Linear Impulse Response from ICESat-2 On-Orbit Data

ICE, CLOUD, AND LAND ELEVATION SATELLITE-2

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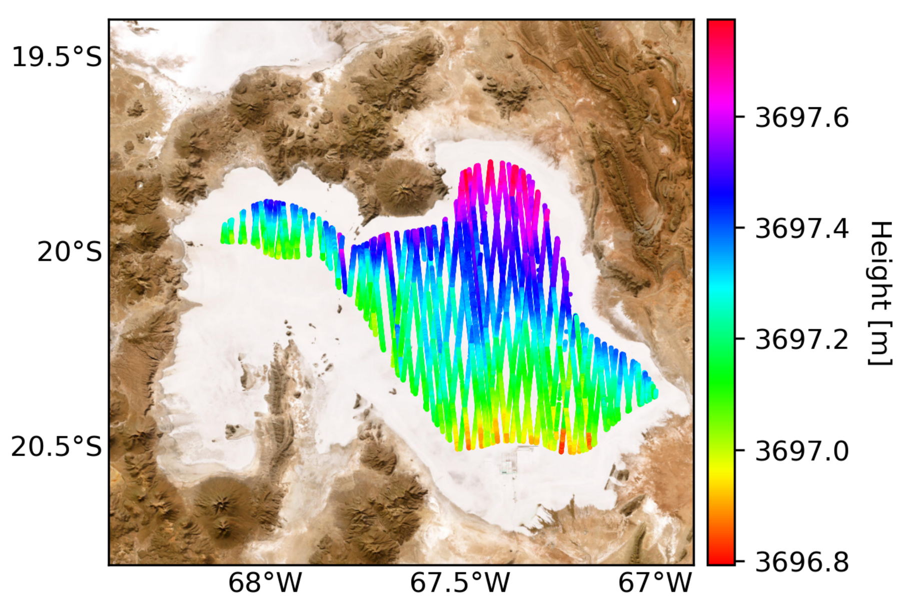
Introduction

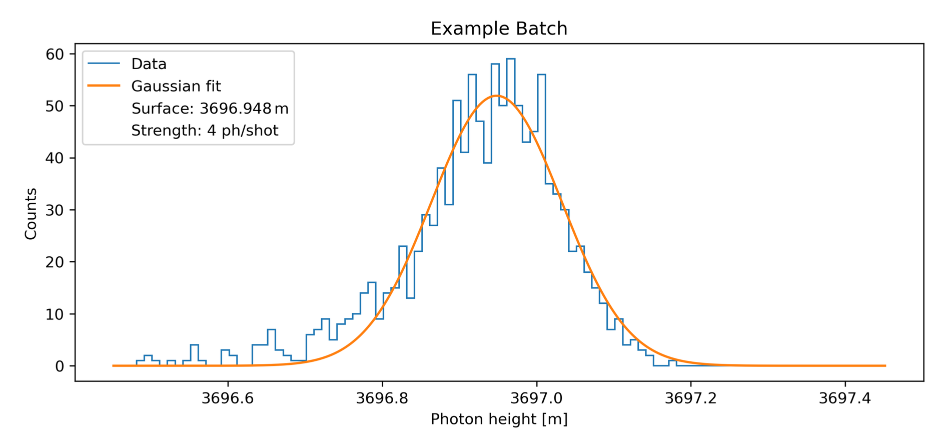
The impulse response is dominated by the shape of the transmitted laser pulse, but also influenced by the optics and electronics within the ATLAS receiver. We measure the impulse response using returns from the Salar de Uyuni, a large salt flat with little topographic variation and a suitable photon return rate (neither too high nor too low). An updated data selection removes artifacts and spot-to-spot inconsistencies present in previous measurements. This work aims to provide a path forward for proper handling of afterpulses in studies where subsurface data analysis is desired.

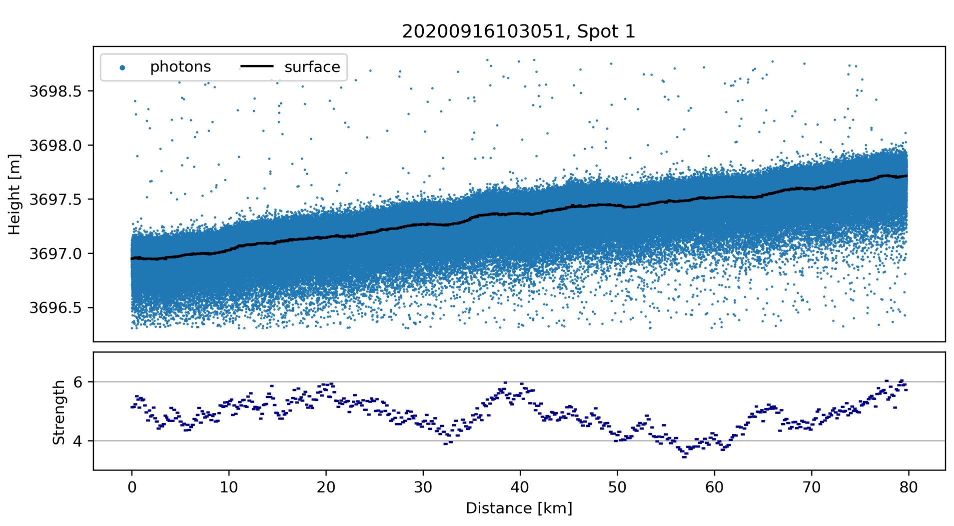
Data and Selection

- All ICESat-2 passes over the Salar de Uyuni, a large salt flat in Bolivia.



- Divide data into batches of ...
  - at least 0.005s length (1/4 major frames),
  - at least 1000 photons,
  - no data gaps,
  - roughly constant strength.
- In each batch:
  - Estimate background using photons in 3705-3720 m window.
  - Find surface height by fitting a Gaussian to the background subtracted data.
    - Surface height = mean of Gaussian
    - Strength = area under Gaussian per number of shots
  - Discard batches with poor fit results.

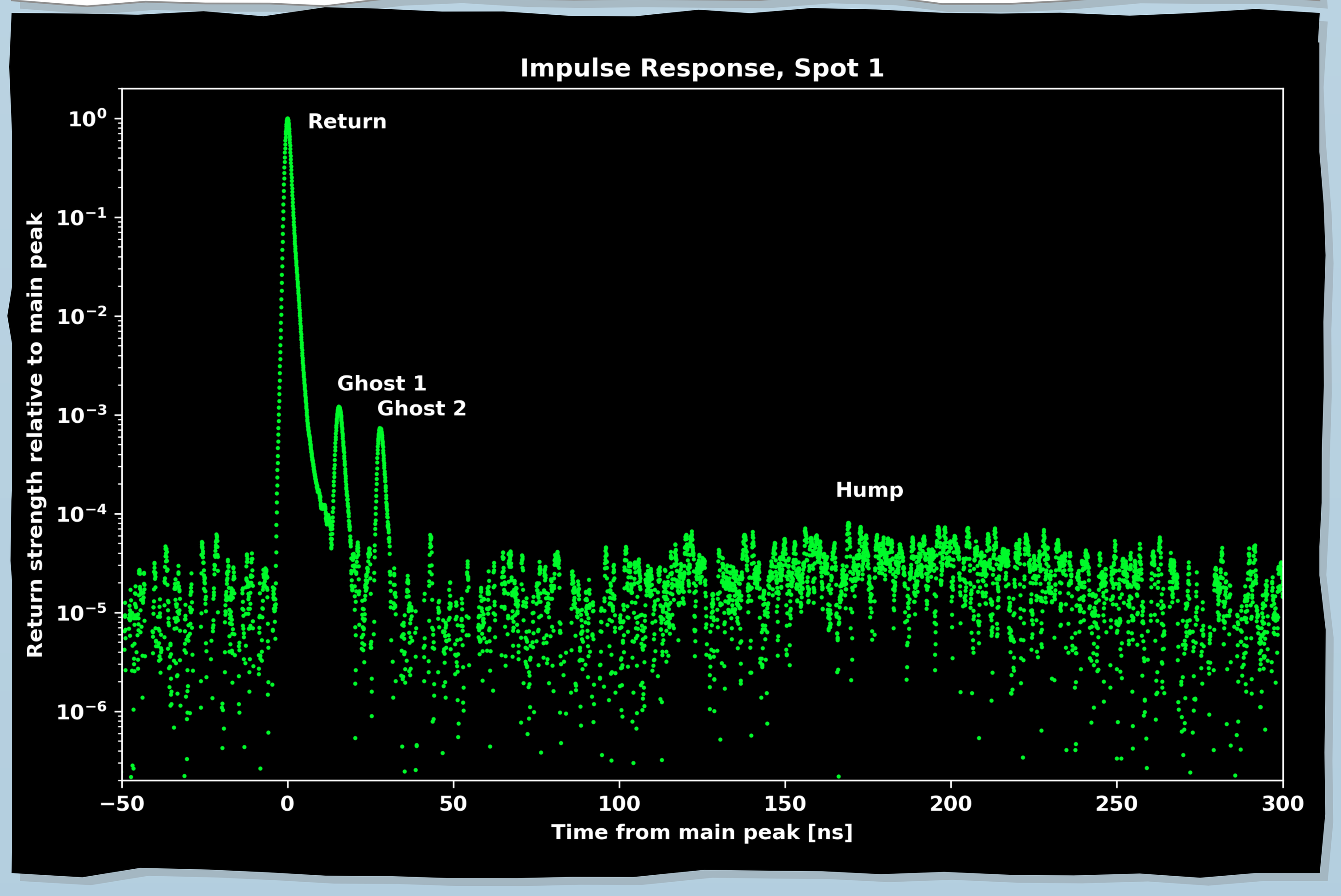




- Aggregate all the data:
  - Align peaks using the estimated surface height in each batch.
  - Subtract background using observed number of photons in 5-40 m window above the surface.
  - Correct background and signal estimates for bandwidth differences: In order to limit data transmission, only photons within a varying band around the predicted surface are sent to Earth. The varying bandwidth changes the data rate at the tail of the impulse response distribution and needs to be accounted for.

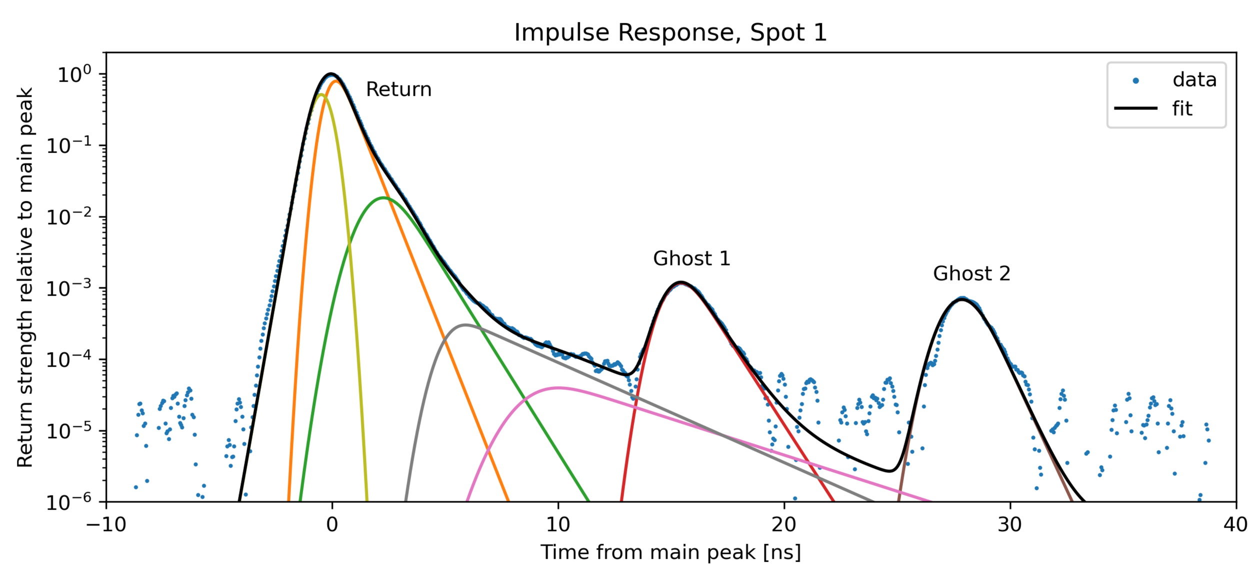
Impulse Response

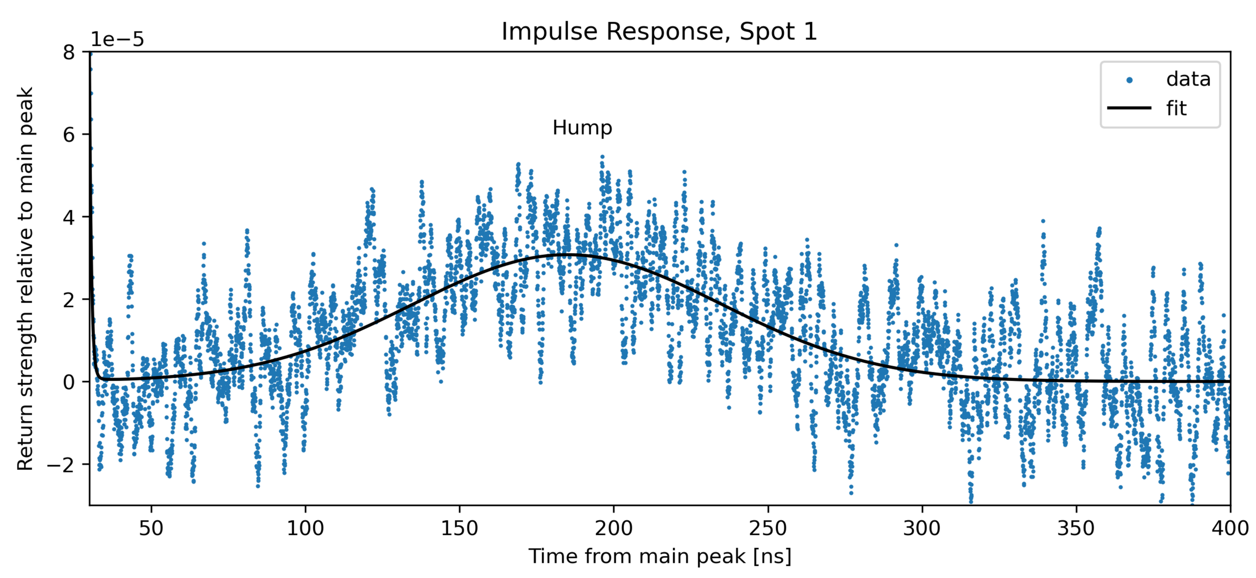
The main peak and the two ghost reflections are driven by optical paths in the receiver optics, and match the prediction of ray trace analysis. The wide, low hump is probably due to effects within the photomultipliers.



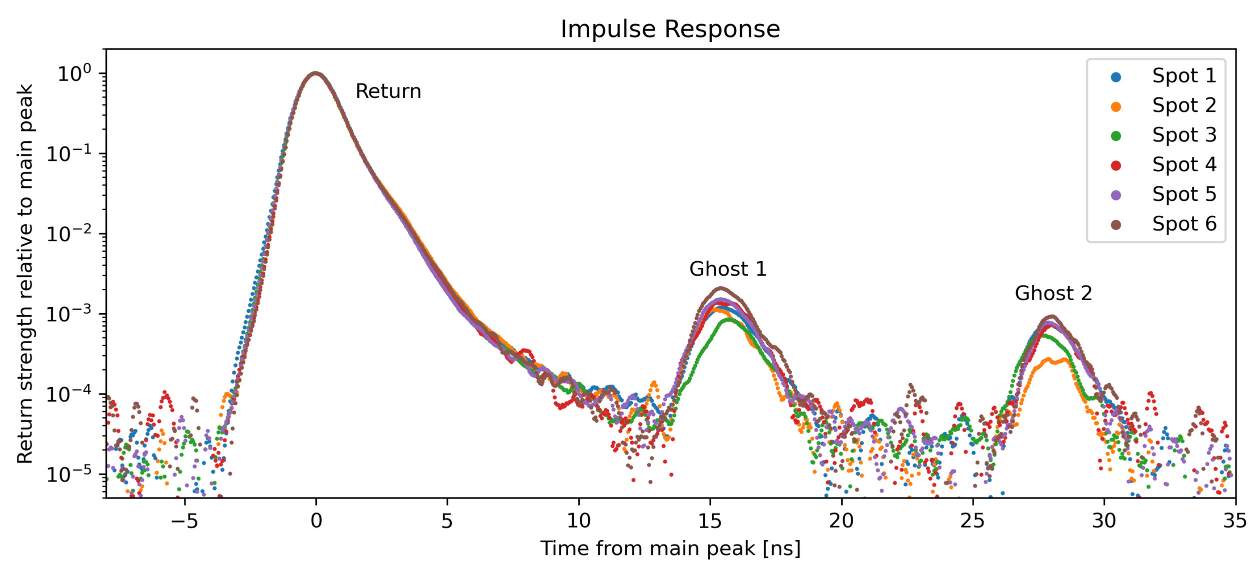
Functional Form

In order to provide a smooth distribution, several exponentially modified Gaussians (EMGs) are fitted to the impulse response. Using 8 EMGs describes the data reasonably well for all spots.





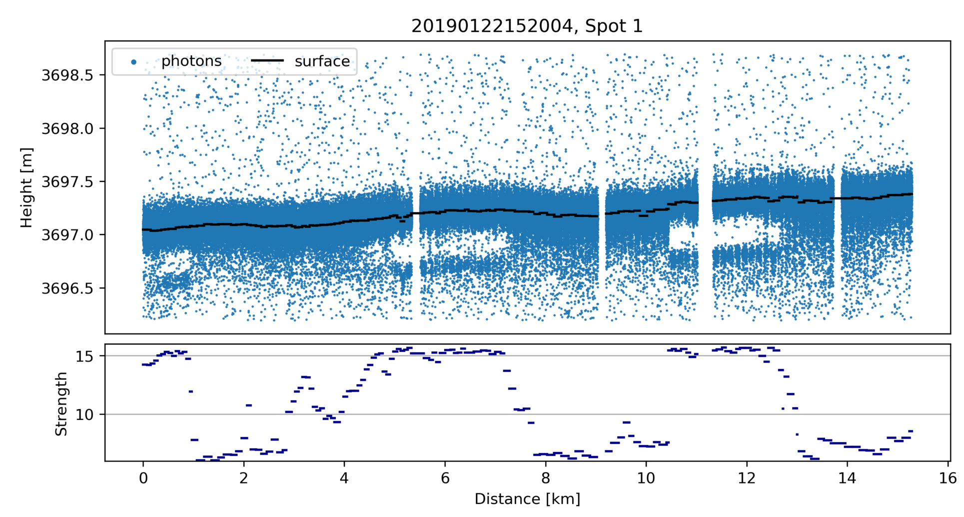
Spot Comparison



Challenges

Non-instrument related factors, such as surface roughness, water, atmospheric conditions, and clouds, influence the signal shape.

- Standing water on the salt flat causes high reflection which saturates the ATLAS instrument. This can be controlled by dividing the data into different categories of *strength*, the number of detected photons per laser shot, and discarding batches with inappropriate strength.



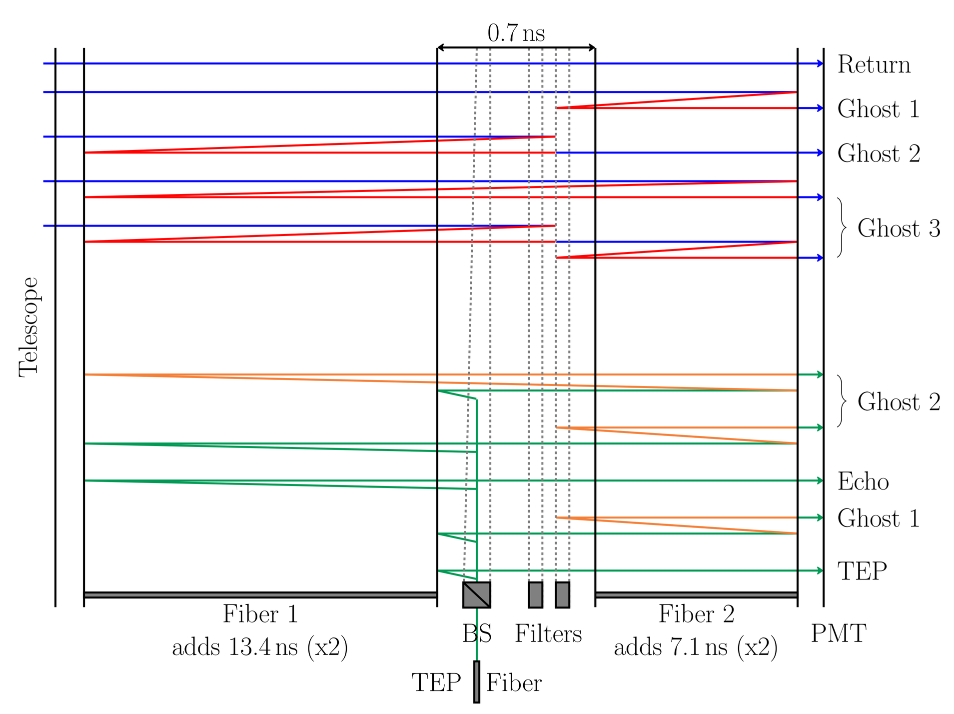
- Surface roughness and other factors widen the signal distribution noticeably. This is currently controlled by discarding batches with a too large surface fit uncertainty.

Ray Trace

Ray trace analysis of the receiver optics predicts ghost reflections in the impulse response. Each ghost peak is composed of many different optical paths, examples are shown in red and blue.

- Ghost after ~15.5 ns, due to Fiber 2 detour.
- Ghost after ~28 ns, due to Fiber 1 detour.
- Ray trace analysis predicts the next ghost reflection at ~43 ns at even lower order, which can not be observed with the current statistics.

The Transmitter Echo includes consists of several peaks due to similar optical paths, examples are shown in green and orange.



You - the User

Talk to me about use cases, data format, smoothing, binning, data cleaning, surface roughness, beta testing, ...!

I want to hear from you!

Talk to me or write me: almut.m.pingel@nasa.gov

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ATLAS ADVANCED TOPOGRAPHIC LASER ALTIMETER SYSTEM