ICESat-2 Photon Classification: Finding Signal Photons in the ATL03 Geolocated Photon Data Product

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Abstract

ICESat-2 carries NASA's next-generation laser altimeter, ATLAS, (Advanced Topographic Laser Altimeter System), designed to measure changes in ice sheet height, sea ice freeboard, and vegetation canopy height. ATLAS contains a photon-counting lidar which transmits green (532-nm) pulses at 10kHz. Each pulse is split into 3 pairs of beams (one strong and one weak). Approximately 1014photons per pulse travel from ATLAS through the atmosphere to reflect off the Earth's surface. Some return back into the ATLAS telescope where they are recorded. Photons from sunlight and instrument noise at the same wavelength are also recorded. The flight software time tags all photons within a 500m to 6 km range window and generates histograms. Using the histograms, it selects a telemetry window which varies from 20m over flat surfaces to hundreds of meters over rougher terrain. ATL03 contains the time, height (relative to the WGS-84 ellipsoid), latitude and longitude of every photon within the telemetry window. The basic challenge is to determine which of these photons were reflected off the surface. We have developed an algorithm that identifies these signal photons and assigns a confidence level (low, medium, or high) to each signal photon based on the signal to noise ratio. We present an overview of the signal identification algorithm and show the results on actual ICESat-2 data over ice sheet, sea ice, vegetated, and water surfaces. Higher level ATLAS products work with aggregations of the photons in order to determine the ellipsoidal height of the Earth, canopy height and structure, and other quantities of geophysical interest.

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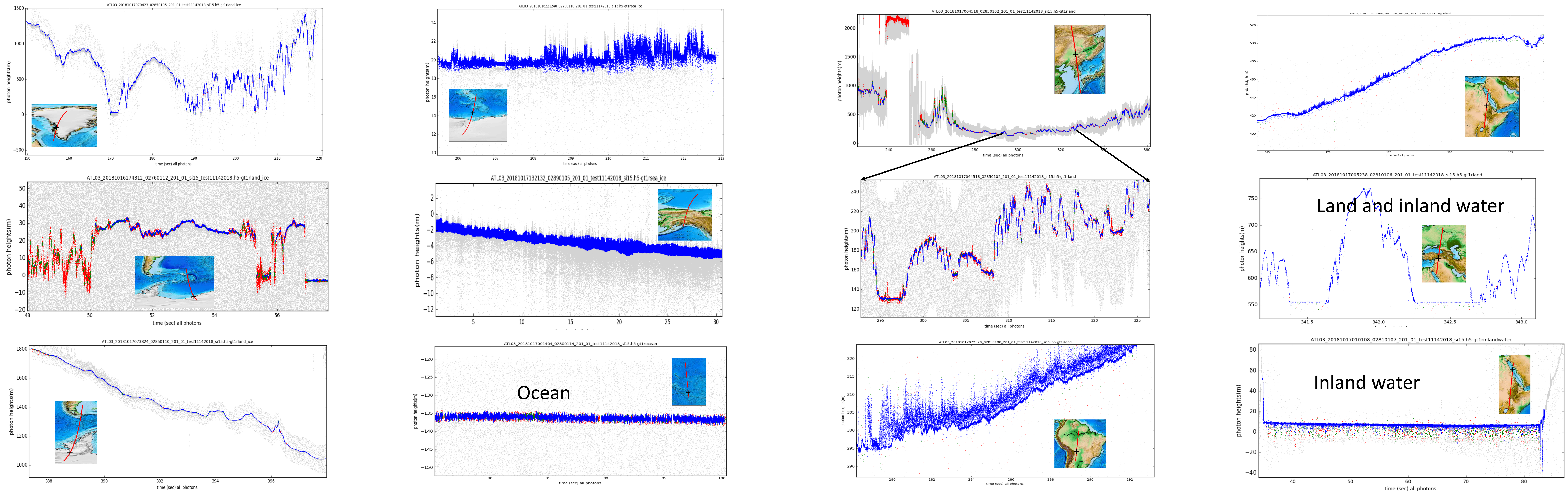
Actual Photon Classification on ATL03

Ice sheet | Sea ice | Land | Land



Photon classification Key

High confidence signal — Medium confidence signal — Low confidence signal — Non-signal (noise)

Photon Classification Algorithm

Problem - telemetered photon events (spanning 30m to 2000m in heights) on ATL03 contain both signal and background photon events.

Solution - a photon classification algorithm to provide an initial discrimination between signal and background photon events.

Goal - identify all signal photon events while minimizing false positives

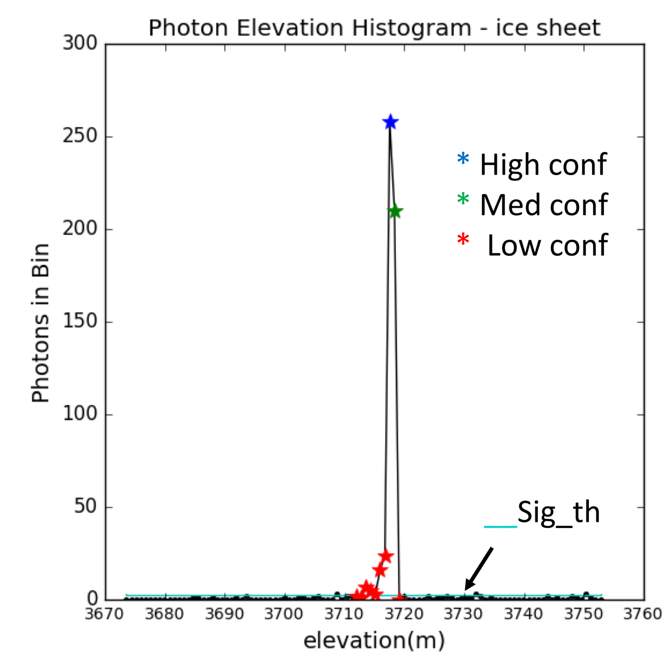
A: Determine background photon rate
1. Use atmospheric histogram: sum of 400 laser shots in 30m height bins spanning ~14km in height
   a) Remove bins containing signal using n*sigma editing
   b) Calculate mean, μ_{bg}, and standard deviation, σ_{bg}, of remaining bins

B: Calculate a signal threshold: $Sig_{th} = \mu_{bg} + e_m \times \sigma_{bg}$.

C: Histogram the ellipsoidal height of the telemetered photons over time period, **dt**, using height bins of size **dz**.
1. Scale sig_{th} to **dt** and **dz**
2. Identify signal bins as those that exceed sig_{th}
3. Throw out signal bins where the number of photons is < r x maximum number of photons in one histogram bin
4. Add bins on each side of the signal bins until find two bins where the number of photons $< \mu_{bg}$
5. If no signal is found increment **dt** and **dz** and iterate until maximum values of dt and dz reached.

D: Identify additional signal missed by ellipsoidal height histogramming
1. Strong beams over land or land ice histogram the height relative to the surface slope as defined by signal identified in c. Perform steps as in c to identify additional signal.
2. Weak beams over all surfaces histogram the height relative to the surface slope defined by signal photon events corresponding to the strong beam in the pair after adjusting for the fore/aft offset between the weak and strong beams. Perform steps as in c to identify additional signal.

E: Assign a confidence level to each photon event for each surface type:
1. Identified signal
   a) 4: High-confidence signal (SNR ≥ 100)
   b) 3: Medium-confidence signal (100 > SNR ≥ 40)
   c) 2: Low-confidence signal (40 > SNR ≥ 3)
2. Non-signal photon confidence levels:
   a) 1: within +/- 10m of mean surface calculated from the signal-identified photons
   b) 0: probable background photon event
   c) -1: not assessed for that surface type



signal_conf_ph:

Five columns: land, ocean, sea ice, land ice, inland water

N rows: corresponds to number of photon events

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