ATLAS/ICESat-2 L3A Land and Vegetation Height, Version 7

USER GUIDE

How to Cite These Data

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

Neuenschwander, A. L., Pitts, K. L., Jelley, B. P., Robbins, J., Markel, J., Popescu, S. C., Nelson, R. F., Harding, D., Pederson, D., Klotz, B., & Sheridan, R. (2025). *ATLAS/ICESat-2 L3A Land and Vegetation Height* (ATL08, Version 7). [Data set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ATLAS/ATL08.007 [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/atl08

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DATA DESCRIPTION

The ATL08 data product is described in detail in the ICESat-2 Algorithm Theoretical Basis Document for the Land - Vegetation Along-Track Products (ATBD for ATL08 V7 | https://doi.org/10.5067/JDZIJEU0L481).

1.1 Summary

ATL08 contains along-track estimates of terrain height, canopy height, and canopy cover, as well as beam and reference parameters. 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 Granule Regions

ATL08 data are segmented into granules that span about 1/14th of an orbit. Granule boundaries are delineated by lines of latitude that define 14 regions, numbered 01–14, as shown in Figure 1:

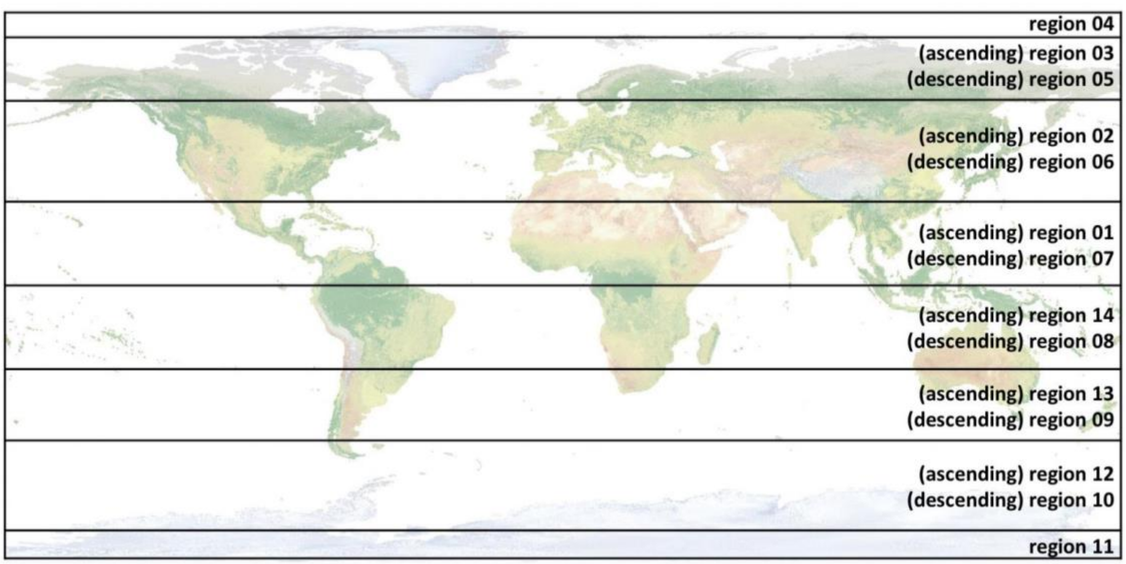

Figure 1. ATL08 region/granule boundaries.

The following table lists the latitude bounds and region numbers for all 14 granule regions:

Table 1. ATLAS/ICESat-2 Granule Boundaries and Region Numbers

Region #	Latitude Bounds	Region #	Latitude Bounds
01	Equator → 27° N (ascending)	08	Equator → 27° S (descending)
02	27° N → 59.5° N (ascending)	09	27° S → 50° S (descending)
03	59.5° N → 80° N (ascending)	10	50° S → 79° S (descending)
04	80° N (ascending) → 80° N (descending)	11	79° S (descending) → 79° S (ascending)
05	80° N → 59.5° N (descending)	12	79° S → 50° S (ascending)
06	59.5° N → 27° N (descending)	13	50° S → 27° S (ascending)
07	27° N (descending) → Equator	14	27° S → Equator (ascending)

1.2.3 File Contents

A complete list of all ATL08 parameters is available in the ATL08 Data Dictionary.

Within data files, similar variables and metadata are grouped together according to the HDF model. ATL08 data files contain the top-level groups shown in the following figure:

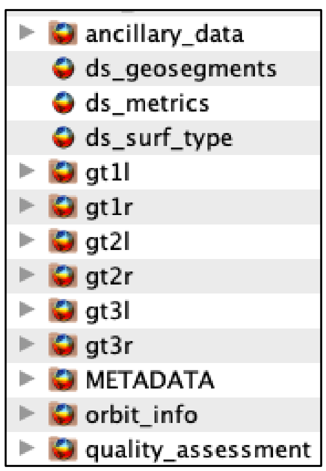

Figure 2. ATL08 top-level data groups and variables.

1.2.3.1 ancillary_data

Information that is ancillary to the data product. This may include product characteristics, instrument characteristics and/or processing constants. This group also contains the `/land` subgroup, which houses constants specific to the land/vegetation product.

1.2.3.2 Dimension Scales

Three HDF5 dimension scales are stored at the top level alongside the data groups—`ds_geosegments`, `ds_metrics`, and `ds_surf_type`—which index the within-land geosegments, metrics arrays, and surface type, respectively.

1.2.3.3 gt1l–gt3r

Six `gt[x]` groups, each of which contains the parameters for one of the six ATLAS ground tracks. Each `gt[x]` top-level group contains the following subgroups:

- **`/land_segments/`** contains data categorized as land at 100 m intervals. Key parameters include time, latitude, and longitude of the centermost signal photon; the number of signal photons in the segment (`n_seg_ph`); a night flag; land, snow, and water masks; and descriptive statistics. This group also contains the following subgroups:
    - `/canopy/` that contains height parameters based on the land algorithm
    - `/terrain`/ that contains terrain parameters aggregated at 100 m
- **`/signal_photons/`** contains parameters related to individual photons, including the classification flag for each photon (noise, ground, canopy, or canopy top) and indexes to trace photons back to the ATL03 source product.

1.2.3.4 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.

1.2.3.5 orbit_info

Parameters that are constant for a granule, such as the RGT number and cycle, the spacecraft orientation, and elapsed time.

1.2.3.6 quality_assessment

Quality assessment (QA) data for the granule, including QA counters, QA along-track data, and/or QA summary data.

1.2.4 Naming Convention

Data files utilize the following naming convention:

`ATL08_[yyyymmdd][hhmmss]_[ttttccss]_[vvv_rr].h5`

Example:

`ATL08_20210131231229_05951005_007_01.h5`

The following table describes the file naming convention variables:

Table 2. File Naming Convention Variables and Descriptions

Variable	Description
ATL08	ATLAS/ICESat-2 L3A Land and Vegetation Height product
yyyymmdd	Year, month, and day of data acquisition
hhmmss	Data acquisition start time, hour, minute, and second (UTC)
tttt	Four-digit Reference Ground Track (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.
ss	Region number (see Figure 1). ATL08 data files cover approximately 1/14th of an orbit. Region numbers range from 01–14.
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. If you encounter multiple granules with the same file name, please use the granule with the highest revision number.

Each data file has a corresponding XML file that contains additional science metadata. XML metadata files have the same name as their corresponding `.h5` file, but with `.xml` appended.

1.2.5 Browse Files

Browse files are provided as JPGs designed to quickly assess the usability of each granule's data. Available browse files are listed in the following table.

Table 3. Images Available as Browse

Image	Description
groundtrack	Map of ATL08 segment IDs
h_canopy_abs	Absolute segment canopy height
h_te_median	Median canopy height within the segment
n_ca_photons	Number of photons classified as canopy within the segment
n_te_photons	Number of photons classified as terrain within the segment

An example browse image is shown in Figure 3.

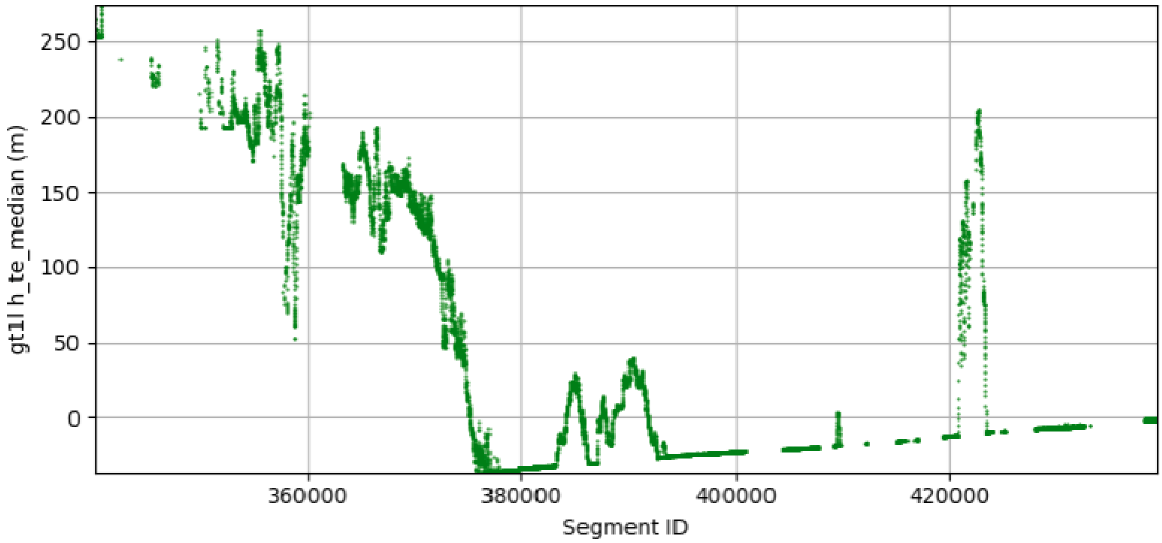

Figure 3. Browse image (`h_te_median`) showing median canopy height within the segment.

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

1.3 Spatial Information

1.3.1 Coverage

Spatial coverage is nearly global (approximately 88° N to 88° S).

ATL08 data can be referenced by numbered geographical regions, unique to the ATL08 product, which roughly correspond to continents (Greenland is assigned to its own region and Antarctica is divided into four), for a total of 11 regions (see Figure 4). The ATL08 regions encompassed by the ATL03 input granule are stored in `\ancillary_data\land\atl08_region`.

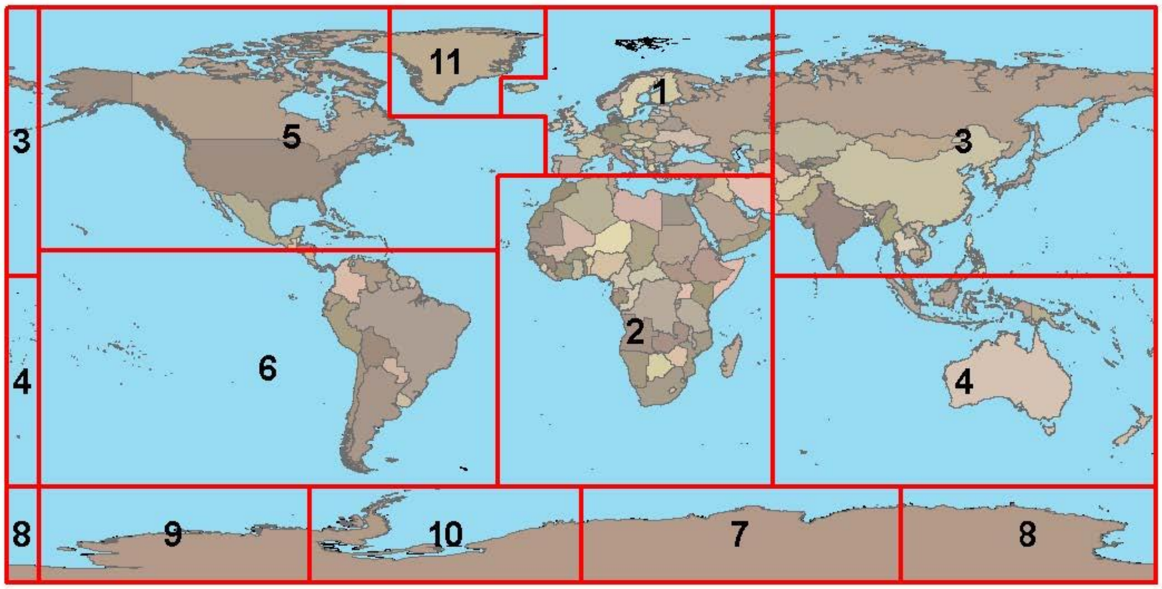

Figure 4. ATL08 geographic regions.

Note that the Land and Vegetation Height product does not produce data granules for orbital segments that span open ocean only (i.e., do not cross a land surface).

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's surface. Therefore, the vertical resolution varies. For ATL08, the canopy and ground surfaces are processed in fixed 100 m data segments, which typically contain more than 100 signal photons. If a segment has less than 50 photons, then all height fields are reported as invalid. If a segment has more than 50 photons but terrain height cannot be determined, then only the interpolated surface height is reported.

1.3.3 Geolocation

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`) 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

ICESat-2 flies along each of its 1,387 Reference Ground Tracks (RGT) 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

Determining global canopy heights relies on the ability to detect both the canopy surface and underlying topography. The ATL08 framework captures upper and lower surface signal photons while rejecting noise photons.

2.2 Acquisition

ATL08 data are derived from geolocated, time-tagged photon heights, along with other parameters, passed from the ATLAS/ICESat-2 L2A Global Geolocated Photon Data (ATL03) product.

2.3 Processing

The following sections outline the approach implemented by the ATL08 algorithm. More detailed descriptions are available in "Section 3 | Algorithm Methodology" and "Section 4 | Algorithm Implementation" of the ATBD for ATL08.

2.3.1 Noise Filtering

Removing solar background photons represents one of the biggest challenges with photon counting lidar data. The results of two noise-filtering methods are combined to ensure all potential signal photons for land surfaces are provided as input: (1) medium- to high-confidence classed photons from ATL03 and (2) Differential, Regressive, and Gaussian Adaptive Nearest Neighbor (DRAGANN) output.

2.3.2 Surface Finding Algorithm

After the signal photons are determined, the ground and canopy photons within the point cloud are located. The composite ground surface is utilized to classify individual photons as ground, canopy, top of canopy, or noise (Figure 5).

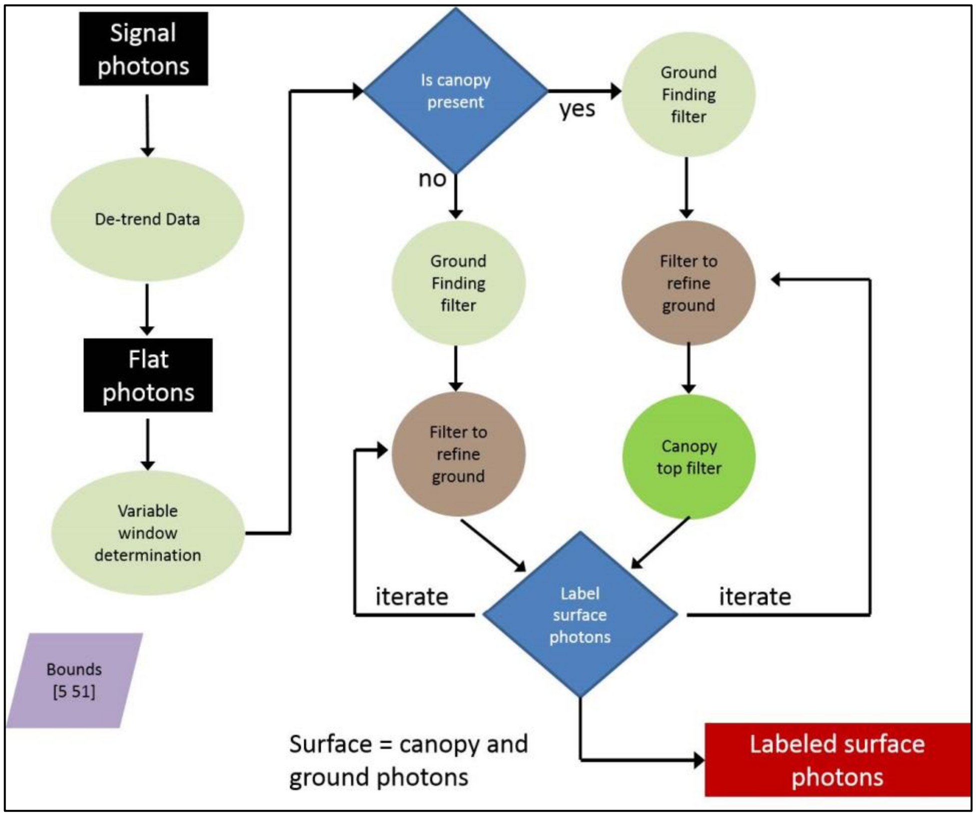

Figure 5. Flowchart of ATL08 Surface Finding Method

The steps of the surface finding algorithm are as follows:

1. De-trend signal photons: remove the effect of topography on the input data by subtracting a heavily smoothed "surface" derived from the input data
2. Determine canopy: automatically account for the presence of canopy along a given segment
3. Determine variable window: use a variable window size to compute statistics and filter/smooth the data for each segment
4. Compute descriptive statistics: employ a moving window to compute descriptive statistics on the de-trended data (mean, min, max, and standard deviation of heights)
5. Apply ground finding filter: combine iterative median filtering and smoothing filter to derive output solution of ground and canopy surfaces.

The same approach used to find the ground is applied to locate the top of canopy. The de-trended data are "flipped" by multiplying the photon heights by -1 and adding the mean of all the heights back in.

2.3.3 Photon Classification

After a composite ground surface is determined, photons are labeled as ground photons if they fall within the point spread function of the surface—approximately 35 cm rms. Signal photons that are not labeled as ground and are below the ground surface (buffered with the point spread function) are labeled as noise but retain the signal label. The top-of-canopy photons are used to generate an upper canopy surface by applying a shape-preserving surface fitting method. All signal photons that are not labeled ground, lie above the ground surface (buffered with the point spread function), and lie below the upper canopy surface are labeled as canopy photons. Signal photons that lie above the top-of-canopy surface are labeled as noise but retain their signal label (Section 3.4, ATBD for ATL08).

2.3.4 Refining the Photon Classifications

During the first surface finding iteration, the algorithm may mislabel some photons (most likely classifying noise as canopy). After the first iteration, the algorithm then rejects photons as mislabeled based on set of criteria designed to identify statistically unlikely and unphysical canopy classifications.

In addition, photons labeled as ground are evaluated and reassigned as needed based on the how the ground surface was determined and whether canopy photons have been detected. If no canopy photons are present for a segment, then the final ground surface is interpolated from the identified ground photons and the segment receives a final round of median filtering and smoothing. If canopy photons are present, then the final ground surface is interpolated based on the amount of canopy at that location along the segment and constructed iteratively as a composite of various intermediate surfaces. See "Section 3.5 | Refining the Photon Labels" of the ATBD for ATL08.

2.3.5 Canopy Height Determination

After the final ground surface is determined, canopy heights for individual photons are computed by removing the ground surface height for that photon’s latitude and longitude. These relative canopy photon height values are then used to compute the canopy statistics. Vegetation parameters are derived at the fixed segment length of 100 m to ensure that canopy (and terrain) metrics are consistent between segments (Sections 3.6 and 3.7, ATBD for ATL08).

2.4 Quality, Errors, and Limitations

Uncertainty in computed terrain height estimates depends on the uncertainties in the ATL03 data passed to the algorithm combined with any local uncertainties within each 100 m segment, beginning with the number of photons classified as terrain photons. Potential error sources in ATL08 height retrievals are detailed in Sections 1.5–1.8 of the ATL08 ATBD. Topics include vertical sampling error, background noise, misidentified photons, complex topography, dense vegetation, and dense and sparse canopies. Further, several parameters are available to help determine the performance of the surface finding algorithm (Table 5.2 of the ATL08 ATBD).

3 VERSION HISTORY

Table 4. Version History Summary

Version	Date	Description of Changes
7.0	26 Aug 2025	• Remove canopy finding flag in ATL08 regions 7, 8, 9, 10, and 11 • Incorporate the CAB delineation of a ground surface to remove noise bands from the ATL03 data product prior to DRAGANN. • Align the weak beam to the strong beam from ATL09 based on along-track distance for CAB profile cloud filtering • Updated description for MSW flag • Incorporated a single surface search to improve ground finding • Updated parameters on the quality_ph flag to allow certain photons as input into ATL08 • Added a terrain and canopy quality score • Added steps for identifying whether photons are from a single surface or multi-surface • Added ground finding correction based on a priori DEM bias • Added extension of nighttime canopy photons, above FINALGROUND surface • Added steps to reject photons in the presence of fog or low-lying clouds
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)	11 Jan 2024	Data access was removed for v5.0. Data coverage was 14 Oct 2018 to 13 Oct 2022.
6.0	18 May 2023	• Added a quality check to reject segments for which the canopy photons fall more than 150 m below the reference DEM. • Calculated the background noise rate and number of noise photons within a canopy segment and adjusted the canopy radiometric rate accordingly. • For segments with a solar elevation angle > 20°, if the background noise rate is < 0.98 of the canopy rate, then reassign the canopy photons as noise photons. • Incorporated the YAPC photon weights from the ATL03 data product into the ground-finding approach. • Reduced the number of labeled photons required to report the canopy or terrain heights within each segment for the strong and weak beams, resulting in more ATL08 reported values.

4.0 (retire)	13 Jun 2022	Data access was removed for v4.0. Data coverage was 14 Oct 2018 to 15 Jul 2021.
3.0 (retire)	25 Jan 2022	Data access was removed for v3.0. Data coverage was 14 Oct 2018 to 11 Nov 2020.
5.0	29 Nov 2021	• Added terrain_best_fit_geosegment parameter at the 20 m (geosegment) rate. • Added h_canopy_geosegment which represents the 20 m estimate of the 98% relative canopy height. • Added latitude_20 to the data product for geolocation of the 20 m terrain and canopy height estimates • Added longitude_20 to the data product for geolocation of the 20 m terrain and canopy height estimates. • Updated the segment_landcover with the 2019 100-m-resolution Copernicus landcover to replace the MODIS landcover value derived from the 2014 MODIS product. • Updated the urban_flag parameter with the DLR Global Urban Footprint (GUF) as a potential indicator of man-made/built structures. • Added segment_woody_vegetation_fractional cover, derived from the Copernicus fractional forest and fraction shrub data products.
2.0 (retire)	21 May 2021	Data access was removed for v2.0. Data coverage was 14 Oct 2018 to 15 Nov 2019.
4.0	13 Apr 2021	• Used PPD flag of ATL03, degraded POD/PPD solutions were flagged and ignored in the ATL08 algorithm. • To reduce the amount of cloud contamination in the signal photons, all photons from 120 m or more above the reference DEM are considered clouds. • Added a saturation flag that is based on the ATL03 saturation flags to indicate that a segment within 100 m is saturated (likely due to water). • Included a ph_h parameter to the photon group reflecting the height of each photon above the estimated ground surface. • Changed calculation of absolute canopy heights and height metrics. • Expanded the canopy height metrics to every 5% ranging 5–95%. • Removed the Landsat canopy cover check in the algorithm, which was preventing canopy from being detected in areas with low canopy cover (e.g., savannas) even though reflected photons from woody vegetation are observed at the photon level. • Changed the search radius parameter from 15 m to 100 m for the initial top of canopy determination in an effort to pull in more previously missed top-of-canopy photons. • Incorporated the quality_ph flag of the ATL03 product which should exclude many after-pulsing events from the ATL08 algorithm due to detector saturation and other detector events (water bodies such as wetlands, rivers, etc). This should result in a more accurate surface representation, particularly for wetlands where standing water is often found. • Added the calculation of the photon rates for terrain and canopy points to improve future radiometry studies.
1.0 (retire)	3 Jun 2020	Data access was removed for v1.0. Data coverage was 14 Oct 2018 to 14 Jan 2019.
3.0	5 May 2020	• Added subset_te_flag and subset_can_flag to indicate 100 m segments that are populated by less than 100 m worth of data.

		• Fine-tuned and improved the ground-finding methodology: photons are first histogrammed to better detect ground returns in cases where the canopy is dense.
2.0	24 Oct 2019	• Removed the segment_id parameter from the product. • Added the layer_flag parameter (from ATL09) to allow users to filter by cloud cover. • Updated the description of the multiple scattering warning flag (msw_flag) to account for values of “-1” in cases where the presence of clouds or blowing snow could not be determined. • Removed the cloud_flag_asr parameter; added cloud_flag_atm and cloud_fold_flag for users to identify and filter potentially errant heights due to cloud cover. • Developed a method to evaluate flagged results from DRAGANN (noise filtering) and correct intermittent, erroneous flags that can occur well above and below land and vegetation due to changing background rates and clouds. • Reduced the minimum average canopy coverage pixel percentage (from 5% to 3%) from Landsat tiles. • Reduced the smoothing window size used to refine ground surface-finding, regardless of calculated smoothing window sizes for the initial ground and top of canopy finding. • Added brightness_flag to indicate potential snow accumulation (and similar bright surfaces) for each 100 m.
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

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).

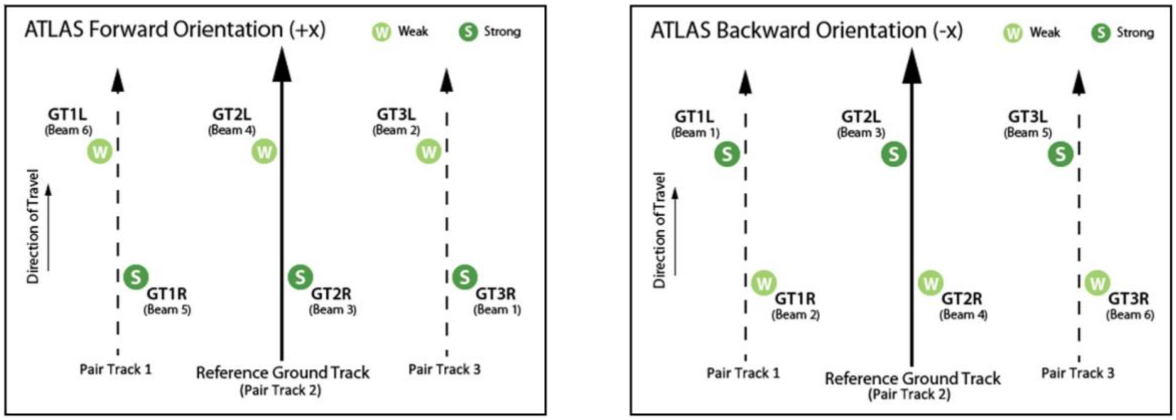

Figure A - 1. Spot and Ground Track (GT) naming convention.

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.

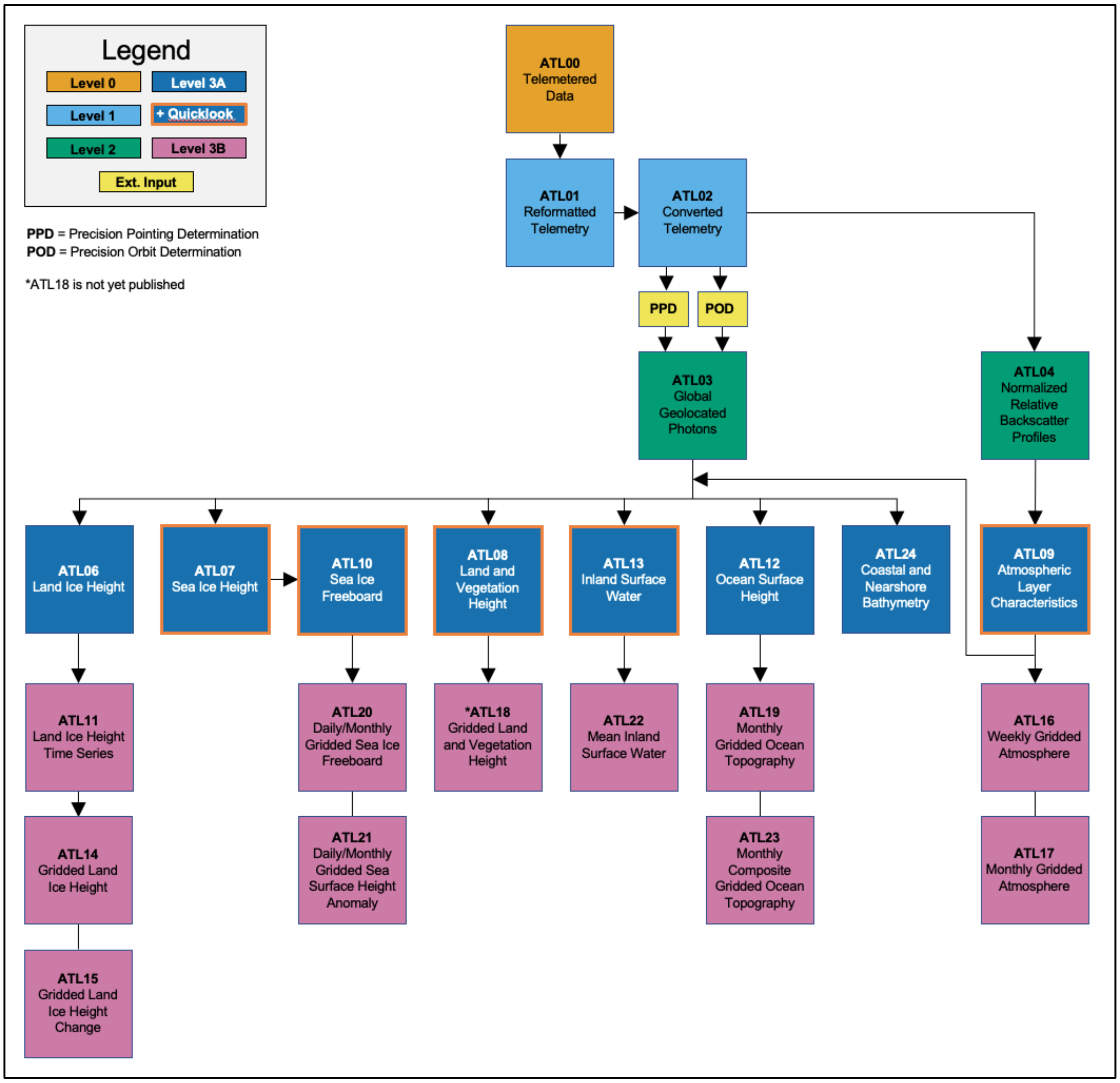

Figure A - 2. Schematic of ICESat-2 data processing and data products.

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.

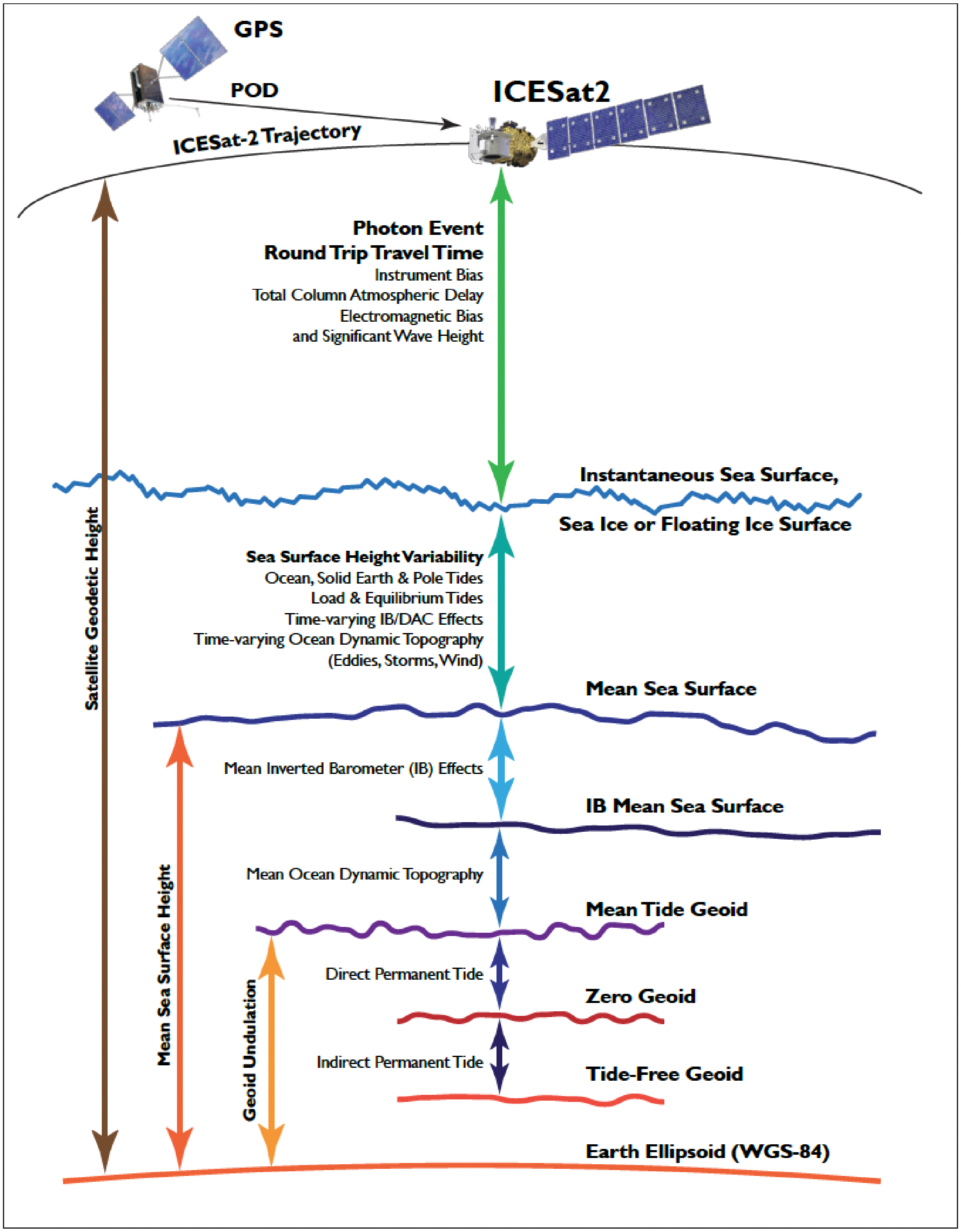

Figure A - 3. Geophysical corrections used in satellite altimetry (Source: *ICESat-2 Data Comparison User's Guide for Rel007,* available on the ATL03 data set landing page).