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A Novel Method for Correction of Slope-Induced Errors in Radar Altimetry

Weiran Li, Cornelis Slobbe, and Stef Lhermitte
Department of Geoscience & Remote Sensing, Delft University of Technology, Delft, Netherlands (w.li-7@tudelft.nl)

Satellite altimetry has been an important tool for observing the cryosphere. Various radar altimetry missions including CryoSat-2, Sentinel-3, and AltiKa have been exploited to measure ice-sheet elevation or to capture ice-sheet anomalies (e.g. the extensive melt in Greenland in 2012). These studies usually serve for understanding the change and status of the ice sheet, thus require highly accurate height measurements. However, multiple error sources exist that significantly lower the accuracy of the radar altimeter-derived heights. A potential multi-meter source of error is the slope-induced error caused by the undulating topography within the kilometre-wide pulse-limited footprint. The topography directs the reflecting point of radar pulse from the nadir to the point on the ground that is closest to the satellite.

To correct for this error, different methods have been developed to determine the impact point, which all rely on footprint assumptions: e.g. slope-method, which assumes a constant slope within the footprint, or the refined point-based method, which assumes a fixed footprint size and defines the reflecting point as the shortest mean range of points within each assumed footprint. Each of these methods have shortcoming as they either neglect the actual topography or the actual footprint that can be estimated by a combination of the leading edge and topography.

To overcome this shortcoming, we present a novel Leading Edge Point-Based (LEPTA) method that corrects for the slope-induced error by including the leading edge information of the radar waveform to determine the impact point. The principle of the method is that only the points on the ground that are within range determined by the begin and end of the leading edge are used to determine the impact point. This requires the assistance of a high-resolution DEM, e.g. 100m resolution. To assess the performance of the LEPTA method, we adopt it to all CryoSat-2 LRM acquisitions over Greenland in 2019 and benchmark it to the slope- and point-based method. To evaluate the results, we use the newly-launched laser altimeter, ICESat-2.

Validation results show that heights obtained by LEPTA have good agreements with ICESat-2 height observations, both in the flat, interior regions of Greenland and in regions with more complex topography. The median difference between the slope-corrected CryoSat-2 heights and the ICESat-2 heights is almost negligible, whereas the other methods can have a 0.22m and 0.69m difference, and the Level-2 data provided by ESA have a 0.01m difference. The median absolute deviation, which we use as an indicator of the variation of errors, is also the lowest in LEPTA (0.09m) in comparison to the aforementioned methods (0.22m and 0.13m) and ESA Level-2 data

(0.15m). Based on that, we recommend considering LEPTA to obtain accurate height measurements with radar altimetry data, especially in regions with complex topography.