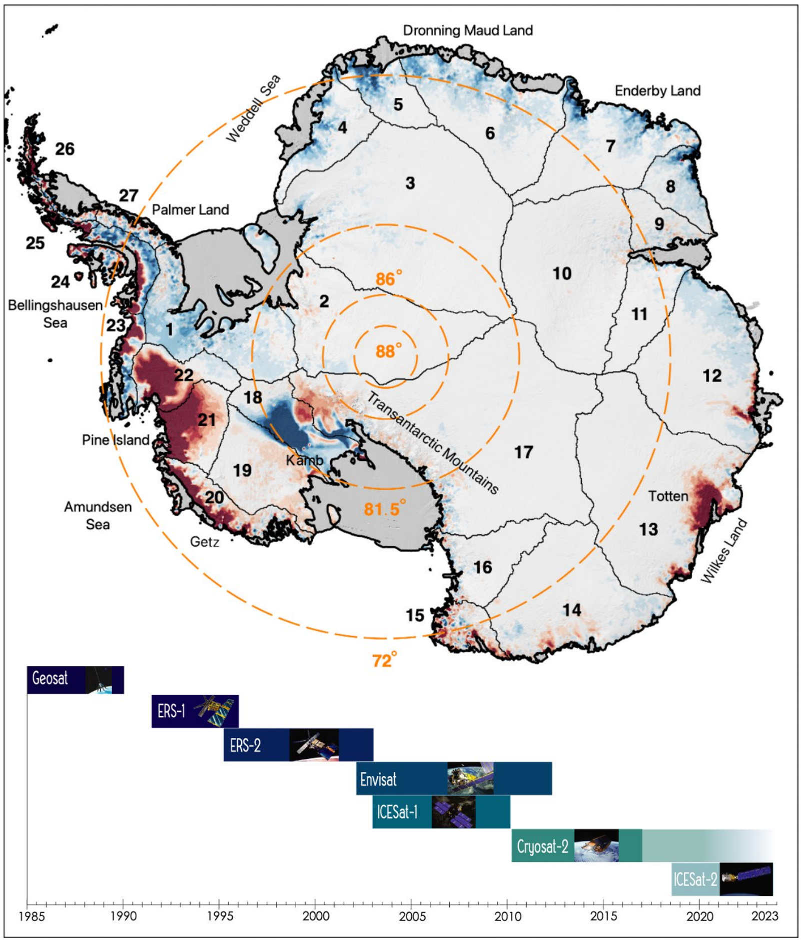

Figure 1. Spatial and temporal coverage of the seven satellite altimetry missions used to produce the elevation change data. Concentric dashed circles and labels (orange) indicate orbital limits of each mission (Geosat 72º; ERS-1 and -2, and Envisat 81.5º; ICESat 86º; and CryoSat-2 and ICESat-2 88º), and are plotted over elevation change rates (1992–2020), with blue indicating positive and red negative changes in elevation. Source: Nilsson et al. 2021.

2.2 Processing

The processing steps undertaken to generate the monthly ice sheet elevation change data are outlined below. They are discussed in further detail in Nilsson et al. 2021.

2.2.1 Imagery Selection and Corrections

Data products were selected and corrected in order to minimize error. Radar altimeters are sensitive to surface properties that can lead to biases in surface elevation measurements. In the case of ice sheets this includes snow grain size, temperature, density, and water content. To account for this, radar altimetry data is generally provided with corrections via waveform retracking, a postprocessing technique used to remove erroneous measurements. Radar altimetry data was selected to include these retracking corrections. Laser altimeters are not sensitive to these properties and thus did not require retracking. Quality flags were also used to filter data when available.

2.2.1.1 GEOSAT

The Geosat data came from the “ice data record” (IDR) of the Radar Ice Altimetry Group at NASA Goddard Space Flight Center (GSFC), which provides geolocated and corrected surface elevations. To mitigate noise in derived surface elevations, only records with a valid retracking correction and waveforms containing a single return echo were used.

2.2.1.2 ERS-1 and ERS-2

For ERS-1 and -2 data, the REprocessing of Altimeter Products for ERS (REAPER) product was used. The data were separated for the “ocean” and “ice” operational modes for each satellite record. The REAPER product provides different retracking solutions and this data set uses the ICE1 retracker, also known as the “offset center of gravity” (OCOG) retracker, with a 30% threshold of the maximum waveform amplitude. Poor quality observations were excluded from the analysis using the product’s Ku-chirp and ICE-1 quality flags.

2.2.1.3 Envisat

Envisat data came from the RA-2 Geophysical Data Record (GDR) version 2.1. Due to changes in Envisat orbit introduced in October 2010 that impede ice sheet elevation calculations, only data collected from 2002-2010 was used. As with the REAPER product, the GDR product provides data using the ICE1 retracker with a 30% threshold of maximum waveform amplitude. As with the ERS-1 and -2 data, poor quality observations were excluded from the analysis using the product’s Ku-chirp and ICE-1 quality flags.

2.2.1.4 CryoSat-2

CryoSat-2 data came from the mission’s altimeter system, SIRAL, which operates in two modes over ice sheets: a synthetic aperture radar interferometric (SARIn) mode over the marginal areas and a low-resolution mode (LRM) over the ice sheet interiors. The data was processed using the ESA L1b Baseline-C product for 2010–2018. For the LRM mode, a 10% threshold of the maximum waveform amplitude was used for retracking.

2.2.1.5 ICESat and ICESat-2

ICESat data came from the GLAS06 product (release 34). Poor quality observations were excluded using quality flags. For ICESat-2, surface elevation from the ATL06 product was used. Poor quality observations were removed with the ATL06 quality flag as well as a segmentation filter, rejecting points with differences between consecutive points exceeding a threshold of 2 m.

2.2.2 Slope Error Corrections

A slope-dependent measurement error, on the order of 0-100 m depending on surface slope magnitude, is present in radar altimetry over ice sheets. This error was corrected for using an ancillary elevation model. This error is not present in the laser altimetry data.

2.2.3 Elevation Change Estimation

2.2.3.1 Remove static topography

The static topography was removed for each satellite mission and operating mode. This was done by fitting a mathematical surface using least squares to the topography. This approach required the implementation of various methods to account for differences in orbital geometry of missions, ascending versus descending range estimates, and measurement density.

2.2.3.2 Correct radar altimetry data for temporal and spatial characteristics

The radar altimetry data required corrections for several temporal and spatial characteristics that affect surface properties. As laser data is not sensitive to surface properties, these corrections were only performed on the radar altimetry data. Firstly, as radar altimeters are sensitive to ice sheet surface properties, a retracking algorithm was applied to all radar altimetry data to remove elevation variability that was correlated with changes in the received radar waveform shape. This algorithm was in addition to the retracking algorithms applied to data from each individual sensor as outlined in 2.2.1. Secondly, a radar signal's interaction with the surface and subsurface layers can result in artificially large seasonal amplitudes and trends. This effect was addressed by using information from the waveform parameters and normalizing the seasonal amplitudes to CryoSat-2 data, as this mission is less sensitive to seasonal amplitude changes.

2.2.3.3 Integrate missions and modes

A cross-calibration scheme was applied to merge elevation changes from all satellite altimetry missions and modes into one continuous monthly time series. Elevation anomalies were aligned to a common reference surface by solving for intermission offsets. These offsets were estimated using a least-squares adjustment and then subtracted from the time series elevation data to provide an initial cross-calibrated record of elevation change. A secondary cross-calibration was performed on offset coefficients that did not conform to the linear model of the first calibration.

2.2.3.4 Grid time series data in space and time

The binned and cross-calibrated time series data were gridded in space and time using filtering, interpolation, and extrapolation to obtain the final three-dimensional data cube product. Erroneous observations were filtered out and the monthly elevation change estimates were then interpolated onto a 1920 m grid using collocation (e.g. ordinary kriging). Extrapolation for each monthly time epoch was used to fill the large spatial gap in satellite coverage between the maximum latitude reached and the south pole (e.g. the pole hole). Interpolated and extrapolated values can be included or excluded using the quality flag included with the data product.

2.3 Quality, Errors, and Limitations

2.3.1 Temporal Coverage Gaps

The final elevation change data cube contains monthly values of elevation change from 1992-2020 or 1985-2020, depending on spatial location. For the 1985-2020 coverage period, the 1990-1992 timeframe is empty as no altimetric data was available.

2.3.2 Spatial Coverage Gaps

The data includes spatial coverage gaps due to the pole hole and satellite mission orbit coverage. Spatial coverage has been extrapolated to fill the pole hole from 1992-2020. The size of the pole hole, and thus extrapolation, varies due to orbital coverage of different missions (Figure 1). Extrapolation of the pole hole can be removed using the quality flag field. For time periods between 1985-1990, data is only available to -72 degrees latitude due to Geosat orbit coverage.

2.3.3 Relative Accuracy and Validation of Elevation Change

The relative accuracy of the time series data from each mission and mode was determined through an internal crossover analysis (Figure 2).

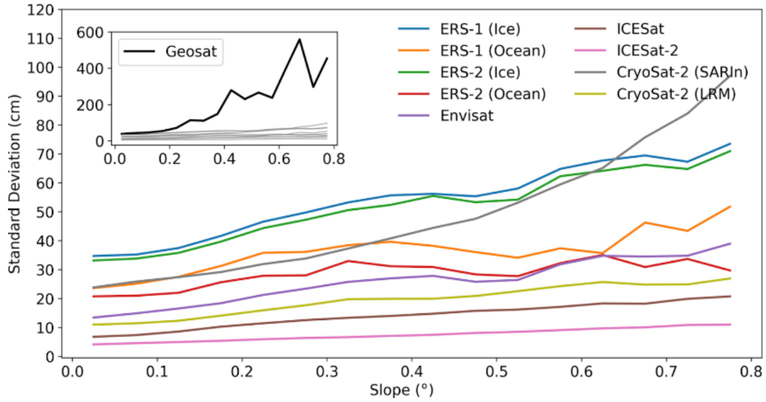

Figure 2. Standard deviation (cm) of intra-mission and intra-mode crossovers for the Antarctic Ice Sheet as a function of surface slope (degrees). Source: Nilsson et al. 2022.

The data product was validated by comparing computed elevation rates with those derived from Operation IceBridge and pre-Operation IceBridge data using the Airborne Topographic Mapper (ATM) laser altimeter from 2002-2019. ATM elevation change rates were calculated through solving a linear model at each measurement location with a search radius of 175 m. The measurements were corrected to the reference track with the local slope. Solutions were rejected based on various quality metrics.

2.4 Instrumentation

For more information about the missions, satellites, and instruments used to create this data set, see the following websites:

The European Space Agency

- ERS-1 and -2
- Envisat
- CryoSat-2

The National Aeronautics and Space Administration

- Geosat
- ICESat and ICESat-2

3 SOFTWARE AND TOOLS

The code and algorithm used to create this data set can be accessed at the following GitHub repository: https://github.com/nasa-jpl/captoolkit.

4 RELATED DATA SETS

MEaSUREs Data at NSIDC

MEaSUREs Antarctic Boundaries for IPY 2007-2009 from Satellite Radar

5 REFERENCES

Nilsson, J., A. Gardner, and F. Paolo (2021). Elevation Change of the Antarctic Ice Sheet: 1985 to 2020. *Earth System Science Data Discussions*, 2021, 1–39. https://doi.org/10.5194/essd-2021-287.

6 DOCUMENT INFORMATION

6.1 Publication Date

February 2023

6.2 Date Last Updated

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