



ATLAS/ICESat-2 L3B Mean Inland Surface Water Data, Version 4

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., Robins, J., & Nattala, J. (2025). *ATLAS/ICESat-2 L3B Mean Inland Surface Water Data* (ATL22, Version 4). [Data set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center.
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FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT <https://nsidc.org/data/ATL22>



National Snow and Ice Data Center

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1 DATA DESCRIPTION

The ATL22 data product is described in detail in the ICESat-2 Project Algorithm Theoretical Basis Document (ATBD) for Mean Inland Surface Water Data (Jasinski et al., 2025).

1.1 Summary

ATL22 includes the per-beam mean surface water height, mean surface height standard deviation, and mean ATLAS 532 nm attenuation coefficient over a water body transect, reported at the center of the beam transect. Additional parameters include the beginning and end of the transect, transect length, and center of transect. ATL22 is derived from ATLAS/ICESat-2 L3A Along Track Inland Surface Water Data (ATL13).

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 ATL22 parameters is available in the [ATL22 Data Dictionary](#).

Within data files, similar variables such as science data, instrument parameters, and metadata are grouped together according to the HDF model. Figure 1 shows data groups stored at the top level in ATL22 data files.

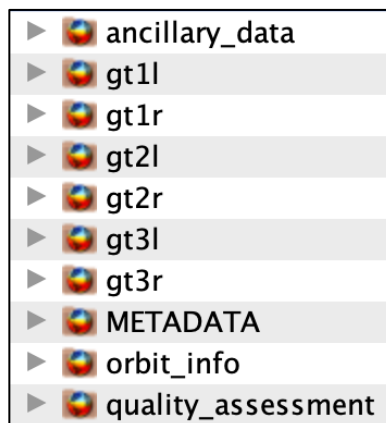


Figure 1. ATL22 top-level data groups.

The following sections describe the data groups and their contents in ATL22 data files.

1.2.2.1 ancillary_data

Information ancillary to the data product such as product and instrument characteristics and processing constants.

1.2.2.2 gt1l–gt3r

Six ground track groups (gt1l, gt1r, gt2l, gt2r, gt3l, gt3r) that contain the per-beam data parameters. Parameters of interest include:

- **inland_water_body_id**: Identifying signature of an individual inland water body. Each body of water is represented by a unique numeric value.
- **inland_water_body_region**: Region code based on ATL13-created shapefile representing relevant bodies of water over which to implement the ATL13 water-surface-finding algorithm only within a region of processing interest.
- **inland_water_body_type**: Type of inland water body, where 1=Lake, 2=Known Reservoir, 4=Ephemeral Water, 5=River, 6=Estuary or Bay, and 7=Coastal Water. (Note: 3, 8, and 9 are reserved for future use)
- **transect_dist_from_eq**: Along-track distance from the equator to the start of the first filtered short segment in the transect
- **transect_1lat**: Reporting latitude of transect statistics
- **transect_1lon**: Reporting longitude of transect statistics
- **transect_time**: Reporting time of transect statistics
- **transect_length**: Length of the transect, determined as the distance from the first filtered observed reference photon in the water body to the final filtered observed photon in the body
- **transect_mean_ht_WGS84**: Mean geodetic height of the transect with respect to the WGS84 ellipsoid, determined as the mean of all filtered short segment height values in the transect
- **transect_mean_ht_ortho**: Mean orthometric height of the transect with respect to the EGM2008 geoid, determined as the mean of all filtered short segment height values in the transect
- **transect_mean_slope_trk_bdy**: Mean ATL13 along track water body surface slope, as reported per short segment ID per water body
- **transect_mean_subsurf_atten**: Mean subsurface attenuation (alpha) of the transect, determined as the mean of all filtered alphas along the transect

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.

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:

ATL22_[yyyymmdd][hhmmss]_[ttttccss]_[vrv_r]_h5

Example:

ATL22_20230607051246_11891901_004_01.h5

Table 1. File Naming Convention Variables and Descriptions

Variable	Description
ATL22	ATLAS/ICESat-2 L3B Mean Inland Surface Water Data product
yyyymmdd	Year, month, and day of data acquisition
hhmmss	Start time hour, minute, and second of data acquisition (UTC)
tttt	Four-digit RGT of the first ATL10 granule used in the monthly gridded data set. The ICESat-2 mission has 1,387 RGTs, numbered from 0001 to 1387.
cc	Cycle number of the first ATL10 granule used in the monthly gridded data set. Each of the 1387 RGTs is targeted in the polar regions once every 91 days. The cycle number tracks the number of 91-day periods that have elapsed since ICESat-2 entered the science orbit.
ss	Region number. This number corresponds to the first of the ICESat-2 along-track regions considered for input into ATL22 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.
vrv_r	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.

1.2.4 Browse Files

Browse files are provided as JPGs that contain per-beam data images for each granule, as described in Table 2.

Table 2. Images Available as Browse

File	Description
ht_ortho_eurasia	Mean orthometric height of the transect with respect to the EGM2008 geoid (Eurasia)
ht_ortho_global	Mean orthometric height of the transect with respect to the EGM2008 geoid (Global)
ht_ortho_north_america	Mean orthometric height of the transect with respect to the EGM2008 geoid (North America)
trans_leneurasia	Length of the transect (Eurasia)
trans_lenglobal	Length of the transect (Global)
trans_lennorth_america	Length of the transect (North America)

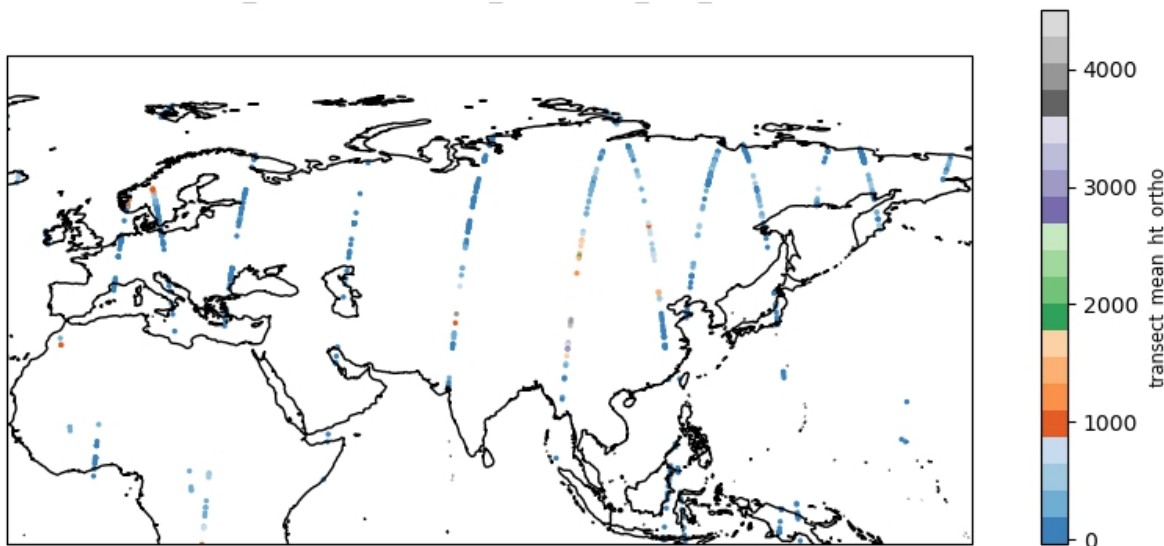


Figure 2. Example browse image for mean orthometric height of the transect (ht_ortho_eurasia).

1.3 Spatial Information

1.3.1 Coverage

Spatial coverage spans approximately 88° N latitude to 88° S.

1.3.2 Resolution

Data are averaged over individual inland water transects of varying sizes.

1.3.3 Geolocation

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) 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

Repeat observations for any given water body depend on its size and geographic location. The frequency at which ATLAS/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 $\pm 65^\circ$), 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).

2 DATA ACQUISITION AND PROCESSING

2.1 Background

ATL22 has been developed as a higher level, more convenient alternative to ATL13 for hydrologists, water resource engineers, scientists from other disciplines, and applied science users who only require mean surface water products such as surface water height. Some potential applications for ATL22 are estimating river discharge and changes to water storage in a lake or reservoir. ATL22 offers valuable data, especially in remote areas such as high-latitude boreal zones where in situ data are sparse or non-existent. Furthermore, ATL22 can serve as a source of high-resolution data to calibrate other radar altimeters.

2.2 Acquisition

ATL13 contains the high-resolution, along-track inland water surface profiles derived from analysis of the geolocated photon clouds from the ATL03 product. Starting from ATL13, ATL22 computes the mean surface water quantities with no additional photon analysis. ATL22 and ATL13 can be used in conjunction as they include the same orbit and water body nomenclature independent from version numbers.

2.3 Processing

Inland water bodies are defined as contiguous continental water bodies of the following types: lakes and reservoirs greater than about 0.1 km²; rivers greater than about 50–100 m wide; transitional water, including estuaries and bays; and a near-shore 7 km buffer. Globally, about 1.5 million water bodies are defined by unique IDs in ATL22.

In ATL22, water bodies are identified by a set of polygons. An ICESat-2 water body transect is any portion of an ICESat-2 beam that crosses a single water body without being interrupted by land (e.g., by islands or peninsulas). An ICESat-2 crossing with no land interruptions would have a single transect. A crossing of a lake encountering a single island would have two transects.

2.3.1 Inland Water Masks

The ATL13/22 Inland Water Body Shape Mask was created to identify ICESat-2 crossings over individual water bodies by delineating their shape and spatial distribution. The mask consists of a composite of lakes, reservoirs, rivers, and transitional waters (estuaries and bays), and near-shore coastal waters. The mask consists of polygons, each representing an entire single lake or reservoir, 7-km wide coast segment, a bay, or a river segment including its tributaries.

To facilitate processing of data only over inland water bodies and near coastal regions, a gridded ATL03 Inland Water Mask was further developed based on the ATL13/22 Inland Water Body Shape Mask. The 0.1 km² resolution mask initially flags if at least one ATL13 shape or partial shape exists in that grid. Grids without water bodies are not preprocessed for ATL13/22 analysis. The implementation of the ATL22 algorithm draws only on ICESat-2 observations that have been flagged as falling within the ATL03 Inland Water Mask. See Sections “3.4 | ATL13/22 Inland Water Body Mask” and “3.5 | The ATL03 Inland Water Mask (Flag)” in the ATBD (Jasinski et al., 2025).

2.3.2 Output

Four ATL13 granules (covering approximately 24 hours) are aggregated into one ATL22 file. The mean ellipsoidal height, mean orthometric height, and mean subsurface attenuation of a given

beam transect are computed as the arithmetic mean of the respective ATL13 segment-rate output. The mean is computed over all non-anomalous ATL13 short segments in a transect and reported at a single index location for each beam in the transect based on the latitude and longitude of each segment. Latitude, longitude, and time for each ATL22 transect are computed based on the short segment index photon location within the transect that is closest to the arithmetic mean of the corresponding ATL13 data set. The length of a transect is defined as the distance between the start and end latitudes and longitudes of the first and last ATL13 segment in the ATL22 transect.

To allow users to conveniently use ATL22 products, a number of attributes from the ATL13 source data are written to ATL22 files. For each ATL22 transect, the ATL13 input file name is provided (`/metadata/lineage`) as well as the water body region, the water body type, and the unique, water body reference identification number (`at113_gran_ndx`) for the water body to which the transect belongs. ATL22 transect output also contains indices that point users to the start and end rows (`transect_start_sseg_idx` and `transect_end_sseg_idx`) of ATL13 input arrays upon which the product is based.

2.4 Quality, Errors, and Limitations

ATL22 data quality relies on the precision of the ATL03 georeferenced photons and associated products that are evaluated prior to their use within ATL13.

Height accuracy, depending on aggregation level and water state, is estimated to be about 10 cm for the strong beam. Section 4.3 “Data Product Precision and Evaluation” of the ATBD details ICESat-2 precision, as well as ATL22 data product evaluation, assessment and validation activities, and calibration activities (Jasinski et al., 2025).

3 VERSION HISTORY

Table 3. Version History Summary

Version	Date	Description of Changes
3.1 (retire)	30 Apr 2026	Data access was removed for v3.1. Data coverage was 14 Oct 2018 to 2 Mar 2025.
4.0	30 Oct 2025	<ul style="list-style-type: none"> • Version 4 of this data set was derived from ATL13 v7. • Added calculation and output of transect mean maximum likelihood alpha • Added sseg_length and sseg dist_from_eq • Calculated the along-track observed linear slope and accompanying root mean squared error • Defined process for fitting heights during along-track slope calculation • Added detrend-based along-track mean slope and ATL13 orthometric height distribution skew and kurtosis • Turned on calculation of along-track slope for lakes and reservoirs; added language for exclusion of invalid values in mean slope calculatio • Added transect mean azimuth calculation and output; reversed 0/1 on/off assignments used for along_trk slope_calc array to match convention used for previous parameters • For skewness and kurtosis calculations, added minimum filtered short segment requirements, controls based on water body type, and clarification to use bias-corrected results • Turned on calculation of linear fit along-track slope for rivers
3.1	1 May 2024	Data from 13 November 2022 to 26 October 2023 were reprocessed using ITRF2014 (replacing ITRF2020) for consistency across the entire data set.
2.0 (retire)	25 Mar 2024	Data access was removed for v2.0. Data coverage was 14 Oct 2018 to 10 Aug 2022.
3.0	12 Sep 2023	Version 3 of this data set was derived from ATL13 v6. The mean values of all parameters improved from ATL22 v2 by filtering ATL13 input heights using histogram analysis that excluded outliers (e.g., land, islands).
2.0	15 Feb 2022	Initial release. Version 2 of this data set was derived from ATL13 v5.

4 REFERENCES

Jasinski, M., Stoll, J., Hancock, D., Robbins, J., Nattala, J., & Carabajal, C. (2025). *Algorithm Theoretical Basis Document (ATBD) for Mean Inland Surface Water Data ATL22 Release 4*. NASA Goddard Space Flight Center. <https://doi.org/10.5067/ONG3H30DUFEL>

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

April 2026

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).

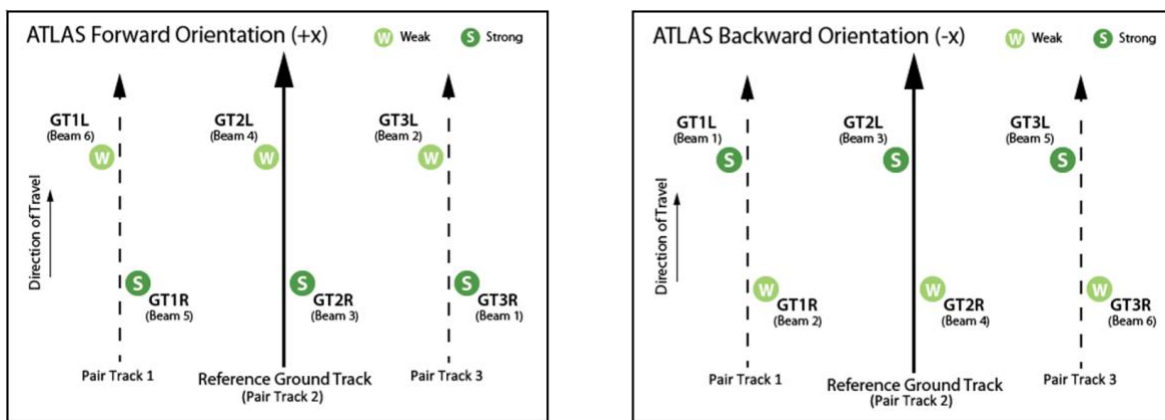


Figure A - 1. Spot and Ground Track (GT) naming convention.

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.

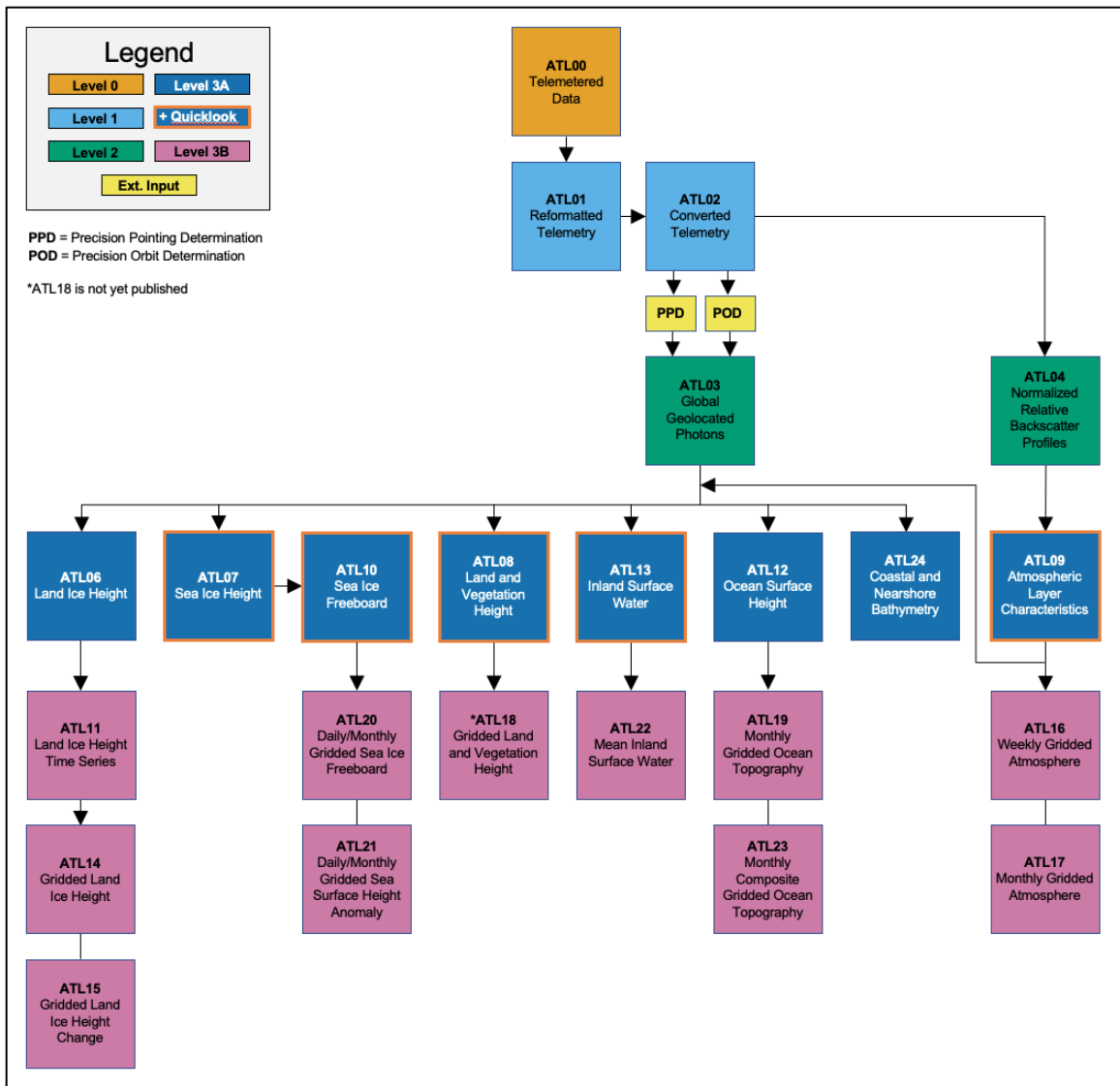


Figure A - 2. Schematic of ICESat-2 data processing and data products.

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)	<i>No geophysical corrections beyond ATL03</i>
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

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

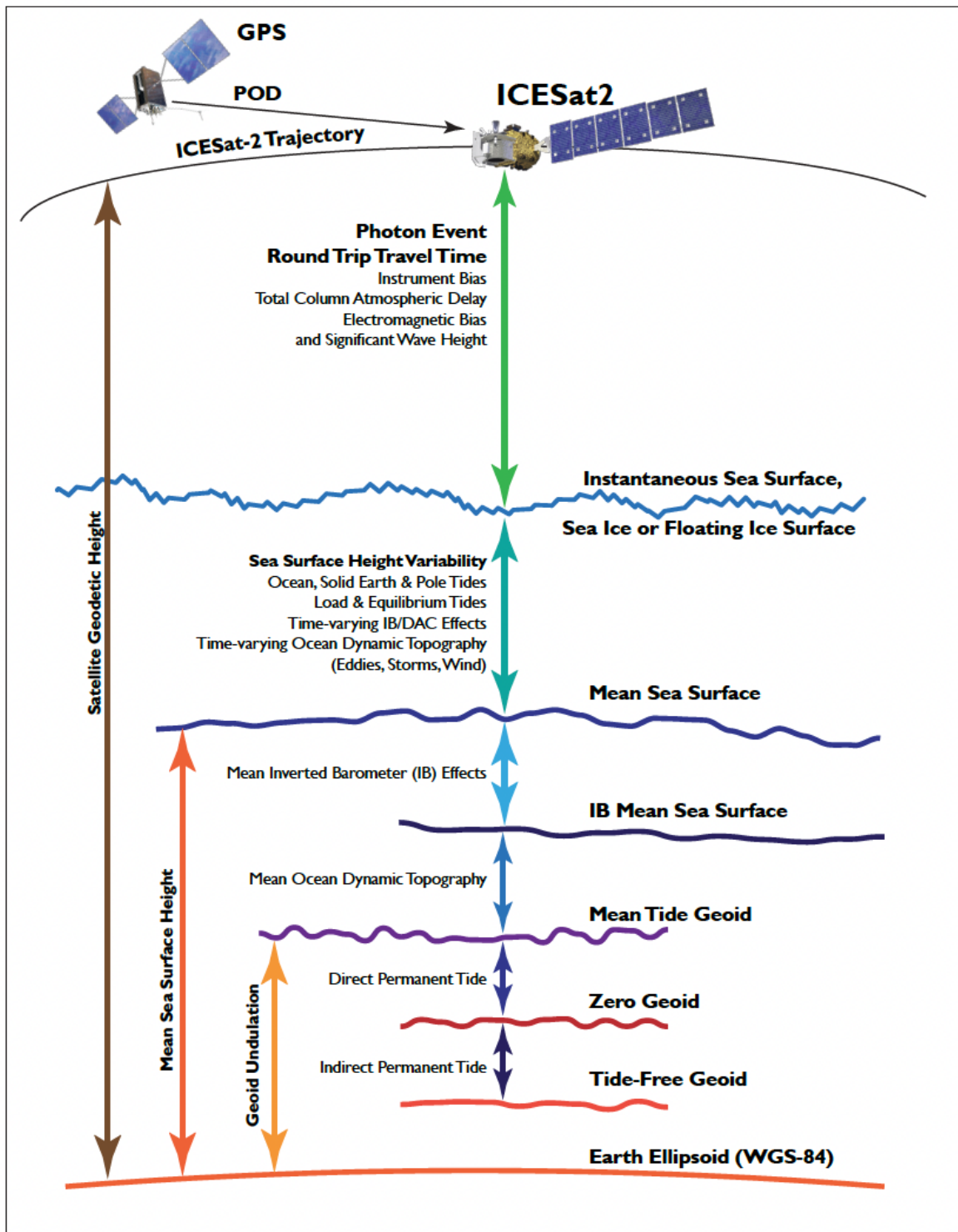


Figure A - 3. Geophysical corrections used in satellite altimetry (Source: *ICESat-2 Data Comparison User's Guide for Rel007*, available on the ATL03 data set landing page).