ATLAS/ICESat-2 L3B Gridded Antarctic and Arctic Land Ice Height Change, Version 3

USER GUIDE

How to Cite These Data

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

Smith, B., T. Sutterley, S. Dickinson, B. P. Jelley, D. Felikson, T. A. Neumann, H. Fricker, A. Gardner, L. Padman, T. Markus, N. Kurtz, S. Bhardwaj, D. Hancock, and J. Lee. 2023. *ATLAS/ICESat-2 L3B Gridded Antarctic and Arctic Land Ice Height Change, Version 3*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ATLAS/ATL15.003. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ATL15

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

This data set contains quarter-year, land ice height changes for the Antarctic ice sheet and regions around the Arctic gridded at four spatial resolutions (1 km, 10 km, 20 km, and 40 km). The data are derived from the ATLAS/ICESat-2 L3B Slope-Corrected Land Ice Height Time Series product (ATL11).

1.2 File Information

1.2.1 Format

Data are provided in netCDF formatted files.

1.2.2 File Contents

Separate data files are available for the four spatial resolutions (1 km, 10 km, 20 km, and 40 km). The data group structure is the same for each spatial resolution. To keep file sizes manageable, the Antarctica data are also split into four quadrants (A1, A2, A3, and A4) along 90º longitudes (Figure 1). Each quadrant is provided as a separate file (see Section 1.2.3 Naming Convention).

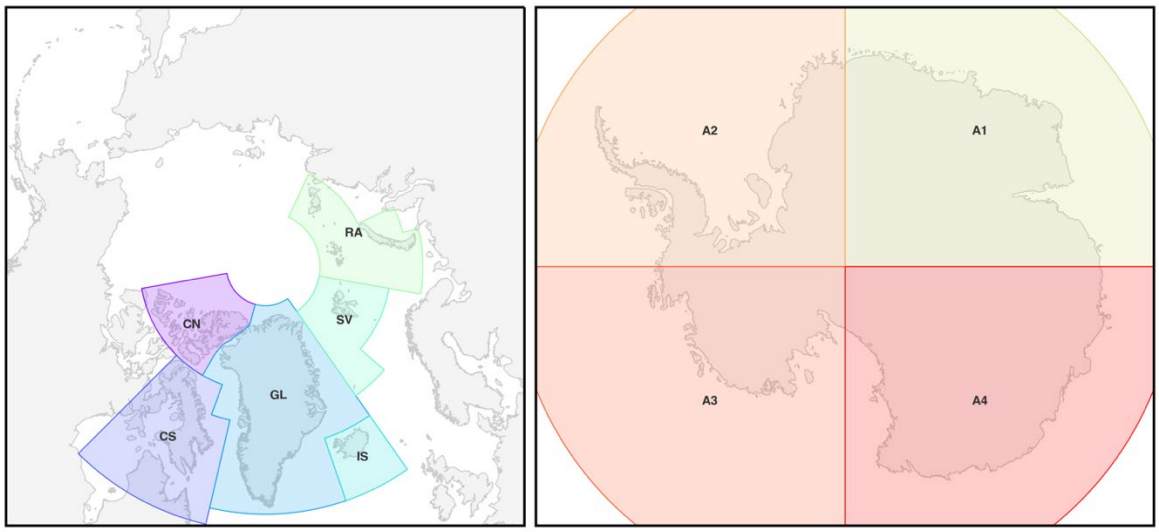
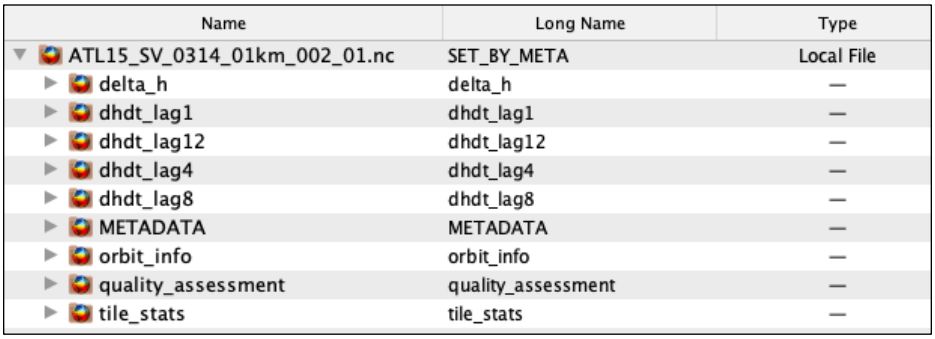


Figure 1. Regions for ATL15.

Within data files, similar variables such as science data, instrument parameters, and metadata are grouped together. The following figure shows the top-level data groups for ATL15 data files:



Name	Long Name	Type
ATL15_SV_0314_01km_002_01.nc	SET_BY_META	Local File
delta_h	delta_h	—
dhdt_lag1	dhdt_lag1	—
dhdt_lag12	dhdt_lag12	—
dhdt_lag4	dhdt_lag4	—
dhdt_lag8	dhdt_lag8	—
METADATA	METADATA	—
orbit_info	orbit_info	—
quality_assessment	quality_assessment	—
tile_stats	tile_stats	—

Figure 2. ATL15 top-level data groups and variables.

The following sections describe the contents of the data groups stored at the top level in ATL15 data files.

1.2.2.1 delta_h

Variables describing height differences between the model surface at any given time and the DEM surface at a resolution of 1 km. Time values are expressed in days since the ICESat-2 epoch (midnight at the start of 01 January 2018). The 1 km files include three additional variables for root mean square (RMS) fitting: `data_count`, `misfit_rms`, and `misfit_scaled_rms`. Also included is an `ice_area` variable that indicates how much ice-covered area is within each grid cell for each time step. The `ice_area` variable is updated for each time step in Antarctica, where a time-varying mask is used to account for ice front calving and advance, and it is updated in other regions to remove cells where the inferred surface height falls below sea level (estimated based on the EGM2008 geoid).

1.2.2.2 dhdt_lag1/dhdt_lag4/dhdt_lag8/dhdt_lag12/dhdt_lag16

Variables associated with the height-change rates corresponding to the time derivative of `delta_h`. Time values for the height-change rates are equal to the midpoints of underlying surface height change times. Height-change rates are provided at the temporal resolutions outlined in the following table:

Table 1. Temporal Resolutions and Corresponding Variables

Time	Variable Name
Quarterly	dhdt_lag1
Annually	dhdt_lag4
Biennially	dhdt_lag8
Triennially	dhdt_lag12
Quadrennially	dhdt_lag16

As the mission duration increases, more groups will be added to span the full length of the ICESat-2 mission. For these groups, the `ice_area` variable indicates the area in each cell that is covered by ice in both the first and the last time steps over the differencing period.

1.2.2.3 METADATA

ISO19115 structured summary metadata.

1.2.2.4 orbit_info

Bounding polygons (in latitude and longitude) for each granule.

1.2.2.5 quality_assessments

Quality assessment data for the granule as a whole, including a pass/fail flag and a failure reason indicator. These variables will be marked as *valid(0)* in all released granules.

1.2.2.6 tile_stats

Parameters pertaining to the fitting process, defined for each overlapping 61x61 km tile on which the algorithm was calculated. Each `tile_stat` grid gives statistics of the fit for tiles centered on each point in the grid.

For additional information, see the following Documentation on the ATL15 data set landing page:

- ATL15 Data Dictionary (complete list of variables stored)
- “Section 4.2: ATL15 product” in the “ATBD for Land-ice DEM (ATL14) and Land-ice height change (ATL15)”
- “Section 4.3: Parameters common among groups” in the “ATBD for Land-ice DEM (ATL14) and Land-ice height change (ATL15)”

1.2.3 Naming Convention

Data files utilize the following naming convention:

```
ATL15_[RR]_[CCCC]_[nn]km_[vvv_rr].nc
ATL15_CN_0319_10km_003_01.nc
```

Table 2. File Naming Convention Variables and Descriptions

Variable	Description
ATL15	ATLAS/ICESat-2 L3B Gridded Antarctic and Arctic Land Ice Height Change product
RR	Region code. Antarctica = A1, A2, A3, or A4;; Arctic Canada North = CN; Arctic Canada South = CS; Greenland and peripheral ice caps = GL; Iceland = IS; Svalbard = SV; Russian Arctic = RA.
CCCC	First and last cycles of repeat-track data included in the file (i.e., 0314 includes cycles 3 through 14, inclusive)
nn	Two-digit spatial resolution. Options are 01, 10, 20, and 40.
vvv_rr	Version and revision number*

NOTE: From time to time, NSIDC receives reprocessed granules from our data provider. These granules have the same file name as the original (i.e., date, time, ground track, cycle, and segment number), but the revision number has been incremented. Although NSIDC deletes the superseded granule, the process can take several days. As such, if you encounter multiple granules with the same file name, please use the granule with the highest revision number.

Each data file has a corresponding XML file that contains additional science metadata. XML metadata files have the same name as their corresponding `.h5` file, but with `.xml` appended.

1.2.4 Browse File

Each granule contains JPG browse images called `default1` and `default2`. `default1` visualizes the average quarterly rate of height change (`dhdt_lag1/dhdt`) at a 1 km resolution from cycles 03 to 14. `default2` visualizes the standard deviation (m) of the quarterly rate of height change (`dhdt_lag1/dhdt`) at a 1 km resolution from cycles 03 to 14. Example browse images are shown in Figure 3.

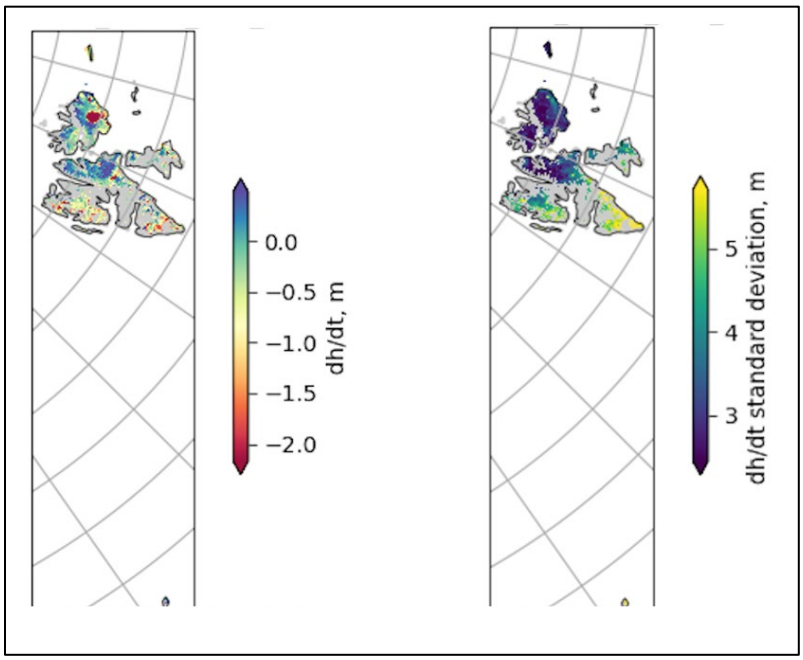


Figure 3. `Default1` (left) and `Default2` (right) browse images for `ATL15_SV_0314_01km_002_01_BRW.h5`.

1.3 Spatial Information

1.3.1 Coverage

North and south polar regions:

- North of 59.0° N
- South of 60.0° S

1.3.2 Resolution

Data are available at the full resolution of 1 km, as well as reduced resolutions of 10 km, 20 km, and 40 km.

1.3.3 Geolocation

The following tables provide information for geolocating this data set.

Table 3. Projection Details

Projected coordinate system	NSIDC Sea Ice Polar Stereographic North	Antarctic Polar Stereographic
Geographic coordinate system	WGS 84	WGS 84
Central meridian	-45°	0°
Latitude of origin	70°	-71°
Scale factor at central meridian	1	1
Datum	World Geodetic System 1984 ensemble	World Geodetic System 1984 ensemble
Ellipsoid/spheroid	WGS 84	WGS 84
Units	meter	meter
False easting	0	0
False northing	0	0
EPSG code	3413	3031
PROJ4 string	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs +type=crs	+proj=stere +lat_0=-90 +lat_ts=-71 +lon_0=0 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs +type=crs
Reference	https://epsg.io/3413	https://epsg.io/3031

1.4 Temporal Information

1.4.1 Coverage

29 March 2019 to present

1.4.2 Resolution

Data are provided at a quarter-annual resolution.

2 DATA ACQUISITION AND PROCESSING

The following sections refer to the Ice, Cloud, and land Elevation Satellite (ICESat-2) Project Algorithm Theoretical Basis Document (ATBD) for Land-ice DEM (ATL14) and Land-ice height change (ATL15) (ATBD for ATL14/15, V3 | https://doi.org/10.5067/JCMDHAFNY9FX).

2.1 Background

ATL14 and ATL15 bring the time-varying height estimates provided in ATLAS/ICESat-2 L3B Slope-Corrected Land Ice Height Time Series (ATL11) into a gridded format. ATL14 provides a high-resolution (100 m) DEM, which is a spatially continuous gridded data set of ice sheet surface height. It can be used to initialize ice sheet models, as boundary conditions for atmospheric models, or to help with the reduction of other satellite data such as optical imagery or synthetic aperture radar (SAR). ATL15 provides coarser resolution (1 km, 10 km, 20 km, and 40 km) height-change maps at 3-month intervals. This allows visualization of height-change patterns and the calculation of integrated regional volume change.

2.2 Acquisition

ATL14 and ATL15 are derived from the ATLAS/ICESat-2 L3B Slope-Corrected Land Ice Height Time Series (ATL11) product, which contains spatially organized time series of land-ice surface heights derived from the ATLAS/ICESat-2 L3A Land Ice Height product (ATL06). The algorithm that aggregates the DEM for ATL14 and produces a set of gridded height-change maps for ATL15 is summarized in the following sections.

2.3 Processing

The ATL14/15 algorithm works through several steps to fit height and height-change maps to the ATL11 repeat-track-corrected height estimates.

Define subdomains: The ice sheet is divided into 61x61 km tiles to reduce computational costs. Independent calculations are performed on tiles centered on a 40 km grid to minimize edge effects.

Select high-quality data: Reliable along-track and crossover ATL11 data are selected based on a combination of geographic and parameter-based factors.

Compute two-component solution: The solution is a combination of (1) the model comprising the interpolating functions (between the model parameters and ATL11 height measurements) and a set of estimated height biases and (2) a regularized least-squares solution that identifies the simplest model that fits the height data and rejects statistically outlying measurements. This solution is iterated to remove outlying data points.

Calculate model errors: A dominant error source in ATL11 data is the effect of geolocation errors over sloping surfaces. Data biases are included as parameters in the solution to produce a smooth model.

Combine solutions: Error estimates are calculated, each tile solution is recomputed by applying linear constraint at the edges, and the solutions are combined using a weighting scheme to form the final ATL14/15 product. Each data point is assigned an error estimate based on the ATL11 data and bias-parameter constraints.

Details on the processing steps can be found in the ATL14/15 ATBD under “Section 3.0 | Algorithm Theory” and subsections therein.

2.4 Quality, Errors, and Limitations

The feature resolution of ATL14 and ATL15 is limited by the spatial resolution of the ICESat-2 tracks, the temporal sampling of the tracks, and the resolution of the grids chosen for these data products. More detailed information on all three limitations can be found in “Section 2.1 | Limitations of the ATL14/15 product” of the ATL14/15 ATBD. Users should consult the `data_count` and `delta_h_sigma` fields to help understand how spatial coverage by ICESat-2 might affect the accuracy of surface-height estimates.

Error estimation for the ATL14 and ATL15 data sets is detailed in the “Section 3.4.8 | Error estimates” of the ATBD.

Cycles 1 and 2, comprising all data before April 2020, were not collected along the ICESat-2 reference ground tracks. They were collected with larger off-nadir angles than is typical for other cycles. As a result, these data have larger errors than other cycles and are not included in the ATL11 repeat-track calculations. All cycle 1 and 2 data are derived from crossover points—where the ground tracks from these cycles cross the ICESat-2 reference pair tracks—which greatly reduces the number of data points available. Cycles 1 and 2, as represented in ATL15, have much larger errors than the other cycles and should be treated with caution. The first high-quality reference-track data come from cycle 3.

2.5 Instrumentation

The ATLAS instrument on the ICESat-2 satellite utilizes a photon-counting lidar and ancillary systems (GPS and star cameras) to measure the round-trip time of photon pulses from ATLAS to Earth and back again and to determine the geodetic latitude and longitude of these signal photon pulses on the Earth’s surface. Laser pulses from ATLAS illuminate three left/right pairs of spots on the surface that trace out six 14-meter-wide ground tracks as ICESat-2 orbits Earth. The ATL10 data product is organized by ground track, with ground tracks 1L and 1R forming pair one, ground tracks 2L and 2R forming pair two, and ground tracks 3L and 3R forming pair three.

The beams within each pair have different transmit energies—so-called weak and strong beams—with an energy ratio between them of approximately 1:4. The mapping between the strong and weak beams of ATLAS, and their relative position on the ground, depends on the orientation (yaw) of the ICESat-2 observatory, which is changed approximately twice per year to maximize solar illumination of the solar panels.

The Reference Ground Track (RGT) refers to the imaginary track on Earth at which a specified unit vector within the observatory is pointed. The ICESat-2 mission acquires data along 1,387 different RGTs. Each RGT is targeted in the polar regions once every 91 days (i.e., the satellite has a 91-day repeat cycle) to allow elevation changes to be detected. Cycle numbers track the number of 91-day periods that have elapsed since the ICESat-2 observatory entered the science orbit. RGTs are uniquely identified by appending the two-digit cycle number to the RGT number, e.g., 000103 (RGT 0001, cycle 03) or 138705 (RGT 1387, cycle 05).

3 VERSION HISTORY

Table 4. Version History Summary

Version	Release Date	Description of Changes
V1	December 2021	Initial release
V2	November 2022	• Extend temporal coverage through cycle 14 • Include one independent bias parameter for each RGT, cycle, and beam pair in the bias model • In all regions except Antarctica, use minimum error estimate for every unique crossover • Apply a time-variable ice mask, as reflected in the `ice_area` variable • Achieve tile-to-tile matching using linear constraint at tile edges • Decrease computation tile size to 61x61 km, and compute tiles in two stages instead of three
V3	October 2023	All regions: • Additional 4 cycles of ICESat-2 data from ATL11 Antarctica: • Updated and improved time-varying ocean mask based on data from the IceLines project • Data from the 400x400 km square surrounding the pole were calculated on 44 km tiles rather than 60 km tiles • Data are split into four quadrants (A1, A2, A3, and A4) along 90° longitudes Greenland: • New time-varying ice-front mask

Note: Version 1 of this data set was derived from ATL11, Version 4. Versions 2 was derived from ATL11, Version 5. Version 3 is derived from ATL11, Version 6.

4 RELATED DATA SETS

- ATLAS/ICESat-2 L3A Land Ice Height (ATL06)
- ATLAS/ICESat-2 L3B Slope-Corrected Land Ice Height Time Series (ATL11)
- ATLAS/ICESat-2 L3B Antarctic and Arctic Land Ice Height (ATL14)

5 DOCUMENT INFORMATION

5.1 Publication Date

October 2023

5.2 Date Last Updated

October 2023