Quantifying Volumetric Scattering Bias in ICESat-2 Altimetry over Snow-Covered Surfaces

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ABSTRACT

The ICESat-2 mission has collected global measurements of surface elevation for over three years. The sole onboard instrument, the Advanced Topographic Laser Altimeter System (ATLAS), operates at 532 nm, and ice and snow absorb weakly at this wavelength. Previous modeling studies found that aged or melting snow may induce 0.45 m in altimetry bias, though there has yet to be a formal assessment on ICESat-2 acquisitions during the melting season. There is a recent interest in using ICESat-2 data for snow applications, so it is vital to quantify these biases to ensure accurate measurements over snow-covered surfaces.

We perform two case studies that utilize lidar altimetry data from ICESat-2 and the Airborne Topographic Mapper (ATM) over the Greenland Ice Sheet to quantify volumetric scattering bias in snow. The case studies are conducted near the end of the melting season in September 2019. A Monte Carlo photon-tracking model and snow grain sizes derived from ATM waveforms and the Next Generation Airborne Visible/Infrared Imaging Spectrometer (AVIRIS-NG) are used to attribute ICESat-2 biases to snow.

Our results indicate that ICESat-2 and ATM experience centimeter-level bias across the Greenland Ice Sheet, and we generally see increases in bias with increasing grain size. Relative to the ATM 1064 nm beam, we find that mean biases derived from ICESat-2 and ATM over the Greenland Ice Sheet are 6.9 cm and 6.01 cm, respectively. These biases agree best with modeled results when simulated snow density is 250-350 kg m^{-3}. Although the ICESat-2 errors are within mission accuracy requirements, we cannot rule out more significant errors in regions of melting snow, particularly over forested or sloped terrain. We expect to continue this study over mid-latitude field sites in support of the SnowEx mission, with a bias correction algorithm and regional snow depth retrievals as future research goals.

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