ATLAS/ICESat-2 L1B Converted Telemetry Data, Version 3

USER GUIDE

How to Cite These Data

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

Martino, A. J., M. R. Bock, C. Gosmeyer, C. Field, T. A. Neumann, D. Hancock, R. L. Jones III, P. W. Dabney, C. E. Webb, and J. Lee. 2020. *ATLAS/ICESat-2 L1B Converted Telemetry Data, Version 3*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/ATLAS/ATL02.003. [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

These Level-1B (L1B) data are used for system–level, quality control analysis by the 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. To obtain higher-level ATLAS/ICESat-2 data which contain geolocated, geophysical data sets, visit the ICESat-2 page.

Users seeking a complete description of the ATL02 data product should consult the ICE, Cloud, and land Elevation Satellite (ICESat-2) Project Algorithm Theoretical Basis Document (ATBD) for ATL02 (Level-1B) Data Product Processing (ATBD for ATL02 | V03).

The primary goal of the ATL02 product is to provide input to the Level-2 geolocated photon (ATL03) and normalized relative backscatter (ATL04) data sets. The data processing chain starts with the ATLAS/ICESat-2 L1A Reformatted Telemetry (ATL01) product, which reformats and unpacks the Level-0 ICESat-2 data and converts them into engineering units. ATL02 processing applies instrument corrections to the ATL01 data, for example removing biases from timing and pointing measurements and correcting for the effects of temperature and voltage variations on the ATLAS electronics. The POD and PPD also draw from ATL02 to determine the position of the ICESat-2 observatory and pointing vector for ATLAS as functions of time.

The following figure illustrates the family of ICESat-2 data products and the connections between them:

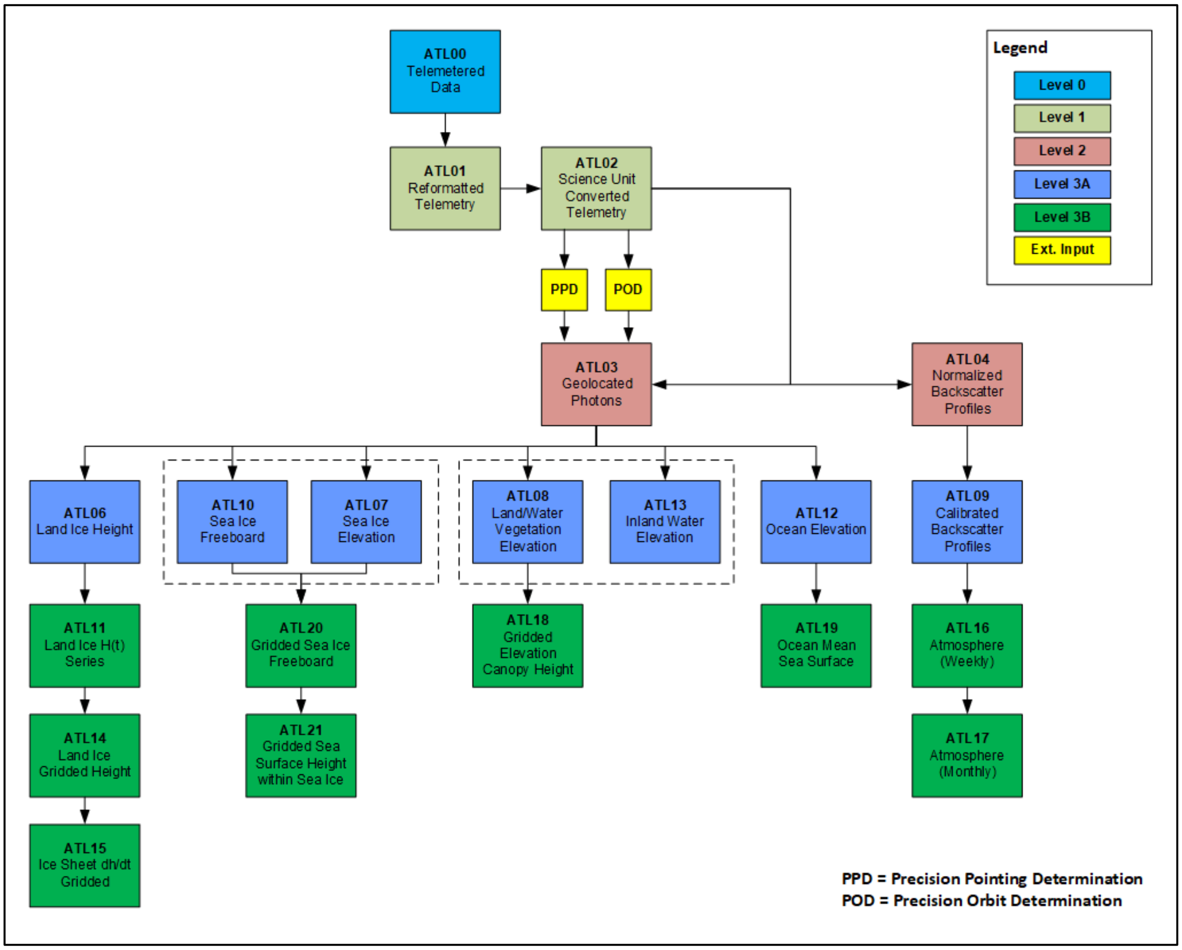

Figure 1. Schematic of the ICESat-2 data processing flow. The ATL01 algorithm reformats and unpacks the Level-0 data and converts it into engineering units. ATL02 processing converts ATL01 data to science units and applies instrument corrections. The Precision Pointing Determination (PPD) and Precision Orbit Determination (POD) solutions compute the pointing vector and position of the ICESat-2 observatory as a function of time.

1.1 Parameters

Time ordered telemetry data, converted to science units and corrected for known system calibrations and environmental effects.

1.2 File Information

1.2.1 Format

Data are provided as HDF5 formatted files. HDF is a data model, library, and file format designed specifically for storing and managing data. For more information about HDF, visit the HDF Support Portal.

The HDF Group provides tools for working with HDF5 formatted data. HDFView is free software that allows users to view and edit HDF formatted data files. In addition, the HDF - EOS | Tools and Information Center web page contains code examples in Python (pyhdf/h5py), NCL, MATLAB, and IDL for accessing and visualizing ICESat-2 files.

1.2.2 ATLAS/ICESat-2 Description

The following brief description of the ICESat-2 observatory and Advanced Topographic Laser Altimeter System (ATLAS) instrument is provided to help users better understand the file naming conventions and hierarchical structure within ATL02 data files. Detailed information is available in the ICE, Cloud, and land Elevation Satellite (ICESat-2) Algorithm Theoretical Basis Document (ATBD) for ATL02 (Level-1B) Data Product Processing (ATBD for ATL02 | V03).

The ATLAS instrument and ICESat-2 observatory utilize a photon-counting lidar and ancillary systems (GPS, star cameras, and ground processing) to measure the time a photon takes to travel from ATLAS to Earth and back again and determine the reflected photon's geodetic latitude and longitude. Laser pulses from ATLAS illuminate three left/right pairs of spots on the surface that trace out six approximately 14 m wide ground tracks as ICESat-2 orbits Earth. Each ground track is numbered according to the laser spot number that generates it, with ground track 1L (GT1L) on the far left and ground track 3R (GT3R) on the far right. Left/right spots within each pair are approximately 90 m apart in the across-track direction and 2.5 km in the along-track direction. Higher level ATLAS/ICESat-2 data products (ATL03 and above) are organized by ground track, with ground tracks 1L and 1R forming pair one, ground tracks 2L and 2R forming pair two, and ground tracks 3L and 3R forming pair three. Each pair also has a Pair Track—an imaginary line halfway between the actual location of the left and right beams (see figures 1 and 2). Pair tracks are approximately 3 km apart in the across-track direction.

The beams within each pair have different transmit energies—so-called weak and strong beams—with an energy ratio between them of approximately 1:4. The mapping between the strong and weak beams of ATLAS, and their relative position 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 (see Figure 2). In this orientation, the weak beams lead the strong beams and a weak beam is on the left edge of the beam pattern. In the backward orientation, ATLAS travels along the -x coordinate, in the instrument reference frame, with the strong beams leading the weak beams and a strong beam on the left edge of the beam pattern (see Figure 3). The first yaw flip was performed on December 28, 2018, placing the spacecraft into the backward orientation. The current spacecraft orientation, as well as a history of previous yaw flips, is available in the ICESat-2 Major Activities tracking document (.xlsx).

The Reference Ground Track (RGT) refers to the imaginary track on Earth at which a specified unit vector within the observatory is pointed. Onboard software aims the laser beams so that the RGT is always between ground tracks 2L and 2R (i.e. coincident with Pair Track 2). The ICESat-2 mission acquires data along 1,387 different RGTs. Each RGT is targeted in the polar regions once every 91 days (i.e. the satellite has a 91-day repeat cycle) to allow elevation changes to be detected. 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, for example in ATL02 file names, by appending the two-digit cycle number (cc) to the RGT number, e.g. 0001cc to 1387cc.

Under normal operating conditions, no data are collected along the RGT; however, during spacecraft slews, or off-pointing, some ground tracks may intersect the RGT. Off-pointing refers to a series of plans over the mid-latitudes that have been designed to facilitate a global ground and canopy height data product with approximately 2 km track spacing. 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 had been adequately resolved and the instrument had pointed directly at the reference ground track for at least a full 91 days (1387 orbits).

Users should note that between 14 October 2018 and 30 March 2019 the spacecraft pointing control was not yet optimized. As such, ICESat-2 data acquired during that time do not lie along the nominal RGTs, but are offset at some distance from the RGTs. Although not along the RGT, the geolocation information for these data is not degraded.

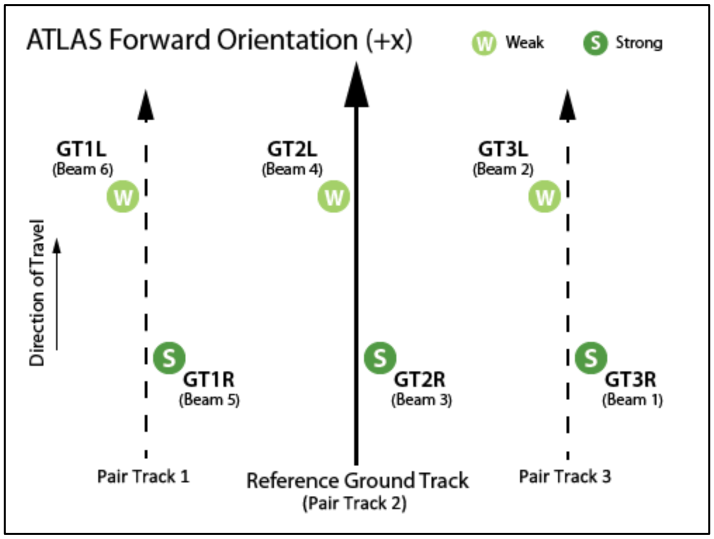

Figure 2. Spot and ground track (GT) naming convention with ATLAS oriented in the forward (instrument coordinate +x) direction.

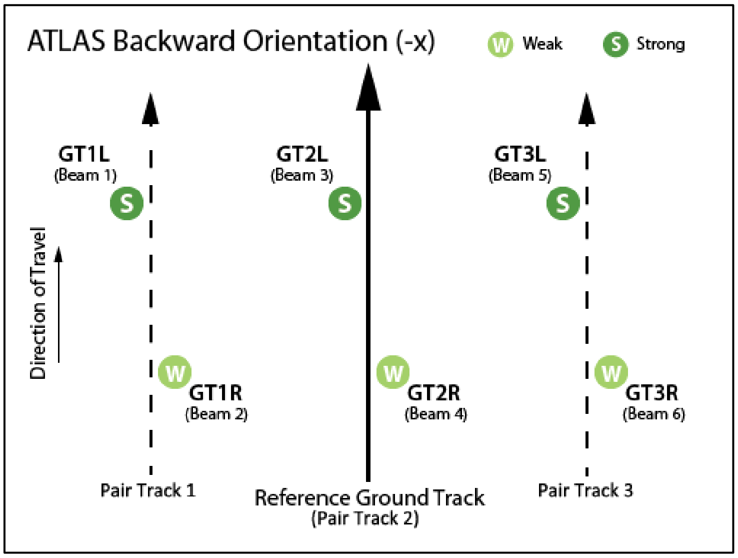

Figure 3. Spot and ground track (GT) naming convention with ATLAS oriented in the backward (instrument coordinate -x) direction.

1.2.3 File Contents

ATL02 data are segmented into granules (files) that span about 1/14th of an orbit. Granule boundaries are delineated by lines of latitude that define 14 regions, numbered from 01-14 as shown in Figure 4:

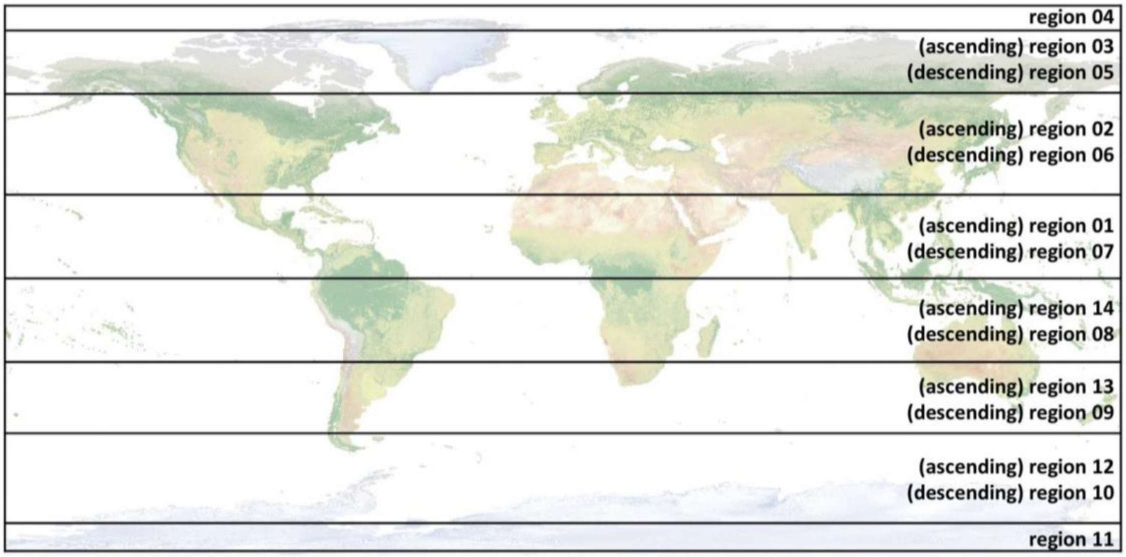

Figure 4. ATL02 region/granule boundaries

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)

1.2.4 Data Groups

The following sections summarize the data structures within ATL02 data files. This product comprises some 1400 output parameters that are used for system–level quality control, POD and PPD computations, or as pass-through data for higher-level products. A comprehensive discussion of ATL02 processing and output variables is beyond the scope of this user guide. However, detailed information is available in the Appendix A of the ATBD for ATL02.

Within data files, similar variables and metadata are grouped together according to the HDF model. ATL02 data files contain the top-level groups:

- METADATA
- ancillary_data
- atlas
- lrs (Laser Reference System)
- orbit_info
- quality_assessment

Each top-level group contains subgroups and/or data sets, as shown in the following figure:

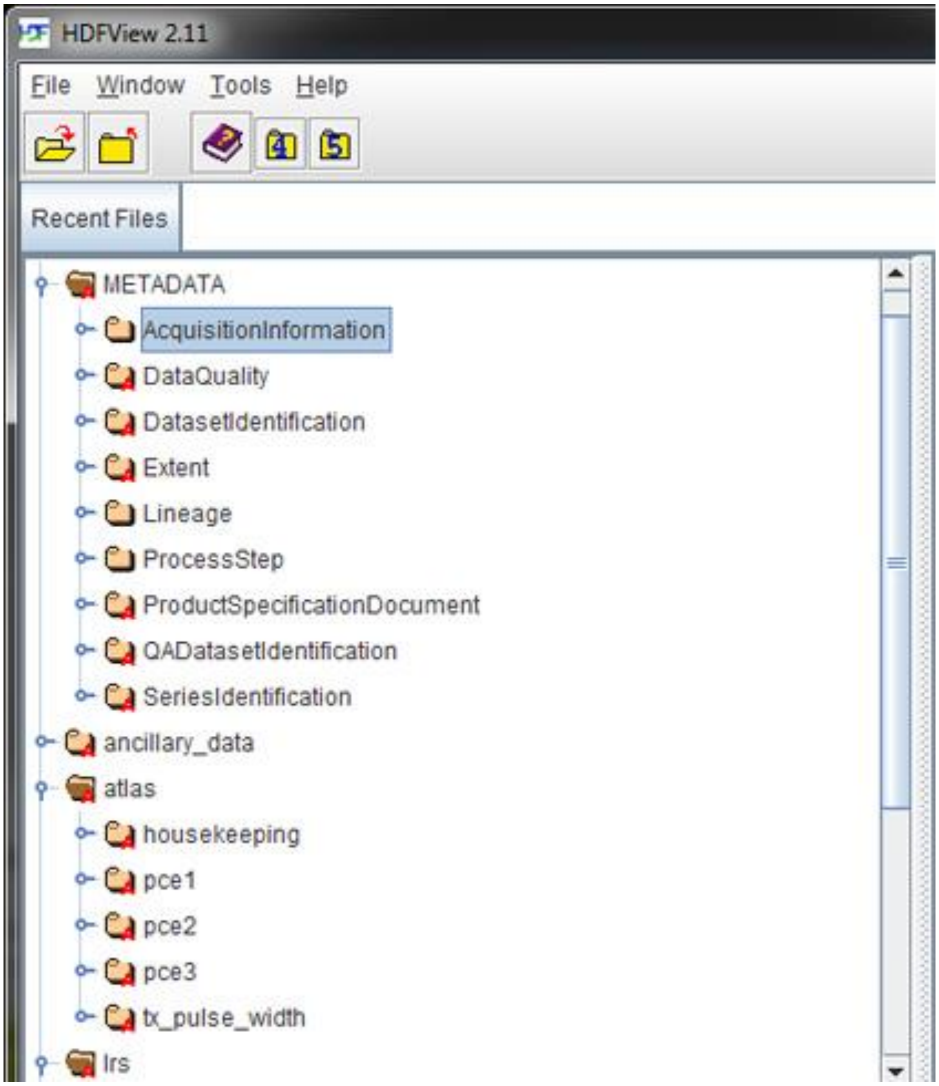

Figure 5. Data groups and subgroups displayed by HDFView.

For more details about the data and metadata structures within ATL02 data files, consult the ATBD for ATL02.

1.2.5 Naming Convention

Data files utilize the following naming convention:

Example:

- ATL02_20181221123517_04890103_941_01.h5
- ATL02_[yyyymmdd][hhmmss]_[ttttccss]_[vvv_rr].h5

The following table 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. The ICESat-2 mission has 1,387 RGTs, numbered from 0001 to 1387.
cc	Cycle Number. 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	Segment number. ATL02 data files are segmented into approximately 1/14th of an orbit. Segment numbers range from 01-14. Note that some segments may not be available.
vvvv_rr	Version and revision number*

NOTE: *From time to time, NSIDC receives duplicate, reprocessed granules from our data provider. These granules have the same file name as the original (i.e. date, time, ground track, cycle, and segment number), but the revision number has been incremented. Although NSIDC deletes the superseded granule, the process can take several days. As such, if you encounter multiple granules with the same file name, please use the granule with the highest revision number.

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.

1.2.6 File Size

Data files range in size from approximately 50 to 150 MB.

1.3 Spatial Information

1.3.1 Coverage

Spatial coverage spans approximately 88° N latitude 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, however, that the number of photons that return to the telescope varies.

1.3.3 Geolocation

Geographic locations are presented in geodetic latitude, longitude, and ellipsoidal height (above the WGS 84 ellipsoid, ITRF2014). The following table contains details about WGS 84:

Table 3. Geolocation Details

Geographic coordinate system	WGS 84
Projected coordinate system	WGS 84
Longitude of true origin	Prime Meridian, Greenwich
Latitude of true origin	N/A
Scale factor at longitude of true origin	N/A
Datum	World Geodetic System 1984
Ellipsoid/spheroid	WGS 84
Units	degree
False easting	N/A
False northing	N/A
EPSG code	4326
PROJ4 string	+proj=longlat +datum=WGS84 +no_defs
Reference	https://epsg.io/4326

1.4 Temporal Information

1.4.1 Coverage

14 October 2018 to 11 November 2020

1.4.2 Resolution

Each of ICESat-2's 1387 RGTs is targeted once every 91 days (i.e. the satellite has a 91-day repeat cycle).

2 DATA ACQUISITION AND PROCESSING

2.1 Background

Figure 6 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” these measurements are made. In order 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 the atmospheric conditions.

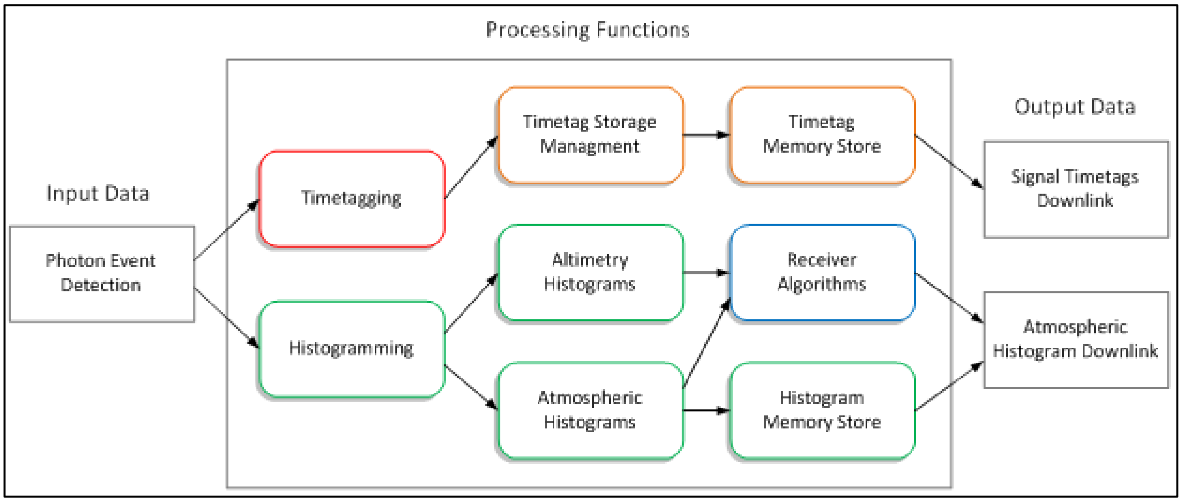

Figure 6. Block diagram illustrating ATLAS on-board data processing.

Three Photon Counting Electronics (PCE) cards perform this function on-board via histogramming and so-called 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 both the strong and weak beams of one reference ground track. The sole 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 in real-time the signal location around the ground and instruct the hardware to telemeter a vertical band of received time-tags about this location. 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 width of the horizontal range window depends on the surface type (for example, ocean, land ice, 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 and converts them into engineering units. 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

Users who are interested in the theory and computations used to generate the ATL02 product should consult the ATBD for ATL02. The ATBD includes sections that describe: time of day (Section 2) and time of flight (Section 3) calculations; the ATLAS transmitter echo path (TEP) pick-off feature (Section 4); ATLAS/ICESat-2 radiometry products (Section 5); POD, PPD, and photon bounce point geolocation (Section 6); atmospheric histogram generation (Section 7); and products created as data pass-throughs.

In general, ATL02 processing converts Level-1A parsed, partially reformatted, and time ordered telemetry data (ATL01) into science 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 scientific units;
- Reconstructed absolute time-bias corrected Time of Day (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, range-corrected to height and aggregated to 25 Hz frames;
- Approximate locations for each beam footprint on the WGS 84 reference surface, using the Spacecraft GPS position and Spacecraft pointing control data.

2.4 Quality, Errors, and Limitations

To ensure that the ATL02 data product is generated appropriately and its contents are legitimate, a multi-faceted data quality assurance process is applied using the following utilities:

- Custom python scripts developed by the ATL02 ATBD team were used pre-launch to validate the ATBD algorithm implementations, telemetry conversions, etc., in the ATLAS Science Algorithm Software (ASAS) code.
- On-board ASAS QA scripts are integrated directly into the utilities which 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.

- The ICESat-2 Science Computing Facility (SCF) has the ability to perform rote limit checks (Limit Checking Scripts) on parameters contained in the ATL02 HDF5 data products. These scripts check the values contained in the ATL02 product and alert the responsible party when something is out of bounds. At this time, SCF 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.
- The ICESat-2 Instrument Support Facility (ISF) has the ability to track overall trends in the results output by the ATL02 HDF5 data product. ISF 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 will be used to help identify areas where additional investigation may be needed, but a halt in ATL02 product creation isn't necessary.

3 VERSION HISTORY

Version 3 (May 2020)

Changes for this version include:

- 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 for ATL02 to the equation which interpolates transmit/receive misalignment between AMCS offset updates (Equation 5-13).
- Addressed several issues related to units and descriptions within the ATL02 file metadata.
- Removed the temperature parameter from /ancillary_data/calibrations/nominal_rx_sensitivity. This parameter was no longer needed as the nominal receiver sensitivity calibration is no longer indexed by temperature.
- 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. This update corrects for a coarse count issue that occurs simultaneously with the fine count swap issue described above.
- Updated the temperature used for CAL-47 referencing to the correct thermistor (fixes a code error).

4 CONTACTS AND ACKNOWLEDGMENTS

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5 DOCUMENT INFORMATION

5.1 Publication Date

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5.2 Date Last Updated

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