ATLAS/ICESat-2 L1B Converted Telemetry Data, Version 7

USER GUIDE

How to Cite These Data

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

Martino, A. J., Pingel, A., Lee, J., Bock, M. R., Gosmeyer, C., Field, C., Neumann, T. A., Hancock III, D. W., Jones III, R. L., Dabney, P. W., & Webb, C. E. (2025). *ATLAS/ICESat-2 L1B Converted Telemetry Data* (ATL02, Version 7) [Data set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ATLAS/ATL02.007 [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/ATL02

National Snow and Ice Data Center

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1 DATA DESCRIPTION

The ATL02 data product is described in detail in the ICESat-2 Project Algorithm Theoretical Basis Document (ATBD) for ATL02 (Level 1B) Data Product Processing (ATBD for ATL02 V7 | https://doi.org/10.5067/Q4W8ENZCR1PL).

1.1 Summary

These Level 1B time-ordered telemetry data are used for system-level, quality control analysis by the Advanced Topographic Laser Altimeter System (ATLAS) ICESat-2 Science Investigator-led Processing System (SIPS). They also provide source data for the Level 2 products and the Precision Orbit Determination (POD) and Precision Pointing Determination (PPD) computations.

1.2 File Information

1.2.1 Format

Data are provided as HDF5-formatted files.

1.2.2 Granule Regions

ATL02 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:

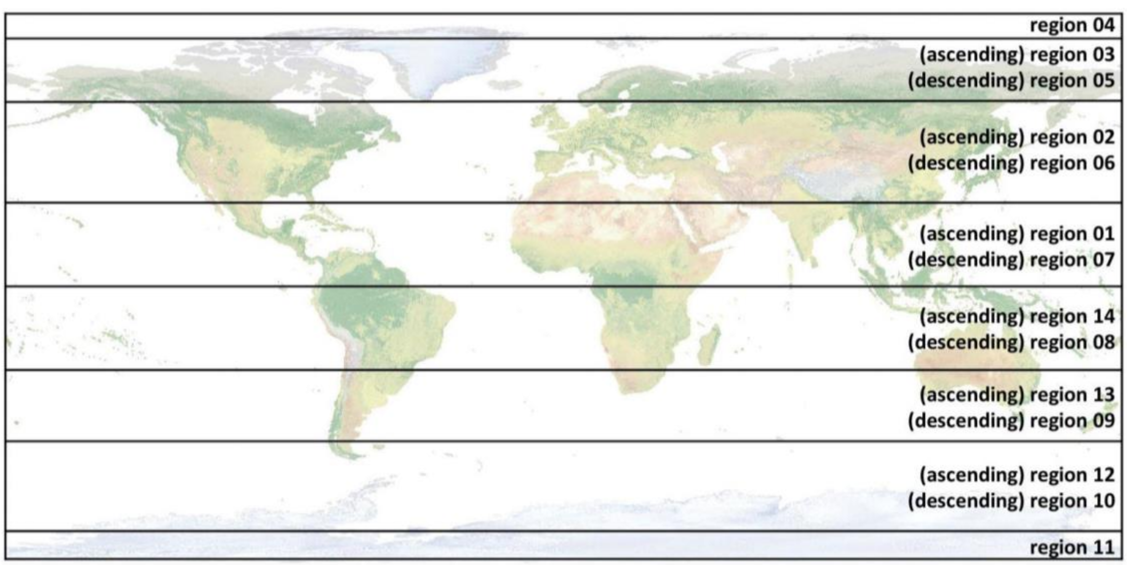

Figure 1. ATL02 region/granule boundaries.

The following table lists the latitude bounds and region numbers for the 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 ATL02 parameters is available in the ATL02 Data Dictionary.

Within data files, similar variables and metadata are grouped together according to the HDF model, as shown in Figure 2.

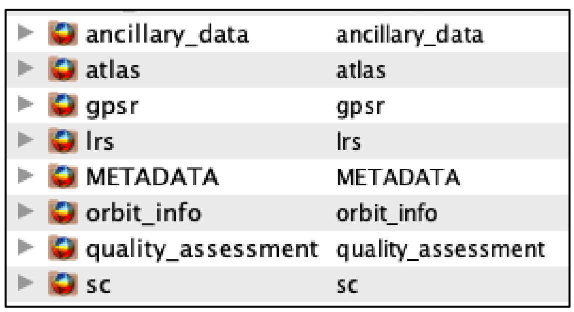

Figure 2. ATL02 top-level data groups.

Descriptions of the top-level groups are as follows:

- `ancillary_data`: information ancillary to the data product. This may include product characteristics, calibration data, instrument settings, and processing settings.
- `atlas`: instrument housekeeping data; data from the photon-counting electronics relating to laser fire times and pulse characteristics, photon times of flight, atmospheric return histograms, background counts, and on-board software.
- `gpsr`: parameters related to the GPS receiver.
- `lrs`: parameters relating to the laser reference system, including data related to instrument pointing and alignment.
- `METADATA`: ISO19115 structured metadata represented within HDF5.

- `orbit_info`: orbit information.
- `quality_assessment`: quality assessment data, such as QA counters, QA along-track data, and/or QA summary data.
- `sc`: spacecraft (SC) ancillary science packet #1 decommutated data.

1.2.4 Naming Convention

Data files utilize the following naming convention:

`ATL02_[yyyymmdd][hhmmss]_[ttttccss]_[vvv_rr].h5`

Example:

`ATL02_20230606000821_11701908_007_01.h5`

Table 2 describes the file naming convention variables.

Table 2. File Naming Convention Variables and Descriptions

Variable	Description
ATL02	ATLAS/ICESat-2 L1B Converted Telemetry Data
yyyymmdd	Year, month, and day of data acquisition
hhmmss	Hour, minute, and second of data acquisition (UTC)
tttt	Reference Ground Track (RGT). 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. ATL02 data files (granules) cover regions as described in Table 1. Note that data files may not be available for some regions on some orbits.
vvvv_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.

1.3 Spatial Information

1.3.1 Coverage

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

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.

1.3.3 Geolocation

World Geodetic System 1984 (EPSG: 4326)

1.4 Temporal Information

1.4.1 Coverage

Temporal coverage is 13 October 2018 through the most current processing.

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 Reference Ground Tracks 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

Figure 3 illustrates the on-board data processing from photon input capture to intermediate data output to downlink telemetry. The processing includes a function to time tag key events such as laser transmit, return events, and the time of day (TOD) these measurements are made. To reduce the volume of data downlinked to Earth, ICESat-2 uses on-board flight software and a statistical approach to identify and downlink the most likely signal photons as well as data on atmospheric conditions.

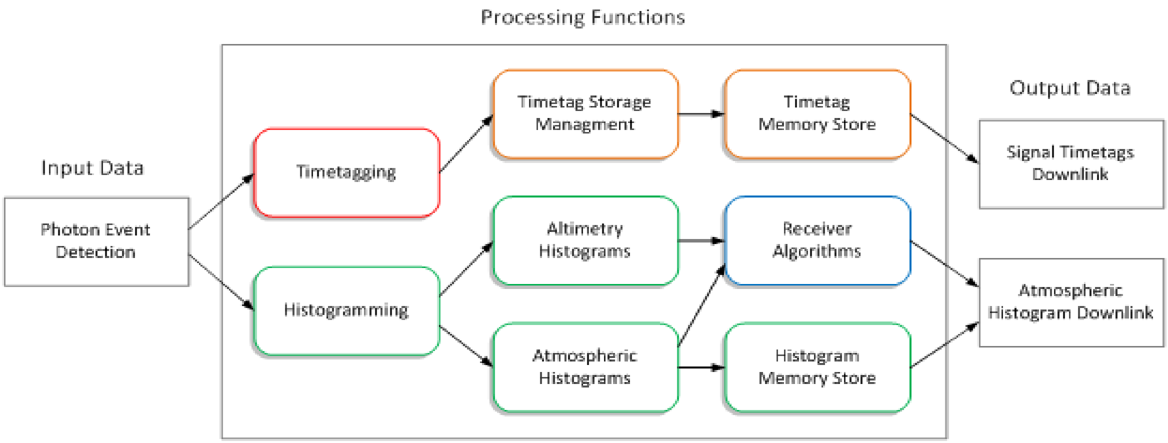

Figure 3. Block diagram illustrating ATLAS on-board data processing.

Three PCE cards perform this function on-board via histogramming and receiver algorithms. Three receiver algorithms run concurrently on three identical processors, one on each of the three PCE cards. Each PCE card contains the electronics for one strong/weak beam pair. The purpose of these algorithms is to reduce the volume of telemetry data while maximizing the probability of downlinking surface returns.

To that end, these algorithms count the received photon events and generate histograms to aid the statistical signal processing. The receiver algorithms also select the signal location around the ground and instruct the hardware to telemeter a vertical band of received time-tags about this location in real-time. To achieve this, the algorithms set a vertical range window between -500 meters (i.e., below ground) and 6 kilometers, bin the histograms at 3 meters, and time-tag photon events within the bins over 200 consecutive laser shots. The size of the range window depends on the surface type (for example, ocean, land ice, or land) as well as the topography.

Concurrently, the algorithms generate atmospheric histograms (strong beams only) that aggregate photon events within 30-meter bins over 400 consecutive laser shots. Thus, atmospheric histograms are generated every 0.04 seconds and span 280 meters of along-track distance.

2.2 Acquisition

The ATL01 algorithm unpacks and reformats the Level 0 data. These data, along with ancillary products comprising instrument configuration parameters, calibrations, and ruler clock (Ultra-Stable Oscillator) behavior, are input to ATL02 for processing.

2.3 Processing

In general, ATL02 processing converts Level 1A parsed, partially reformatted, and time-ordered telemetry data (ATL01) into physical-unit-converted, time-ordered telemetry. ATL02 processing also generates some preliminary products needed by the Level 2, Level 3A, and Level 3B data products. The list of ATL02 products includes but is not limited to:

- All data, including house-keeping and ancillary data, converted to physical units
- Reconstructed absolute time-bias corrected TOD for all laser fire times and time tagged data
- Time of flight (TOF) for each photon event, corrected for known system time biases and time base errors
- Raw histogram atmospheric profiles, aggregated to 25 Hz frames
- Approximate location of the spacecraft on the WGS 84 reference surface using the spacecraft GPS data

2.4 Quality, Errors, and Limitations

A multi-faceted data quality assurance process is applied to the ATL02 data product using the following utilities:

- Custom Python scripts are used for pre-launch validation of the algorithm implementations, telemetry conversions, etc., in the ATLAS Science Algorithm Software (ASAS) code.
- ASAS QA scripts are integrated directly into the utilities that create the ATL02 HDF5 data products. These scripts screen for catastrophic errors in the product and, if found, halt further processing of the granule. These scripts are executed each time an ATL02 data product is created.
- ICESat-2 Science Computing Facility (SCF) Limit Checking Scripts are used to perform rote limit checks on parameters contained in the HDF5 data products. These scripts check the values contained in the ATL02 product and alert the responsible party when something is out of bounds. Limit checking flags issues that warrant additional investigation but are not severe enough to halt the processing of the granule. These scripts are executed each time an ATL02 data product is created.
- ICESat-2 Instrument Support Facility (ISF) Trending enables tracking of overall trends in the results output by the ATL02 HDF5 data product. Trending is used to evaluate the long-term stability of the ATLAS instrument as well as key parameters that are used to produce the ATL02 HDF5 data products. ISF trends are monitored within the context of operations and engineering judgement. These trends are used to help identify areas where additional investigation may be needed without halting ATL02 product creation.

3 VERSION HISTORY

Table 3. Version History Summary

Version	Date	Description of Changes
7.0	31 Jul 2025	• Updated calibration data products that affect computation of TOF • Updated radiometric calibrations • Updated variable names related to sensitivity dependence on misalignment • Added "maximum apparent strength" values to dead-time correction tables • Mitigated an issue that caused erroneous jumps in inertial measurement unit gyro timestamps at granule boundaries • Corrected the computation of timetags for the A_MCE_POS packet • Updated the PCE alignment code to avoid using transmit events with missing threshold crossings when aligning transmit events across PCEs
5.0 (retire)	13 Nov 2023	Data access was removed for v5.0. Data coverage was 13 Oct 2018 to 1 Jan 2023.
6.0	11 May 2023	• Corrected the implementation of the computation of receiver sensitivity as a function of transmit/receive misalignment • Updated calibration data products that affect computation of TOF, i.e., delay line cell widths, receiver channel skews, and start skews
4.0 (retire)	13 Jun 2022	Data access was removed for v4.0. Data coverage was 13 Oct 2018 to 1 Aug 2021.
3.0 (retire)	25 Jan 2022	Data access was removed for v3.0. Data coverage was 13 Oct 2018 to 11 Nov 2020.
5.0	29 Nov 2021	• Changed transmit/receive optical misalignment calculation to use the history of the Alignment Monitoring Control System (AMCS) calibration results rather than the control loop setpoints • Added functionality to detect and correct start event/return event (TX/RX) slips; this includes discarding data from some shots and major frames and re-associating affected transmit and receive events
2.0 (retire)	21 May 2021	Data access was removed for v2.0. Data coverage was 13 Oct 2018 to 11 Mar 2020.
4.0	13 Apr 2021	**Group: /atlas/pcex/algorithm_science** • Added parameters alt_band_channel_mask, alt_band_mask, alt_nbands, /s_w/alt_error_flags, /s_w/ds_2samples • Changed /useflag/flag_meanings dimensions value to "[16]" • Changed /useflag/flag_meanings value to "['stby', 'science', 'test', 'manual', 'radio', 'unknown', 'unused', 'unused', 'unused', 'unused', 'stby_alt_amcs', 'science_alt_amcs', 'test_alt_amcs', 'manual_alt_amcs', 'radio_alt_amcs', 'unknown_alt_amcs']" **Group: /atlas/pcex/atmosphere_sw** • Changed /useflag/flag_meanings dimensions value to "[16]" • Changed /useflag/flag_meanings value to "['stby', 'science', 'test', 'manual', 'radio', 'unknown', 'unused', 'unused', 'unused', 'unused', 'stby_alt_amcs', 'science_alt_amcs', 'test_alt_amcs', 'manual_alt_amcs', 'radio_alt_amcs', 'unknown_alt_amcs']" **Group: /atlas/pcex/background** • Changed /useflag/flag_meanings dimensions value to "[16]" • Changed /useflag/flag_meanings value to "['stby', 'science', 'test', 'manual', 'radio', 'unknown', 'unused', 'unused', 'unused', 'unused', 'stby_alt_amcs', 'science_alt_amcs', 'test_alt_amcs', 'manual_alt_amcs', 'radio_alt_amcs', 'unknown_alt_amcs']" **Group: /atlas/pcex/sxp_ssr_sw** • Added group /sxp_ssr_sw **Group: /gpsr/navigation/nsm** • Changed /flag_meanings dimensions value to "[7]"

Version	Date	Description of Changes
		• Changed /flag_meanings value to "['propagated', 'cold_lsq_no_gdop', 'lsqm_w_svs', 'normal_lsqm', 'normal_kalman', 'unused', 'invalid_solution']" • Changed /flag_values value from "[1 2 3 4 5 7]" to "[1 2 3 4 5 6 7]" **Group /gpsr/time_correlation/imt** • Changed /datatype value from double precision to 64-bit integer • Changed /description value to "Time Correlation Data Record (TCDR) - Time Correlation Data Record (TCDR) - Instrument Measurement Time (IMT) representation of the synchronization time stamp. IMT precisely describes how the GPSR clock oscillator behaves, and is for internal and maintenance use only. This field contains the raw 64-bit IMT value. (Be aware of possible precision loss possible when converting to seconds.)". • Changed /source value to "ATL01/sc4/gpsr/time_correlation" • Changed /units value to "counts" • Changed /flag_meanings dimensions value to "[7]" • Changed /flag_meanings value to "['propagated', 'cold_lsq_no_gdop', 'lsqm_w_svs', 'normal_lsqm', 'normal_kalman', 'unused', 'invalid_solution']" • Changed /flag_values to "[1 2 3 4 5 6 7]" **Group /quality_assessment/record_counts** • Added parameter /pcex/qa_n_sxp_ssr
1.0 (retire)	3 Jun 2020	Data access was removed for v1.0. Data coverage was 13 Oct 2018 to 20 May 2019.
3.0	5 May 2020	• Improved/fixed a number of QA parameters to better reflect phenomena of concern • Updated the receiver return sensitivity code to match a correction in the ATBD to the equation that interpolates transmit/receive misalignment between AMCS offset updates • Addressed several issues related to units and descriptions within the file metadata • Removed the temperature parameter from /ancillary_data/calibrations/nominal_rx_sensitivity • Added a patch that detects and corrects anomalous transmit fine count swaps • Added a new method when swapping fine counts that subtracts 1 from the coarse count if the start marker is equal to 1 • Updated the temperature used for CAL-47 referencing to the correct thermistor (fixes a code error)
2.0	24 Oct 2019	• Fully verified and debugged outputs used to help confirm the TOF and TEP calculations • Receiver skews are now calculated from on-orbit data to improve precision and fidelity • Updated the description of ph_id_channel to clarify and correct errors in the documentation • Clarified and corrected errors in the ATBD and data dictionary related to units and descriptions • Changed the thermistor used for LRS-based laser energy conversions from the LRS_HKT packet to the ldc_t (channel 33) • Fixed the code to correctly record the CAL47 calibrations used to compute receiver sensitivity • Replaced a bad CAL47 instance, which affected “spot 2” background and return sensitivity, with a corrected instance • Fixed an issue that erroneously set the useflag to “AMCS CAL”
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

July 2025

5.2 Date Last Updated

July 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).

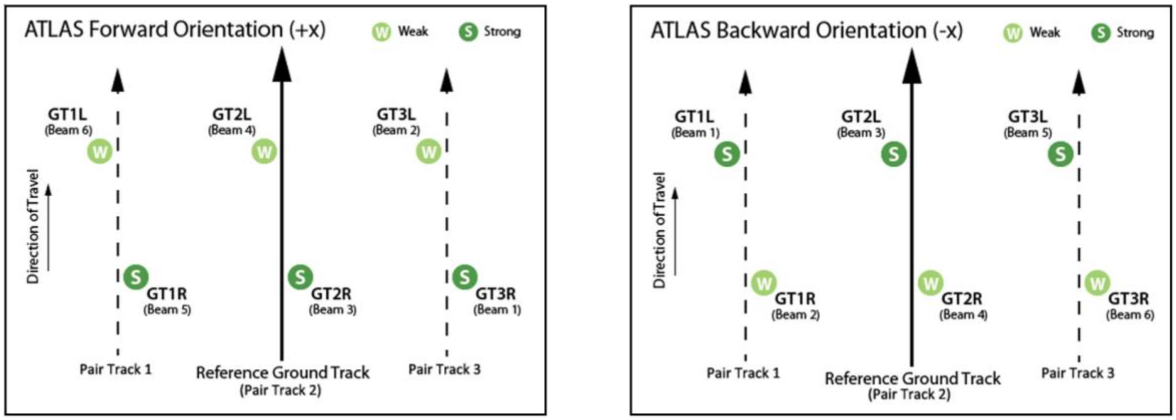

Figure A - 1. Spot and ground track (GT) naming convention.

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.

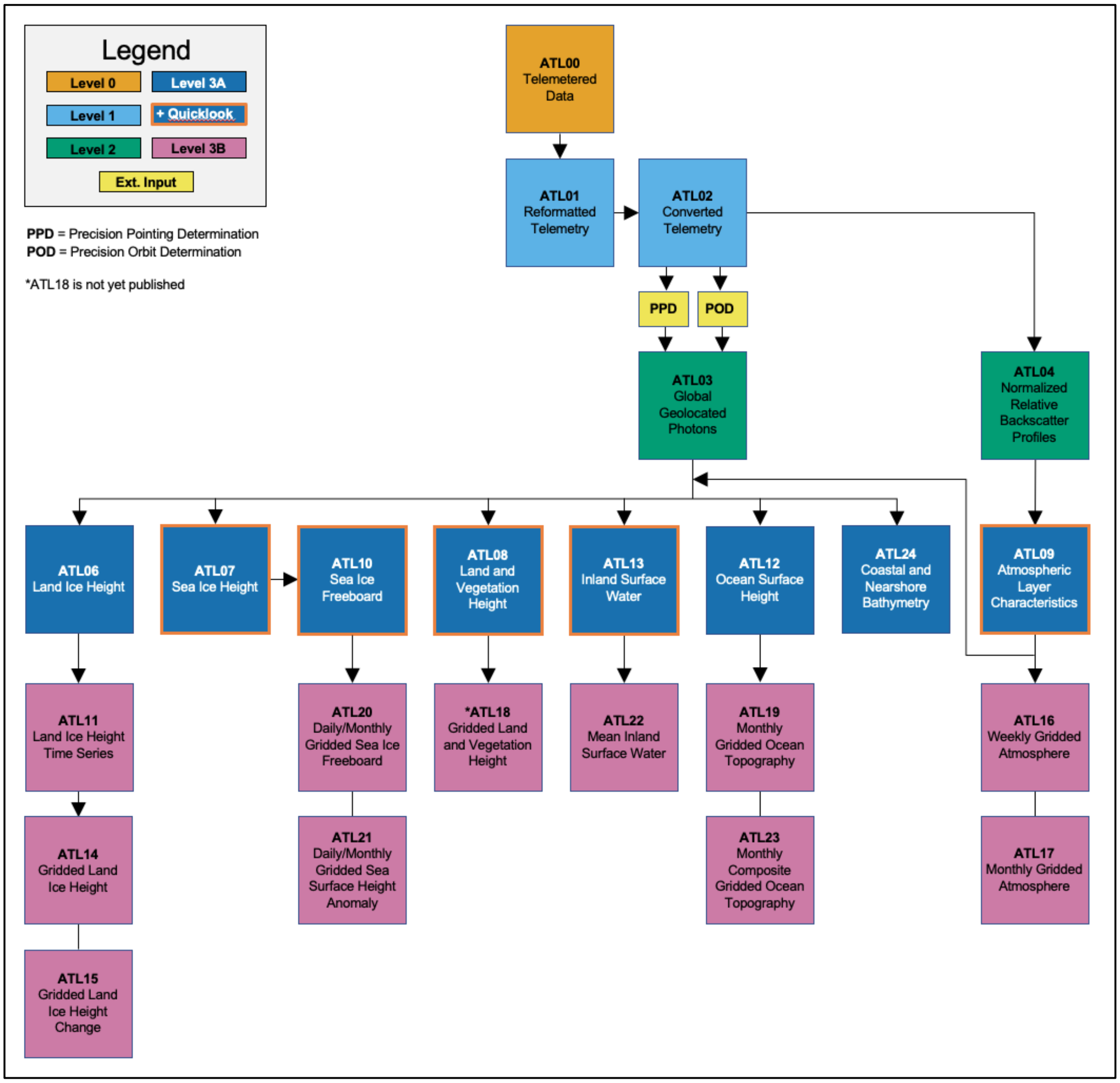

Figure A - 2. Schematic of ICESat-2 data processing and data products.

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.

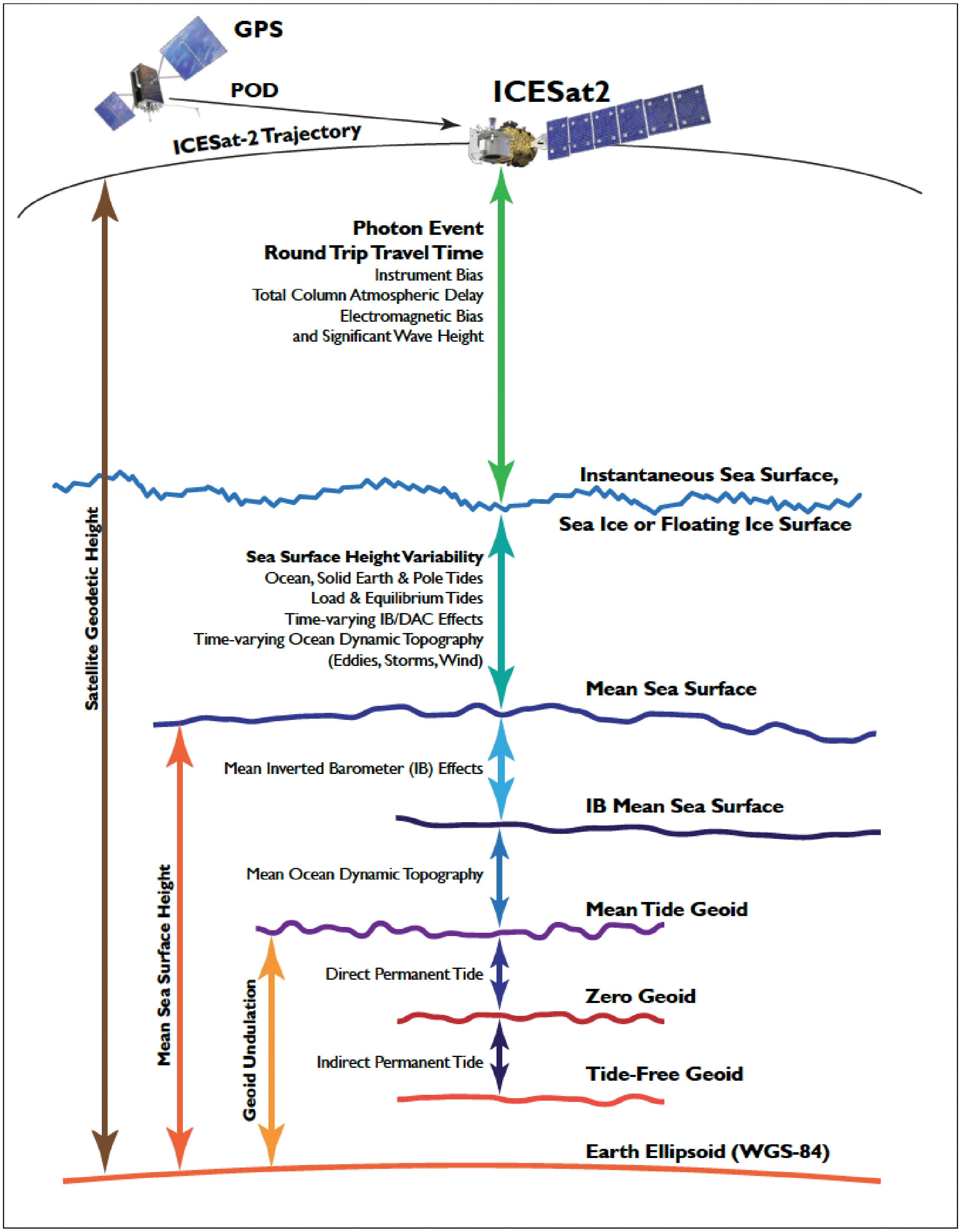

Figure A - 3. Geophysical corrections used in satellite altimetry
(Source: *ICESat-2 Data Comparison User's Guide for Rel007,*
Available on the ATL03 Data Set Landing Page).