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

## 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. W. Hancock III, and J. Lee. 2022. *ATLAS/ICESat-2 L3B Gridded Antarctic and Arctic Land Ice Height, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ATLAS/ATL14.002. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ATL14

National Snow and Ice Data Center

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# 1 DATA DESCRIPTION

## 1.1 Parameters

This data set contains a high-resolution (100 m) gridded digital elevation model (DEM) for the Antarctic ice sheet and regions around the Arctic. The data are derived from the ATLAS/ICESat-2 L3B Slope-Corrected Land Ice Height Time Series product (ATL11, V5).

## 1.2 File Information

### 1.2.1 Format

Data are provided in netCDF formatted files.

### 1.2.2 File Contents

Within data files, similar variables such as science data, instrument parameters, and metadata are grouped together. The following figure shows data groups and variables stored at the top level in ATL14 data files:

| Name | Long Name | Type |
|---|---|---|
| ATL14_SV_0314_100m_002_01.nc | SET_BY_META | Local File |
| data_count | DEM data count | Geo2D |
| h | DEM height | Geo2D |
| h_sigma | DEM uncertainty | Geo2D |
| ice_area | DEM grid ice-covered area | Geo2D |
| METADATA | METADATA | — |
| misfit_rms | DEM per-node data residual | Geo2D |
| misfit_scaled_rms | DEM per-node scaled data uncertainty | Geo2D |
| orbit_info | orbit_info | — |
| Polar_Stereographic | Polar Stereographic | — |
| quality_assessment | quality_assessment | — |
| tile_stats | tile_stats | — |
| x | Polar stereographic x | 1D |
| y | Polar stereographic y | 1D |

Figure 1. ATL14 top-level data groups and variables.

The following sections describe the contents of the data groups stored at the top level in ATL14 data files.

#### 1.2.2.1 METADATA

ISO19115 structured summary metadata.

#### 1.2.2.2 orbit_info

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

#### 1.2.2.3 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.

#### 1.2.2.4 tile_stats

The `tile_stats` group contains information specific to the tiles (overlapping subdomains) on which the ATL14/15 solution was originally computed. These data sets are intended to help identify tiles on which there were significant problems.

- `N_bias`: number of bias values solved for
- `N_data`: number of data used in fit
- `RMS_bias`: root mean of squared, scaled bias values
- `RMS_d2z0dx2`: root mean square of the constraint equation residuals for the second spatial derivative of z0
- `RMS_d2zdt2`: root mean square of the constraint equation residuals for the second temporal derivative of dz
- `RMS_d2zdx2dt`: root mean square of the constraint equation residuals for the second temporal derivative of dz/dt
- `RMS_data`: root mean of squared, scaled data misfits
- `sigma_tt`: weighting values for the constraint equations on the second temporal derivatives of the surface height
- `sigma_xx0`: weighting values for the constraint equations on the second spatial derivatives of the DEM
- `sigma_xxt`: weighting values for the constraint equations on the second spatial derivatives of the height-change rate
- `x`: tile-center x-coordinate in projected coordinates
- `y`: tile-center y-coordinate in projected coordinates

#### 1.2.2.5 Data variables

The following variables are stored at the top level of ATL14 data files alongside the data groups described above:

- `data_count`: weighted number of data contributing to each node in the DEM
- `h`: DEM surface height, referenced to WGS84
- `h_sigma`: uncertainty in the DEM surface height
- `ice_area`: ice-covered area of each grid cell accounting for the area distortion in the polar stereographic projections
- `misfit_rms`: root mean square or the residuals associated with each DEM node

- `misfit_scaled_rms`: root mean square of the error-scaled residuals associated with each DEM node
- x: x coordinate of the DEM cell centers in projected coordinates
- y: y coordinate of the DEM cell centers in projected coordinates

For additional information, see the following Documentation on the ATL14 data set landing page:

- ATL14 Data Dictionary (complete list of variables stored)
- "Section 4.1: ATL14 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:

```
ATL14_[RR]_[CCCC]_100m_[vvv_rr].nc
ATL14_CN_0314_100m_002_01.nc
```

Table 1. File Naming Convention Variables and Descriptions

| Variable | Description |
|---|---|
| ATL14 | ATLAS/ICESat-2 L3B Gridded Antarctic and Arctic Land Ice Height product |
| RR | Region code. Antarctica = AA; 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) |
| 100m | Spatial resolution |
| vvv_rr | Version and revision number* |

*NOTE: From time to time, NSIDC receives duplicate, 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 an HDF5 browse file with two browse images called `default1` and `default2` within the default group. `default1` visualizes the DEM surface height (`h`), and `default2` visualizes the uncertainty in the DEM surface height (`h_sigma`). Example browse images are shown in Figure 2.

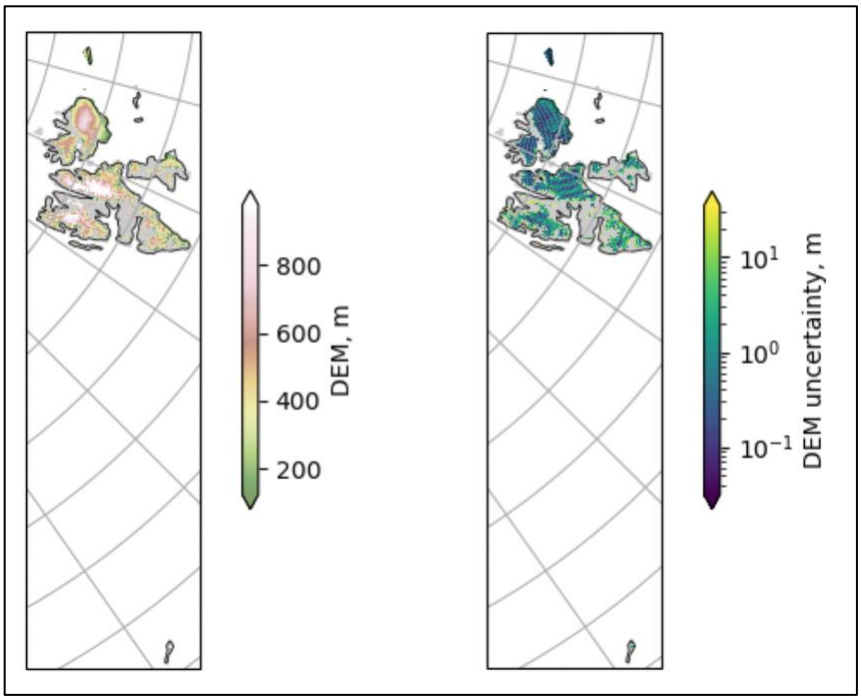


Figure 2. `Default1` (left) and `Default2` (right) browse images for `ATL14_SV_0314_100m_002_01_BRW.h5`.

## 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

100 m

### 1.3.3 Geolocation

The following table provides information for geolocating this data set.

Table 2. 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 23 March 2022

### 1.4.2 Resolution

A single DEM is provided for a reference date (decimal year 2020.0, equivalent to 12 AM GMT, 01 January 2020). Quarter-annual height-change maps for dates before and after the reference date are provided in the ATL15 data set.

# 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/ATL15 | V02; DOI: 10.5067/1E2WBH2Q1M9Q). This ATBD provides detailed descriptions of the following ATLAS/ICEsat-2 products:

- ATLAS/ICESat-2 L3B Gridded Antarctic and Arctic Land Ice Height (ATL14)
- ATLAS/ICESat-2 L3B Gridded Antarctic and Arctic Land Ice Height Change (ATL15)

## 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 "Section 3.4.8 | Error estimates" of the ATBD.

## 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 3. Version History Summary

| Version | Release Date | Description of Changes |
|---|---|---|
| V1 | December 2021 | Initial release |
| V2 | November 2022 | The changes from Versions 1 to 2 include the following:<br>• Extend temporal coverage through cycle 14<br>• Include one independent bias parameter for each RGT, cycle, and beam pair in the bias model<br>• In all regions except Antarctica, use minimum error estimate for every unique crossover<br>• Apply a time-variable ice mask, as reflected in the `ice_area` variable<br>• Achieve tile-to-tile matching using linear constraint at tile edges<br>• Decrease computation tile size to 61x61 km, and compute tiles in two stages instead of three |
| V2 | April 2024 | Data set retirement |

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

# 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 Change (ATL15)

# 5 CONTACTS AND ACKNOWLEDGMENTS

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# 6 DOCUMENT INFORMATION

## 6.1 Publication Date

November 2022

## 6.2 Date Last Updated

April 2024