

# ATLAS/ICESat-2 L3B Daily and Monthly Gridded Polar Sea Surface Height Anomaly, Version 1

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## 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, N. Kurtz, J. Wimert, J. Lee, and D. Hancock. 2021.  
*ATLAS/ICESat-2 L3B Daily and Monthly Gridded Polar Sea Surface Height Anomaly, 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/ATL21.001>. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT [NSIDC@NSIDC.ORG](mailto:NSIDC@NSIDC.ORG)

FOR CURRENT INFORMATION, VISIT <https://nsidc.org/data/ATL21>



National Snow and Ice Data Center

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# 1 DATA DESCRIPTION

## 1.1 Parameters

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This data set contains daily and monthly gridded polar sea surface height (SSH) anomalies, derived from along-track ATLAS/ICESat-2 L3A Sea Ice Height product ([ATL10, V4](#)).

NOTE: Version 4 of the ATL07 and ATL10 sea ice products were converted to a tide-free system to be consistent with ATL03. However, ATL21 data have been put into mean-tide system to allow easier derivation of geophysical quantities such as dynamic ocean topography. For detailed conversion information see the Algorithm Theoretical Basis Document (ATBD) for Sea Ice Products ([ATBD for ATL07/ATL10/ATL20/ATL21 | V04, DOI: 10.5067/BHFDVX8Q6FKW](#)) and the known issues document under “Technical References” on the [ATL21](#) data set landing page.

## 1.2 File Information

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### 1.2.1 Format

Data are provided as HDF5 formatted files. HDF is a data model, library, and file format designed specifically for storing and managing data. For more information about HDF, visit the [HDF Support Portal](#).

### 1.2.2 File Contents

Data files contain gridded SSH anomalies for two time-spans: 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 ATL21 data files:

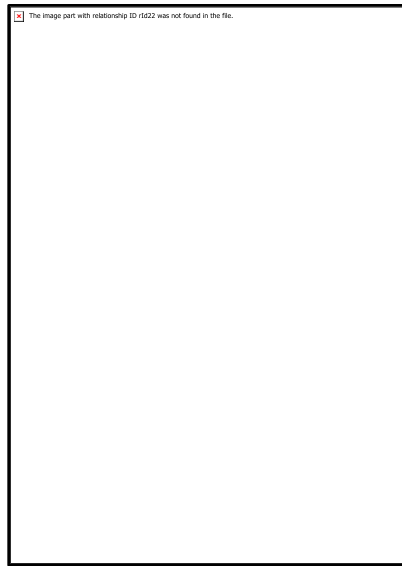


Figure 1. ATL21 Top-Level Data Groups and Variables

The following sections describe the data groups and their contents plus the variables stored at the top level in ATL21 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 SSH anomaly (mean\_ssh); gridded mean sea surface (mean\_weighted\_mss); EGM2008 geoid sampled at each reference surface height location (mean\_weighted\_geoid); number of reference surface heights in each grid cell (n\_refsufs); and daily standard deviation (sigma).

#### 1.2.3.4 monthly

Monthly gridded SSH anomaly (mean\_ssh), gridded mean sea surface (mean\_weighted\_mss), EGM2008 geoid sampled at each reference surface height location (mean\_weighted\_geoid), number of reference surface heights in each grid cell (n\_refsufs), and monthly standard deviation (sigma).

### 1.2.3.5 orbit\_info

Orbit parameters that are constant for a granule, such as the 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 ATL21 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 additional information, see the following technical references on the [ATL21 data set landing page](#):

- ATL21 Data Dictionary (complete list of variables stored)
- ATBD for ATL07/ATL10/ATL20/ATL21 | V04

## 1.2.4 Naming Convention

Data files utilize the following naming convention:

Example:

ATL21-02\_20190201001042\_05280201\_001\_01.h5  
 ATL21-[HH]\_[yyyymmdd][hhmmss]\_[tttccss]\_[vvv\_rr].h5

Variable	Description
ATL21	ATLAS/ICESat-2 L3B Daily and Monthly Polar Sea Surface Height Anomaly 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 Reference Ground Track number. The ICESat-2 mission has 1,387 RGTs, numbered from 0001 to 1387.

Variable	Description
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 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 superceded 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.

### 1.2.5 Browse File

An HDF5 browse file is provided for each granule that contains a composite image of the monthly mean sea surface height anomalies.

## 1.3 Spatial Information

### 1.3.1 Coverage

Spatial coverage includes regions in the ice-covered oceans of the Northern and Southern Hemispheres that have > 50% sea ice concentration and lie > 25 km away from the coast.

### 1.3.2 Resolution

25 km

### 1.3.3 Geolocation

Data are mapped on a planimetric grid using the SSM/I Polar Stereographic Projection.

Table 1. Northern Hemisphere Projection Details

<b>Geographic coordinate system</b>	Unspecified datum based upon the Hughes 1980 ellipsoid
<b>Projected coordinate system</b>	NSIDC Sea Ice Polar Stereographic North
<b>Longitude of true origin</b>	-45°

<b>Latitude of true origin</b>	70°
<b>Scale factor at longitude of true origin</b>	1
<b>Datum</b>	Not_specified_based_on_Hughes_1980_ellipsoid
<b>Ellipsoid/spheroid</b>	Hughes 1980
<b>Units</b>	Meters
<b>False easting</b>	0
<b>False northing</b>	0
<b>EPSG code</b>	3411
<b>PROJ4 string</b>	+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
<b>Reference</b>	<a href="https://epsg.io/3411">https://epsg.io/3411</a>

Table 2. Southern Hemisphere Projection Details

<b>Geographic coordinate system</b>	Unspecified datum based upon the Hughes 1980 ellipsoid
<b>Projected coordinate system</b>	NSIDC Sea Ice Polar Stereographic South
<b>Longitude of true origin</b>	0°
<b>Latitude of true origin</b>	-70°
<b>Scale factor at longitude of true origin</b>	1
<b>Datum</b>	Not_specified_based_on_Hughes_1980_ellipsoid
<b>Ellipsoid/spheroid</b>	Hughes 1980
<b>Units</b>	Meters
<b>False easting</b>	0
<b>False northing</b>	0
<b>EPSG code</b>	3412
<b>PROJ4 string</b>	+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
<b>Reference</b>	<a href="https://epsg.io/3412">https://epsg.io/3412</a>

Table 3. Grid Details

Hemisphere	North	South
Grid cell size (x, y pixel dimensions)	25 km, 25 km	25 km, 25 km
Number of rows	448	332
Number of columns	304	316
Geolocated lower left point in grid	30.98° (Lat) 168.35° (Lon)	-39.23° (Lat) 317.76° (Lon)
Nominal gridded resolution	25 km	25 km
Grid rotation	N/A	N/A
ulxmap – x-axis map coordinate of the center of the upper-left pixel (XLLCORNER for ASCII data)	-3850 projected km	-3950 projected km
ulymap – y-axis map coordinate of the center of the upper-left pixel (YLLCORNER for ASCII data)	5850 projected km	4350 projected km

## 1.4 Temporal Information

### 1.4.1 Coverage

01 November 2018 to 01 July 2021

### 1.4.2 Resolution

Two resolutions are provided: daily and monthly. 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. This ATBD provides detailed descriptions of the following ATLAS/ICESat-2 products:

- ATLAS/ICESat-2 L3A Sea Ice Height (ATL07)
- ATLAS/ICESat-2 L3A Sea Ice Freeboard (ATL10)
- ATLAS/ICESat-2 L3B Daily and Monthly Gridded Sea Ice Freeboard (ATL20)
- ATLAS/ICESat-2 L3B Daily and Monthly Gridded Sea Surface Height Anomaly (ATL21)

To obtain the ATBD for Sea Ice Products, see “Technical References” on the [ATL21 data set landing page](#).



## 2.1 Background

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The ATL10 product identifies leads\* in sea ice and establishes a reference sea surface used to estimate SSH in 10 km along-track segments. ATL21 aggregates the ATL10 along-track SSH estimates and computes daily and monthly gridded SSH anomaly 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

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The ATL21 algorithm inputs ATL10 granules and computes gridded daily and monthly SSH anomaly as described in the following section.

## 2.3 Processing

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To compute SSH anomalies, the algorithm collects all the ATL10 center strong beam SSH (10 km reference surface height) segments from the time span of interest and performs the following calculations. This version of ATL21 uses only the center strong beam as beam alignment efforts are still on-going. For more detail see the known issues document under “Technical References” on the [ATL21 data set landing page](#).

### Daily

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

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

$$\sigma^2(x, y, D) = \frac{\sum_N (h_s^i)^2}{N} - \bar{h}^2(x, y, D)$$

In the equations above,  $h$  is the SSH for segment  $i$  and  $N$  is the number of segments in the given daily grid-cell.

### Monthly

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

$$\bar{h}_M(x, y) = \frac{\sum_D \bar{h}(x, y, D)}{N_D}$$

$N_D$  is the number of days in the month. Additional information about how ATL21 is constructed is available in “Section 6.3 | Dataflow and procedural steps (ATL21)” in the ATBD for Sea Ice Products.

## 2.4 Quality, Errors, and Limitations

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

- Sampling error (heights reflect random point samples 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 ATL21. 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

Version 1 (02 August 2021).

Note: Version 1 of this data set was derived from Version 4 of ATL10.

## 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 Sea Ice Freeboard \(ATL20\)](#)

## 5 RELATED WEBSITES

- [Polar Stereographic Data | NSIDC Polar Stereographic Grid Definitions](#)

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## 7 DOCUMENT INFORMATION

### 7.1 Publication Date

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02 August 2021

### 7.2 Date Last Updated

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14 December 2021

## 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 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 - 1 Figure 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 [ATL10](#) 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.

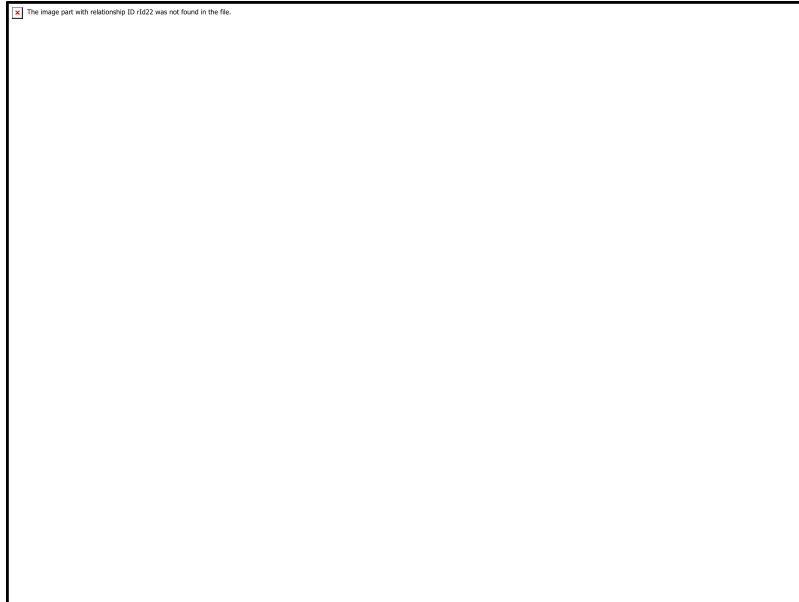


Figure A - 1. Spot and ground track (GT) naming convention with ATLAS oriented in the forward (instrument coordinate +x) direction.

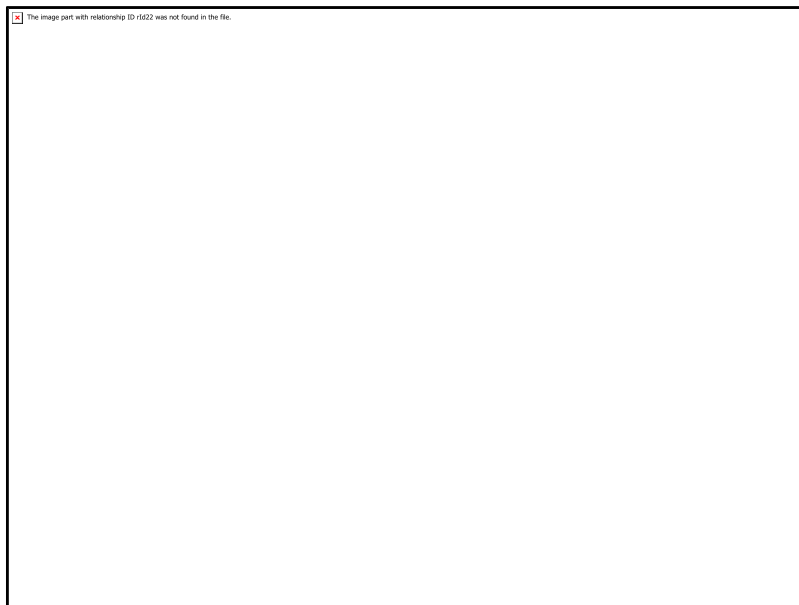


Figure A - 2. Spot and ground track (GT) naming convention with ATLAS oriented in the backward (instrument coordinate -x) direction.