

1 **On-Orbit Radiometric Performance on ICESat-2**

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6 **Key Points:**

- 7 • The ICESat-2 instrument is radiometrically stable over short time scales and exhibits a
8 long-term trend over the first 1.5 years of the mission

9 Abstract

10 NASA's ICESat-2 mission measures Earth's elevation with the Advanced Topographic Laser
11 Altimeter System (ATLAS), a 6-beam photon-counting laser altimeter. The Global Geolocated
12 Photon data product (ATL03) is the primary source of photon information used by surface-type-
13 specific higher-level products, along with the Atmospheric Layer Characteristics product
14 (ATL09). ATL03 provides time-tagged, geolocated photon heights referenced to the ellipsoid
15 and a parameter providing an initial classification of photon events as signal or background. We
16 use this classification to evaluate ATLAS radiometry (number of signal photons per transmitted
17 laser pulse) over short time scales and over the mission to date. The radiometric performance of
18 ATLAS will in part determine what differences in the signal and background photon rates are
19 significant and indicate geophysical, rather than instrumental, changes. We find the ATLAS
20 radiometry is very stable over short time scales and exhibits a long-term decrease of ~ 1 signal
21 photon per laser pulse ($\sim 12\%$) in the strong spots over the first 1.5 years of the mission.

23 Plain Language Summary

24 We examine the first 1.5 years of the ICESat-2 mission to evaluate the radiometric stability of
25 the ATLAS instrument. We find the ATLAS weak spots are very stable through time, but the
26 strong spots show a decline of about 1 signal photon per pulse per year. This is perhaps the first
27 indication of instrument degradation on ICESat-2.

28 1 Introduction

29 The Ice, Cloud, and land Elevation Satellite – 2 (ICESat-2) observatory launched on
30 September 15, 2018 with objectives to measure changes in ice sheet elevation, monitor sea ice
31 freeboard, and enable a global assessment of vegetation and canopy height (Markus et al., 2017).
32 ICESat-2 uses green laser light emitted by the Advanced Topographic Laser Altimeter System
33 (ATLAS) as the basis for elevation measurements between 88° north and south latitudes
34 (Martino et al., 2019). ATLAS provides the data necessary for ground processing to calculate the
35 round-trip photon time-of-flight from the observatory to Earth and back again. These
36 components are combined with the laser beam pointing vectors (Bae & Webb, 2017) and the
37 position of the observatory in space (Luthcke et al., 2019) to generate the Global Geolocated
38 Photon data product (ATL03) (Neumann et al., 2020a, Neumann et al., 2020b) which provides a
39 unique latitude, longitude, and elevation for each photon event telemetered for ground processing
40 and an initial discrimination between a band of signal photons (emitted by ATLAS and reflected
41 by Earth) and background photons (emitted by the sun in the same part of the electromagnetic
42 spectrum). Schematics of the ATLAS transmitter and receiver are found in Neumann et al., 2019,
43 Figures 2 and 3 respectively.

44 The ATLAS telescope collects incoming light and is fiber-coupled to filters which only
45 transmit light of the same wavelength as emitted by ATLAS ($532 \text{ nm} \pm 0.15$) (Neumann et al.,
46 2019). After passing through these filters, light for a given spot is distributed across the elements
47 of a multi-element photomultiplier tube to convert optical energy to electrical energy to be time
48 tagged (a photon event) for further analysis. The ATL03 product is organized by ground tracks,
49 which refer to the relative location of the 6 beams on the ground. Since the spacecraft orientation
50 changes every ~ 9 months in order to optimize the position of the solar array relative to the sun,
51 ATLAS strong and weak spots change their relative orientation (from left to right). We organize

our analyses by ATLAS spots which do not change with spacecraft orientation. ATLAS spots are numbered 1-6 indicating laser illumination from the instrument field of view, where 1, 3, and 5 are “strong” spots and have four times the energy of spots 2, 4, and 6, referred to as “weak” spots. Each of the three ATLAS strong spots have 16 detection elements (pixels) which supply 16 individual timing channels. Similarly, each of the three ATLAS weak spots have 4 independent pixels and timing channels (Neumann et al., 2019, Martino et al., 2020a). ATL03 contains information to determine from which pixel a given photon was detected. ATLAS was designed to distribute incoming light uniformly across pixels in a given detector to allow for consistent estimates of detector gain, which can be used to reconstruct signal rates during periods of very large photon rates (Smith et al., 2019).

During the design process, the ICESat-2 mission developed design cases to provide a performance baseline that would ensure a sufficient number of signal photons per laser pulse are detected to meet elevation measurement requirements for accuracy and precision for the surface-specific higher-level data products (Markus et al., 2017). These cases determine requirements for the expected signal level for strong and weak laser spots for a variety of surface types and environmental conditions. For example, as part of the initial ATLAS optimization process, the transmitted laser energy per pulse was set such that ATLAS recorded between 8 and 9 signal photons per pulse over the ice sheet interior for strong spots. The laser energy can be adjusted on-orbit throughout the mission to maintain a consistent number of signal photons/pulse as needed. The only requirement for the radiometric stability of ATLAS is over short length scales (~100 meters) to enable differentiation of sea ice and ocean leads on the basis of either the signal photon rate or the background photon rate (Kwok et al., 2016).

Here we evaluate the radiometric stability of ATLAS by considering two metrics for all six ATLAS spots. First, we consider to what extent incoming laser light is evenly distributed among the pixels in each detector used to detect photons within each spot. Second, we evaluate the number of signal photons/pulse reported in ATL03 over the highly reflective high-altitude parts of the Greenland and Antarctic ice sheets over the first 1.5 years of the mission.

Signal photons per laser pulse metrics describe the number of received photons that are considered signal in the ATL03 photon classification algorithm (Neumann et al., 2019, Neumann et al., 2020a). We consider as signal any photon with a confidence level of low, medium, or high on ATL03. To minimize variations in the many different geophysical conditions that determine the signal photon rate (e.g. surface reflectivity, atmospheric transmittance), we examine ATLAS radiometry over the interiors of the Greenland and Antarctic ice sheets. Cloud-cleared ice sheet data are ideal test cases, as these regions are relatively flat with little roughness and high albedo. The interior of Greenland analysis is not considered our best estimate of radiometric performance due to likely measurable surface reflectivity changes through time, where episodic seasonal surface melt is well-documented (Abdalati & Steffen, 1997, Ettema et al., 2009, Hanna et al., 2012, Nghiem et al., 2012). Given the discretized nature of photon-counting lidars such as ATLAS, such high signal rate cases (~9 signal photons/pulse for a strong spot) make it easier to identify changes in signal rate compared with low signal rate cases such as the ocean (~1 signal photon/pulse for a strong spot).

2 Data and Methods

2.1 Data

We use the ATLAS/ICESat-2 L2A Global Geolocated Photon Data (Neumann et al., 2020b), Release 003 data product, publicly available at the National Snow and Ice Data Center. Each granule of ATL03 data spans $\sim 1/14$ th of an orbit (~ 2700 km in along-track distance). Granules used to evaluate pixel illumination are considered in their entirety, as the discrimination between signal versus background photons is immaterial for this purpose. For assessing changes in signal rate, we restrict our analyses to Antarctic ice sheet data south of 87° south latitude, and Greenland ice sheet data above 2500 meters above sea level. ATL03 granules with clear skies are selected approximately two to four times per calendar month between 20 October 2018 and 6 July 2020 as data quality allow and are subset either by latitude (Antarctica) or elevation (Greenland). These analyses exclusively use data collected at laser energy level 4, after the instrument energy was lowered from level 6 to 4 on 15 October, 2018.

2.2 Pixel Illumination

The pixel illumination for each spot is calculated as the number of photons received for each pixel (16 pixels for each strong spot, 4 pixels for each weak spot) divided by the total number of received photons for a given spot, and multiplied by 100 to express the result as a percentage. Expected pixel illumination percentages are 6.25% and 25% for strong and weak spots, respectively. We do not distinguish between signal or background photons differently for these metrics. The number of granules considered are 102 and 69 for Antarctica and Greenland, respectively.

2.3 Signal Photons per Pulse

We sum the number of signal (low, medium, high confidence) photons over ~ 50 milliseconds and divide by the total number of received pulses (nominally 200). Signal photons in the ATL03 product can span up to 30 m above and below the reference DEM, but are generally much closer to the surface in clear-sky conditions over the ice sheet interiors, with aggregate biases in Antarctica on the order of 5 cm or better (Brunt et al., 2019, Neumann et al., 2020a). Signal photons capture the majority of the impulse response function with some truncation of the tail of the returned pulse. The truncation elevates estimated surface heights by 1.5 cm or less, but does not impact radiometric analyses (Brunt et al., 2019, Neumann et al., 2019, Smith et al., 2019). In some low-signal cases, not every transmitted laser pulse has associated signal photons. Conversely, in highly reflective geophysical conditions, all available ATLAS detector elements may detect photons within a short period of time (~ 3 nanoseconds) and cannot immediately record additional photon events in a pulse (Martino et al., 2019, Neumann et al., 2019, Lu et al., 2021). Any laser pulse that has 16 photons in a strong beam or 4 photons in a weak beam within 0.5 m of height is considered saturated and is not considered further. Rejected saturated pulses account for $\sim 10\%$ or fewer pulses in weak spots, and near 0% in strong spots, suggesting the calculated signal photons per pulse are minimally impacted by saturated pulse rejection. The number of received pulses is also adjusted accordingly if saturation is detected. Over each data subset (e.g. data south of 87° S) we histogram the signal photon rates of the unsaturated laser pulses and determine the mode of the distribution (Figure 1). We accept data within ± 1 and ± 0.25 for strong and weak spots, respectively of the mode. This rejects data segments that may be impacted by clouds, blowing snow, or other conditions that substantially reduce the signal photon rate.

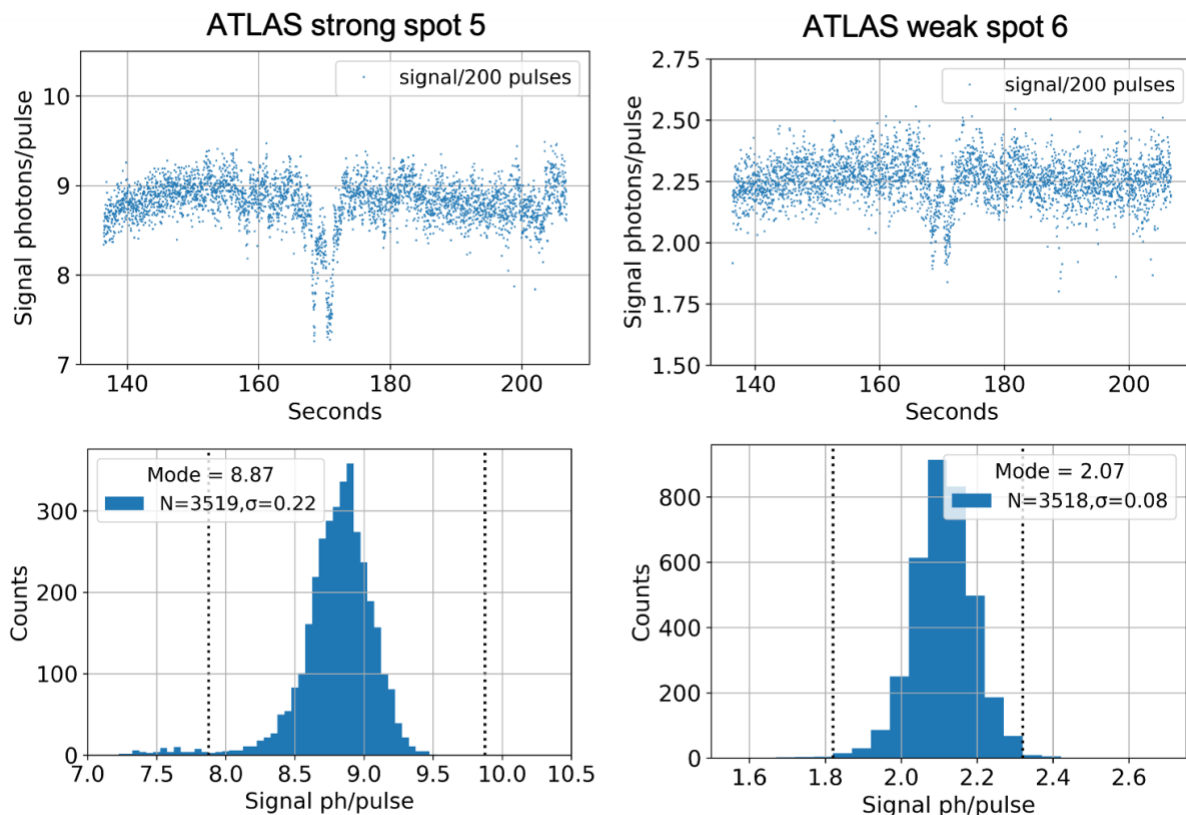


Figure 1. Examples of signal photons/pulse for every 200 pulses (top), and the corresponding histograms (bottom) for a strong spot (left) and a weak spot (right) south of 87°S in Antarctica. The mode of each histogram is the reported signal rate metric. Black dotted lines (mode ± 1 and ± 0.25) mark the span used to calculate the standard deviation for strong and weak spots, respectively.

Using the ATLAS/ICESat-2 L3A Calibrated Backscatter Profiles and Atmospheric Layer Characteristics (ATL09) data product, we verify that more than 72%, 81% of granules used in this study over Antarctica and Greenland have mostly clear skies, with at least 60% of data segments likely clear of clouds.

Any changes in laser output energy directly affects signal photon rates. On June 25, 2019 ATLAS turned off unexpectedly (a “safehold” event) due to a spacecraft anomaly. Several ATLAS performance metrics show a behavior change before and after this event. The transmitted internal laser energy on the ATLAS/ICESat-2 L1B Converted Telemetry Data (ATL02) Release 003 product (Martino et al., 2020b) shows changes of -6.38% and -1.92% per year before and after safehold respectively for all spots. We use these rates to adjust the signal photons/pulse values before and after safehold to remove any trends that may result from changes in laser power.

Furthermore, changes in the background photon rate can impact signal photon rates. Background photons are either solar photons at the same wavelength as the ATLAS laser, or photon events generated within ATLAS (i.e. dark counts). We expect the instrument dark count rate to be

constant through time, but the rate of solar background photons changes with sun angle. We use the background rate provided on the ATL03 product at the 50-pulse rate to subtract the number of background photons that fall within the vertical band of signal photons during a 200-pulse interval. This method allows us to correct for changes in both the solar background rate, as well as any changes in the ATLAS dark count rate, and provides the best available background removal. The resulting signal photon rates are therefore independent of background rate variations, regardless of the source.

We calculate signal photon rates over two length scales. To analyze long-term trends, we compute aggregate statistics over $\sim 2^\circ$ of latitude following the along-track near-polar orbit (from 87°S to 88°S and back to 87°S). This spans ~ 220 km or some 314,000 individual laser pulses (~ 31.4 seconds). This study combines data from 80 (59) such ATL03 granules for Antarctica (Greenland). To assess the variability within a given granule, we calculate the standard deviation of the signal rates per 200 laser pulses for those segments within ± 1 signal photon/pulse of the mode for the strong spots, and within ± 0.25 signal photons/pulse of the mode for the weak spots. This captures the majority of the signal photon rate variation; we also use these histograms to reject regions contaminated by clouds or blowing snow (Figure 1). By considering many such segments over the life of the mission, we evaluate the degree to which the number of signal photons/pulse has changed.

To examine short-scale variability in the signal photon rate, we consider the statistics computed over individual 20 m along-track segments. This represents approximately 28 laser pulses (~ 2.8 milliseconds) and is as small a scale as we can confidently calculate statistics. We use the same approach as described above to determine the short-scale mode and standard deviation of the number of signal photons/pulse.

To identify any trends, linear least-squares fits and significance tests statistics are calculated for each spot through time, with the slope reported as the change in signal photons/pulse per year. The selected granules are a subset of those used in pixel illumination analyses, with 22 and 10 granules rejected for contaminated signal due to clouds or blowing snow for Antarctica and Greenland, respectively leaving 80 and 59 granules used in our analyses.

3 Results

3.1 Pixel Illumination

Pixel illumination is stable across our clear-sky ATL03 granules for the Antarctic and Greenland ice sheet interiors. Some variability of illumination is expected between spots, owing to small differences in ATLAS hardware, particularly across spot pairs since each pair has its own set of Photon Counting Electronics (PCE) (Martino et al., 2019). Figure 2 shows that the average pixel illumination is within $\pm 5\%$ of the expected values of 6.25% and 25% for all pixels of the strong and weak spots in each granule considered. Differences among pixels within a given strong or weak spot are small (within-spot ranges of $< 1.5\%$, $< 4\%$ respectively) and are consistent with variability observed in ATLAS pre-launch testing (Martino et al., 2020a). The long-term trends for a given pixel are generally statistically significant but very small, on the order of 0.05% change per year or less. Some small seasonal variability is also apparent and very likely due to seasonal solar illumination.

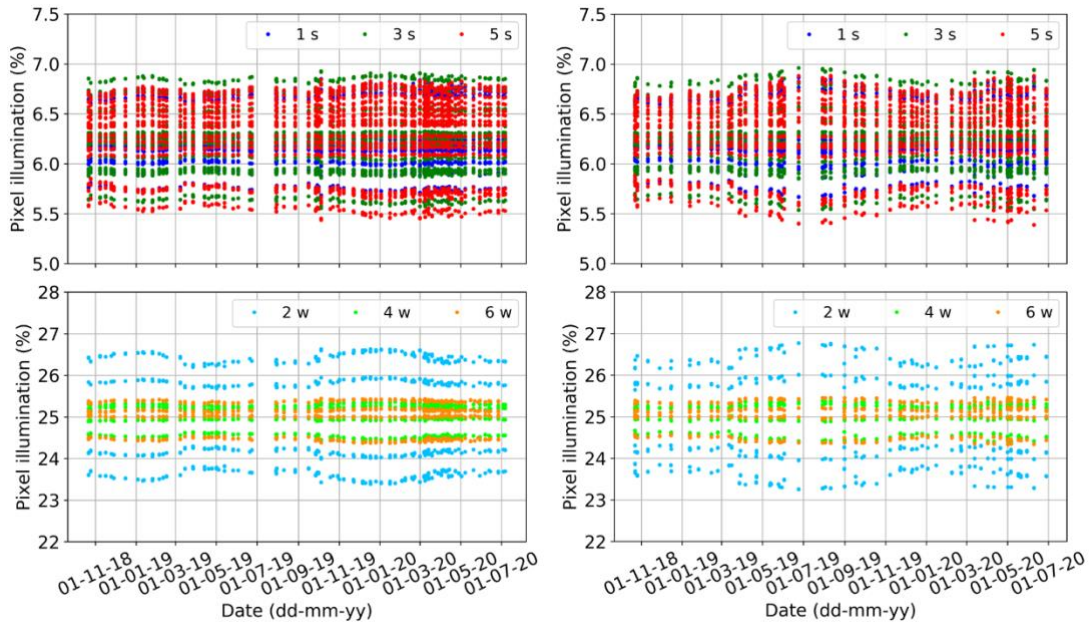


Figure 2. Percent pixel illumination for select ATL03 granules over Antarctica (left) and Greenland (right). Colors correspond to ATLAS spot number with strong spots in top panels, weak spots in lower panels, with one point for each pixel. Percent illumination changes are generally within $\pm 0.05\%$ per year.

3.2 Signal Photons per Pulse

Signal photons/pulse over ice sheet interiors are approximately ~ 8.5 for strong spots and ~ 2.0 for weak spots (Figure 3). Signal rates in spots 3 and 4 are consistently lower than the other four spots across time and regions studied. Such differences between pairs of spots (e.g. spots 1 and 2 compared to spots 3 and 4) are consistent with the specifications of ATLAS hardware and pre-launch testing analyses (Martino et al., 2020c, Martino et al., 2019). Linear least-squares fits suggest a decreasing signal rate over time, with statistically significant ($p \leq 0.05$) signal photons/pulse per year slopes on the order of ~ -0.7 for strong spots in both regions, and ~ -0.2 for weak spots in Greenland over the duration of the study (Table 1). Weak spot slopes for the full study period in Antarctica are not statistically significant, as noted in Table 1, and are on the order of ~ 0.03 or fewer signal photons/pulse per year.

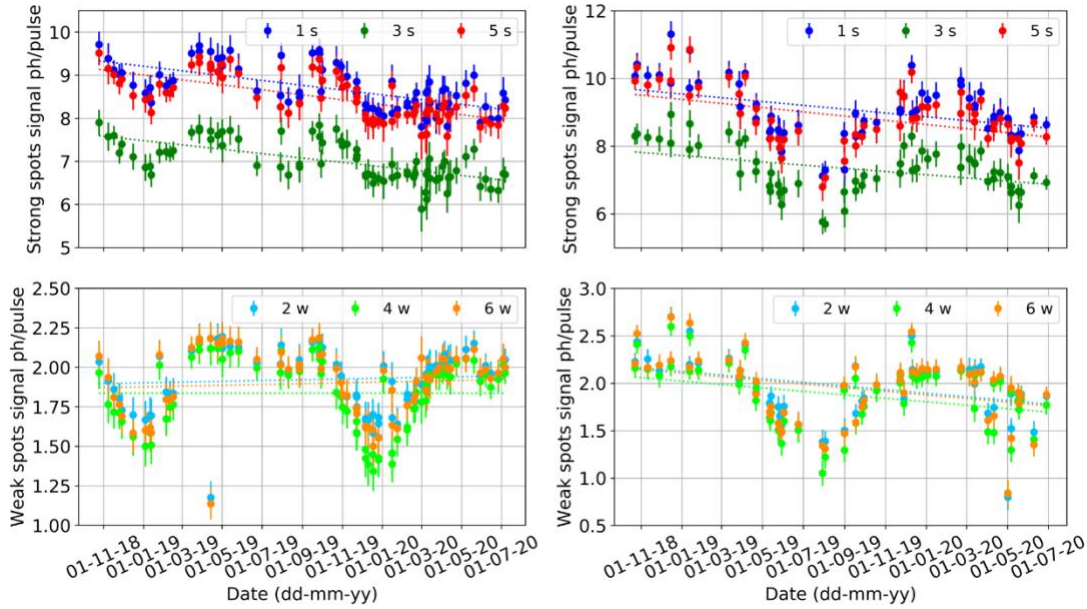


Figure 3. Signal photons/pulse for select ATL03 granules over Antarctica (left) and Greenland (right). Colors correspond to ATLAS spot number with ± 1 standard deviation and the corresponding least-squares fit. Linear least-squares fits suggest declines in signal photons/pulse per year are statistically significant ($p < 0.05$) in strong spots for Antarctica, and all spots for Greenland over the mission lifetime. Slopes for each spot are detailed in Table 1.

Figure 3 indicates different signal rates before and after July 2019, when ICESat-2 experienced a safeshold event. Antarctic signal photons/pulse per year fits are different in magnitude and direction before and after safeshold. Signal photons/pulse per year changes are ~ 0.3 and -0.9 for strong spots and 0.6 and 0.07 for weak spots before and after safeshold respectively. Fits for weak spots before safeshold and strong spots after safeshold are statistically significant ($p < 0.05$) over Antarctica. Greenland fits before and after July 2019 are approximately -3.2 and 0.5 signal photons/pulse per year for strong spots, and -1.2 and -0.02 for weak spots. Fits are statistically significant ($p \leq 0.05$) in all spots before safeshold over Greenland.

Short (20 m) aggregates over ~ 10 km near 88°S show modes (standard deviations) of ~ 8.5 (0.39) signal photons/pulse for strong spots and ~ 2 (0.18) for weak spots. These statistics are representative of many different granules evaluated. As expected, the standard deviations are larger for these smaller aggregates than the larger aggregates considered in Figure 3.

4 Discussion

In order to use metrics of the changes in the number of signal photons through time to address geophysical problems, it is critically important to determine if the ATLAS instrument is changing through time. We chose the interior of Antarctica (south of 87°S latitude) as a radiometrically stable surface. Although clouds or blowing snow can attenuate laser energy, our methodology is designed to capture signal rates and changes through time under consistent clear-sky atmospheric conditions. As such, we consider our Antarctic results our best assessment of changes within the ATLAS instrument. The results from Greenland and Antarctica show seasonality with higher rates in summer and lower rates in winter, suggesting an error in the background removal we have yet to diagnose. The Greenland results could also be affected by

geophysical changes and are not considered further in the assessment of changes in radiometry. Below, we discuss potential sources of change within the ATLAS instrument.

As part of the ATLAS restart after safehold in July 2019, the laser transmit energy was optimized through temperature adjustments within the laser. It is evident that some metrics (notably, the rate of change of the signal photon rate) are different before and after safehold (Figures 4, 5). During safehold, temperatures in the observatory were controlled by survival heating systems, and the component-level temperatures never exceeded the limits established during pre-launch testing. We explored a number of possible mechanisms for radiometric changes within the instrument that could explain the slightly different radiometric decreases before and after safehold without conclusive attribution. As such, we report radiometric performance over the life of the mission, as well as before and after safehold in Table 1.

Strength	Spot	Antarctica ₁	Antarctica ₂	Antarctica ₃	Greenland ₁	Greenland ₂	Greenland ₃
Strong	1	0.39	-0.86	-0.66	-3.44	0.62	-0.67
	3	0.27	-0.90	-0.61	-2.93	0.48	-0.57
	5	0.36	-0.86	-0.69	-3.58	0.53	-0.74
Weak	2	0.51	0.05	0.03	-1.15	-0.02	-0.23
	4	0.85	0.10	0.00	-1.30	0.05	-0.22
	6	0.61	0.06	0.03	-1.32	-0.02	-0.23
	N	24	56	80	23	36	59

Table 1. Signal photons/pulse per year rates for Antarctic and Greenland ice sheets (1) before safehold, (2) after safehold, (3) and overall for each ATLAS spot number, corrected for background rates and laser power changes. The number of ATL03 granules used in each analysis are included in the bottom row, N. Slopes that are statistically significant ($p \leq 0.05$) are in bold.

Pixel illumination is nearly uniform and stable in the data considered here. Illumination distribution may vary slightly at shorter scales, most likely due to solar illumination angle. However, this analysis suggests that any biases among the pixels ('hot' or 'cool' pixels) are small and stable with time, and shows no changes due to the safehold event. This suggests that models for detector gain can be applied uniformly throughout the mission, such as the first-photon bias model used in ATL06 (Smith et al., 2019, Smith et al., 2020).

Over short spatial scales (~20 m), we find ATLAS signal photons rates are consistent and show no significant multi-modal behavior or other large variability in time. The distribution of short-scale aggregates over ~10 km (mode ~8.5 (2), standard deviation ~0.39 (0.18) for strong (weak) spots) serves as a guide for variation due to ATLAS, compared with that due to geophysical changes. We conclude that differences in signal rates larger than 0.39 signal photons/pulse over a few hundred meters are primarily due to geophysical changes (Kwok et al., 2016).

Over the life of the mission, the rate of change of the number of signal photons/pulse are negative in both Greenland and Antarctica, with significant variability among beams and before/after safehold. These changes could be due to changes within ATLAS (e.g. unmeasured

changes in transmitted laser energy, temperature variations), or geophysical changes within the Earth system. The ATL02 data product (Martino et al., 2020b) contains a number of diagnostic parameters that allow us to evaluate some potential causes.

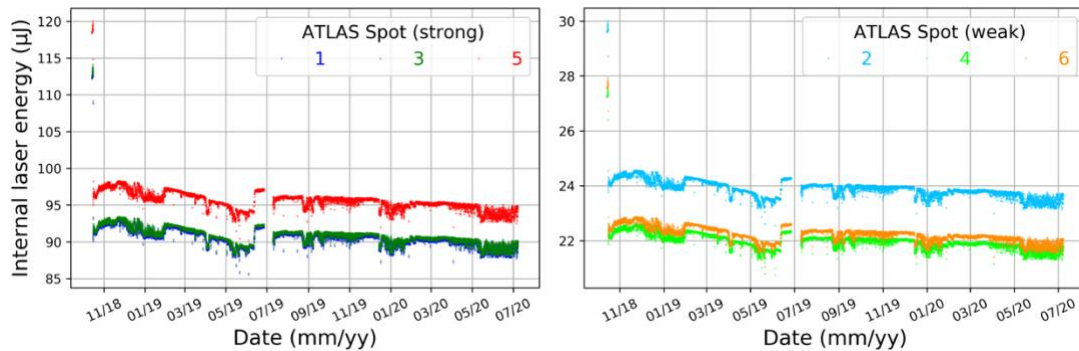


Figure 4. Mean transmitted internal laser energy for each Antarctic ATL02 granule over the mission in microjoules. Colors correspond to ATLAS spots. Linear least-squares fits indicate a decline in transmitted energy of 2.20% per year since the July 2019 safehold.

A potential candidate is a long-term decrease in the transmitted laser energy. Two ATL02 metrics for the ATLAS transmitted laser energy show approximately -1.66% change per year over the first 1.5 years of the mission, and -4.40% and -2.20% change per year before and after safehold respectively, considering only data at laser energy level 4 (Figure 4). Reductions in the transmitted laser energy translate directly into a corresponding decrease in the signal photon rate. The transmitted ATLAS laser energy can be tuned by adjusting temperatures within the laser optical module, and the mission has done 6 such adjustments over time. These adjustments are super-imposed on a gradual long-term decline in transmit energy. ATLAS is currently transmitting at laser energy level 4 (of 11), where each energy level step represents an approximately 10% change in transmit energy (Sawruk et al., 2015, Neumann et al., 2019). As described above, we correct signal photons/pulse to account for the laser energy changes before and after safehold, so the observed decrease in the corrected signal photon rate (e.g. Table 1 or Figure 3) has been corrected for transmitted laser power changes. We note that these metrics of transmitted energy are upstream of a number of other optical components in ATLAS that could impact the transmitted energy of a given beam (e.g. beam forming optics, diffractive optical element). Therefore, we must look elsewhere to explain the observed signal rate decrease.

ATLAS contains means of monitoring changes in the timing and radiometric stability for two of the ATLAS strong beams through photons following the Transmitter Echo Path (TEP) (Martino et al., 2019, Neumann et al., 2019). The TEP is necessary for impulse response function approximation, range bias determination, and monitoring internal optical pathways. Briefly, the TEP routes a small fraction of the outgoing laser energy just after the beam exits the laser transmitter, and directs the light into the optical filters in the receiver optical path. From there, these photons are recorded and evaluated along with the other photons. Since these photons arrive shortly after the transmitted laser pulse, ATL02 identifies potential TEP photons and ATL03 further refines this classification. Changes in the TEP photon rate could indicate ageing of several components of the ATLAS receiver (e.g. photomultiplier tubes, photon-counting electronics) after accounting for changes in the ATLAS transmitted laser energy.

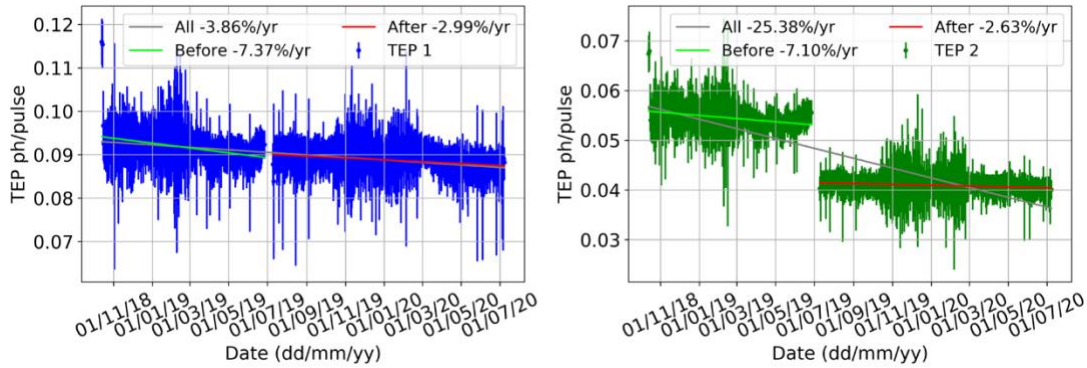


Figure 5. Mean TEP photons per pulse for each day of the mission through 7 July 2020. Linear least-squares fit slopes show percent change per year overall, before, and after safehold. a decline in TEP rates of 2.99% (TEP 1) and 2.63% (TEP 2) per year since safehold.

Before the safehold event, the number of TEP photons/pulse declined by -7.37% and -7.10% TEP photons/pulse per year ($p < 0.01$) for TEP 1 and 2 (Figure 5). The number of TEP photons/pulse are decreasing more slowly after the safehold event, with percent changes per year of -2.99 and -2.63 for TEP 1 and 2 ($p < 0.01$). Since the TEP path is formed shortly after the laser pulse exits the laser module (Martino et al., 2019) we expect TEP signal strength to be closely correlated with the transmit laser energy. Given the similar rates of TEP signal decrease and laser energy decrease (-2.2 percent / year), we conclude that the ATLAS receiver sensitivity downstream of where the TEP enters the signal path is not changing significantly through time.

Another means of evaluating the entire ATLAS receiver sensitivity is through changes in the rate of received background photons, which traverse the entire ATLAS receiver path from the telescope to the electronics. Changes in sun angle dominate the observed changes in the background photon rate (Figure 6), so we compare the background photon rate for a given month across the data set. As of this writing, ATLAS has ~1.5 years of data, making longitudinal analyses problematic (e.g. how has the background rate in December over Antarctica changed?). However, by comparing the available data, we see no meaningful difference in the background rate between the 2018 and 2019 austral summers implying receiver sensitivity is stable.

We have no compelling explanation for the observed decrease in the number of signal photons/pulse over the interior of the Antarctic ice sheet. The two most obvious possibilities are changes in the unmonitored parts of the ATLAS instrument (particularly those optical components after the laser energy monitors before the beams exit ATLAS) which may be susceptible to photo-darkening (Martino et al., 2019).

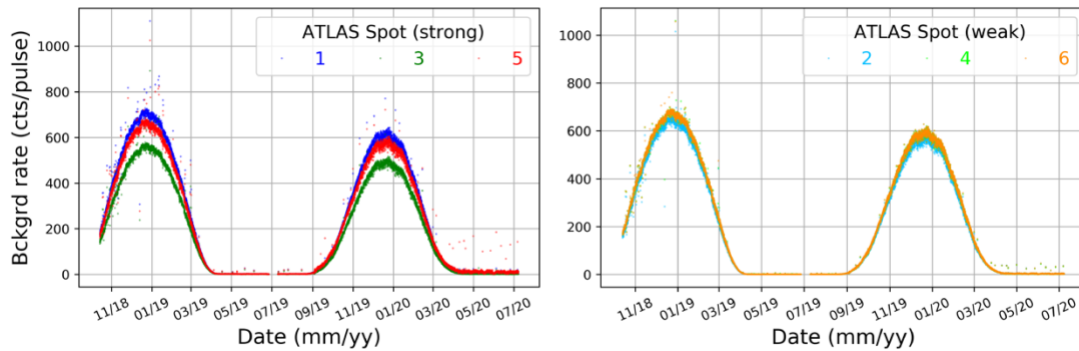


Figure 4. Mean background rate for all Antarctic granules over the mission, in counts per pulse through 7 July 2020. Colors correspond to ATLAS spot. Background rate patterns are primarily determined by sun angle.

Alternatively, there could be changes in the geophysical environment in Antarctica, such as a long-term decrease in the reflectivity of the interior of the Antarctic ice sheet, which we have no reason to suspect. It is apparent that there is a seasonal variation in our Antarctic analyses which could point to either an error in our background rate removal, or seasonal variability in atmospheric transmittance that we are not properly correcting. While the present dataset cannot distinguish between these possibilities, longer term data should allow the photon background rate to confirm or reject changes in environmental conditions. Comparing year-over-year changes in specific months, particularly the Antarctic winter, should help further isolate changes in the environment from changes within ATLAS.

5 Conclusions

Here we present a first analysis of on-orbit radiometric performance of ICESat-2. The ATLAS instrument evenly distributes light across detectors. The signal photons/pulse analyses suggest the ATLAS instrument is very stable on short time scales, and strong spots exhibit a long-term decline of -0.75 signal photons/pulse per year over the first 1.5 years of the mission. This decrease is independent of ATLAS receiver sensitivity, background rates, detector saturation, internal laser power changes, and to the extent possible geophysical changes. Further analyses may be able to delineate observed trends to either instrument or geophysical changes as longer time series become available.

Acknowledgements

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