ATLAS/ICESat-2 L3B Daily and Monthly Gridded Sea Ice Freeboard, Version 4

USER GUIDE

How to Cite These Data

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

Petty, A. A., R. Kwok, M. Bagnardi, A. Ivanoff, N. Kurtz, J. Lee, J. Wimert, D. Hancock. 2023. *ATLAS/ICESat-2 L3B Daily and Monthly Gridded Sea Ice Freeboard, Version 4*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ATLAS/ATL20.004. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ATL20

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DATA DESCRIPTION

1.1 Parameters

This data set contains daily and monthly gridded estimates of sea ice freeboard, derived from along-track freeboard estimates in the ATLAS/ICESat-2 L3A Sea Ice Freeboard product (ATL10, V6).

1.2 File Information

1.2.1 Format

Data are provided as HDF5 formatted files.

1.2.2 File Contents

Data files contain gridded freeboard at two temporal resolutions: daily and monthly.

1.2.3 Data Groups

Within data files, similar variables such as science data, instrument parameters, and metadata are grouped together according to the HDF model. The following figure shows data groups and variables stored at the top level in ATL20 data files:

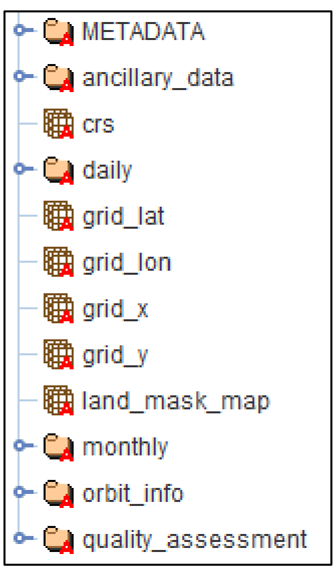

Figure 1. ATL20 Top-Level Data Groups and Variables

The following sections describe the data groups and their contents plus the variables stored at the top level in ATL20 data files.

1.2.3.1 METADATA

ISO19115 structured summary metadata.

1.2.3.2 ancillary_data

Information ancillary to the data product such as product and instrument characteristics and processing constants.

1.2.3.3 daily

Subfolders, one for each day of the month, that contain the day's gridded mean freeboard (`mean_fb`), values used to compute the daily mean freeboard, and daily standard deviation.

1.2.3.4 monthly

Monthly gridded freeboard, values used to compute the monthly freeboard, and the monthly standard deviation.

1.2.3.5 orbit_info

Orbit parameters that are constant for a granule, such as the Reference Ground Track (RGT) number, cycle, and spacecraft orientation.

1.2.3.6 quality_assessment

Quality assessment data for the granule as a whole, including a pass/fail flag and a failure reason indicator.

The following variables are stored at the top level of ATL20 data files alongside the data groups described above:

- `crs`: metadata describing the coordinate reference system
- `grid_lat`: latitude at the center of each grid cell
- `grid_lon`: longitude at the center of each grid cell
- `grid_x`: x value at the center of each grid cell
- `grid_y`: y value at the center of each grid cell
- `land_mask_map`: flags for each grid cell denoting land (1) or ocean/sea ice (0)

For a complete list of variables stored, see the ATL20 Data Dictionary on the data set landing page.

1.2.4 Naming Convention

Data files utilize the following naming convention:

```
ATL20-[HH]_[yyyymmdd][hhmmss]_[ttttccss]_[vvv_rr].h5
```

Examples:

```
ATL20-01_20190101005132_00550201_004_01.h5
ATL20-02_20190101005132_00550201_004_01.h5
```

Variable	Description
ATL20	ATLAS/ICESat-2 L3B Daily and Monthly Gridded Sea Ice Freeboard product
HH	Hemisphere code. Northern Hemisphere = 01, Southern Hemisphere = 02
yyyymmdd	Year, month, and day of data acquisition
hhmmss	Data acquisition start time, hour, minute, and second (UTC)
tttt	Four-digit RGT number. The ICESat-2 mission has 1,387 RGTs, numbered from 0001 to 1387.
cc	Cycle Number. Each of the 1387 RGTs is targeted in the polar regions once every 91 days. The cycle number tracks the number of 91-day periods that have elapsed since ICESat-2 entered the science orbit.
ss	Segment number. Not used. Always 01.
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. 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.

1.2.5 Browse File

JPG browse files are provided for each granule that show the monthly accumulated freeboard lengths (`length_sum`), monthly mean freeboard (`default1` and `mean_fb`), monthly population count (`default1` and `n_segs`), and monthly standard deviation (`sigma`).

1.3 Spatial Information

1.3.1 Coverage

Coverage is global; however, the input ATL10 freeboards are only reported where ice concentration is >50%.

1.3.2 Resolution

25 km

1.3.3 Geolocation

Data are mapped using NSIDC's Polar Stereographic Projection.

Table 1. Projection Details

Projected coordinate system	**NSIDC Sea Ice Polar Stereographic North**	**NSIDC Sea Ice Polar Stereographic South**
Geographic coordinate system	Unspecified datum based upon the Hughes 1980 ellipsoid	Unspecified datum based upon the Hughes 1980 ellipsoid
Longitude of true origin	-45°	0°
Latitude of true origin	70°	-70°
Scale factor at longitude of true origin	1	1
Datum	Unspecified, based on Hughes 1980 ellipsoid	Unspecified, based on Hughes 1980 ellipsoid
Ellipsoid/spheroid	Hughes 1980	Hughes 1980
Units	meter	meter
False easting	0	0
False northing	0	0
EPSG code	3411	3412
PROJ4 string	+proj=stere +lat_0=90 +lat_ts=70 +lon_0=-45 +k=1 +x_0=0 +y_0=0 +a=6378273 +b=6356889.449 +units=m +no_defs	+proj=stere +lat_0=-90 +lat_ts=-70 +lon_0=0 +k=1 +x_0=0 +y_0=0 +a=6378273 +b=6356889.449 +units=m +no_defs
Reference	https://epsg.io/3411	https://epsg.io/3412

Table 2. Grid Details

Hemisphere	North Polar	South Polar
Grid cell size (km)	25 × 25	25 × 25
Grid size (rows × columns)	448 × 304	332 × 316
Geolocated lower left point in grid (km)	(-3850, -5350)	(-3950, -3950)
Nominal gridded resolution	25 km	25 km
Grid rotation	0	0
ulxmap: x-axis coord, center of upper left pixel (XLLCORNER) (km)	-3,837.5	-3,937.5
ulymap: y-axis coord, center of upper left pixel (YLLCORNER) (km)	5,837.5	4,337.5

1.4 Temporal Information

1.4.1 Coverage

14 October 2018 to present

1.4.2 Resolution

Data are provided at daily and monthly resolutions. Months are defined as the first through the last day of each calendar month.

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 Sea Ice Products (ATBD for ATL07/10/20/21 | V6, https://doi.org/10.5067/9VT7NJWOTV3I).

2.1 Background

The ATL10 product identifies leads* in sea ice and establishes a reference sea surface used to estimate along-track freeboard heights. ATL20 aggregates ATL10 along-track freeboard estimates and computes daily and monthly gridded freeboard in NSIDC Polar Stereographic Northern and Southern Hemisphere 25 km grids.

*Leads are narrow, linear cracks in sea ice that form when separate patches of floating ice diverge or shear as they move parallel to each other.

2.2 Acquisition

The ATL20 algorithm inputs ATL10 granules and computes gridded daily and monthly freeboard as described in the following section.

2.3 Processing

To compute daily freeboard estimates, the algorithm collects all the ATL10 individual strong beam freeboard beam segments from the time span of interest and performs the following calculations.

Daily

For each 25 km grid cell (x, y, D), where D is day-of-month, the algorithm calculates the mean length, freeboard, and standard deviation as follows:

$$\overline{L}(x, y, D) = \sum_{N} L_s^i$$

$$\overline{h}(x, y, D) = \frac{\sum_N L_s^i h_s^i}{\sum_N L_s^i}$$

$$\sigma^2\ (x, y, D) = \frac{\sum_N L_s^i \left(h_s^i\right)^2}{\sum_N L_s^i}$$

$$N(x, y, D) = number\ of\ segments$$

In the equations above, *h* is the segment freeboard for segment *i*, *L* is the associated segment length, and N is the population count.

Monthly

Monthly gridded freeboard is computed from the daily composites as follows:

$$\overline{L}_M(x, y) = \sum_{D} \overline{L}(x, y, d)$$

$$\overline{h}_M(x, y) = \frac{\sum_D \overline{h}(x, y, d)\overline{L}(x, y, d)}{\sum_D \overline{L}\ (x, y, d)}$$

$$\sigma_M^2(x,y) = \frac{\sum_D \overline{L}(x,y,d)(\sigma^2(x,y,d) + \overline{h}^2(x,y,d))}{\sum_D \overline{L}(x,y,d)} - \overline{h}_M^2(x,y)$$

$$N_M(x,y) = \sum_D N(x,y,D)$$

Additional information about how ATL20 is constructed is available in “Section 6.2 | Dataflow and procedural steps (ATL20)” in the ATBD for Sea Ice Products.

2.4 Quality, Errors, and Limitations

Errors in the ATLAS/ICESat-2 height retrievals can arise from a variety of sources, including:

- Sampling error (heights reflect random point sample of the height distribution)
- Background noise from random non-signal photon returns
- Misidentified signal photons
- Atmospheric forward scattering delays
- Subsurface scattering within ice or snow
- First-photon bias (inherent with photon-counting detectors)

These errors in ATLAS/ICESat-2 upstream products can propagate into ATL20. Error sources, their impacts, and mitigation strategies are discussed throughout the ATBD for Sea Ice Products. See “Section 2.2.5 | Potential error sources” for an overview.

3 VERSION HISTORY

A summary of the version history is provided in Table 3, followed by a detailed list of changes for the current version.

Table 3. Version History Summary

Version	Release Date
V1	November 2020
V2	April 2021
V3	December 2021
V4	August 2023

Changes for Version 4 are as follows:

- Corrected reported longitude values to agree with NSIDC Polar Stereographic projections.
- Added `grid_mapping` attribute to `land_mask_map` array.

- Updated the mean sea surface (MSS) variable description. Added mentions of the source of the MSS (which uses CryoSat-2 data) and clarified the use of the tide-free system.

4 RELATED DATA SETS

- ATLAS/ICESat-2 L3A Sea Ice Height (ATL07)
- ATLAS/ICESat-2 L3A Sea Ice Freeboard (ATL10)
- ATLAS/ICESat-2 L3B Daily and Monthly Gridded Polar Sea Surface Height Anomaly (ATL21)

5 RELATED WEBSITES

- Polar Stereographic Data | NSIDC Polar Stereographic Grid Definitions

6 DOCUMENT INFORMATION

6.1 Publication Date

August 2023

6.2 Date Last Updated

February 2024

APPENDIX A: ATLAS/ICESAT-2 DESCRIPTION

The ICESat-2 observatory utilizes a photon-counting lidar (the ATLAS instrument) and ancillary systems (GPS and star cameras) to measure the time a photon takes to travel from ATLAS to Earth and back again and to determine the photon's geodetic latitude and longitude. 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. Each pair also has a Pair Track—an imaginary line halfway between the actual location of the left and right beams (see Figure A1). 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 A1, left). 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 A1, right). The first yaw flip was performed on 28 December 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 tracking document (`.xlsx`).

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).

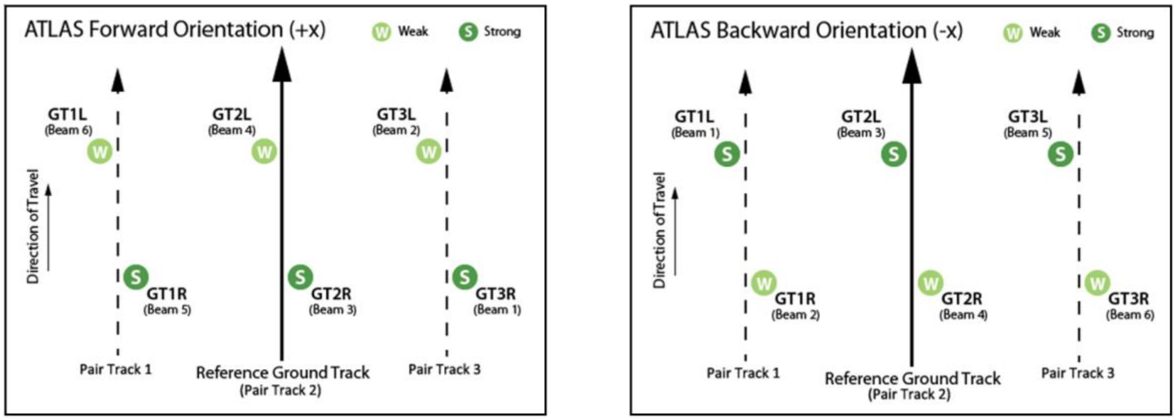

Figure A1. Spot and ground track (GT) naming convention with ATLAS oriented in the forward (instrument coordinate +x) direction and backward (instrument coordinate -x) direction.

Users should note that between 14 October 2018 and 30 March 2019, the spacecraft pointing control was not yet optimized. Thus, 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.

Various reference systems and dynamic processes, or geophysical corrections, occur during an ATLAS/ICESat-2 measurement (Figure A2). Table A1 lists the corrections needed for each surface type and ICESat-2 product. For example, to determine an estimate of the mean sea surface, several well-modeled, time-varying effects must be accounted for.

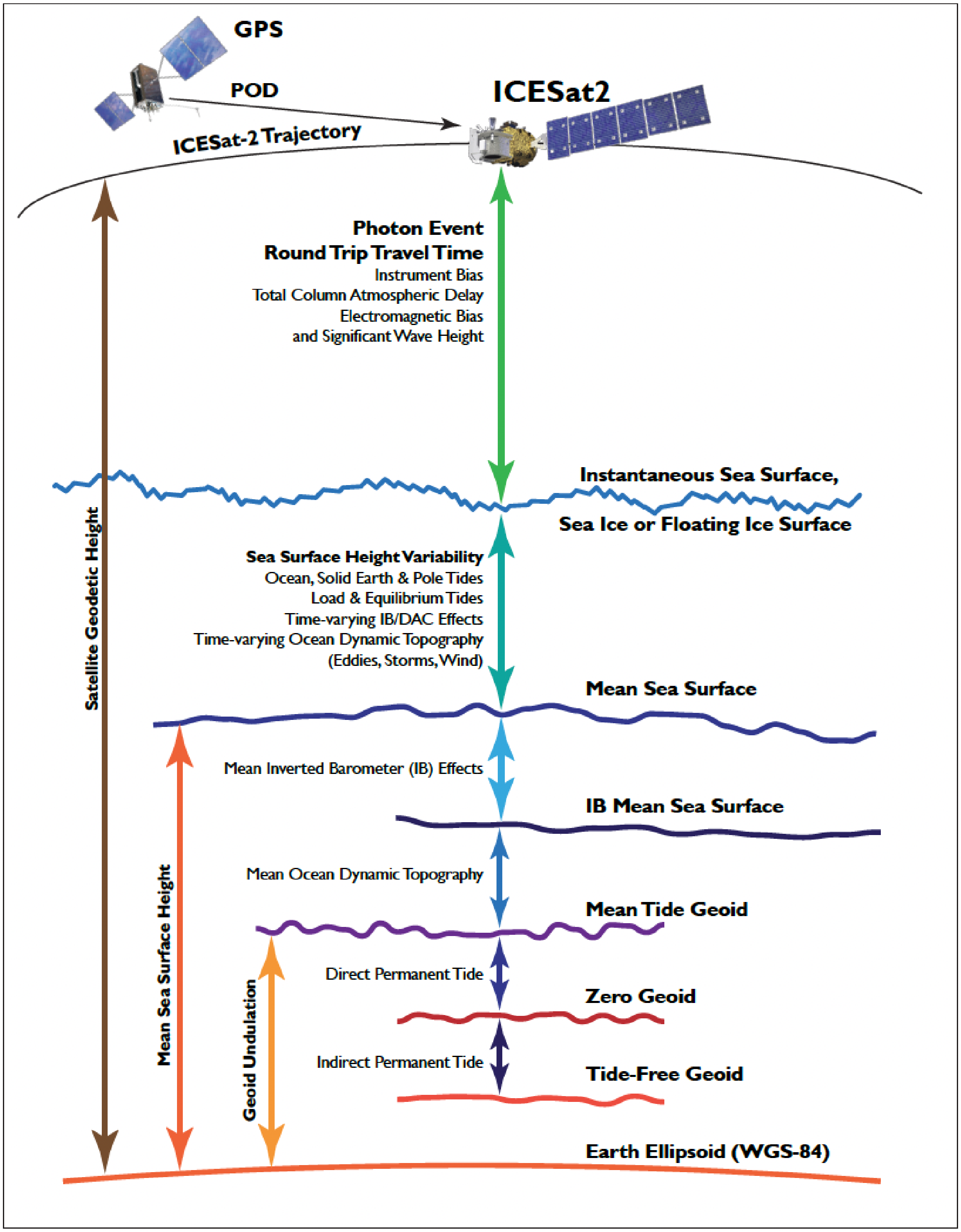

Figure A2. Geophysical corrections used in satellite altimetry.
Taken from *ICESat-2 Data Comparison User's Guide for Rel006*
available on the ATL03 data set landing page.

Table A1. Geophysical Corrections Applied to ICESat-2 Products

ICESat-2 Products by Surface Type	Geophysical Corrections[1]
Photon-level product (ATL03) (i.e., corrections applicable across all surface types)	Ocean loading Solid Earth tide Solid Earth pole tide Ocean pole tide Total column atmospheric range-delay
Land Ice, Land, and Inland Water (ATL06, ATL08, and ATL13)	*No corrections beyond ATL03*
Sea Ice (ATL07 and ATL10)	Referenced to mean sea surface Ocean tide Long period equilibrium ocean tide Inverted barometer (IB)
Ocean (ATL12)	Ocean tide Long period equilibrium ocean tide

[1]For details, see Section 5 of the *ICESat-2 Data Comparison User's Guide for Rel006* available on the ATL03 data set landing page.

NOTE: ICESat-2 reference ground tracks with dates and times can be downloaded as KMZ files from NASA's ICESat-2 | Technical Specs page, below the Orbit and Coverage table.