ATLAS/ICESat-2 L3A Along Track Inland Surface Water Data, Version 7

USER GUIDE

How to Cite These Data

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

Jasinski, M. F., Stoll, J. D., Hancock III, D. W., Robbins, J., Nattala, J., Pavelsky, T. M., Morison, J., Jones, B. M., Ondrusek, M. E., Parrish, C., Carabajal, C., & the ICESat-2 Science Team (2025). *ATLAS/ICESat-2 L3A Along Track Inland Surface Water Data* (ATL13, Version 7). [Data set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ATLAS/ATL13.007 [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ATL13

National Snow and Ice Data Center

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1 DATA DESCRIPTION

The ATL13 data product is described in detail in the ICESat-2 Algorithm Theoretical Basis Document for Along Track Inland Surface Water Data (ATBD for ATL13, Version 7). Please see the ATBD for additional information on the data product, including a citation for the ATBD: https://doi.org/10.5067/46BO943W5S2X.

1.1 Summary

ATL13 provides along-track surface water products for inland water bodies, defined as lakes, reservoirs, bays, estuaries, rivers, and a 7 km near-shore buffer. Data parameters include surface water height statistics and related parameters including significant wave height, transect slope, subsurface signal attenuation, and shallow water bathymetry. Water surface heights are provided as both orthometric height and height referencing the WGS84 ellipsoid. ATL13 is also used to produce the ATLAS/ICESat-2 L3B Mean Inland Surface Water Data product (ATL22).

1.2 File Information

1.2.1 File Format

Data are provided as HDF5-formatted files.

1.2.2 File Contents

A complete list of all ATL13 parameters is available in the ATL13 Data Dictionary.

Each data file (granule) contains inland water body and near-shore coastal water surface heights acquired during four of ATLAS's 1,387 orbits. Within data files, similar variables such as science data, instrument parameters, altimetry data, and metadata are grouped together according to the HDF model. ATL13 data files contain the top-level groups and variables shown in the following figure:

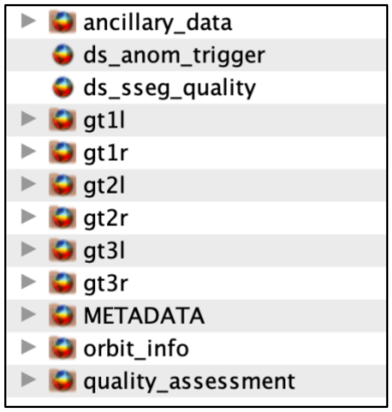


Figure 1. ATL13 top-level data groups and variables.

The following sections summarize the structure and primary variables of interest in ATL13 data files.

1.2.2.1 ancillary_data

Information that is ancillary to the data product. This may include product and instrument characteristics and/or processing constants.

1.2.2.2 gt1l–gt3r

Six ground track groups (gt1l–gt3r) that contain the per-beam data parameters for the specified ATLAS ground track. Parameters of interest include:

- `ht_ortho`: orthometric surface height, i.e., height above the EGM2008 MSL
- `ht_water_surf`: water surface height above the WGS84 ellipsoid
- `segment_geoid`: applicable mean-tide system geoid value at reporting location for all short segment statistics
- `qf_sseg_length`: short segment length flag
- `sseg_mean_lat`: short segment mean latitude
- `sseg_mean_lon`: short segment mean longitude
- `sseg_mean_time`: mean time of short segment signal qualified photons
- `segment_slope_trk_bdy`: along-track water body surface slope

When concatenated, the following four parameters uniquely identify each water body (see "4.7.1.2 | Water Body Reference Identification Scheme" in the ATL13 ATBD):

- `inland_water_body_type`: water body type (1 = lake, 2 = known reservoir, 4 = ephemeral water, 5 = river, 6 = estuary or bay, 7 = coastal water)
- `inland_water_body_size`: water body size; A = area in km^2 (0 = not assigned, 1 = A>10,000, 2 = 10,000>A≥1,000, 3 = 1,000>A≥100, 4 = 100>A≥10, 5 = 10>A≥1, 6 = 1>A≥0.1, 7 = 0.01>A)

- `inland_water_body_source:` source of inland water body shape (1 = HydroLAKES, 2 = Global Lakes and Wetlands Database, 3 = Named Marine Water Bodies, 4 = GSHHG Shoreline, 5 = Global River Widths from Landsat)
- `inland_water_body_id`: identifying signature of an individual inland water body

The gt[x] groups also contain standard deviation, subsurface signal (532 nm) attenuation, significant wave height, wind speed, and coarse depth to bottom topography.

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 and cycle and the 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 File Naming Convention

Data files utilize the following naming convention:

`ATL13_[yyyymmdd][hhmmss]_[ttttccss]_[vvv_rr].h5`

Example:

`ATL13_20230607174704_11971901_007_01.h5`

The following table describes the file naming convention variables:

Table 1. File Naming Convention Variables and Descriptions

Variable	Description
ATL13	ATLAS/ICESat-2 L3A Along Track Inland Surface Water Data
yyyymmdd	Year, month, and day of data acquisition
hhmmss	Data acquisition start time, hour, minute, and second (UTC)
tttt	Four-digit RGT number of the first of four tracks in the granule. The ICESat-2 mission has 1,387 RGTs, numbered from 0001 to 1387.
cc	Cycle number. The cycle number tracks the number of 91-day periods that have elapsed since ICESat-2 entered the science orbit.
ss	Region number. Not used for ATL13. Always 01.[1]
vvv_rr	Version and revision number[2]

[1]Some ATLAS/ICESat-2 products (e.g., ATL03) are provided as files that span 1/14th of an orbit. As such, these products' file names specify a region number that ranges from 01 to 14. Because ATL13 data files span four full orbits, the region number is always set to 01.

[2]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. 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 file level metadata. XML metadata files have the same name as their corresponding .h5 file, but with .xml appended.

1.2.4 Browse Files

Browse files are provided as JPGs designed to quickly assess the location and quality of each granule's data. Browse files utilize the same naming convention as their corresponding data file but with "_BRW" and descriptive keywords appended.

ATL13 includes two browse images per beam: water surface orthometric height (ht_ortho) and granule ground track location and coverage (groundtrack). An example is shown below.

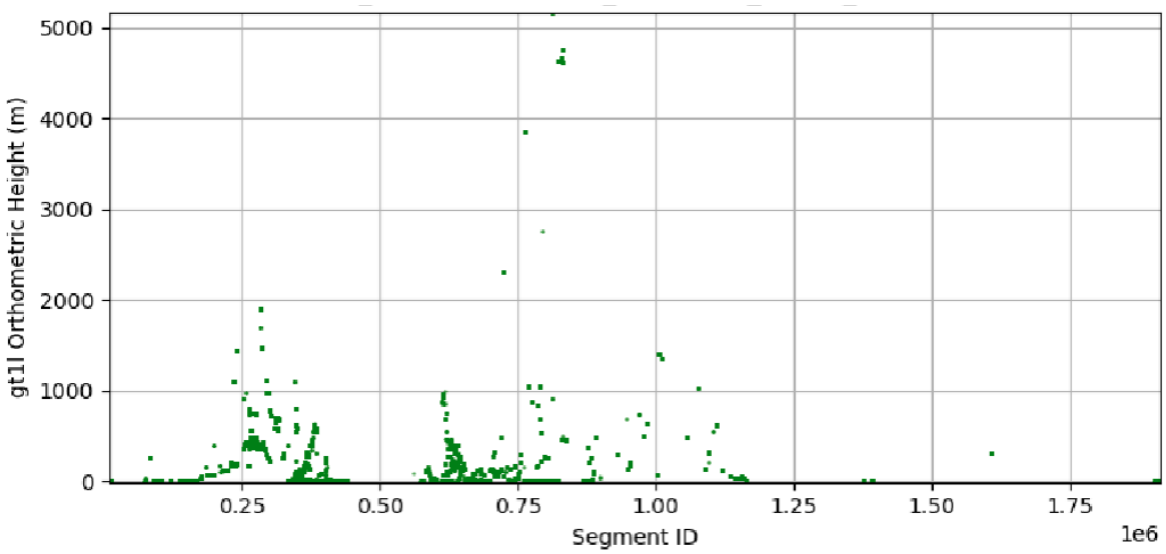


Figure 2. Example browse image for `ht_ortho`.

1.3 Spatial Information

1.3.1 Coverage

Spatial coverage is nearly global (approximately 88° N to 88° S); however, the focus of ATL13 is high-latitude terrestrial regions where the convergence of the ICESat-2 orbits provides spatially dense observations in the pan-Arctic region. Water surface height processing is constrained by an inland water mask (see Section 2.3.1 Water Masks).

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 that the number of photons that return to the telescope depends on surface reflectivity and cloud cover obscuring ATLAS's view of Earth. Therefore, the vertical resolution varies.

Inland water heights are processed in segments that contain a minimum of approximately 100 signal photons, except rivers which only require 75. As such, the segments vary in length from approximately 30 m to several hundred meters, depending on factors such as signal quality and water and atmospheric conditions.

1.3.3 Geolocation

Latitudes and longitudes refer to the World Geodetic System 1984 (WGS84, EPSG: 4326). Water surface heights are provided as heights above the WGS84 ellipsoid (ITRF2020 Reference Frame, (EPSG: 9988) and as heights above mean sea level (EGM2008, EPSG: 3855).

1.4 Temporal Information

1.4.1 Coverage

Temporal coverage is 13 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`) in the lower-level ATL03 product.

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

1.4.2 Resolution

Repeat observations for any given water body depend on its size and geographic location. The frequency at which ICESat-2 crosses inland water bodies depends on how often the spacecraft's orbital pattern intersects with the water body mask. For high-latitude polar regions (approximately ±65°), the mission requirements mandate repeat observations every 91 days along the precisely established reference tracks (i.e., the satellite has a 91-day repeat cycle). However, starting with cycle 04 (28 June 2019), ICESat-2 began conducting a systematic off-pointing scenario at latitudes between ±65° that is designed to achieve approximately 2 km global spacing after two years of data acquisition.

2 DATA ACQUISITION AND PROCESSING

2.1 Background

ATLAS data have enabled understanding of high-latitude hydrology and the pan-Arctic water balance. The ATL13 product helps determine impacts on freshwater fluxes into the Arctic Ocean, melting snow, ocean salinity and circulation, methane distribution, ecosystem dynamics, and geomorphology. The data has been widely used for scientific and application studies.

2.2 Acquisition

ATL13 is primarily derived from geolocated, time-tagged photon heights and other parameters passed from the ATLAS/ICESat-2 L2A Global Geolocated Photon Data (ATL03) product. Inputs include precise latitude, longitude, and height for every received photon, plus applied geophysical corrections such as Earth tides and atmospheric delays. Each photon is classified as signal or background and by surface type (land ice, sea ice, land, ocean, and inland water).

2.3 Processing

2.3.1 Water Masks

Water masks help organize the inland water data and constrain processing to only those land and coastal regions that possess water bodies (Section 3.4, ATBD for ATL13). ATL13 relies on three types of hydrologic masks:

- ATL03 Inland Water Processing Mask (applied to input data)
- ATL13 Regional Basin Mask
- ATL13 Inland Water Body Mask

The **ATL03 Inland Water Processing Mask**, shown in Figure, extracts data for analysis only from those areas required for inland water analysis.

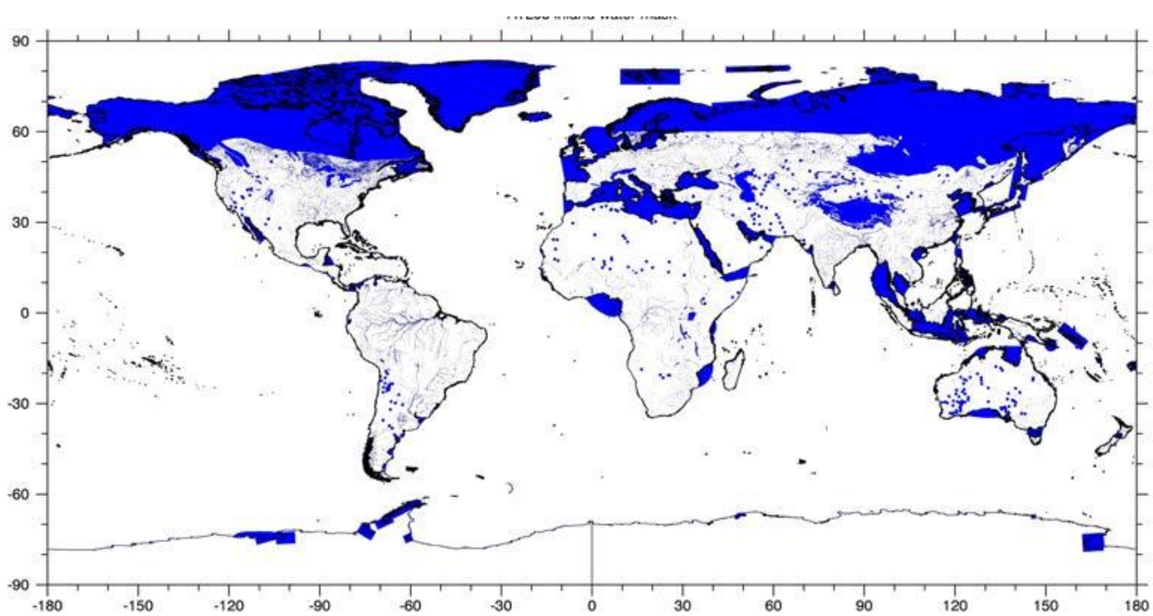
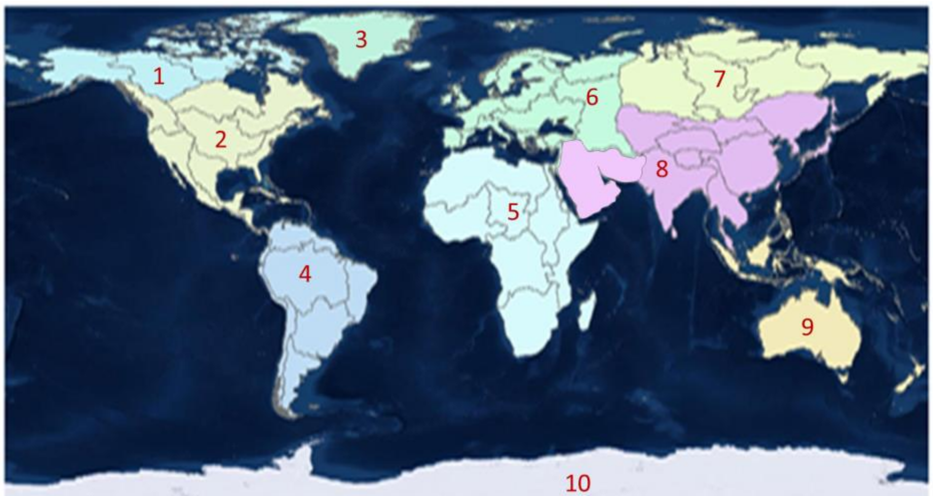


Figure 3. ATL03 Inland Water Processing Mask. The ATL13 algorithm that flags observations as water bodies is only applied in the blue shaded areas. Source: ATL13 ATBD.

This 0.1 km^2 gridded mask was developed from a number of coastline and inland water databases including the Global Self-consistent, Hierarchical, High-resolution Geography (GSHHG) coastlines database and various lake shapefiles, including ephemeral lakes, permafrost extent, and custom shapes created to close larger bays in locations not otherwise addressed.

The **ATL13 Regional Basin Mask** comprises polygons that represent principally the outline of entire large river basins plus some adjacent intervening area. Each polygon contains all the lakes and rivers within that river basin and logically organizes the ATLAS data used to produce the hydrologic products (see figure below).



1 = Northern North America
2 = Southern North America
3 = Greenland
4 = South America
5 = Africa
6 = Europe
7 = Northern Asia
8 = Southern Asia
9 = Australia & Oceania
10 = Antarctica

Figure 4. ATL13 Regional Basin Mask. Source: ATL13 ATBD.

The **ATL13 Inland Water Body Mask** identifies ICESat-2 crossings over individual water bodies. It was designed to delineate the shape and spatial distribution of contiguous individual water bodies, such as lakes, reservoirs, and rivers, and is applied as a shapefile—unlike the gridded ATL03 mask flag described above. The shape mask consists of polygon shapefiles that each represent an entire single lake, reservoir, river segment and tributaries, bay, or 7 km wide coast segment. An approximately 100 m buffer is extended over land to clearly distinguish the land/water interface. Each water body is identified by a unique number, latitude and longitude, and local name if available.

2.3.2 Surface Height Algorithm

The goal of ATL13 is to estimate the mean water surface height in short, statistically representative segments (75–100 signal photons) for each ATLAS beam that crosses a water body in the along-track direction. Thus, computing inland water heights requires distances of about 50 to 100 m, depending on atmospheric, solar, and water conditions. In addition, although the majority of the signal photons that return to ATLAS from a given water body are reflected from the surface, typically a percentage comprise subsurface backscatter. As such, prior to computing the short segments, the algorithm analyzes longer segments (1 to 3 km), which contain a sufficient number of subsurface photons to estimate the volume scattering parameters. The ATL13 product combines physical and statistical modeling approaches to characterize key physical processes related to open water surface dynamics and light propagation and to retrieve inland water heights from (primarily) ATL03 data.

In brief, the algorithm 1) identifies the beginning and ending edges where individual ATLAS beams intersect a contiguous water body; 2) models the reflectance components that contribute to the integrated signal return from the water body; 3) analyzes models of the surface water height statistical distributions, subsurface volume attenuation, and their relation to the distribution of the signal photons from water surface facets; 4) removes background photons to extract the true representation of water reflectance and height; 5) deconvolves the ATLAS instrument response function from the observations; 6) computes along-track statistics (surface water height, subsurface attenuation, coarse-resolution water depth, significant wave height, and the mean and maximum along-track water surface slope and azimuth from the two adjacent strong beams), and 7) evaluates the accuracy and quality of the measurement. The following sections outline the major components used to estimate inland water heights in the ATL13 ATBD.

2.3.2.1 Inland Water Backscatter

"Section 4.2 | Satellite Inland Water Backscatter Model" (ATL13 ATBD) describes the approach used to model inland water backscatter: the water surface specular model, the water surface foam model, the volume scattering model, bottom reflectance, the relative magnitude of anticipated returns, and required atmospheric and meteorological inputs.

Water surface specular reflection is the largest component to the backscatter. Scattering from whitecaps and foam streaks on the water surface is mainly a factor at wind speeds higher than about 10 m/s.

2.3.2.2 Water Surface Height

"Section 4.3 | Water Surface Height Model" (ATL13 ATBD) discusses the approach used to differentiate signal photons associated with water height, including subsections that address removing signal photons not associated with water surface height, estimating the background and signal to background noise ratio, estimating water surface height and slope, and estimating the water surface slope variance.

2.3.2.3 ATLAS Instrument Response Function

"Section 4.4 | Instrument Response Function (Transmitted Pulse Shape)" and "Section 4.5 | Deconvolution of Instrument Response from Lidar Returns" (ATL13 ATBD) describe the approach used to deconvolve the instrument response function (or histogram) from the observed histogram to extract the actual water response histogram.

The short-segment bathymetry originally published in ATL13 v2 has been significantly upgraded for ATL13 Version 7. The algorithm provides an estimate of the along-track bottom topography and water depth over the telemetry range, assuming favorable water clarity and relatively cloudless skies.

2.3.2.4 Output

The overall method processes global inland water body height products and associated products based on the ATL03 processing interval. The algorithm loops through the global inland water body database organized within regional basins during each processing period, analyzing all ground tracks of one water body before proceeding to the next. Along- and across-track data products are computed for all new ground tracks observed for that water body since the previous processing period. Inland water bodies are delineated by shapefiles defined in the ATL13 Inland Water Body Shape mask.

2.4 Quality, Errors, and Limitations

Data quality in this product depends largely on the precision of the georeferenced photons input from ATL03 and associated products evaluated prior to use by the ATL13 algorithm. The overall ensemble error per 100 inland water photons is estimated to be 6.1 cm. This calculation is detailed in "Section 4.9.1 | ICESat-2 Precision" in the ATBD for ATL13.

The Inland Water Team will be evaluating errors in this product as more data are acquired. "Section 4.9.2 | Data Product Evaluation" in the ATBD describes the Inland Water Team's plan to assess ATL13 data quality in conjunction with relevant U.S. agencies, organizations, and university researchers.

The following quality flags are provided:

- **Inland Water Segment POD/PPD Flag**: indicates the quality of input geolocation products for the utilized ATL03 segments on an ATL13 short segment output basis
- **Inland Water Segment Processing Flag**: describes the level of processing used to estimate the surface and subsurface parameters
- **Background Flag**: describes the intensity of the background rate in each short segment
- **Clouds Flag**: cloud confidence
- **Flags Associated with Snow and Ice**: assigned at the short segment rate as: 0 = ice-free water, 1 = snow-free land, 2 = snow, and 3 = ice

- **Flags Associated with Surface Temperature**: ATL09 MET surface (skin) temperature at the short segment rate
- **H_d Adjust Flags**: indicate the level of surface water height adjustment due to deconvolution
- **Detrended Surface Quality Flags**: indicate the standard deviation of the Gaussian fit to the detrended surface at both long and very long segment scales
- **Bias Fit Flag**, **EM Bias Flag**, **Short Segment Length Flag**, and **Long Segment Length Flag** (Sections 4.8.4, 4.8.5, 4.8.6, and 4.8.7 in the ATL13 ATBD)

3 VERSION HISTORY

Table 2. Version History Summary

Version	Date	Description of Changes
7.0	26 Aug 2025	• Introduced parameters to allow for limiting of mode identification to above a certain depth to avoid bright subsurface signal to overwhelm local surface mode. • Reduced sseg signal photon aggregation requirement for small lake/reservoirs, removed instrument effects from all analysis based on photon quality flag, and refined long segment bathymetry results for each member short segment based on its individual photon distribution. • Made mirroring criteria water body type dependent & added apply_mirror parameter to control which types undergo mirroring processing. • Added minimum number of photons required where downscaling long segment bathymetry to short segment scale. • Added sseg_length and sseg_dist_from_eq to output • Reversed 0/1 on/off assignments used for apply_mirror and limit_hist_depth arrays to match convention used for previous parameters. • Added an improved methodology for identifying bathymetry that couples density thresholds with examination of photon distribution in the water column, controllable by water body type. • Added apparent standard deviation to the non-anomalous short segment output. • Updated min mirror cnt for coastal water bodies.
6.1	1 May 2024	Data from 13 Nov 2022 to 26 Oct 2023 were reprocessed using ITRF2014 (replacing ITRF2020) for consistency across the entire data set.
5.0 (retire)	12 Feb 2024	Removed data access for v5.0. Data coverage was 13 Oct 2018 to 13 Oct 2022.
6.0	29 Jun 2023	• Modified the computations of the deconvolution of subsurface backscatter profile and deconvolution of surface water profile. • Expanded iteration range of subsurface parameters within deconvolution scheme and added quality flags • Added surface quality flags • Defined end of partial short segments as the final signal photon • To avoid inadvertently capturing subsurface photons associated with bottom reflection and machine error, such photons are further screened and removed from processing using a mirroring approach applied to the water surface • Replaced “crossing-number” algorithm with “winding number” algorithm for better determination of ICESat-2 transects within the inland water mask shapes
4.0 (retire)	13 Jun 2022	Removed data access for v4.0. Data coverage was 13 Oct 2018 to 15 Jul 2021.

Version	Date	Description of Changes
3.0 (retire)	25 Jan 2022	Removed data access for v3.0. Data coverage was 13 Oct 2018 to 11 Nov 2020.
5.0	14 Dec 2021	• Modified the creation of short segment length to provide additional accuracy for smaller water bodies. • Included the analysis of the partial short segments at the very end of a transect to provide a more accurate river edge detection. • Updated subsurface refraction correction to also include lat/lon position of bottom location. • Updated the surface analysis to include assumed fresh and saltwater indices based on water body type to provide a more accurate estimation of the attenuation coefficient. • Added POD/PPD flags that indicate quality of input geolocation to improve the understanding of product quality. • Replaced the Crossing Number algorithm with the Winding Number algorithm to allow the analysis over lakes previously skipped. This improved the capture of ICESat-2 observations over small and large water bodies. • Updated the external links for the ATL13 height product validation. • Added the count of output signal photons in full and partial non-anomalous and anomalous short segments to improve the understanding of product accuracy. • Fixed bugs.
2.0 (retire)	15 Jul 2021	Removed data access for v2.0. Data coverage was 13 Oct 2018 to 15 Nov 2019.
4.0	15 Jul 2021	• Implemented retention of unused photons associated with the same geolocation segment pulse ID and major frame ID (ph_id_pulse, pce_mframe_cnt) across ATL13 segments/transects. • Implemented exclusion of TEP photon events when forming ATL13 short segments. • Implemented computation of water surface spectral moments and spectral width. The spectral width flag (qf_spec_width) is now reported on the ATL13 product. • Fixed errors related to the identification of photons necessary to define valid crests and upcrossings for the computation of the spectral width parameter and electromagnetic bias (segment_bias_em). • Updated source code for a sign change to compute electromagnetic bias (segment_bias_em) as a positive expression. • Filtered geolocation segments whose composite POD/PPD flag is non-zero, invalidating possibly degraded geolocation solutions. • Updated weak beam interpolation of ATL09 strong beam atmospheric profile source data (e.g. cloud_flag_atm) to be aligned by along-track segment (segment_id) and not time. • Added short segment fractions of near and full saturation, computed from a weighted average of nearly and fully saturated fractions of pulses within ATL03 geo-segments overlapping the segment. • Added DEM height & source at the short segment rate, based on DEM heights and sources of ATL03 reference photons of all geolocation segments overlapping the short segment. • The ATL03 EGM2008 geoid is now reported in the tide free system. Implemented updates to WGS-84 ellipsoid photon heights to re-reference the mean tide system geoid when forming orthometric height, using geoid_free2mean. • Implemented computation of height adjustment to be applied to the apparent surface height to account for deconvolution analysis, and added a flag representing the range of long segment height adjustment values (qf_ht_adj).

Version	Date	Description of Changes
		• Both the first photon bias correction (segment_fpb_correction) and mean height adjustment estimated from deconvolution are now applied to the observed apparent surface height (segment_apparent_height) when computing orthometric heights and heights referenced to the WGS-84 ellipsoid (ht_ortho & ht_water_surf). • Implemented updates to ATL13 short segment along-track water body surface slope (segment_slope_trk_bdy) to include spacecraft velocity in its derivation. • Added additional tiers to the flag that indicates the range of long segment lengths (qf_lseg_length). • Implemented exclusion of very long (L_sub_ID) segments associated with insufficient photon counts within the range of subsurface fit from contributing to the exponential fit to the observed histogram. • Made anomalous short-segment information available in a separate subgroup, anom_ssegs, populated with output parameters such as water body reference ID, standard deviation of signal photon heights per segment and coarse water height (atl13refid, anom_sseg_stdev & coarse_transect_ht) for segments deemed anomalous within each body transect. • Implemented ingestion of ATL03 quality_ph (at photon rate) and computation of short segment photon counts designated at each quality level (as described by elements of the dimension scale vector /ds_sseg_quality) as a rank 2 array for both anomalous & non-anomalous segments (segment_quality & anom_sseg_quality). • The short segment anomaly testing is now inclusive of all anomaly tests. Within the anom_ssegs subgroup, the trigger flag anom_sseg_trigger_flag has been implemented as a rank 2 array, where the magnitude of each row element indicates result of anomaly testing from a specific cause for a given segment, as described by elements of the dimension scale vector /ds_anom_trigger. • Added anomalous short segment averaged coordinates and length based on endpoint locations with the anom_ssegs subgroup.
1.0 (retire)	8 Jun 2020	Removed data access for v1.0. Data coverage was 13 Oct 2018 to 9 Jan 2019.
3.0	8 Jun 2020	• The water body shape file was updated to include improved river shapes. • The first photon bias correction was implemented to calculate the apparent width of the full-width at half-max standard deviation of the ATL13 surface, the apparent strength, and the average detector time. This bug fix improves surface retrievals, especially for highly specular water surfaces. • Implemented an estimate of short segment wind speed from ATL09 input wind vector components at 10m, interpolated to short segment index photon times (gt[x]/met_wind10_atl09); and derived standard deviation of water surface at the long segment rate (gt[x]/met_wind10_atl13). • Using a previously identified water body bottom, implemented a minimum height for the range over which to perform the subsurface deconvolution and the bottom height of the vertical profile for long segments. This improves subsurface attenuation when the bottom is detected. • The threshold procedure that tests photon counts within short-segment histogram multimode bins against sseg_mode_cnt_test, to determine whether to include/exclude from the segment, has been updated to use the standard deviation of signal photon heights per shot segment (sseg_stdev). This bug fix addresses bias due to the removal of ATL13 outputs in the case of large wave heights. • The value of ancillary_data/inland_water/geoseg_edge_buffer is now selected based on the type and size of a given water body. This change fixes a bug in previous versions and improves the identification of shorelines. • Added a parameter in the water surface height computation that incorporates the maximum available geolocation segments from ATL03, as indicated by

Version	Date	Description of Changes
		geoseg_edge_buffer (default = 5), that lie outside both lake mask edge crossings. • Bug fix: changed the sign for electromagnetic bias (H_bias_EM) • The expression for orthometric water surface height and depth from the mean water surface to the detected bottom have been updated to exclude H_bias_EM, when it is designated as invalid, and H_bias_fit is designated as valid. • Implemented a new scheme that removes misidentified water surfaces due to near-shore influences. After testing that a valid number of short segments have passed all other anomaly testing (valid_sseg_count), and determining the maximum length of a short segment that can be marked as anomalous due to shore buffering (shore_buff_sseg_length), the number of short segments to be designated as anomalous, due to near-shore influences (shore_buffer), is implemented as a 9x9 matrix that depends on water body type and size. • Cloud confidence flag parameters gt[x]/cloud_flag_atm_atl09, gt[x]/cloud_flag_asr_atl09, and gt[x]/layer_flag_atl09 are now retrieved from the ATL09 product and reported on ATL13 at the short segment rate using nearest neighbor interpolation. • Implemented surface (skin) temperature (gt[x]/met_ts_atl09) and NOAA snow/ice flag (gt[x]/snow_ice_atl09) at the short segment rate, derived by interpolation/resampling ATL09 inputs (met_ts and snow_ice) at the 1 Hz and 25 Hz rates. • Added six water body transect parameters to gt[x]/ (transect_id; sseg_start_lat; sseg_start_lon; sseg_end_lat; sseg_end_lon; and segment_azimuth)
2.0	24 Oct 2019	NA
1.0	28 May 2019	Initial release

4 REFERENCES

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Magruder, L., Neuenschwander, A., & Klotz, B. (2021). Digital terrain model elevation corrections using space-based imagery and ICESat-2 laser altimetry. *Remote Sensing of Environment, 264*. https://doi.org/10.1016/j.rse.2021.112621

5 DOCUMENT INFORMATION

5.1 Publication Date

August 2025

5.2 Date Last Updated

August 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).

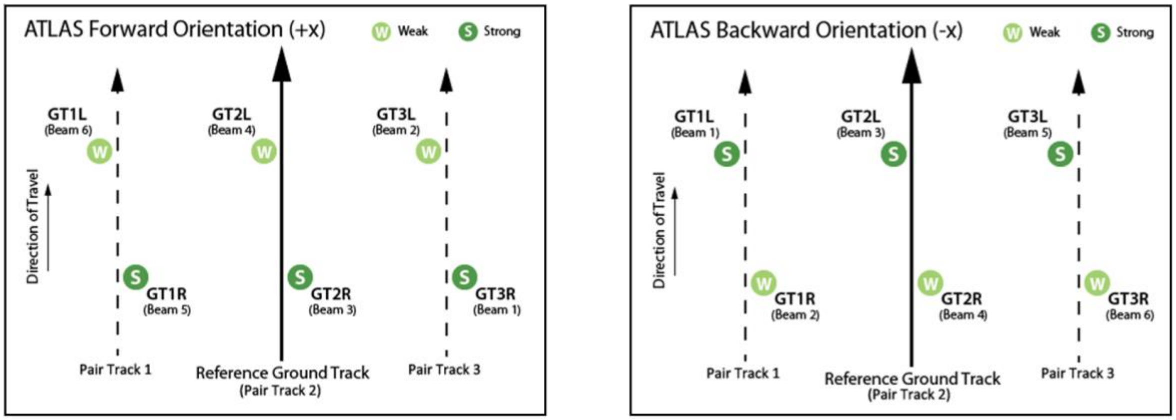

Figure A - 1. Spot and Ground Track (GT) naming convention.

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.

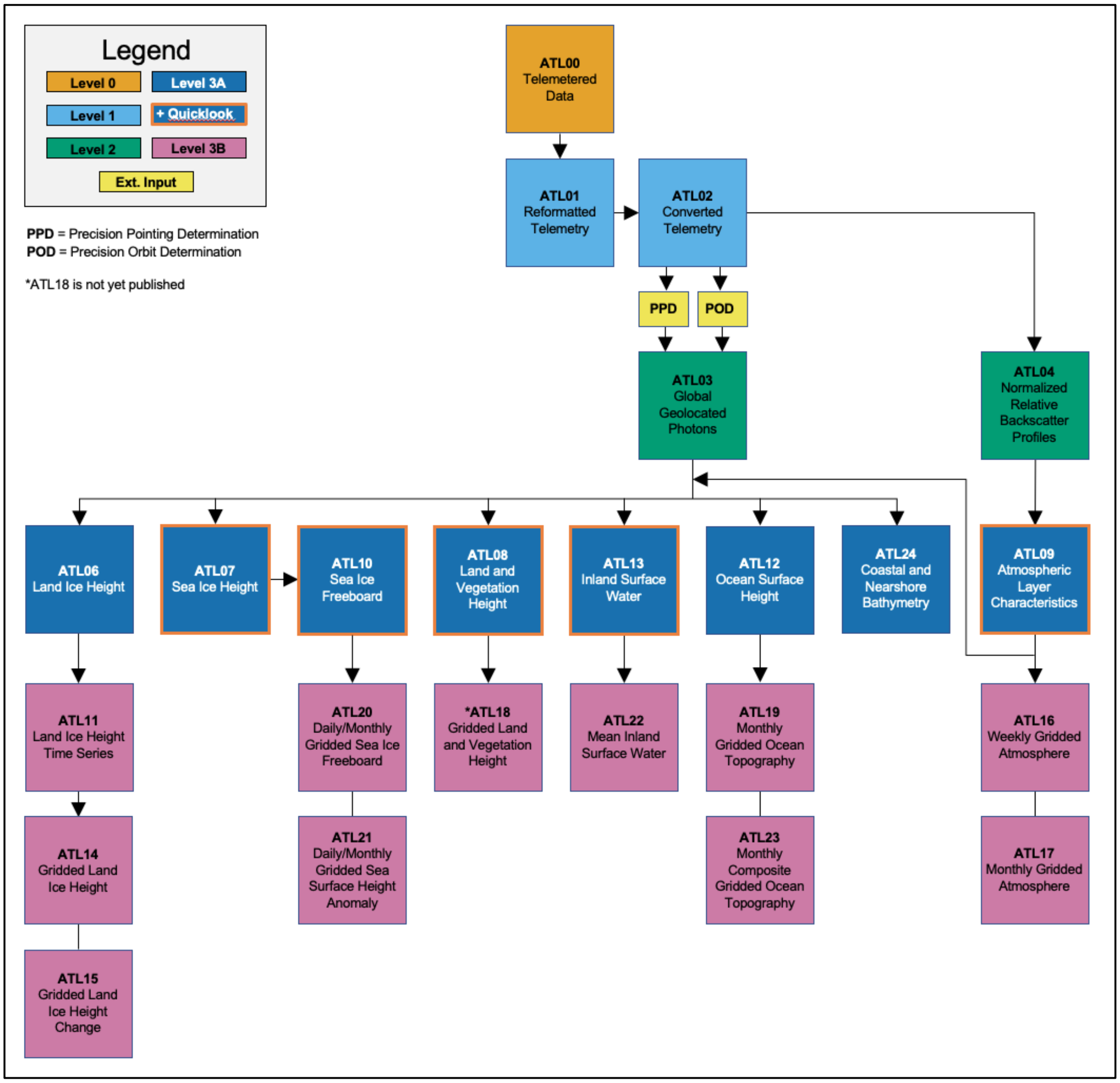

Figure A - 2. Schematic of ICESat-2 data processing and data products.

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.

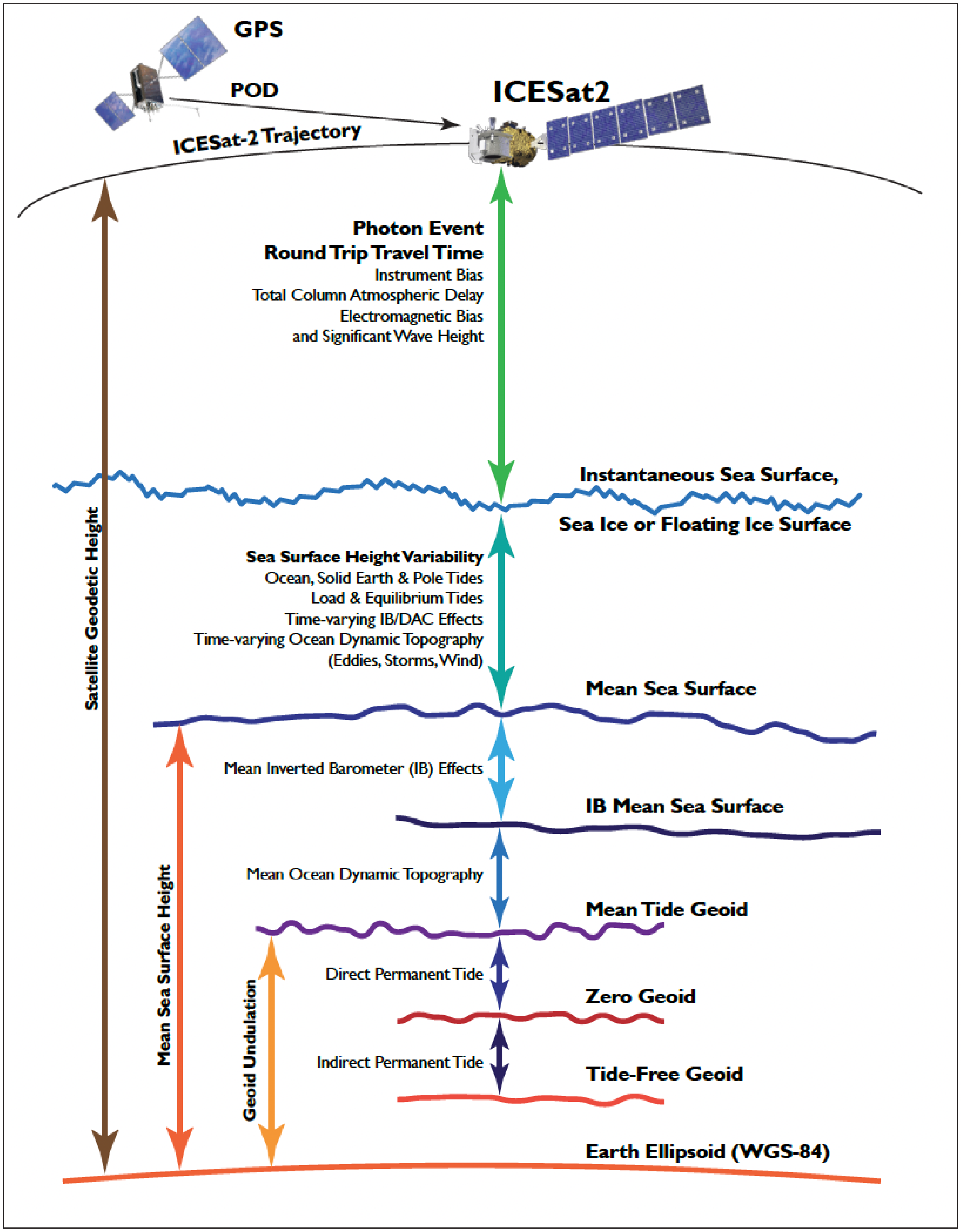

Figure A - 3. Geophysical corrections used in satellite altimetry (Source: *ICESat-2 Data Comparison User's Guide for Rel007,* available on the ATL03 data set landing page).