ATLAS/ICESat-2 L3B Gridded Antarctic and Arctic Land Ice Height, Version 1

USER GUIDE

How to Cite These Data

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

Smith, B., B. P. Jelley, S. Dickinson, T. Sutterley, T. A. Neumann, K. Harbeck. 2021. *ATLAS/ICESat-2 L3B Gridded Antarctic and Arctic Land Ice Height, Version 1*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ATLAS/ATL14.001. [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

TABLE OF CONTENTS

1 DATA DESCRIPTION

1.1 Parameters

This data set contains a high resolution (100 m) gridded digital elevation model (DEM), derived from the ATLAS/ICESat-2 L3B Annual Land Ice Height product (ATL11, V4)

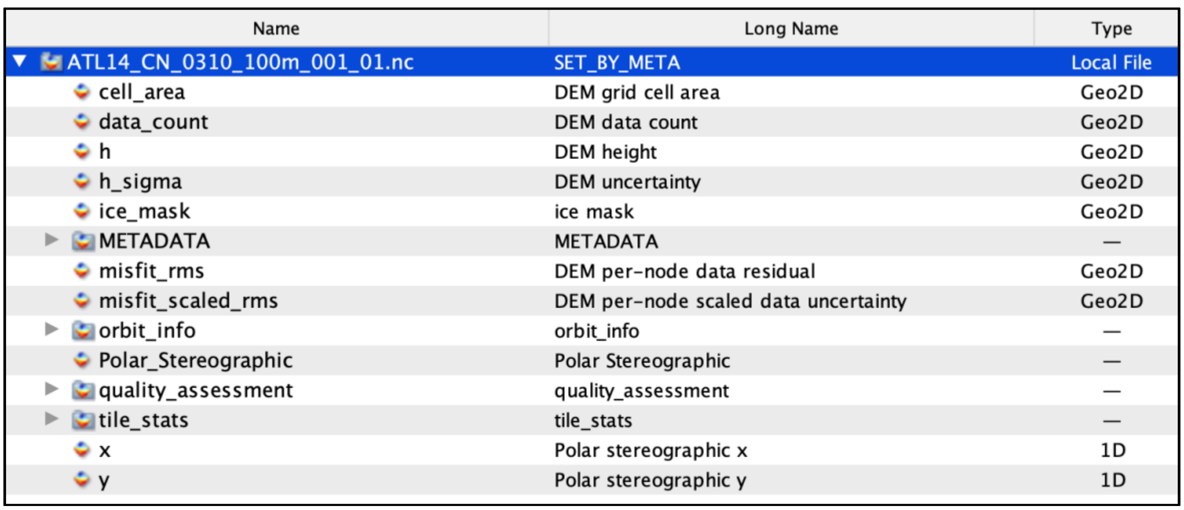
1.2 File Information

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_CN_0310_100m_001_01.nc	SET_BY_META	Local File
cell_area	DEM grid cell area	Geo2D
data_count	DEM data count	Geo2D
h	DEM height	Geo2D
h_sigma	DEM uncertainty	Geo2D
ice_mask	ice mask	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 tie_stats group contains information specific to the tiles on which the ATL14/15 solution was originally computed. These datasets are intended to help identify 40x40 km tiles on which there were significant problems.

•x: tile-center x-coordinate, in projected coordinates
•y: tile-center y-coordinate, in projected coordinates
•N_data: number of data used in fit
•RMS_data: root mean of squared, scaled data misfits
•RMS_bias: root mean of squared, scaled bias values
•N_bias: number of bias values solved for
•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
•Sigma_tt: weighting values for the constraint equations on t

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:

- cell_area: area of each grid cell within the ice mask, accounting for the area distortion in the polar-stereographic projections.
- 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_mask: mask indicating ice (1) or ocean/bare land (0)
- 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 Technical References 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:

Example:

ATL14_CN_0310_100m_001_01.nc
ATL14_[RR]_[CCCC]_100m_[vvv_rr].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; Alaska = AK; 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. 0309 include cycles 3 through 9, 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

An HDF5 browse file is provided for each granule that contains two browse images in the default group called “default1” and “default2”. default1 visualizes the DEM surface height (h) and default2 the uncertainty in the DEM surface height (h_sigma).

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 tables provide information for geolocating this data set.

Table 2. Northern Hemisphere Projection Details

Geographic coordinate system	WGS 84
Projected coordinate system	NSIDC Sea Ice Polar Stereographic North
Longitude of true origin	-45°
Latitude of true origin	70°
Scale factor at longitude of true origin	1
Datum	WGS 1984
Ellipsoid/spheroid	WGS 84
Units	Meters
False easting	0
False northing	0
EPSG code	3413
PROJ4 string	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs
Reference	https://epsg.io/3413

Table 3. Southern Hemisphere Projection Details

Geographic coordinate system	WGS 84
Projected coordinate system	NSIDC Sea Ice Polar Stereographic South
Longitude of true origin	0°
Latitude of true origin	-70°
Scale factor at longitude of true origin	1

Datum	WGS 1984
Ellipsoid/spheroid	WGS 84
Units	Meters
False easting	0
False northing	0
EPSG code	3976
PROJ4 string	+proj=stere +lat_0=-90 +lat_ts=-70 +lon_0=0 +k=1 +x_0=0 +y_0=0 +datum=WGS84 +units=m +no_defs
Reference	https://epsg.io/3976

1.4 Temporal Information

1.4.1 Coverage

29 March 2019 to 23 June 2021

1.4.2 Resolution

A single DEM is provided for a reference date (decimal year 2020.0, equivalent to 12 PM GMT, December 31, 2019). 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 | V01, DOI: 10.5067/ELLR18T0BO5H). 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)

To obtain the ATBD for Land Ice Height Products, see Technical References on the ATL14 data set landing page.

2.1 Background

ATL14 and ATL15 bring the time-varying height estimates provided in ATLAS/ICESat-2 L3B Annual Land Ice Height (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 (1km, 10km, 20km, and 40km) 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 Annual Land Ice Height (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. Details can be found in the ATBD for ATL14/ATL15.

2.3 Processing

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

- Select high-quality ATL11 data
- Generate model fitting and regularization matrices for the selected ATL11 data
- Applying least-squares fitting techniques to derive the simplest model that fits the data and rejects statistically outlying measurements
- Calculate model errors

Details on these four 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 the ATBD section 2.1 | Limitations of the ATL14/15 product. Users should consult the *data_count* and *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 ATBD section 3.4.9 | Error estimates.

2.5 Instrumentation

See Appendix A – ATLAS/ICESat-2 DESCRIPTION for a short instrument description.

3 SOFTWARE AND TOOLS

The .nc data files can be opened using NetCDF visualization software such as Panoply.

4 VERSION HISTORY

Table 4. Version History Summary

Version	Release Date	Description of Changes
V1	December 2021	Initial release
V1	May 2023	Version 1 retired (superseded by V2)

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

5 RELATED DATA SETS

- ATLAS/ICESat-2 L3A Land Ice Height (ATL06)
- ATLAS/ICESat-2 L3B Annual Land Ice Height (ATL11)
- ATLAS/ICESat-2 L3B Antarctic and Arctic Land Ice Height Change (ATL15)

6 CONTACTS AND ACKNOWLEDGMENTS

Benjamin Smith

Applied Physics Lab Polar Science Center

University of Washington

Seattle, WA 98105

Benjamin Jelley

NASA Goddard Space Flight Center

Mail Code: 615

Greenbelt, MD 20771

Suzanne Dickinson

Applied Physics Lab Polar Science Center

University of Washington

Seattle, WA 98105

Tyler Sutterley
Applied Physics Lab Polar Science Center
University of Washington
Seattle, WA 98105

Tom Neumann
NASA Goddard Space Flight Center
Mail Code: 615
Greenbelt, MD 20771

Kaitlin Harbeck
NASA Goddard Space Flight Center
Mail Code: 615
Greenbelt, MD 20771

7 DOCUMENT INFORMATION

7.1 Publication Date

15 December 2021

7.2 Date Last Updated

4 May 2023

APPENDIX A – ATLAS/ICESAT-2 DESCRIPTION

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 as ICESat-2 orbits Earth trace out six ground tracks that are typically about 14 m wide. Each ground track is numbered according to the laser spot number that generates it, with ground track 1L (GT1L) on the far left and ground track 3R (GT3R) on the far right. Left/right spots within each pair are approximately 90 m apart in the across-track direction and 2.5 km in the along-track direction. 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. Each pair also has a Pair Track—an imaginary line halfway between the actual location of the left and right beams (see Figure A - 1Figure A - 2). Pair tracks are approximately 3 km apart in the across-track direction.

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 forward orientation corresponds to ATLAS traveling along the +x coordinate in the ATLAS instrument reference frame (see Figure A - 1). In this orientation, the weak beams lead the strong beams and a weak beam is on the left edge of the beam pattern. In the backward orientation, ATLAS travels along the -x coordinate, in the instrument reference frame, with the strong beams leading the weak beams and a strong beam on the left edge of the beam pattern (see Figure A - 2). The first yaw flip was performed on December 28, 2018, placing the spacecraft into the backward orientation. The current spacecraft orientation, as well as a history of previous yaw flips, is available in the "ICESat-2 Major Activities" document on the ATL14 landing page under the technical references tab.

The Reference Ground Track (RGT) refers to the imaginary track on Earth at which a specified unit vector within the observatory is pointed. During nominal operating conditions onboard software aims the laser beams so that the RGT is between ground tracks 2L and 2R (i.e. coincident with Pair Track 2). 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).

Users should note that between 14 October 2018 and 30 March 2019 the spacecraft pointing control was not yet optimized. As such, ICESat-2 data acquired during that time do not lie along the nominal RGTs, but are offset at some distance from the RGTs. Although not along the RGT, the geolocation information for these data is not degraded.

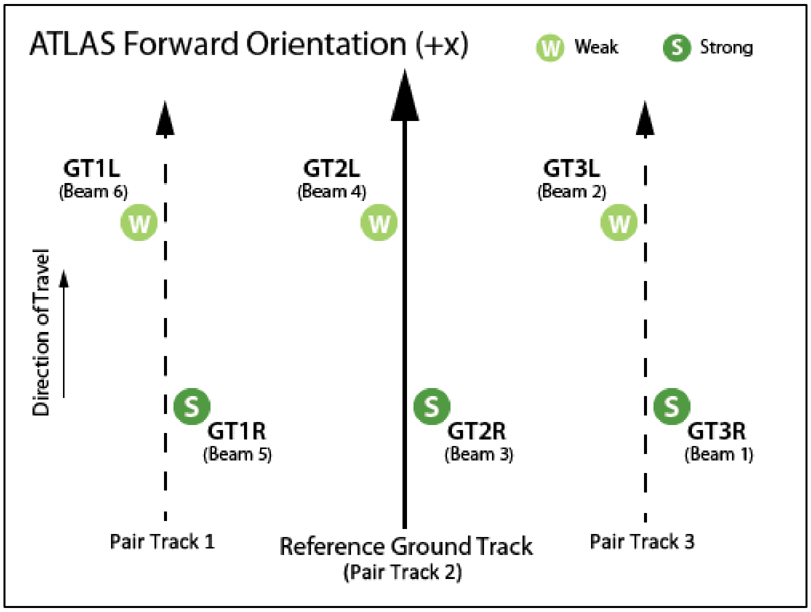


Figure A - 1. Spot and ground track (GT) naming convention with ATLAS oriented in the forward (instrument coordinate +x) direction.

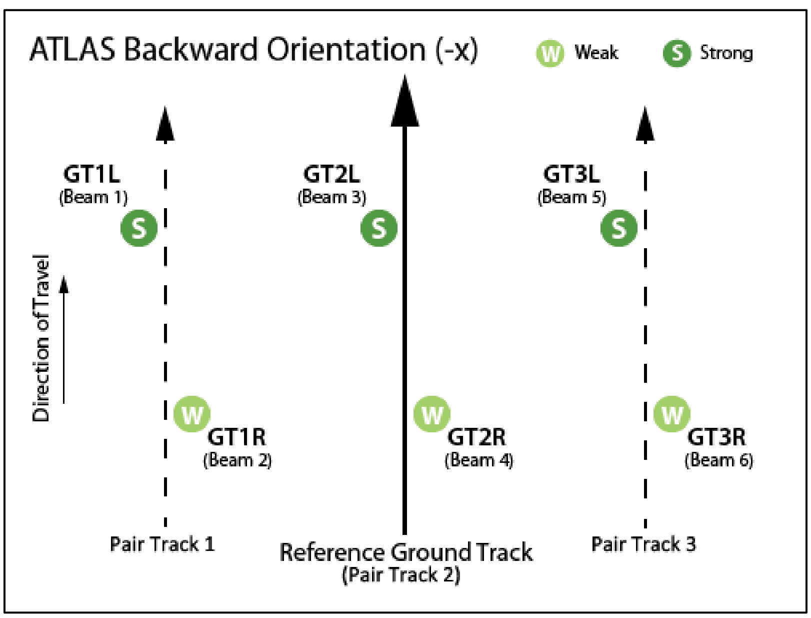


Figure A - 2. Spot and ground track (GT) naming convention with ATLAS oriented in the backward (instrument coordinate -x) direction.