



# ATLAS/ICESat-2 L3A Sea Ice Height Quick Look, Version 6

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## USER GUIDE

### How to Cite These Data

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

Kwok, R., A. Petty, G. Cunningham, T. Markus, D. Hancock, A. Ivanoff, J. Wimert, M. Bagnardi, N. Kurtz, and the ICESat-2 Science Team. 2023. *ATLAS/ICESat-2 L3A Sea Ice Height Quick Look, Version 6*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. <https://doi.org/10.5067/ATLAS/ATL07QL.006>. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT <https://nsidc.org/data/ATL07QL>



National Snow and Ice Data Center

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# 1 DATA DESCRIPTION

NOTE: ATL07QL is the quick look version of ATL07. The ATL07QL products are based on the same algorithms that generate the ATL07 final data products. Once final ATL07 files are available, the corresponding ATL07QL files will be removed. For details on quick look data quality, see Section 2.4.1.

## 1.1 Parameters

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Along-track sea ice and sea surface heights. Sea ice heights are referenced to the time-varying sea surface, which includes ocean tides, the inverse barometer effect, and other corrections.

## 1.2 File Information

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### 1.2.1 Format

Data are provided as HDF5 formatted files.

### 1.2.2 ATLAS/ICESat-2 Description

NOTE: The following brief description of the Ice, Cloud and land Elevation Satellite-2 (ICESat-2) observatory and Advanced Topographic Laser Altimeter System (ATLAS) instrument is provided to help users better understand the file naming conventions, internal structure of data files, and other details referenced by this user guide. The ATL07 data product is described in detail in the Ice, Cloud, and land Elevation Satellite-2 (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>)

The ATLAS instrument and ICESat-2 observatory utilize a photon-counting lidar and ancillary systems (GPS, star cameras, and ground processing) to measure the time a photon takes to travel from ATLAS to Earth and back again and determine the reflected photon's geodetic latitude and longitude. Laser pulses from ATLAS illuminate three left/right pairs of spots on the surface that trace out six approximately 14 m wide ground tracks as ICESat-2 orbits Earth. 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. Higher level ATLAS/ICESat-2 data products (ATL03 and above) are 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 1). 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 , 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 1, 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 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, for example in ATL02 file names, by appending the two-digit cycle number (cc) to the RGT number, e.g., 0001cc to 1387cc.

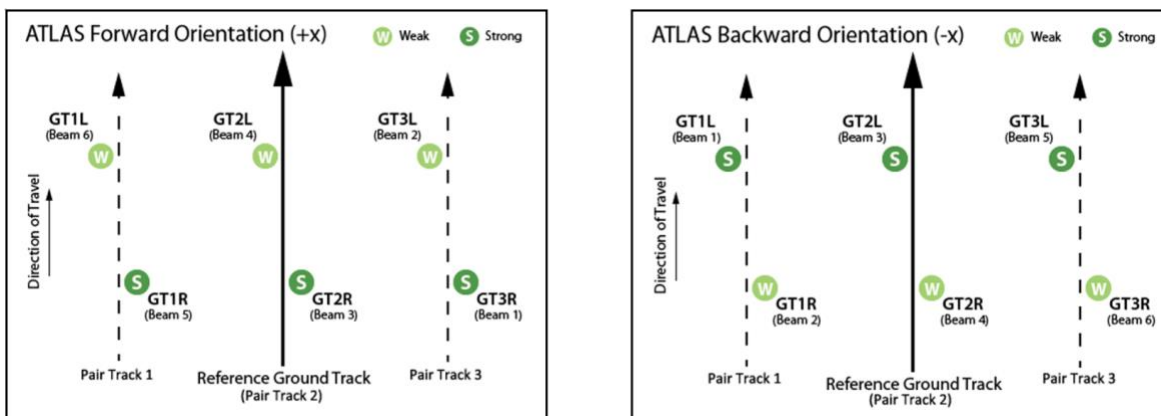


Figure 1. Spot and ground track (GT) naming convention with ATLAS oriented in the forward (instrument coordinate +x) direction and backward (instrument coordinate -x) direction.

Under normal operating conditions, no data are collected along the RGT; however, during spacecraft slews, or off-pointing, some ground tracks may intersect the RGT. Off-pointing refers to a series of plans over the mid-latitudes that have been designed to facilitate a global ground and canopy height data product with approximately 2 km track spacing. Off-pointing began on 1 August

2019 with RGT 518, after the ATLAS/ICESat-2 PPD and POD solutions had been adequately resolved and the instrument had pointed directly at the reference ground track for at least a full 91 days (1,387 orbits).

Users should note that sometimes, for various reasons, the spacecraft pointing may lead to ICESat-2 data collected offset at some distance from the RGTs instead of along the nominal RGT. Although not along the nominal RGT, the geolocation information and data quality for these data are not degraded. As an example, from 14 October 2018 and 30 March 2019, the spacecraft pointing control was not yet optimized. To identify such time periods, refer to the ICESat-2 Major Activities file.

**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.

Various reference systems and dynamic processes, or geophysical corrections, occur during an ATLAS/ICESat-2 measurement (Figure 2). Table 1 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.

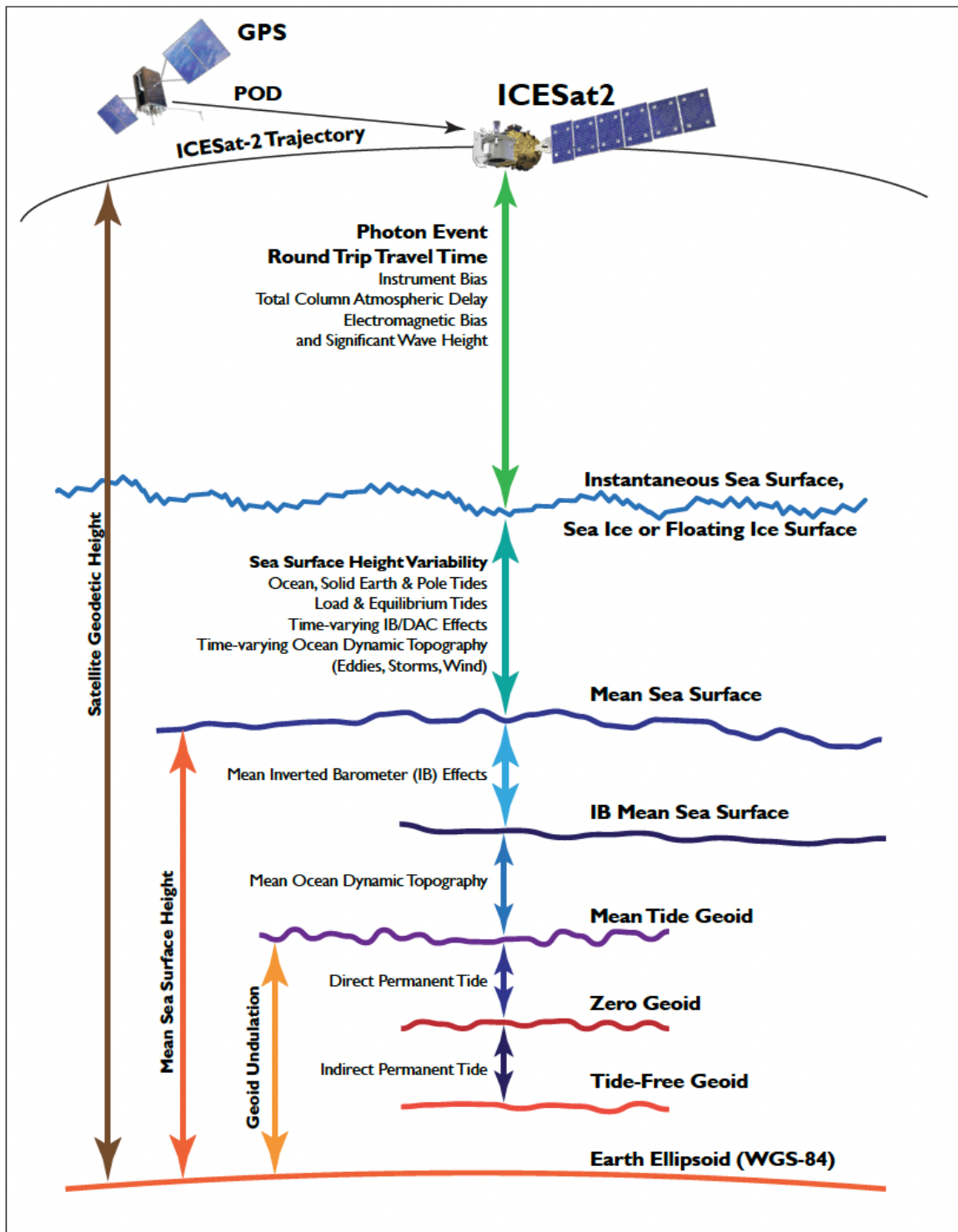


Figure 2. Geophysical corrections used in satellite altimetry. Taken from *ICESat-2 Data Comparison User's Guide for Rel006* available on the ATL03 data set landing page.

Table 1. Geophysical Corrections Applied to ICESat-2 Products

ICESat-2 Products by Surface Type	Geophysical Corrections <sup>1</sup>
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)	<i>No corrections beyond ATL03</i>
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

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

### 1.2.3 File Contents

Data files (granules) contain the sea ice retrievals for one of ATLAS's 1,387 orbits, provided as separate files for Northern Hemisphere and Southern Hemisphere overpasses. Fifteen (and occasionally 16) granules are available per hemisphere per day.

### 1.2.4 Data Groups

Within data files, similar variables such as science data, instrument parameters, and metadata are grouped together according to the HDF model. ATL07 data files contain the top-level groups shown in the following figure.

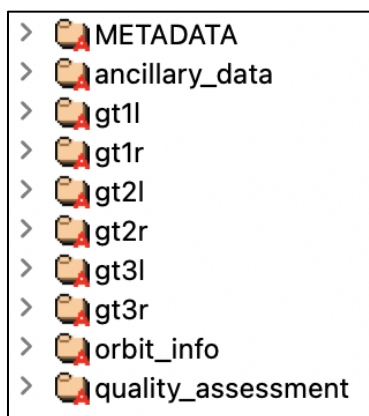


Figure 1. ATL07 top-level data groups shown in HDFView.

The following sections summarize the structure and primary variables of interest in ATL07 data files. Additional details are available in Appendix A of the ATBD for ATL07/10/20/21. The ATL07 Data Dictionary contains a complete list of all ATL07 parameters.

#### 1.2.4.1 METADATA

ISO19115 structured summary metadata.

#### 1.2.4.2 ancillary\_data

Ancillary information such as product and instrument characteristics and processing constants.

#### 1.2.4.3 gt1l–gt3r

Six ground track groups (gt1l–gt3r), each with a `sea_ice_segments` subgroup that contains the parameters for the specified ATLAS ground track. Parameters include mean segment heights (`/heights/height_segment_height`); segment surface type (`/heights/height_segment_type`); segment latitude and longitude; geosegment start and end times; geophysical parameters and corrections (`/geophysical/`); and parameters related to data quality (`/stats/`).

#### 1.2.4.4 orbit\_info

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

#### 1.2.4.5 quality\_assessment

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



## 1.2.5 Naming Convention

Data files utilize the following naming convention:

ATL07QL-[HH]\_[yyyymmdd][hhmmss]\_[ttttccss]\_[vvv\_rr].h5

Examples:

ATL07QL-01\_20210713014743\_02971201\_006\_01.h5

ATL07QL-02\_20210713014743\_02971201\_006\_01.h5

The following table describes the file naming convention variables:

Table 2. File Naming Convention Variables and Descriptions

Variable	Description
ATL07QL	ATLAS/ICESat-2 L3A Sea Ice Height Quick Look product
HH	Hemisphere code. Northern Hemisphere = 01, Southern Hemisphere = 02
yyyymmdd	Year, month, and day of data acquisition for the given RGT
hhmmss	ICESat-2 data acquisition start time in hour, minute, and second (UTC) for the given RGT (not the start of ATL07 data production)
tttt	Four-digit Reference Ground Track number. The ICESat-2 mission has 1,387 RGTs, numbered from 0001 to 1387.
cc	Cycle Number. Each of the 1,387 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 for ATL07QL. 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 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.

## 1.2.6 Browse Files

Browse files are provided as JPGs that contain images designed to quickly assess the location and quality of each granule's data. The following browse images are available:

### 1.2.6.1 Line plots (beams)

- height of segment
- width of best fit Gaussian

- height segment surface type
- length of segment
- height fit quality flag
- ice concentration
- apparent surface reflectivity (25 Hz)

### 1.2.6.2 Histogram

- height of segment
- width of best fit Gaussian
- length of segment

Browse files utilize the same naming convention as their corresponding data file but with "\_BRW" and descriptive keywords appended.

## 1.3 Spatial Information

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### 1.3.1 Coverage

Spatial coverage spans the ice-covered oceans of the northern and southern hemispheres with > 15% sea ice concentration.

#### 1.3.1.1 Sea Ice Mask

[Static surface masks](#) (land ice, sea ice, land, and ocean) are applied to ATL03 to reduce the volume of data that a surface-specific along-track data product is required to process. The [sea ice surface mask](#) directs the ATL07 algorithm to consider data from only those areas of interest.

### 1.3.2 Resolution

The ATLAS instrument transmits laser pulses at 10 kHz. At the nominal ICESat-2 orbit altitude of 500 km, this yields approximately one transmitted laser pulse every 0.7 meters along ground tracks. Note, however, that the number of photons that return to the telescope depends on surface reflectivity and cloud cover (which obscures ATLAS's view of Earth). As such, the spatial resolution varies.

Sea ice heights are derived from segments that vary in length depending on the distance over which 150 signal photons are accumulated, which changes with varying surface types up to a maximum of 150 meters, and the number of available sea surface height segments to derive a reference sea surface. The along-track length of the height segments is stored in `gt[x]/sea_ice_segments/heights/height_segment_length_seg`.

### 1.3.3 Geolocation

Points on Earth are presented as geodetic latitude, longitude, and height above the ellipsoid using the WGS 84 geographic coordinate system (ITRF2014 Reference Frame). The following table contains details about WGS 84:

Table 3. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	N/A
Longitude of true origin	Prime Meridian, Greenwich
Latitude of true origin	N/A
Scale factor at longitude of true origin	N/A
Datum	World Geodetic System 1984
Ellipsoid/spheroid	WGS 84
Units	degree
False easting	N/A
False northing	N/A
EPSG code	4326
PROJ4 string	+proj=longlat +datum=WGS84 +no_defs
Reference	<a href="https://epsg.io/4326">https://epsg.io/4326</a>

For information about ITRF2014, see the International Terrestrial Reference Frame | [ITRF2014 webpage](#).

## 1.4 Temporal Information

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### 1.4.1 Coverage

Quick look data are published ~72 hours after satellite observation and removed once the final files arrive or after three months if the final file does not get released due to quality issues.

NOTE: ATL07QL granules will be removed once the final ATL07 granule is available; therefore, the temporal coverage will be a sliding window.

### 1.4.2 Resolution

Each of ICESat-2's 1,387 RGTs is targeted in the polar regions once every 91 days (i.e., the satellite has a 91-day repeat cycle).

Note that satellite maneuvers, data downlink issues, and other events can introduce data gaps into the ICESat-2 suite of products. ATL03 acts as the bridge between the lower level, instrumentation-specific data and the higher-level products. On the data set landing page under Documentation, users can download and consult a regularly updated list of [ATL03 data gaps](#) (.xlsx).

## 2 DATA ACQUISITION AND PROCESSING

### 2.1 Background

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The ATLAS/ICESat-2 sea ice products are derived from geolocated, time-tagged photon heights plus other parameters passed to them by the ATLAS/ICESat-2 L2A Global Geolocated Photon Data (ATL03) product. The following figure illustrates the suite of ICESat-2 data products:

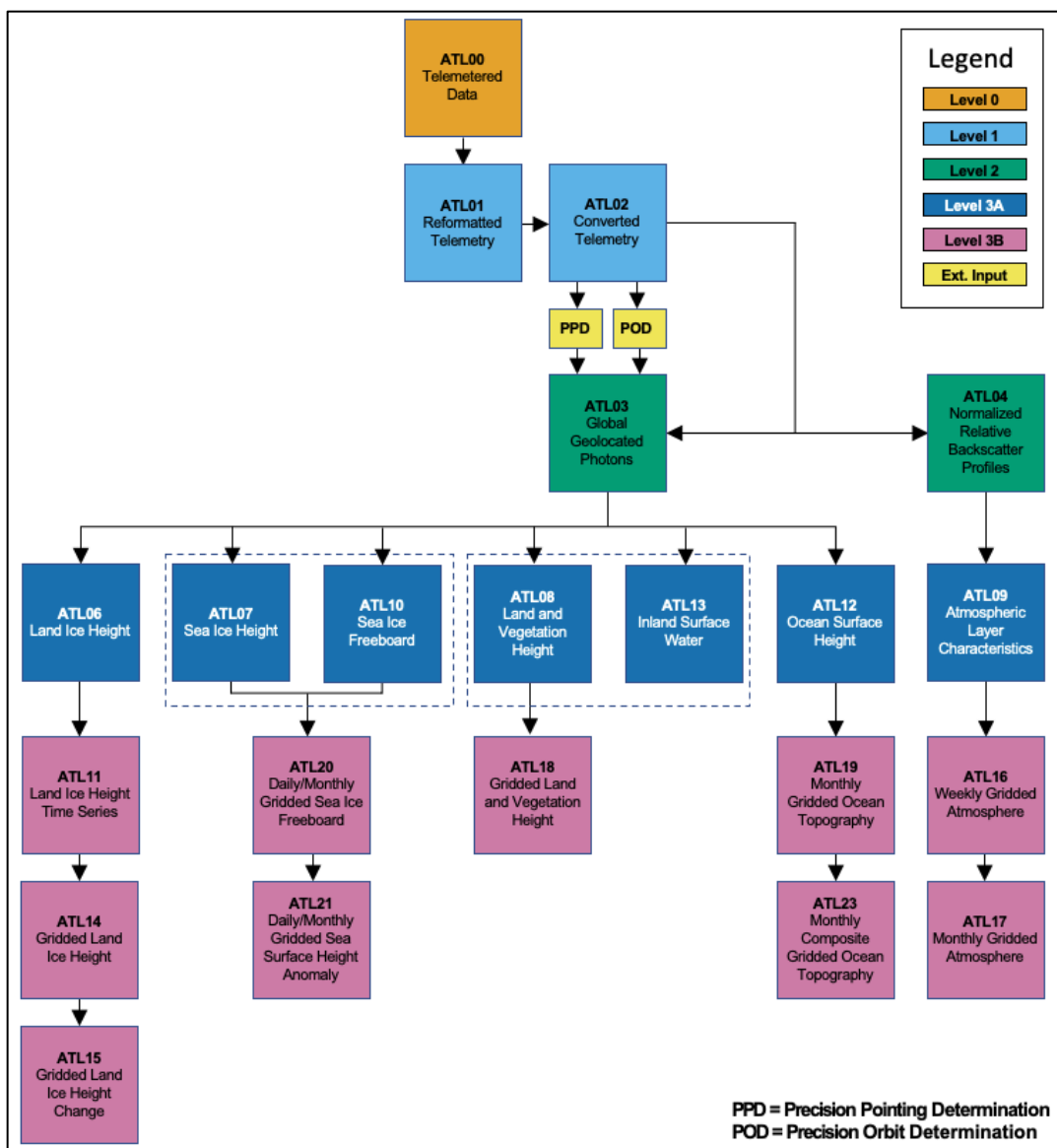


Figure 2. ICESat-2 data processing flow. The ATL01 algorithm reformats and unpacks the Level 0 data and converts them into engineering units. ATL02 processing converts the ATL01 data to science units and applies instrument corrections. The Precision Pointing Determination (PPD) and Precision Orbit Determination (POD) solutions compute the pointing vector and position of the ICESat-2 observatory as a function of time. ATL03 acts as the bridge between the lower level, instrumentation-specific products and the higher-level, surface-specific products.

## 2.2 Acquisition

NOTE: The following sections briefly describe the key input data used to generate the ATL07 product. Input sources include [ATL03](#), [ATL09](#) (the ATLAS/ICESat-2 L3A Calibrated Backscatter Profiles and Atmospheric Layer Characteristics product), plus external sources. More detailed information is available in "Section 3.1.3 | Input from IS-2 Products (ATL03 and ATL09)" and "Section 7.4 | Parameters from Ancillary Sources" in the ATDB for ATL07/10/20/21.

### 2.2.1 ATL03

Input data from ATL03 primarily comprises photon heights, background rates, and geophysical corrections. These corrections include the effects of the atmosphere, as well as tides and solid Earth deformation. Although some corrections are applied by default to generate a best estimate of the photon height, by design each of these can easily be removed by the end user if desired. ATL03 also generates corrections that are not applied by default so that users may decide whether to apply them.

The time-dependent geophysical corrections from ATL03 fall into three categories: (1) corrections that have been applied to the photon ellipsoid heights; (2) corrections that have not been applied but are provided as reference values; and (3) static reference values provided along with their typical, respective, magnitudes. Geophysical corrections are stored in the `gt[x]/sea_ice_elements/geophysical/` group and described in detail in Section 6 of the ATL03 ATBD.

#### 2.2.1.1 Corrections applied due to variations in surface bounce point

- Solid Earth tides; magnitude =  $\pm 40$  cm (max)
- Ocean loading; magnitude < 10 cm
- Solid Earth pole tide deformation due to centrifugal effect from small variations in polar motion; magnitude =  $\pm 1.5$  cm
- Ocean pole tide, a global height correction caused by deformational load upon the Earth due to centrifugal effect from small variations in polar motion; magnitude =  $\pm 2$  mm amplitude

#### 2.2.1.2 Corrections provided as reference values but NOT applied

- Ocean tides, including diurnal and semi-diurnal (harmonic analysis) and longer period tides (dynamic and self-consistent equilibrium) tides; magnitude =  $\pm 5$  m

#### 2.2.1.3 Photon round-trip range corrections

- Total column atmospheric delay; magnitude = -2.6 to -0.9 m
- Geoid (static quantity); magnitude = -105 to +90 m (max)

### 2.2.2 ATL09

Inputs from ATL09 consist of atmospheric parameters that are used to assess potential atmospheric impacts including how clouds effect photon returns. Parameters include:

- Relative/calibrated backscatter
- 25 Hz background photon rates
- 25 Hz cloud statistics
- Sea level pressure, 2 m air temperature, 2 m eastward wind, 2 m northward wind

## 2.2.3 External inputs

- Ice concentration (daily fields)
- Mean sea surface (MSS) height from ICESat and CryoSat-2
- Land Mask
- Distance from Land Mask

## 2.3 Processing

NOTE: The following description briefly outlines the product coverage and approach used to generate the ATL07 product. Users seeking a detailed description of the algorithm and processing steps should consult "Section 4 | Algorithm Description: ATL07" of the ATBD for ATL07/10/20/21.

### 2.3.1 Product Coverage

The marginal ice zone is defined as that part of the ice cover with < 15% ice concentration, determined from daily ice concentration fields from satellite passive microwave brightness temperatures. Returns with ice concentrations < 15% are not processed.

The ATL07 product contains the sea surface height and sea ice height for segments along each of the six ground tracks. The along-track length of these segments is determined by the distance over which approximately 150 signal (surface) photons are accumulated, which changes with varying surface types up to a maximum of 150 meters. Cloudy conditions are identified using parameters input from ATL09, and height estimates are not produced for segments contaminated by clouds.

### 2.3.2 Surface Finding

In brief, the algorithm locates the ice and sea surfaces in the photon clouds obtained from ATL03 using a two-step procedure: coarse surface finding, followed by fine. Prior to surface finding, the mean sea surface is removed from the ATL03 data and the inverted barometric (IB) correction is calculated using the sea level pressure from ATL09. Corrected heights are computed as:  $h = h_{ph} - h_{mss} - h_{IB}$ , where  $h_{ph}$  are the ATL03 photon heights,  $h_{mss}$  is the mean sea level height, and  $h_{IB}$  is the computed IB correction (the sign convention follows that used in ATL03).

The ATL03 product provides photon clouds in 30 m height windows that include the surface return. For the three strong beams, the coarse surface finding algorithm aims to produce an estimate of the mean surface height within  $\pm 0.5$  m of the local surface over an L-km long segment of the orbit; this approach narrows the search space and the computational load of the subsequent fine surface finding process. The fine-tracking algorithm breaks up the coarse segments into  $N = 150$  photon aggregate segments (although this number can be changed. See "Section 4 | Algorithm Description: ATL07" in the ATBD for ATL07/10/20/21). As a result, the last aggregate in

the coarse along-track segment may have fewer than N photons; when this occurs, the  $N < 150$  segment is flagged and skipped over. When the coarse-tracking algorithm advances to the next L-km along-track segment, it starts from the location of flagged aggregate segments. Consequently, no valid data are erroneously removed.

For weak beams, coarse height estimates are derived from the results of the fine surface-finding algorithm for the adjacent strong beams. That is, each weak beam is slaved to the fine-tracker output from its corresponding strong beam.

### 2.3.3 Surface Type

Each surface height segment is labeled as belonging to a surface type based on a classification algorithm that determines the most likely surface type from photon and background rates. The surface type of an individual height segment (stored in `gt[x]/sea_ice_segments/heights/seg_surf_type`) is labeled based on three parameters: surface photon rate, the width of photon distribution (or fitted Gaussian) and the background rate. The combination of these parameters reduces ambiguity in identifying the surface type and the possibility of undetected cloud contamination in that segment. Conceptually, these three parameters are used as follows:

- The surface photon rate (photon returns per pulse) is a measure of the brightness, or apparent surface reflectance, of that height segment. In general, low surface rates indicate water or thin ice in open leads. However, specular and quasi-specular returns have been observed from smooth open water/thin ice surfaces in both ICESat/GLAS and a pre-launch, airborne testbed instrument. As such, very high observed photon rates are handled differently; specular returns from these surfaces are especially useful since they provide large numbers of photons for surface finding.
- The width of the photon distribution provides a measure of the surface roughness and can be used to partition the height segments within four ranges that correspond to different surface types.
- The background rate provides useful information when the solar elevation is high and sufficient photons are present to yield a relatively accurate rate estimate. For example, for Lambertian surfaces under clear skies, the surface photon rate should be approximately linearly related to the background rate. When it is not, and the solar elevation is high, this indicates shadows (cloud shadows or ridge shadows), specular returns, or possibly, atmospheric effects. In the case of specular returns from a dark lead, the near linear behavior would deviate significantly from expected; that is, the surface photon rate is high but the background rate would be very low. In the shadow case, the background would be lower than expected. When the solar elevation angle is low, the uncertainty in the background rate is high, and this parameter is not used for surface type classification.

"Section 4 | Algorithm Description: ATL07" in the ATBD for ATL07/10/20/21 contains a complete description of algorithm strategy and implementation. Of particular interest, Sections 4.2.4 through



4.2.5 detail expected uncertainties associated with the surface height retrieval and describe a number of statistical quality metrics computed during product generation.

"Section 7 | Algorithm Implementation Considerations" in the ATBD discusses implementation details including how surface finding and classification are applied to ATLAS/ICESat-2's multi-beam architecture, product coverage, and the internal and external parameters required to produce the sea ice products.

## 2.4 Quality, Errors, and Limitations

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"Section 10 | Constraints, Limitations, and Assumptions" in the ATBD for ATL07/10/20/21 discusses the constraints, limitations, and assumptions that impact the coverage, quality, and interpretation of the sea retrievals.

The `/gt[x]/sea_ice_segments/heights/` subgroups contain key segment quality indicators, such as:

- `height_segment_confidence`: confidence level in the surface height estimate based on analysis of the error surface
- `height_segment_fit_quality_flag`: quality of the along-track fit from 1 (best) to 5 (poor)
- `height_segment_quality`: binary indicator (1 = good, 0 = bad) of height segment quality
- `height_segment_surface_error_est`: error estimate of the surface height (meters)

Errors in height retrievals from photon counting lidars like ATLAS can arise from a variety of sources. For example:

- Sampling error: ATLAS height estimates are based on random point samplings of the surface height distribution.
- Background noise: sampled photons include some random outliers that are not from the surface.
- Misidentified photons: the retrieval algorithms do not always utilize the correct photons as surface photons when estimating surface height.
- Atmospheric forward scattering: photons traveling downward through a cloudy atmosphere may be scattered through small angles and yet still be reflected by the surface within the ATLAS field of view. As such, these photons will be delayed and produce an apparently lower surface.
- Subsurface scattering: photons may be scattered many times within ice or snow before returning to the detector and may yield surface height estimates with a low bias.
- First-photon bias: this error, inherent to photon-counting detectors, results in a high bias in the mean detected photon height that depends on signal strength.

Error sources, corrections, and mitigation strategies are also discussed throughout the ATBD. In particular, users may wish to consult "Section 2.2.5 | Potential Error Sources" and "Section 4 | Algorithm Description: ATL07."

## 2.4.1 Quick Look Data Quality

The ATL07 quick look products (ATL07QL) are based on the same algorithms that generate the ATL07 final data products. There are two primary differences between final and quick look products: (a) the geolocation uncertainty of the segment and (b) the uncertainty in the reported segment heights.

Analysis to date shows that between 1% and 2% of granules have substantially larger errors than reported below. The ICESat-2 Project Science Office is working to identify and withhold these from further distribution.

### 2.4.1.1 Geolocation Uncertainty

The final data (ATL07) are based on the best possible solutions for the position of the observatory in space through time. These data use the final orbits of the GPS constellation tracked by the GPS receiver aboard ICESat-2. These products have a geolocation uncertainty of < 5 m. That is, the latitude and longitude of the segments in the ATL07 product are accurately located with less than a 5 m uncertainty.

The ATL07QL data use less precise orbits of the GPS constellation tracked by the GPS receiver aboard ICESat-2. These quick look data have a geolocation uncertainty of ~100 m. That is, the latitude and longitude of the segments in the ATL07QL data are accurately located with approximately 100 m uncertainty.

### 2.4.1.2 Height Uncertainty

As a result of the larger uncertainty on the position of the ICESat-2 observatory in space, the ATL07QL segment heights are impacted. For ATL07, Kwok et al. (2019) showed standard errors of heights are < 12 cm in comparison with ATM data from Operation IceBridge over 10 km segments. For ATL07QL data, the reported segment heights are lower than the segment heights on the final data products by 2.7 m and have a standard deviation of ~7 m. To get the most accurate heights, users can add 2.7 m to the segment heights reported on ATL07QL data; the resulting heights have a mean bias (measured over a month) of approximately zero and a standard deviation of approximately 7 meters.

### 3 VERSION HISTORY

Changes for Version 6 include:

- Added new uncorrected sea ice segment height parameter, which is directly computed using ATL03 photon heights. This provides additional coverage for areas where corrected sea ice segment heights cannot be processed, such as regions with low sea ice concentration and regions with missing geophysical corrections.
- Added AMSR2 sea ice concentration (SIC) data, which provide a higher resolution grid than the existing SIC file.
- Implemented land filtering. The introduction of uncorrected heights (which can be processed anywhere) caused many returns over land, so `distance_to_land` and bathymetry ancillary files were introduced. The bathymetry file and `distance_to_land` filter remove and lower the mean sea ice height.
- Added ANC10 ancillary file to read in sea level pressure, which was previously input from ATL09, to provide mean sea level pressure over the oceans for the dynamic inverted barometer (IB) correction.
- Added Yet Another Photon Classifier (YAPC) parameters by aggregating YAPC metrics from ATL03 to ATL07 sea ice segment heights data.
- Introduced interpolation and extrapolation routines for ocean tides and MSS. The ocean tide reported on ATL03 (GOT4.8 model) has spatial gaps and the MSS grid lacks coverage along coasts and in bays. If the missing parameters are interpolated, then the interpolated geophysical corrections are applied, and corrected heights are produced. Extrapolated parameters are not used to compute a corrected height, and only uncorrected heights are available.
- Updated the `PODPPD_flag` filter so that a processing option is available for every flag value.
- In V5 and earlier, the IB correction was computed using a static mean ocean sea level pressure. V5 introduced a dynamically computed IB correction by computing mean ocean sea level pressure for each granule but continued to use static IB in sea ice processing. V6 uses dynamic IB for processing and reads/interpolates sea level pressure directly from ANC10. The updated dynamic IB improves model accuracy and is comparable to the IB corrections commonly provided by other altimetry missions.
- Previously, lineage information was missing in the metadata. The metadata has been updated so that lineage information for ANC10 and ANC48 is written to the ATL07 data product.
- Updated the MSS variables description, added mentions of the source of the MSS (which uses CryoSat-2 data), and clarified the use of the tide free system.

25 May 2023 – minor version upgrade:

- SIC data switched from AMSR2 to SSM/I ([G10016](#)) beginning on 25 May 2023 to address an issue that occurs based on the presence or absence of ANC49 inputs during processing.

## 4 REFERENCES

Kwok, R., Kacimi, S., Markus, T., Kurtz, N. T., Stundinger, M., Sonntag, J. G., Manizade, S. S., Boisvert, L. N., & Harbeck, J. P. (2019). ICESat-2 surface height and sea ice freeboard assessed with ATM lidar acquisitions from Operation IceBridge. *Geophysical Research Letters*, 46, 11228-11236. <https://doi.org/10.1029/2019GL084976>

## 5 DOCUMENT INFORMATION

### 5.1 Publication Date

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January 2023

### 5.2 Date Last Updated

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