Accuracy of Terrain Heights from Spaceborne Laser Altimetry in Brunei's Tropical Peatlands

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Abstract

Tropical peatlands are estimated to hold carbon stocks of 70 Pg C or more as partly-decomposed organic matter, or peat. Peat may accumulate over thousands of years into gently mounded deposits called peat domes with a relief of several meters over distances of kilometers. The curved shape of peat domes accounts for much of the carbon storage in these landscapes, but their subtle topographic signal is difficult to measure. As many of the world's tropical peatlands are remote and inaccessible, spaceborne laser altimetry data from missions such as NASA's Global Ecosystem Dynamics Investigation (GEDI) and the Advanced Topographic Laser Altimeter System (ATLAS) instrument on the Ice, Cloud and land Elevation Satellite-2 (ICESat-2) observatory could help to describe these deposits. However, for better and for worse, tropical peatlands may also support forests with high above-ground biomass—averages of over 200 Mg C / ha have been reported—which increases their carbon stocks but further complicates determination of their surface topography using laser altimetry. In this work, we evaluate retrieval of ground elevations and canopy metrics derived from GEDI waveform data, as well as single-photon data from ATLAS, with reference to an airborne laser scanning dataset covering an area of over 100 kmˆ2 in the Belait District of Brunei Darussalam. We find that despite infrequent ground retrievals, with regularization these spaceborne platforms can provide useful data for tropical peatland surface altimetry.

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Introduction

Tropical peatlands are estimated to hold carbon stocks of 70 Pg C or more as partly-decomposed organic matter, or peat. Peat accumulates over thousands of years into gently mounded deposits called peat domes with a relief of several meters over distances of kilometers.

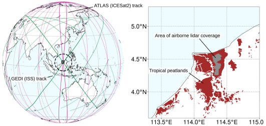

Fig. 1. Study site in Brunei Darussalam.

The curved shape of peat domes accounts for much of the carbon storage in these landscapes, but their subtle topographic signal is difficult to measure, and many of the world's tropical peatlands are remote and inaccessible. Spaceborne laser altimetry data could help to describe these deposits. However, the dense canopies in some tropical peat forests create challenges for laser altimetry.

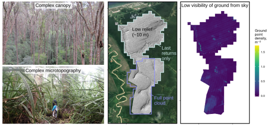

Fig. 2. GEDI and ATLAS coverage of study area.

We evaluated retrieval of ground elevations derived from GEDI waveform data, as well as single-photon data from ATLAS, with reference to an airborne laser scanning dataset in the Belait District of Brunei Darussalam.

GEDI: Methods and Results

NASA's Global Ecosystem Dynamics Investigation (GEDI) mission was designed to characterize changes in terrestrial ecosystems. One of GEDI's science requirements is to acquire profiles from canopy to ground under 95% to 98% canopy cover[1]. The high energy of GEDI shots could make them useful for estimating peatland topography.

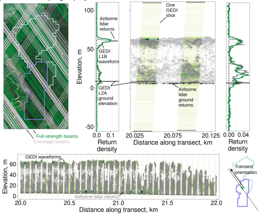

Fig. 3. Profiles of GEDI waveforms (green; full power beams at night) and airborne lidar (gray).

Canopy cover in much of the study site is over 98%, resulting in the GEDI L2A product sometimes interpreting waveform signals from the canopy as ground. We found that a morphological filter developed for airborne lidar data[2] could remove these high false ground points.

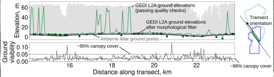

Fig. 4. GEDI L2A ground elevations before (dashed line) and after filtering (green points), and ALS ground points (gray).

ATLAS: Methods and Results

The Advanced Topographic Laser Altimeter System (ATLAS) instrument on the Ice, Cloud and land Elevation Satellite-2 (ICESat-2) observatory is a photon-counting lidar system that was designed primarily to quantify changes in ice-sheet thickness[3]. It has a lower pulse energy than GEDI and transmits fewer photons per along-track distance.

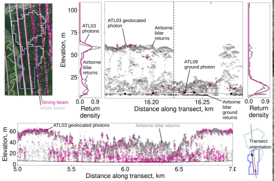

Fig. 5. Profiles of ATLAS photons (fuchsia; strong beams at night) and airborne lidar (gray).

Because of the dense canopy at the study site, the ATLAS ATL08 product also sometimes misidentified reflections from upper- or mid-canopy surfaces as photons reflected from the ground. These high false ground points could again be removed with a morphological filter. The remaining ATL08 ground photons were observed to coincide well with the airborne lidar ground surface, with a small positive bias.

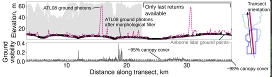

Fig. 6. ATL08 ground elevations before (dashed line) and after filtering (green points), and ALS ground points (gray).

Conclusions

Both GEDI L2A and ATLAS ATL08 products produced useful data for surface altimetry in this peatland. The dense canopy cover at the site resulted in a number of high outliers in both products due to misclassification of upper- or mid-canopy reflections as ground reflections.

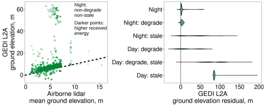

Fig. 7. Comparison of GEDI L2A ground elevations with the elevation of airborne lidar ground returns in the GEDI footprint.

We found that these outliers could be removed using a spatial filter. In complex terrain, this approach could be difficult to apply, especially on GEDI data, for which the scale of spatial information is the ~60 m along-track shot spacing. Nonetheless, spatial filters could be useful tools for finding misclassified ground points in landscapes, like peatlands, in which the surface is known to be smooth.

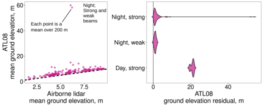

Fig. 8. ATLAS ATL08 vs. airborne lidar mean ground elevation along 200 m intervals.

References

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