ATL03: Known issues

June 2022

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(3) Transmitter Echo Path (TEP) Photons
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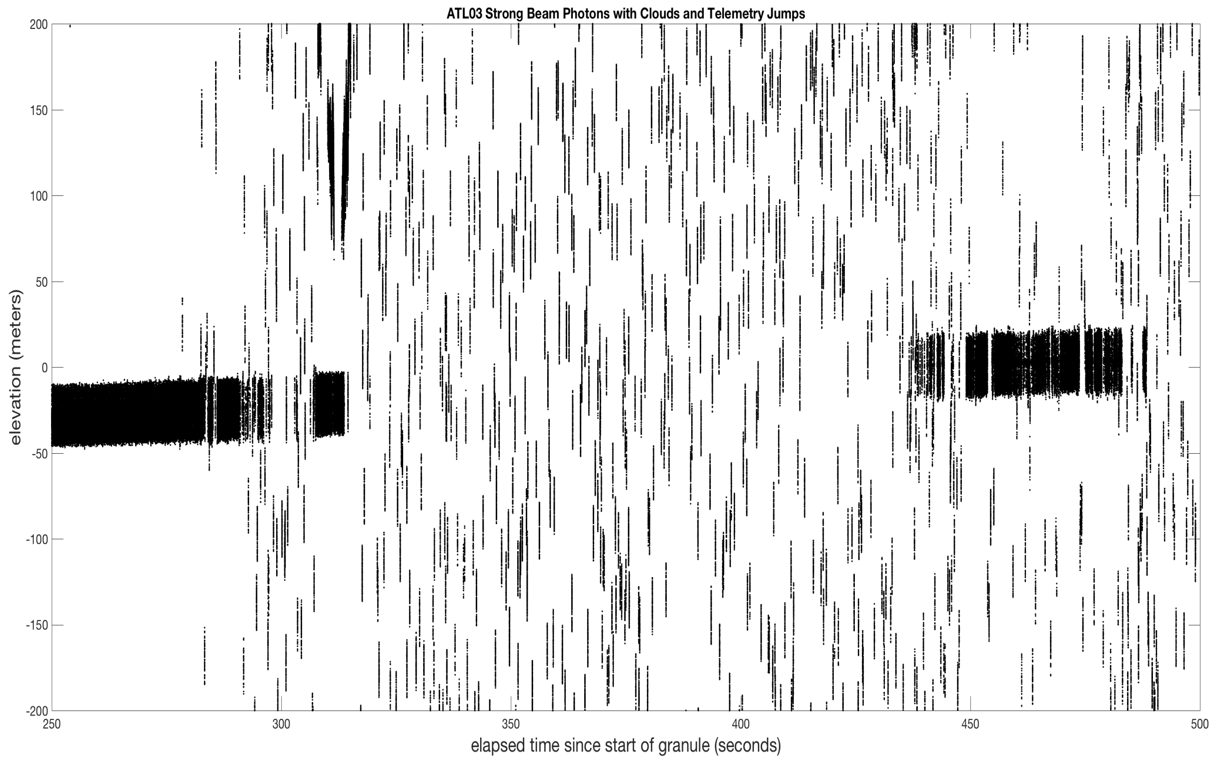
Issue 1. Presence of Clouds

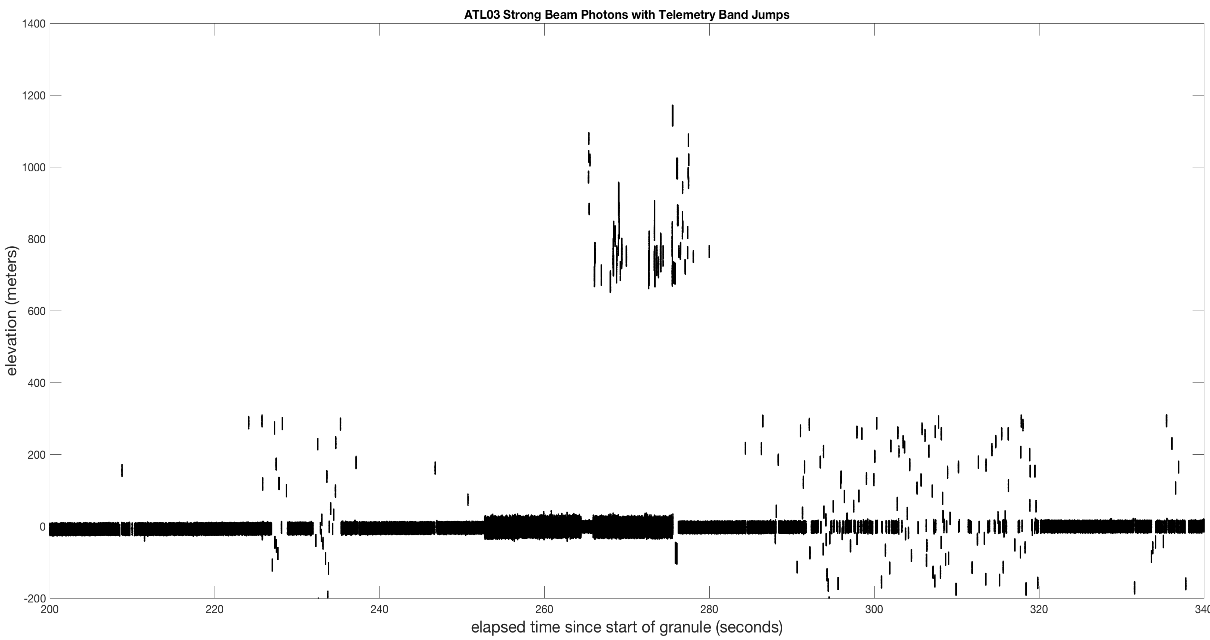


At times, the on-board signal finding is unable to find the surface echoes owing to the reflection of sunlight from clouds. In those cases, the telemetry band may or may not include the surface. The telemetry band can change every 200 shots (or ~140m along track, or ~0.05 seconds). The figure above is an example of cloud data over sea ice, with widely discontinuous telemetry bands. Users may also notice that in this example, the telemetry band containing the surface is below 0 meters. This is because a geoid correction has not been applied to this ocean dataset.

This circumstance nearly always is due to high background photon rates due to sunlight reflecting off of clouds. Unfortunately, even if the instrument happened to telemeter the data near the true surface, it would most likely not be usable as the transmit photon path lengths have been altered by the presence of clouds.

In release 003 and later, photons that are not contained in the telemetry band that contains the reference DEM will no longer be classified as potential signal. This greatly reduces the amount of clouds being identified as signal, although the photons still are present in the photon cloud.

Issue 2. Multiple Telemetry Bands



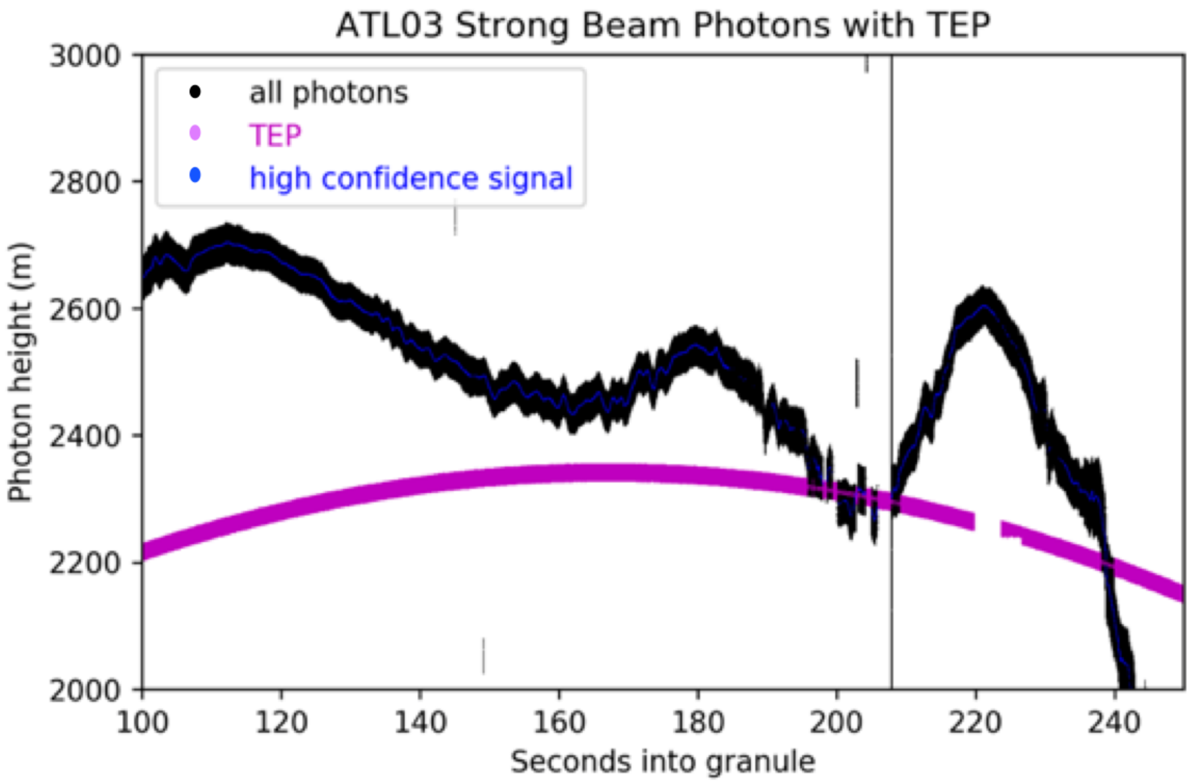
In the above figure, the presence of clouds is evident in several places (e.g. 230 seconds, 285-320 seconds). At other times (e.g. 270-285 seconds) there are multiple telemetry bands. When the ATLAS on-board software is not confident that it found the primary surface return, it can open a second telemetry band to send more photon data. Generally, only one of the two bands contain surface returns. The other telemetry band is often either cloud tops (which can generate a significant reflection) or a false positive of some other type.

In most cases, these additional telemetry bands do not contain high-confidence signal photons. In these situations, signal_conf_ph may be a suitable way to filter out photons from additional telemetry bands.

Another way to exclude these erroneous additional telemetry bands is by comparison with an *a priori* estimate of the surface elevation (e.g. the geoid in this case).

In release 003 and later, photons that are not contained in the telemetry band that contains the reference DEM will no longer be classified as potential signal. This greatly reduces the amount of clouds being identified as signal, although the photons still are present in the photon cloud.

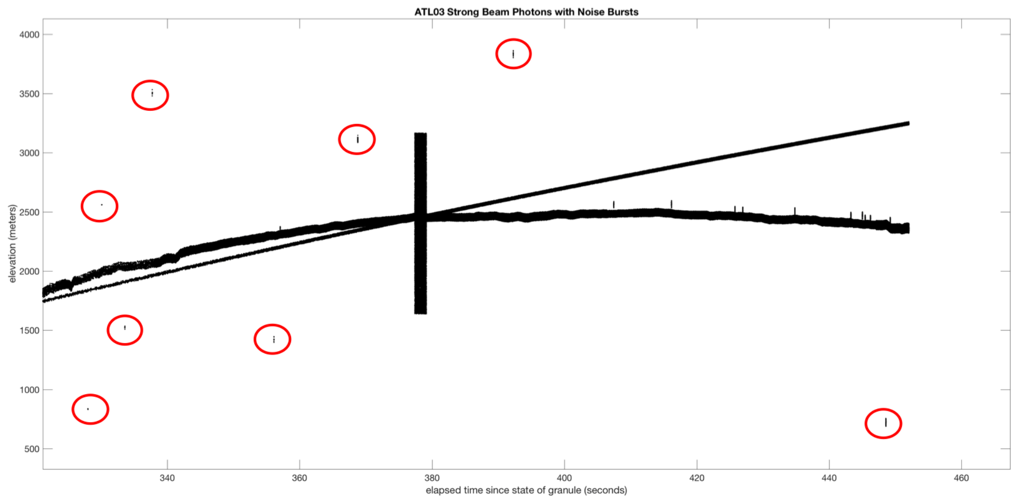
Issue 3. Transmitter Echo Path Photons (TEP)



The example above has all telemetered photons in the ATL03 granule (black), high-confidence signal photons (blue) and an obvious arc passing through the granule just below the apparent surface return.

The photons that form the arc beneath the apparent ground returns are the ATLAS Transmitter Echo Path (TEP) photons. ATLAS samples a part of the outgoing laser beam and routes this light into two of the detection optics and electronics for two of the strong beams. This light source is relatively weak (~1 photon every 10 transmitted pulses), and is telemetered in a separate band by the on-board software under some circumstances. Likely TEP photons are classified with a -2 flag in the /gtx/heights/signal_conf_ph parameter, and a user can either choose to use these photons or reject them from additional analysis *(see Issues 10 and 16 for related known issues)*.

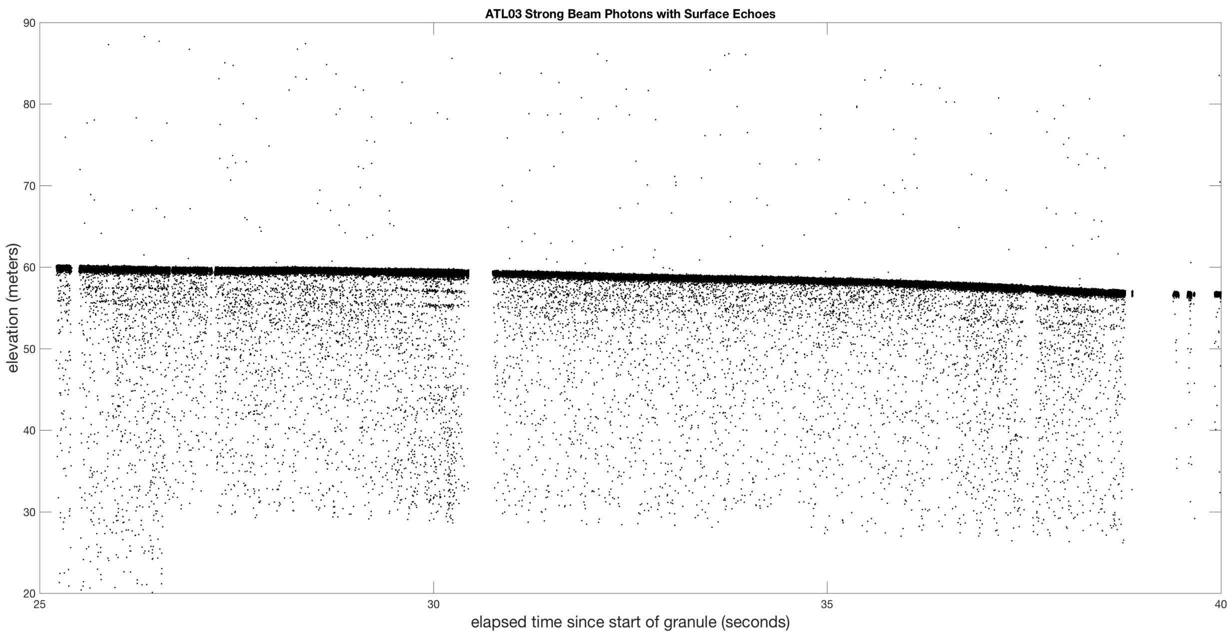
Issue 4. Photon Noise Bursts



At times, ATLAS telemeters groups of many closely-spaced photons (indicated by red circles above). The root cause of these "noise" bursts are under investigation. The "noise bursts" are characterized by a dense clustering of many (more than 20) photons recorded during a single laser pulse. Transmitted laser pulses are spaced in time by 100 microseconds; these photon bursts space ~200 nanoseconds in time. The current leading hypothesis for the cause of the "noise bursts" is gamma ray collisions exciting the detectors.

The impact of these is primarily visual, making the ATL03 data look noisy. Depending on root cause determination, future releases of ATL03 may edit these bursts out.

Issue 5. Apparent Multiple Surface Returns

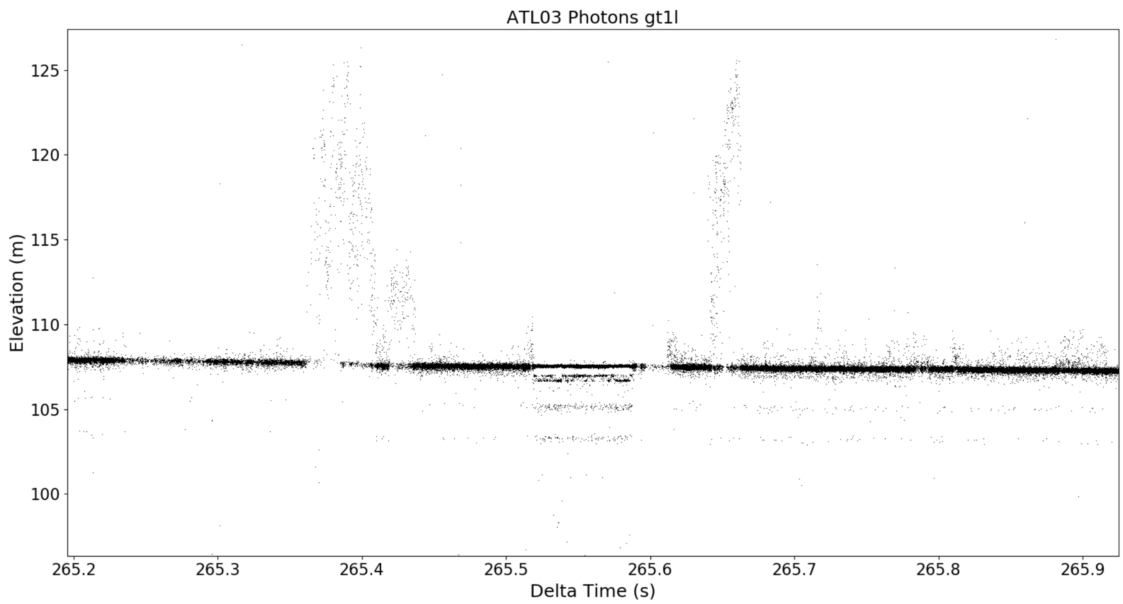


Over relatively flat surfaces, when plotting ATL03 as along track distance or time, double echoes are sometimes seen at ~2.3m below the primary surface and ~4.2m below the primary surface return. The amount of energy in these additional horizons are typically 1/1000 of the energy in the surface echo. The double echoes appear visually prominent in plots, such as above, because all of the surface return photons are stacked on top of one another, given little changes in photon density.

After investigation, it has been determined that these additional horizons are most likely due to small after-pulses in either the ATLAS transmitted laser pulse, or a small amount of electronic noise following the arrival of the primary surface return (“ringing”). The science team has investigated these additional horizons by careful examination of transmitter echo path (TEP) photons and have showed that aggregates of TEP photons also contain these structures. Multiple surface echoes like those shown above are typically seen in granules containing very smooth open water surfaces (such as inland water or leads in sea ice) when surface winds are negligible.

Two parameters on ATL03 in release 003 and later identify the fraction of shots per geolocation segment that are likely nearly saturated or fully saturated. While these parameters are just informational at this time, it is likely that in the future, upper-level products may use these parameters to exclude subsurface returns that occur from likely saturation of the ATLAS detectors.

Issue 6. Specular Returns



Over flat water, at times the returning laser light will be specular or nearly so. In these cases, the returning laser light will have had minimal pulse spreading and minimal energy loss from light scattering out of the receiver field of view. The returning pulse is therefore narrower and stronger than ATLAS was designed to handle. In these circumstances (e.g. 265.5 to 265.6 seconds), ATLAS detects multiple surface returns, with echoes spaced by either one or two times the ATLAS dead time.

The ATLAS dead time is most simply thought of as the time required for a single detection element of ATLAS to detect a single photon and reset to be able detect a second event. When photons arrive in intervals shorter than the dead time, those photons are not detected. In the example above, the primary return at 107.5m is followed by a second return ~0.5 m below the surface, and a tertiary return < 0.5 m below that. These horizons are separated by the effective ATLAS dead time. The other two apparent surfaces at 105.2 m and 103.3 m are consistent with ATLAS after-pulses, described above in Issue 5.

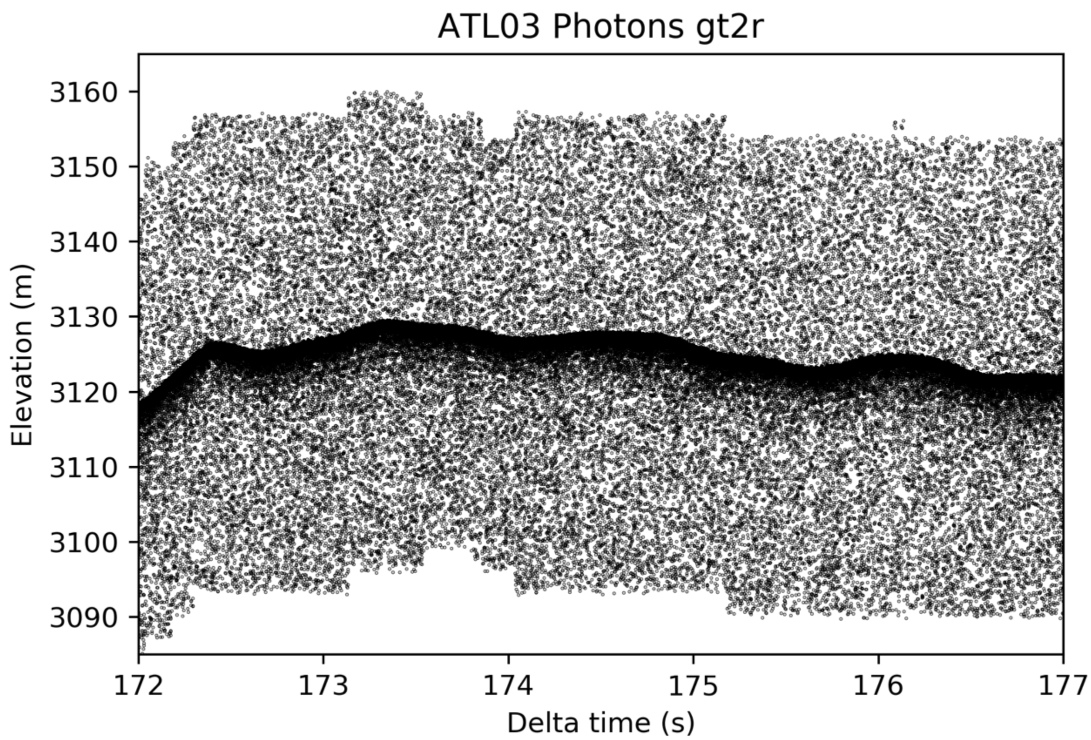
Two parameters on ATL03 in release 003 and later identify the fraction of shots per geolocation segment that are likely nearly saturated or fully saturated. While these parameters are just informational at this time, it is likely that in the future, upper-level products may use these parameters to exclude subsurface returns that occur from likely saturation of the ATLAS detectors.

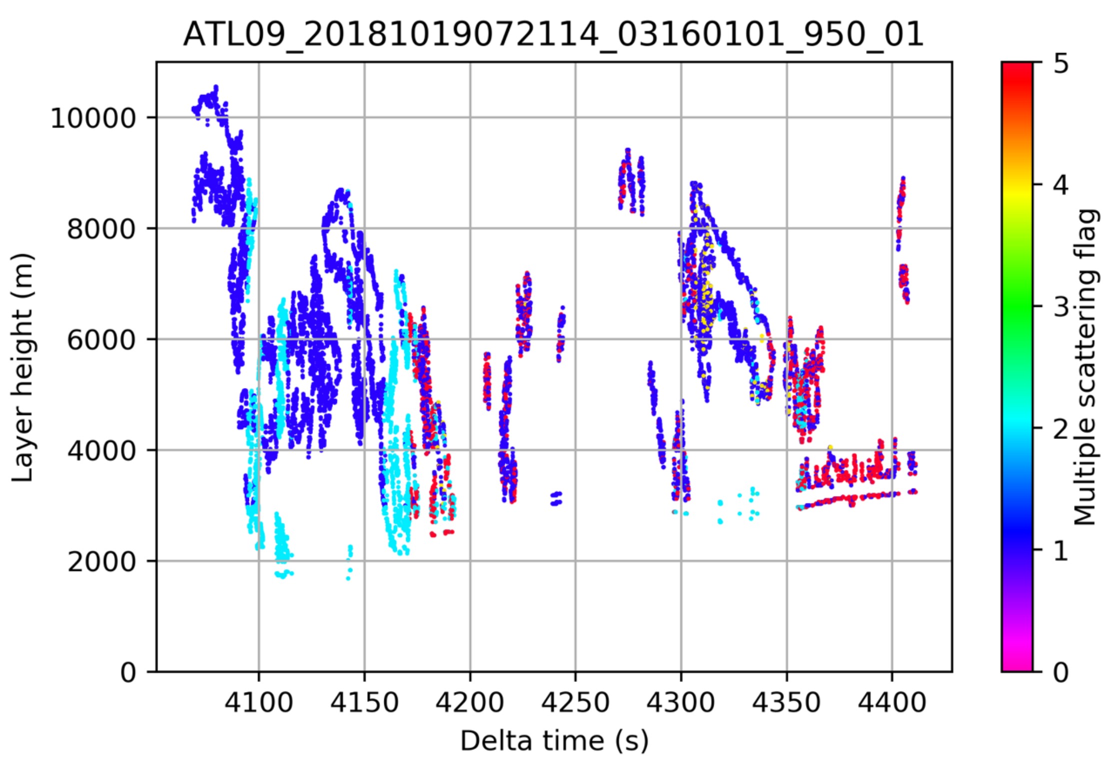
Issue 7. Empty Files

When ATLAS is taken out of science mode (for example to conduct any one of a number of internal calibrations) photon-rate data is not collected, but the ATL03 structure, ancillary data, and metadata for that time period is created. This is done to indicate than an attempt to generate the file was made, but that there was insufficient data to complete processing and data granule creation.

The easiest way to isolate these files is to identify data granules that are ~50MB or smaller, which indicate an empty ATL03 data granule. ATL03 data granules that contain actual photon data are typically ~1GB or larger.

Issue 8. Multiple Scattering





As shown in the ATL03 example above, the photon cloud can at times be denser below the surface than above. The phenomenon is due to multiple scattering and can occur over surfaces with heavy blowing snow, such as the example shown here, or over dense fog. Such conditions result in a widening of the surface return, and more photons apparent below the surface. The effect of multiple scattering is more prominent at night when the solar background signal is absent.

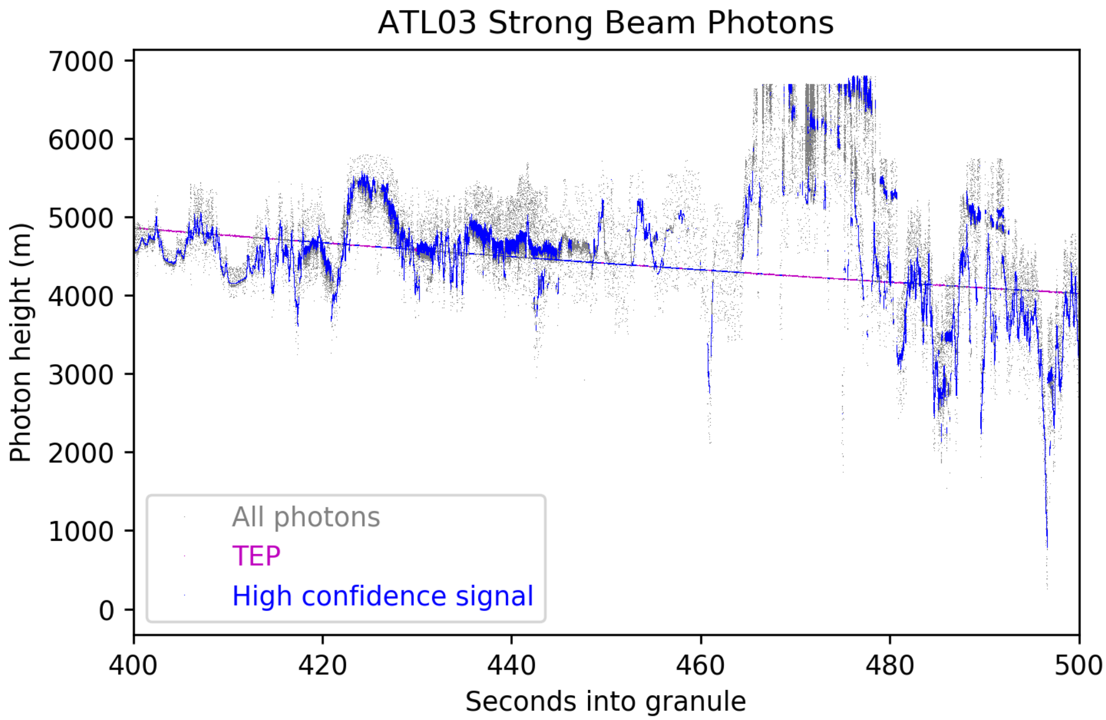
The second figure shows the top and bottom detected layer heights in meters from ATL09 over the same time period as the entire ATL03 granule, where colors indicate the value of the ATL09 multiple scattering flag. Multiple scattering flag values of 4 or 5, shown here in yellow and red respectively, indicate blowing snow detection. The multiple scattering flag and a blowing snow confidence flag are available on the ATL09 product.

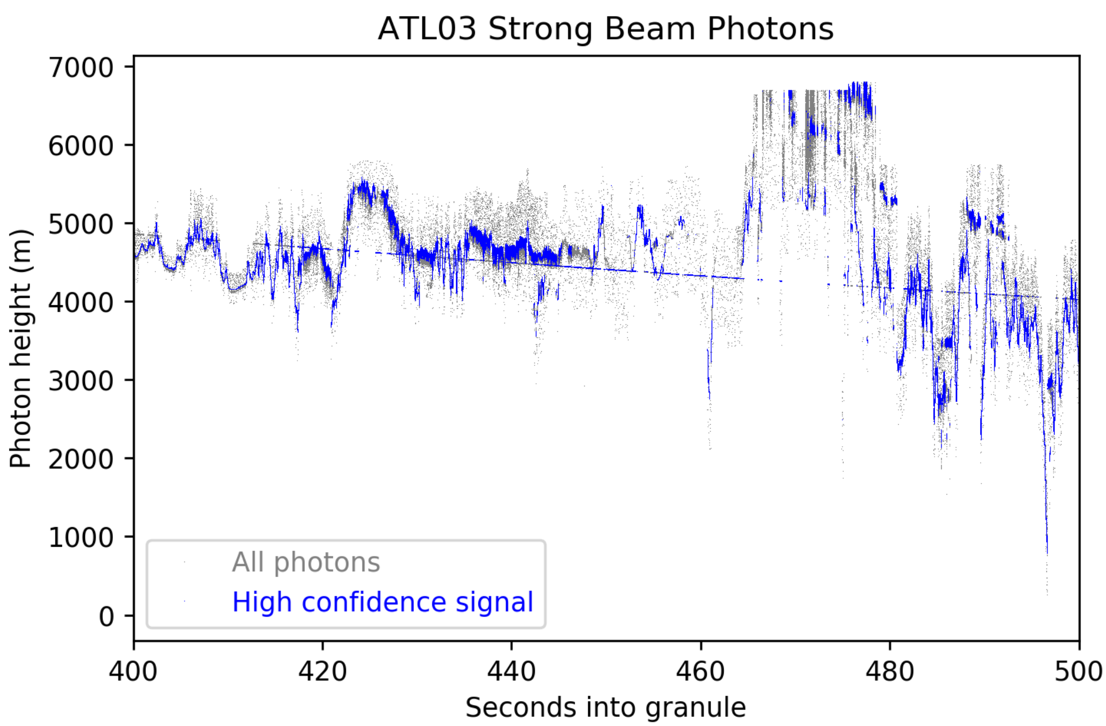
Issue 9. Future Parameter Updates

Future releases will contain updates to multiple parameters; this list is current as of 01 November 2021.

The values for along- and across-track geolocation and height uncertainties (all found in the /gtx/geolocation group: sigma_h, sigma_along, sigma_across, sigma_lat and sigma_lon) are currently set to static values. In future releases of ATL03, these values will by dynamically calculated by the GEODYN software used for geolocation (Luthcke et al., 2003).

Issue 10. TEP Misidentified as Signal

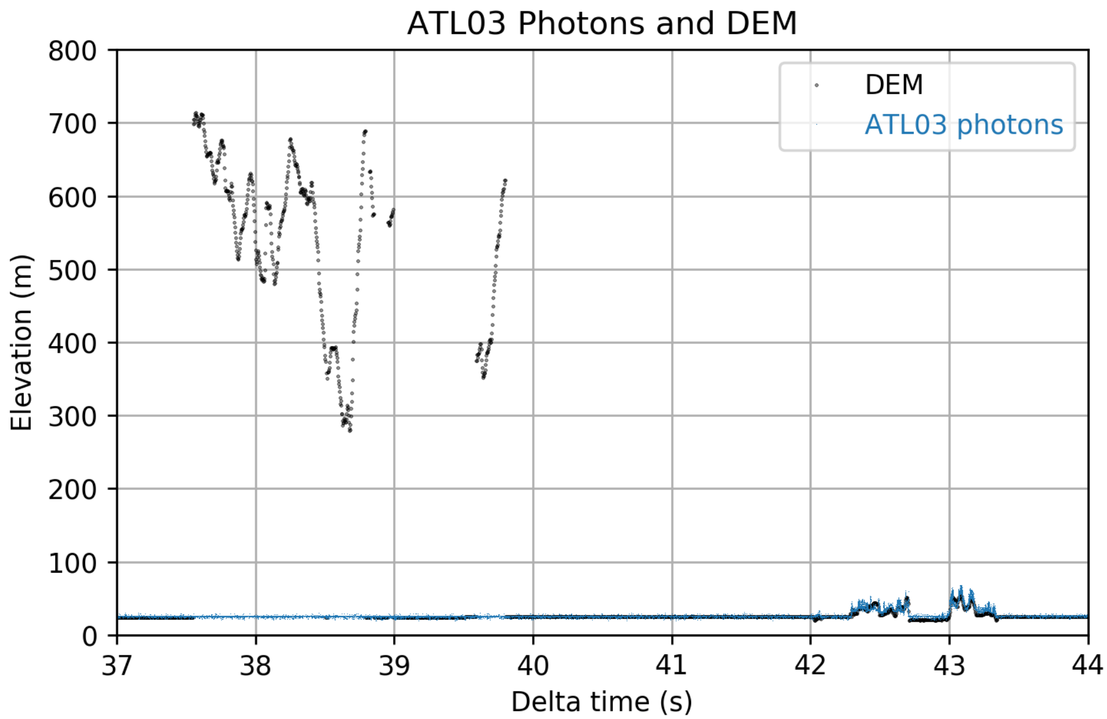




In cases where the TEP intersects the ground surface, there is a chance that TEP photons may be misclassified as signal. The figures above show the same scene with and without photons identified as TEP (purple), where the straight line through the surface is the TEP. The line of TEP photons is still clearly visible in the second figure and some TEP photons are misclassified as high confidence signal (blue). Very few cases have been identified to date, and TEP signal confidence levels generally accurately identify TEP photons.

Depending on root cause determination, future releases of ATL03 will amend signal photon classification to prevent misclassifying TEP as signal.

Issue 11. Reference DEM Height Errors



In release 002 and later, the ATL03 product includes the best-available reference digital elevation model (DEM) heights at the reference photon location. The DEM heights reported are prioritized by source: ArcticDEM, Reference Elevation Model of Antarctica (REMA), Multi-Error-Removed Improved Terrain (MERIT), then DTU13 Mean Sea Surface (MSS).

ATL03 uses the best-available DEMs, however DEM heights may be inaccurate in some locations, on the order of a few to several hundred meters. The figure above shows ATL03 signal photons in blue and the reference DEM in black, with an anomaly in the DEM several hundred meters above the surface measured by ATLAS. Relatively small inconsistencies between DEM heights and ATL03 photon clouds are expected, such as that demonstrated by the right side of the figure, generally on the order of tens of meters or fewer. Users are advised to use the DEMs on ATL03 with discretion. ATL03 will update the reference DEMs in subsequent ATL03 releases and/or as updates to the DEM sources become available.

Issue 12: Errors in Absolute Heights Following Drag Makeup Maneuvers (DMUs)

The user is cautioned to be aware of Drag Make-Up maneuvers (DMUs) which take place periodically to ensure that ICESat-2 remains in its nominal orbit. The effect of the DMU is not yet completely modeled by the Precision Orbit Determination (POD) processing, resulting in geolocated photons that can be significantly in error (commonly causing an error in the vertical component that can approach -100m). Evidence has shown that when the ICESat-2 spacecraft is in forward orientation, the presence of the DMU-caused geolocation error exists for a portion of a single orbit (on the order of 10 granules). When the ICESat-2 spacecraft is in reverse orientation, the presence of the DMU-caused geolocation error can persist for more than an entire orbit (15+ granules).

Information on when these DMUs take place is provided in the document ICESat2_major_activities.xlsx

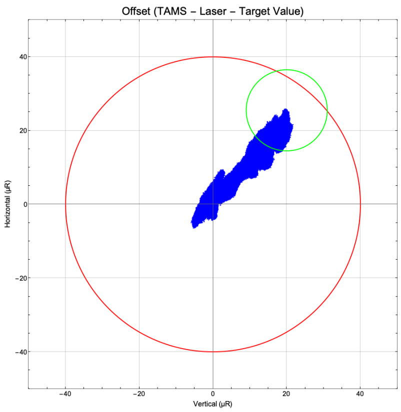
Issue 13: Data from July 2019

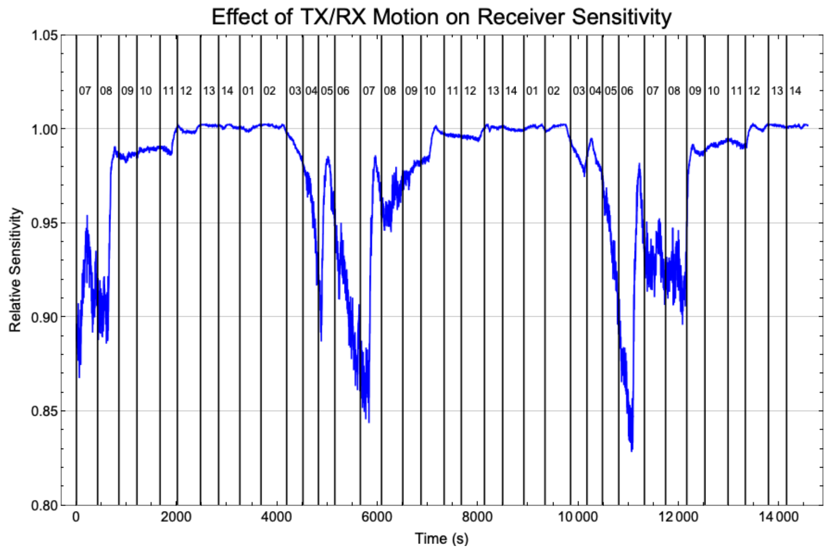
Data collected between 9-26 July 2019 have a small timing bias resulting from an erroneous Earth orientation parameter uploaded during the spacecraft's return to operations following a safehold event on 26 June 2020. This caused an error in spacecraft pointing, resulting in an extra approximately 1 degree of forward pitch, and shifted the onboard attitude control system interpretation of spacecraft time by roughly 19 seconds. The primary manifestation of this issue is telemetry band errors at steep coastal areas, at times resulting in loss of surface returns. We note that there may be some increased height errors from data collected during this time period, those errors are generally within the conservative estimates of geolocation and height uncertainty currently provided on the ATL03 product.

Issue 14. Background Count Rates and Saturation

Background count rates calculated from altimetric histograms on ATL03 do not currently account for photons likely due to ATLAS instrument effects in saturated conditions. Whether background rates are over or under estimated depends on the signal confidence classification of photons in saturated pulses (e.g. additional photons are not signal with signal_conf_ph ≤ 1, then background rates may be overestimated). The user is advised to proceed with caution if under saturated conditions, which are indicated at the geolocation segment rate (/gtx/geolocation/full_sat_fract) and at the photon rate (/gtx/heights/quality_ph).

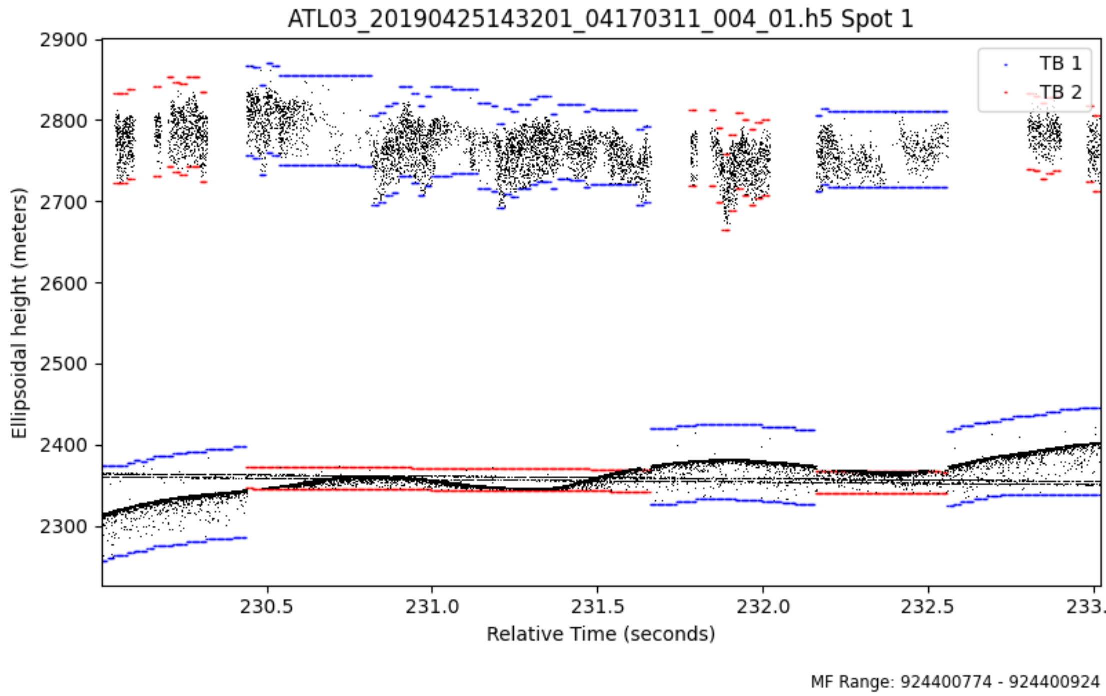
Issue 15. Beam Steering Mechanism freeze March 23-31, 2022





On March 23, 2022, the Beam Steering Mechanism (BSM) stopped moving due to a floating point exception causing a suspension in the flight software control loop process. The control loop keeps the laser centered in receiver field of view. The left figure above shows the misalignment between the transmitter (TX) footprint center and receiver (RX) field of view center when the period the BSM was functioning in blue, the receiver field of view in red, and the transmitter footprint at greatest misalignment in green. During periods of maximum misalignment some signal photons are lost as they are outside of the receiver field of view. These losses (up to a 15% reduction in signal strength) mainly affect the Arctic Ocean, northern hemisphere, and the tropics on descending tracks, as shown in the figure on the right by region number. Normal operations resumed on March 31, 2022.

Issue 16. Data Gaps due to TEP Crossing Surface



An apparent gap in signal can sometimes occur due to the ATLAS Flight Science Receiver Algorithms' (RxAlgs) handling of the Transmitter Echo Path photons (TEP). The RxAlgs on-board signal processing selects the window of photons to telemeter that most likely contains the signal. To avoid selecting the TEP as signal, the TEP region (a 27-meter vertical window) is excluded in the RxAlgs signal processing. When the actual signal is too close to the TEP region, the RxAlgs parameters are set so the telemetry bands contain the signal most of the time. However, if the RxAlgs find a false signal (e.g. a cloud layer) outside the TEP region, that false signal will be selected and the actual signal may be missed. In the example above, the cloud is selected as signal (230.5 to 231.5 seconds) when the actual signal and the TEP region intersect, causing gaps in the true signal (at 230.4 and 232.1 seconds).