ATLAS/ICESat-2 L3A Sea Ice Height, Version 7

USER GUIDE

How to Cite These Data

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

Kwok, R., Petty, A., Cunningham, G., Markus, T., Hancock III, D. W., Ivanoff, A., Wimert, J., Bagnardi, M., Kurtz, N., & the ICESat-2 Science Team (2025). *ATLAS/ICESat-2 L3A Sea Ice Height* (ATL07, Version 7). [Data set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ATLAS/ATL07.007 [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ATL07

NSIDC National Snow and Ice Data Center

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1 DATA DESCRIPTION

The ATL07 data product is described in detail in the ICESat-2 Project Algorithm Theoretical Basis Document (ATBD) for Sea Ice Products (ATBD for ATL07/10/20/21 | Version 7, https://doi.org/10.5067/KPMXUOH7TNIY).

1.1 Summary

ATL07 contains along-track sea surface height and sea ice height for segments of variable lengths for all beams as well as fixed 10-meter segments for strong beams. Heights are also computed using the DDA-Bifurcation algorithm for strong beams. The data were acquired by the Advanced Topographic Laser Altimeter System (ATLAS) instrument on board the ICESat-2 observatory.

1.2 File Information

1.2.1 Format

Data are provided as HDF5-formatted files.

1.2.2 File Contents

A complete list of all ATL07 parameters is available in the ATL07 Data Dictionary.

The ATL07 product consists of up to 32 files (granules) per day: 16 for the Northern Hemisphere and 16 for the Southern Hemisphere. Each granule contains sea ice retrievals from data acquired over half an orbit. Six ground tracks within each granule span the width of the orbital swath with an across-track distance of 6 km.

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 and subgroups shown in the following figure.

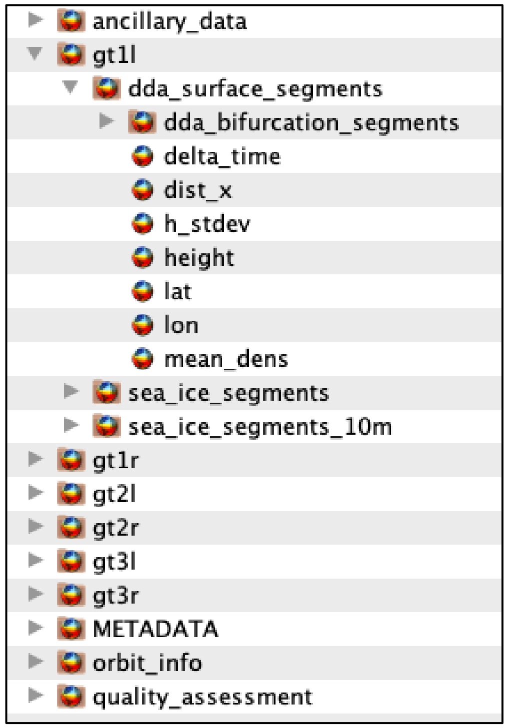

Figure 1. ATL07 top-level data groups and subgroups.

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.

1.2.2.1 ancillary_data

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

1.2.2.2 gt1l–gt3r

Six ground track groups (`gt1l–gt3r`), with the following subgroups:

Strong beams:

- `dda_surface_segments`: group for the DDA-derived surface heights, including those for the top surface. Potential melt pond characteristics of bifurcation segments and DDA-Bifurcation derived surface heights for the bottom surface are stored in the `dda_bifurcation_segments` subgroup. If the algorithm returns empty results, then this subgroup will be absent.
- `sea_ice_segments`: group for sea ice segments as computed by the ATL07 algorithm.
- `sea_ice_segments_10m`: group for sea ice segments as computed by the ATL07 algorithm using overlapping 10-meter, constant length segments.

Weak beams:

- `sea_ice_segments`: group for sea ice segments as computed by the ATL07 algorithm.

1.2.2.3 METADATA

ISO19115 structured summary metadata for the granule, including content that describes the required geospatial information. The version(s) of the input files are included in the file name attribute under the `Lineage` group.

1.2.2.4 orbit_info

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

1.2.2.5 quality_assessment

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

1.2.3 Naming Convention

Data files utilize the following naming convention:

```
ATL07-[HH]_[yyyymmdd][hhmmss]_[ttttccss]_[vvv_rr].h5
```

Examples:

```
ATL07-01_20230607222955_12001901_007_01.h5
ATL07-02_20230607222955_12001901_007_01.h5
```

The following table describes the file naming convention variables:

Table 1. File Naming Convention Variables and Descriptions

Variable	Description
`ATL07`	ATLAS/ICESat-2 L3A Sea Ice Height product
`HH`	Hemisphere code. Northern Hemisphere = 01, Southern Hemisphere = 02
`yyyymmdd`	Year, month, and day of data acquisition for the given Reference Ground Track (RGT)
`hhmmss`	ICESat-2 data acquisition start time, hour, minute, and second (UTC) for the given RGT (not the start of ATL07 data production)
`tttt`	Four-digit RGT 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.

Variable	Description
ss	Region number. This number corresponds to the first of the ICESat-2 along-track regions considered for input into ATL07 processing. This region number will always be "01" except when a granule is split along a spacecraft orientation change, in which case, the region number is the last region before the switch and the first region after the switch, in consecutive granules.
vvv_rr	Version and revision number*.

*Occasionally, 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 region 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.

1.2.4 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 for each beam:

Along-track plots

- 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)

Histograms

- 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. An example browse image is shown below.

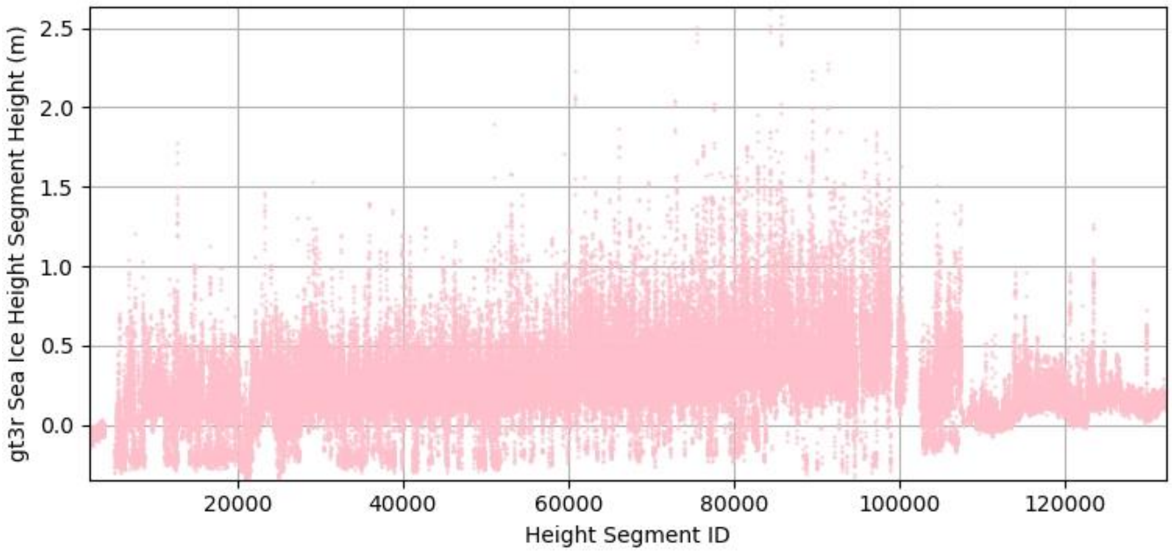

Figure 2. Example browse image for sea ice height segment height (`height_segment_height`).

1.3 Spatial Information

1.3.1 Coverage

Spatial coverage spans the ice-covered oceans of the Northern and Southern Hemispheres with greater than 15% sea ice concentration (SIC).

SIC is determined by AMSR2 by default (AU_SI12). If AMSR2 is unavailable, then SSMI (G02202) is used. If G02202 data are unavailable, then near-real-time SSMI data (G10016) are used.

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

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 of height segments is stored in `gt[x]/sea_ice_segments/heights/height_segment_length_seg`. Fixed 10-meter segment heights are also provided for strong beams.

1.3.3 Geolocation

Points are presented in geodetic latitude, longitude, and ellipsoidal height.

World Geodetic System 1984 (EPSG: 4326)
ITRF2020 (EPSG: 9988)

1.4 Temporal Information

1.4.1 Coverage

Temporal coverage is 14 October 2018 through the most current processing.

Satellite maneuvers, data downlink issues, and other events can introduce data gaps into the ICESat-2 products. Users can download and consult a regularly updated list of data gaps (`.xlsx`) on the data set landing page.

> Note: Temporal updates to the product are made available to users a few times per year; these new files are not reflected in the Version History section of the user guide.

1.4.2 Resolution

ICESat-2 flies along each of its 1,387 RGTs once every 91 days (i.e., the orbit has a 91-day repeat cycle). During many repeat cycles, the beam pattern is shifted from the previous cycle's pointing pattern a variable amount in the cross-track direction during parts of each orbit to increase the density of spatial coverage.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

ICESat-2 provides multiple profiles of sea ice and sea surface heights for improved freeboard and thickness retrievals. ATL07 contains sea ice and sea surface height estimates of the ice-covered oceans derived from each ATLAS beam.

2.2 Acquisition

The required inputs are classified photons and height corrections from ATLAS/ICESat-2 L2A Global Geolocated Photon Data (ATL03), atmospheric parameters from ATLAS/ICESat-2 L3A

Calibrated Backscatter Profiles and Atmospheric Layer Characteristics (ATL09), and time-varying and static fields from external sources (i.e., ice concentration, mean sea surface, and a land mask).

2.3 Processing

Processing begins with a two-step procedure to locate the ice and sea surfaces in the photon distributions provided by ATL03. Then, each surface height segment is assigned to a surface type based on the photon and background rates. Cloudy conditions are identified using parameters in ATL09. To minimize the computational load, the weak beam in each beam-pair takes advantage of the estimated heights in the adjacent strong beam. The processing steps are described in the following sections.

2.3.1 Surface Finding

Prior to surface finding, ATL03 is filtered to remove all transmit echo pulse (TEP) photons and all geolocation segments where the PODPPD_flag is greater than 0 (i.e., degraded geolocation quality); then, ATL03 geolocation segments are read in and interpolated. It is assumed that all ATL03 photon heights already have corrections applied.

Surface finding begins with producing a coarse estimate of the mean surface height over a segment that is within ±0.5 m of the local surface to narrow the search space (strong beams only). See "Section 4.1.1.4 | Dataflow and procedural steps" of the ATBD. Then, the coarse height estimates are refined for individual segments by aggregating shots, constructing histograms, adjusting for first photon bias, and tracking the surface. See "Section 4.1.1.8 | Dataflow and procedural steps" of the ATBD.

The background photon rate is used to estimate the segment height error, refine the ground window, and classify surface type.

2.3.2 Surface Classification

Each surface height segment is assigned 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 is determined from three parameters: surface photon rate, the width of photon distribution, 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 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. If a sea ice height return does not provide a good fit to the standard expected waveform table using Gaussian distributions, then the height segment is reprocessed using a lognormal expected waveform table. The original results are kept, and the results of the reprocessed height segment are stored as new lognormal parameters.
- 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.

The classification approach should vary seasonally and regionally in both the Arctic and Antarctic; thus, the number of surface types are dependent on location and time. See "Section 4.1.1.17 | Dataflow and procedural steps" of the ATBD.

2.4 Quality, Errors, and Limitations

A constraint imposed by the inherent capability of the instrument is the impact of clouds on the visibility of sea ice cover. In particular, a reduction in coverage is significant during the summer after the spring-to-summer seasonal transition. Further, the first photon bias is an inherent problem with the photon-counting detectors selected for ATLAS. Even though the biases are at centimeter to sub-centimeter levels for most sea ice surfaces, the effect is large for intense pulses and for pulses from flat surfaces where the return energy is concentrated over a short duration.

Limitations are imposed by height retrievals and surface classification. Multiple scattering within the ice or snow volume is not quantified and may impact height retrievals. For sea ice, these effects are mitigated in the surface-finding process via windowing of the photon height distributions to avoid potential tails in the distributions. Because snow properties may be unknown at the time of ATLAS acquisitions, a height correction due to subsurface scattering must be determined independently using external data. The design of the surface type retrieval procedure focuses on sea surface signatures, and there are uncertainties associated with the labeling of the other ice types.

There are also assumptions related to height retrievals: (1) sampled photon heights are random realizations from a normal distribution and (2) the first photon bias correction assumes that the photon statistics at a given height remain stationary over time. For more details, see "Section 10 | Constraints, Limitations, and Assumptions" in the ATBD.

The `/gt[x]/sea_ice_segments/heights/` subgroup contains 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)

3 VERSION HISTORY

Table 2. Version History Summary

Version	Date	Description of Changes
7.0	7 Oct 2025	• Added starting along-track distance of sea-ice segment to main data group. Average along-track distance remains on product. The entire span of an ATL07 segment can be found using starting along-track distance and segment length. • Introduced lognormal distributions to be used as alternate expected waveform table. If a sea ice height return does not provide a good fit to the standard expected waveform table using Gaussian distributions, re-process the height segment using lognormal expected waveform table. The original results are kept, and the results of the re-processed height segment are stored on new lognormal parameters. • Implemented the option to process sea ice heights at half-stepping, 10-meter segment lengths. By default, the sea ice heights are constructed at variable-length segments, constructed by aggregating 150 photons. The segment length, and the amount of overlapping, can be modified with the control file (the constant-length segmenting may be run by adding the following override command to the control file: asas.atl07.buffered_segments_flag=1) • Introduced DDA-Bifurcation algorithm. DDA provides a new surface finding algorithm which provides independently computed heights along with the ATL07 heights. The routine also allows for the bifurcation of the surface to detect and measure potential melt ponds. ATL07 sea ice segments within these potential melt ponds are flagged. These results should be considered experimental as sufficient testing has not been completed. • Updated algorithm to apply Dynamic Atmosphere Correction (DAC) as a geophysical correction. Static and Dynamic inverted barometer corrections (computed within atlas_l3a_si) were used as geophysical corrections in v5 and v6. DAC is provided on ATL03 and does not need to be computed within atlas_l3a_si. This change introduces product consistency with surface height returns from the ATL12 ocean surface heights product. • Introduced new fine-tracker algorithm to make it modular and introduce custom data groups to help with data handling and writing. Testing is ongoing with the updated algorithm, so the default algorithm is used by

<table>
<tr><th>Version</th><th>Date</th><th>Description of Changes</th></tr>
<tr><td></td><td></td><td>default. The new algorithm may be run by adding the following override command to the control file: asas.atl07.finetrack_flag = 1.</td></tr>
<tr><td>6.1</td><td>1 May 2024</td><td>Data from 13 Nov 2022 to 26 Oct 2023 were reprocessed using ITRF2014 (replacing ITRF2020) for consistency across the entire data set.</td></tr>
<tr><td>5.0 (retire)</td><td>12 Feb 2024</td><td>Removed data access for v5.0. Data coverage was 14 Oct 2018 to 12 Oct 2022.</td></tr>
<tr><td>6.0</td><td>3 Aug 2023</td><td>
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.
Added AMSR2 sea ice concentration (SIC) data as follows:
Use AMSR2 by default (AU_SI12)
Where AMSR2 is unavailable, use SSMI (G02202)
Where G02202 data are unavailable, use near-real-time SSMI data (G10016)
Implemented land filtering. The introduction of uncorrected caused many returns over land, so <code>distance_to_land</code> and bathymetry ancillary files were introduced. The bathymetry file and <code>distance_to_land</code> 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 <code>PODPPD_flag</code> filter so that a processing option is available for every flag value.
Apply dynamic IB for processing and read/interpolate 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.
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, and clarified the use of the tide free system.
</td></tr>
<tr><td>5.1</td><td>25 May 2023</td><td>SIC data switched from AMSR2 to SSMI (G10016) to address an issue that occurs based on the presence or absence of ANC49 inputs during processing.</td></tr>
<tr><td>4.0 (retire)</td><td>13 Jun 2022</td><td>Removed data access for v4.0. Data coverage was 14 Oct 2018 to 15 Jul 2021.</td></tr>
<tr><td>3.0 (retire)</td><td>25 Jan 2022</td><td>Removed data access for v3.0. Data coverage was 14 Oct 2018 to 11 Nov 2020.</td></tr>
<tr><td>5.0</td><td>29 Nov 2021</td><td>
The ATL07 QA check (atl07_qa_mod) for insufficient output failure has been updated to only check for valid sea ice segments. Previously, total number of sea ice segments written (valid and invalid) were counted.
The description of height_segment_confidence was updated so that it agrees with the coded procedure.
A max_incidence_angle filter was implemented and added as a controllable override. If the beam incidence angle exceeds max_incidence_angle, the surface type will be set to -1.
</td></tr>
</table>

Version	Date	Description of Changes
		• A contrast filter has been implemented, but turned off by default. Two new controllable parameters have been added. • The podppd flag has been added to the ATL07 product and is used to filter heights and segment surface type. • A new parameter height_segment_n_pulse_seg_used has been added to the ATL07 product. This parameter excludes the number of specular returns filtered out of processing, unlike height_segment_n_pulse_seg. • The description of photon_rate has been updated so that it is clear how the parameter is computed. • Modified the integration test scripts to generate browse products and check for the presence of default1 and default2 plots. • Updated the ANC31 sea ice concentration interface to read either v1 or v2 of the sea ice concentration files. • New parameters of mean ocean sea level pressure and dynamic inverted barometer effect are calculated in ATL07. These are not currently applied to the heights but could be in future releases. The new parameters are: /ancillary_data/sea_ice /mean_ocean_slp: Mean ocean sea level pressure computed in ATL07 and /gtx/sea_ice_segments/geophysical/height_segment_dynib: Dynamic inverted barometer.
2.0 (retire)	21 May 2021	Removed data access for v2.0. Data coverage was 14 Oct 2018 to 15 Nov 2019.
4.0	13 Apr 2021	• Confirmed proper marking of invalid parameters from ATL03 to ATL09, including ocean tide. If an invalid is found, the average for the segment is set to invalid. • Meteorological data from ATL09 for the weak beam has been properly aligned with the strong beam by using distance instead of time. • Removed geolocation segments with poor orbit or poor pointing quality from being used by using the podppd_flag from ATL03. • Dynamically converted MSS values to the tide-free system. • Dynamically adjusted sea ice coarse track height filters for the tide-free system. • Read the free2mean parameters from ATL03 and averaged them to a sea ice segment rate in to ATL07. • Fixed error in calculation of sea ice segment length to correctly measure length and remove negative results. • Fixed error in the computation of first photon bias.
1.0 (retire)	11 Jun 2020	Removed data access for v1.0. Data coverage was 14 Oct 2018 to 14 Jan 2019.
3.0	11 Jun 2020	• Added additional sea ice browse images to allow for better qualitative assessment of the product. • Fixed a bug related to temporal/geographic bounds that placed ATL07 granules in the wrong hemisphere on Earthdata Search. • Sea ice processing now limited to medium and high confidence photons when determining if a photon return is specular. This addresses overlap in the land ice and sea ice masks and issues with over-counting photons prior to calculating specular returns. • The algorithm was updated to account for the additional photons in the larger land ice telemetry window in regions where the land and sea ice masks overlap. This improves coverage around coastal Antarctica and the Arctic coast—in particular around Arctic shelves and Canadian Arctic Archipelago passages. • Removed TEP photons from consideration for sea ice processing.
2.0	24 Oct 2019	• The parameters "tep_used_gt1_strong", "tep_used_gt1_weak", "tep_used_gt3_strong", and "tep_used_gt3_weak" are now filled with a

Version	Date	Description of Changes
		value which shows which TEP was used (beam_3 or beam_5) to create the waveform table for the corresponding beam. • The code now uses sea level pressure from ATL09 (instead of surface pressure), smoothed by averaging over 8 seconds. • The default value for the number of photons collected for a fine track segment has been updated to 150. • The apparent surface reflectance (ASR) and background computations have been updated to use the proper return sensitivity value. • The equilibrium tide is now read from ATL03. Values are averaged over a sea ice segment and written to the geophysical group. • The code has been updated to use the equilibrium tide when there is a valid ocean tide correction to the photon heights.
1.0	28 May 2019	Initial release

4 REFERENCES

Magruder, L. A., Brunt, K., Neumann, T., Klotz, B., & Alonzo, M. (2020). Passive ground-based optical techniques for monitoring the on-orbit ICESat-2 altimeter geolocation and footprint diameter. *ESS Open Archive*. https://doi.org/10.1002/essoar.10504571.1

5 DOCUMENT INFORMATION

5.1 Publication Date

October 2025

5.2 Date Last Updated

October 2025

APPENDIX A – ICESAT-2/ATLAS DESCRIPTION

The ICESat-2 observatory utilizes a photon-counting lidar (the ATLAS instrument) and ancillary systems (GPS, star tracker cameras, and ground processing) to measure the round-trip time a photon takes to travel from ATLAS to Earth and back again. The time-of-flight, absolute time, spacecraft location and pointing are used to determine the reflected photon's geodetic height, latitude, and longitude.

The ATLAS instrument uses a single laser and a beam splitter to illuminate six different “spots” that each trace out a ~11 m wide track (Magruder et al., 2020) as ICESat-2 orbits Earth (Figure A - 1). Three of the spots are considered “strong” (spots 1, 3, and 5) and the other three “weak” (spots 2, 4, and 6). Three independent Photon Counting Electronics (PCEs) record the photons returned to the telescope, each for a single pair of strong/weak spots. PCE1 records spots 1 and 2; PCE2 records spots 3 and 4; and PCE3 records spots 5 and 6.

Higher-level ATLAS/ICESat-2 data products are organized by ground track (GT), with GT1L and GT1R forming pair one, GT2L and GT2R forming pair two, and GT3L and GT3R forming pair three. Each GT is numbered according to the relative location of the laser spot that generates it, with GT1L on the far left and GT3R on the far right. Left/right beams within each pair are approximately 90 m apart in the across-track direction and 2.5 km in the along-track direction.

The mapping between the strong and weak spots of ATLAS, and their relative positions 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 (Figure A - 1, left), with the weak spots leading the strong spots. In the backward orientation, ATLAS travels along the -x coordinate in the instrument reference frame, with the strong spots leading the weak spots (Figure A - 1, right). Atmospheric profiles are generated from strong spots only, and the instrument orientation determines which GT label ("gtx") corresponds to which profile. The spacecraft orientation is tracked in the ICESat-2 Major Activities document (.xlsx).

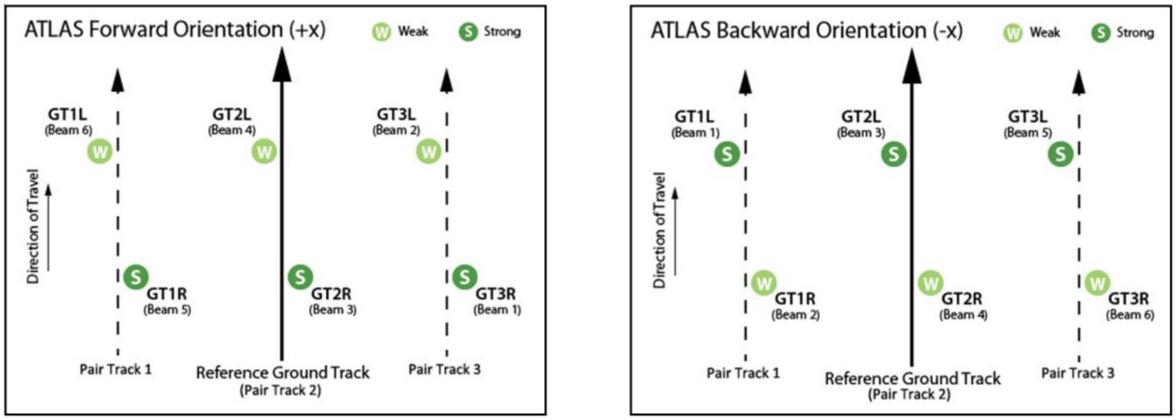

Figure A - 1. Spot and Ground Track (GT) naming convention.

The Reference Ground Track (RGT) is an imaginary track on Earth through the six-spot pattern that is used to point the observatory. 1,387 RGTs are sampled over the course of 91 days, allowing seasonal height changes to be detected. Onboard software aims the laser beams so that the RGT is between GT2L and GT2R (i.e., coincident with Pair Track 2). Nominal RGT pointing occurs over the oceans and polar regions and is periodically adjusted over vegetated land areas to broaden global coverage. 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 (cc) to the RGT number.

Over lower latitudes, the satellite points slightly off the RGT during most cycles to measure canopy and ground heights. Off-pointing began on 1 August 2019 with RGT 518 after the ATLAS/ICESat-2 Precision Pointing Determination (PPD) and Precision Orbit Determination (POD) solutions were adequately resolved, and the instrument had pointed directly at the RGT for at least a full 91 days (1,387 orbits).

NOTE: ICESat-2 RGTs with dates and times can be downloaded as KML files from NASA's ICESat-2 | Technical Specs page, below the Orbit and Coverage table. Pointing plans summarized by cycle and off-pointing angle are posted in the ICESat-2 Major Activities document.

The ATLAS data and data collected from ancillary systems are telemetered to the ground and processed into several data products (Figure A - 2). The ATL01 algorithm reformats and unpacks the Level 0 data and converts it into engineering units. ATL02 processing converts ATL01 data to science units, applies instrument corrections, and produces photon time-of-flight data. The PPD and POD solutions compute the pointing vector and position of the ICESat-2 observatory as a function of time. ATL02, PPD, and POD are used to produce the global geolocated photon data of ATL03 and the normalized relative backscatter profiles of ATL04, which are the base products for all higher-level data sets.

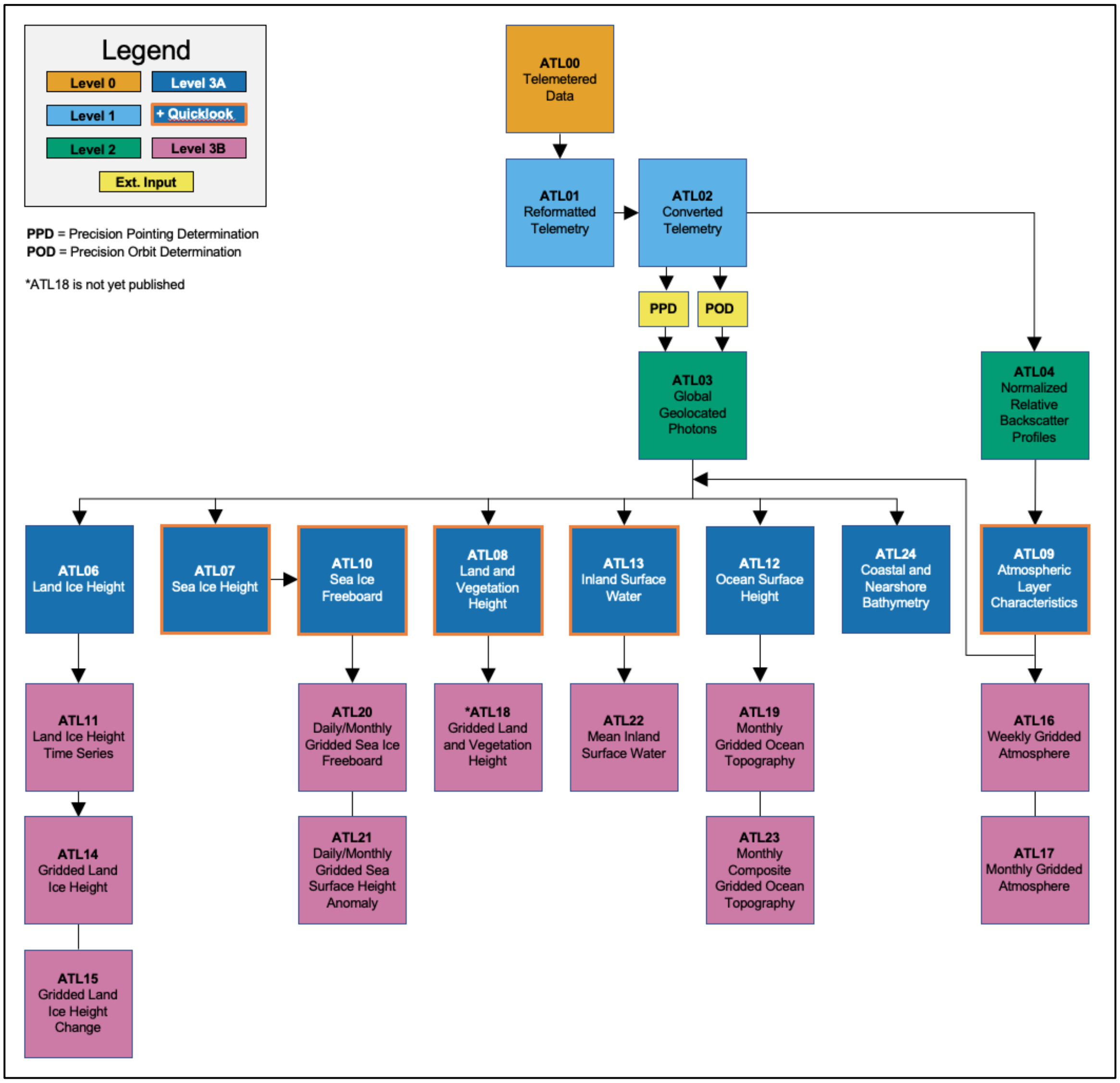

Figure A - 2. Schematic of ICESat-2 data processing and data products.

In satellite altimetry, the reflection point of an emitted signal occurs on an instantaneous and often dynamic planetary surface (Figure A - 3). For ICESat-2, reflective surfaces include oceans, inland water bodies, solid ground, ice, vegetation, and manmade structures. Depending on the product and surface type, geophysical corrections are applied to measurements to account for various time-varying processes (Table A - 1). Upper-level products may undergo additional height corrections, including corrections for pulse shape and instrument characteristics. For more information, refer to the data product's ATBD.

Table A - 1. 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 delay
Land Ice, Land, and Inland Water (ATL06, ATL08, and ATL13)	*No geophysical corrections beyond ATL03*
Sea Ice (ATL07 and ATL10)	ATL03 corrections Referenced to mean sea surface Ocean tide Long period equilibrium ocean tide Dynamic atmosphere correction
Ocean (ATL12)	ATL03 corrections Ocean tide Long period equilibrium ocean tide

[1]For details, see Section 5 of the *ICESat-2 Data Comparison User's Guide for Rel007* available on the ATL03 data set landing page.

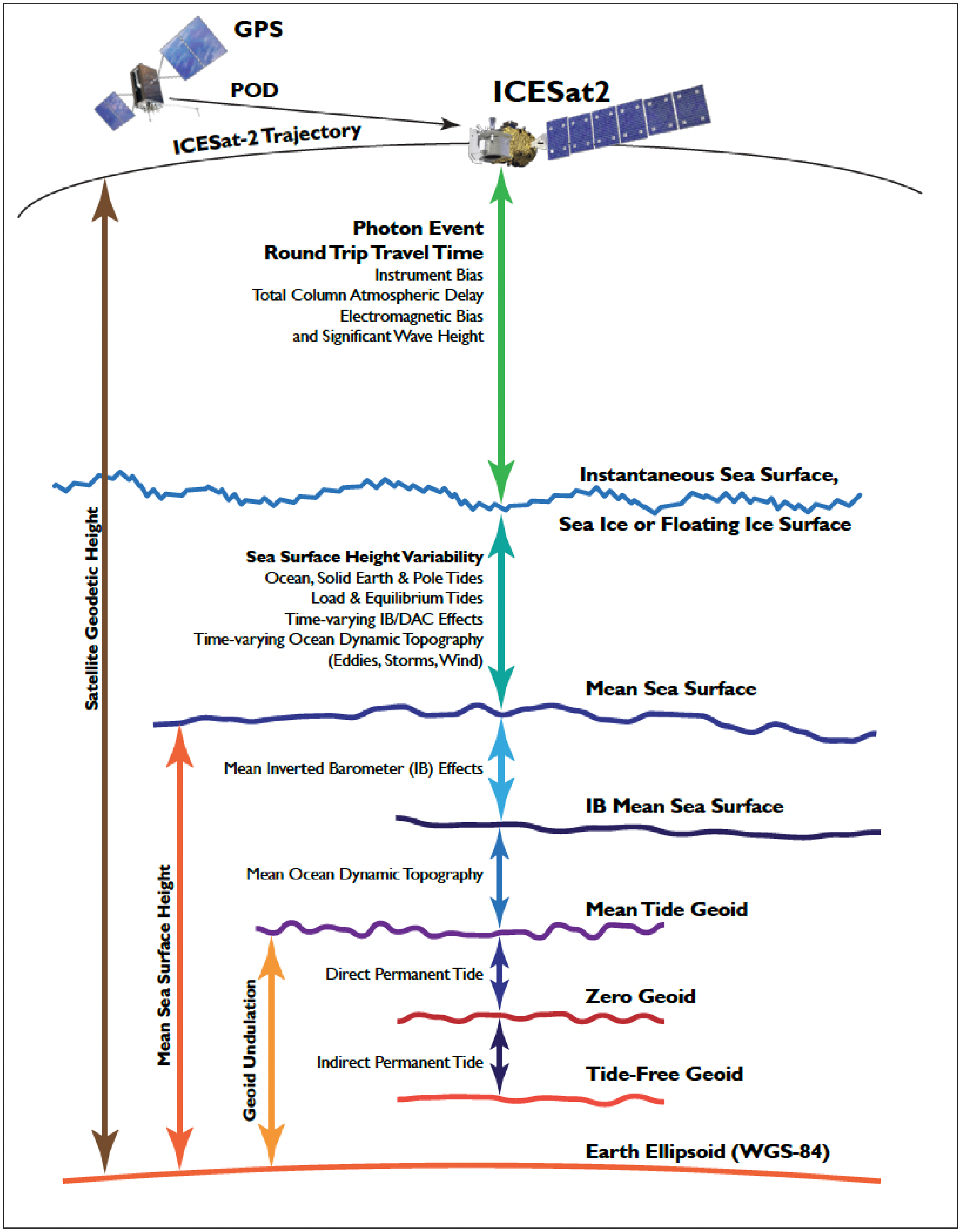

Figure A - 3. Geophysical corrections used in satellite altimetry (Source: *ICESat-2 Data Comparison User's Guide for Rel007,* available on the ATL03 data set landing page).