Evaluation of Satellite Methods for Estimating Supraglacial Lake Depth in Southwest Greenland

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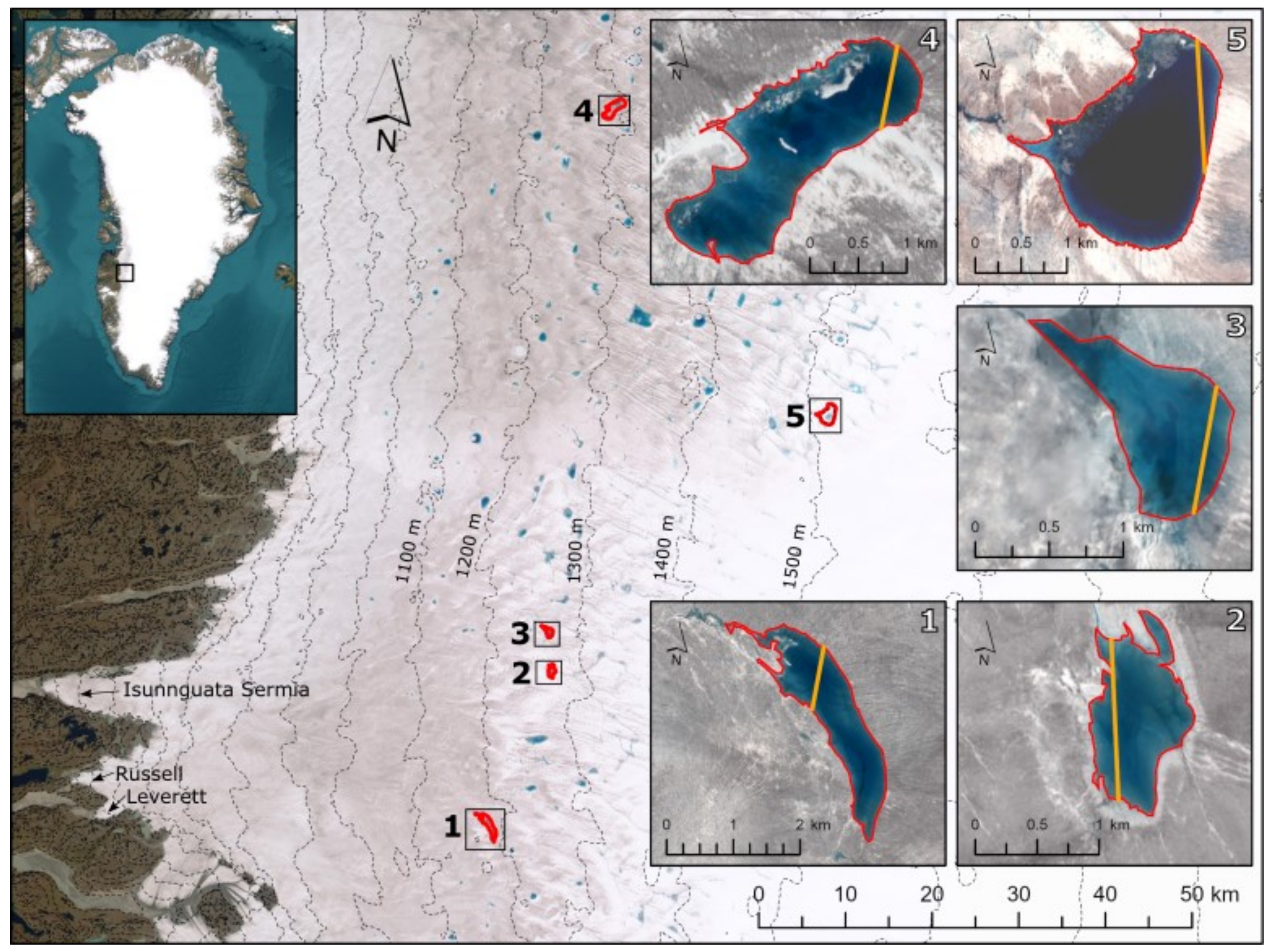
① Study Location & Data



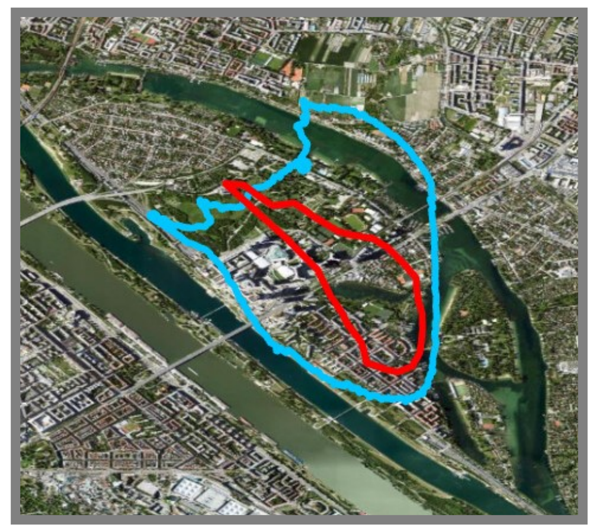
ArcticDEM digital elevation models (DEMs), ICESat-2 laser altimetry, and a physically based radiative transfer equation (RTE)[1] were used to estimate supraglacial lake (SGL) depth. Five SGLs in the southwest Greenland ice sheet were identified through cross-referencing data availability of each dataset. Each SGL has an associated ICESat-2 track with concurrent Sentinel-2 (S2) imagery, and an ArcticDEM DEM exhibiting an empty basin.

Radiative Transfer Equation (RTE)

z = Depth (m)
A_d = Bottom albedo
R_w = Pixels of interest
R_∞ = Deep water reflectance
g = Spectral radiance loss in the water column

$$z = \frac{\ln(A_d - R_\infty) - \ln(R_w - R_\infty)}{g}$$

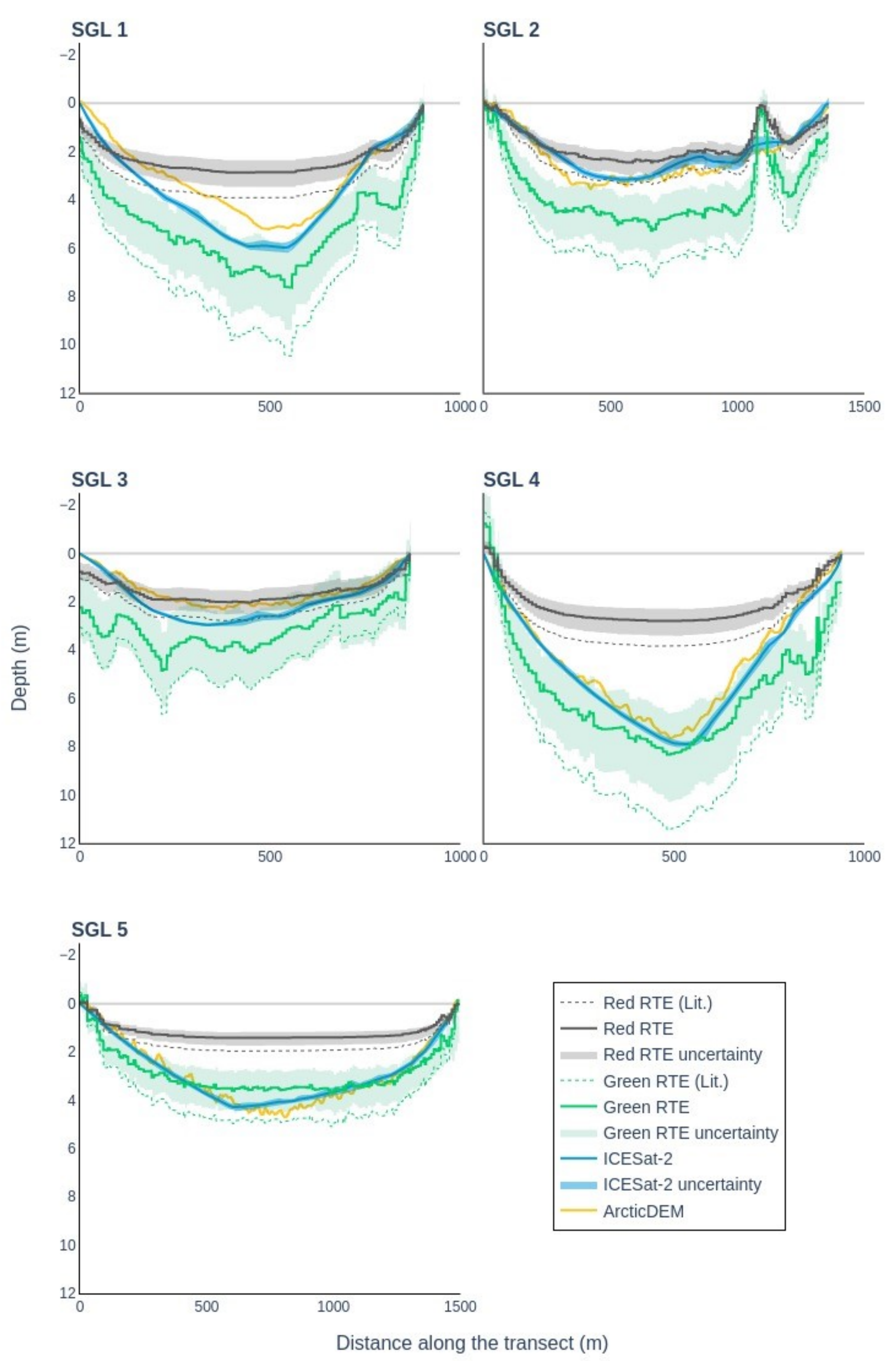
On the left is a map of the study area with inset maps of each of the five SGLs. The SGL outline is in red and the ICESat-2 tracks are shown as orange lines.



The size of the smallest SGL (#3, red, 0.8 km^2) and the largest SGL (#5, blue, 3.1 km^2) compared to the Austria Center Vienna is on the right.

[1] Philpot, W. D. (1987). Radiative transfer in stratified waters: a single-scattering approximation for irradiance. Applied Optics, 26(19), 4123.

② ICESat-2, ArcticDEM & the RTE



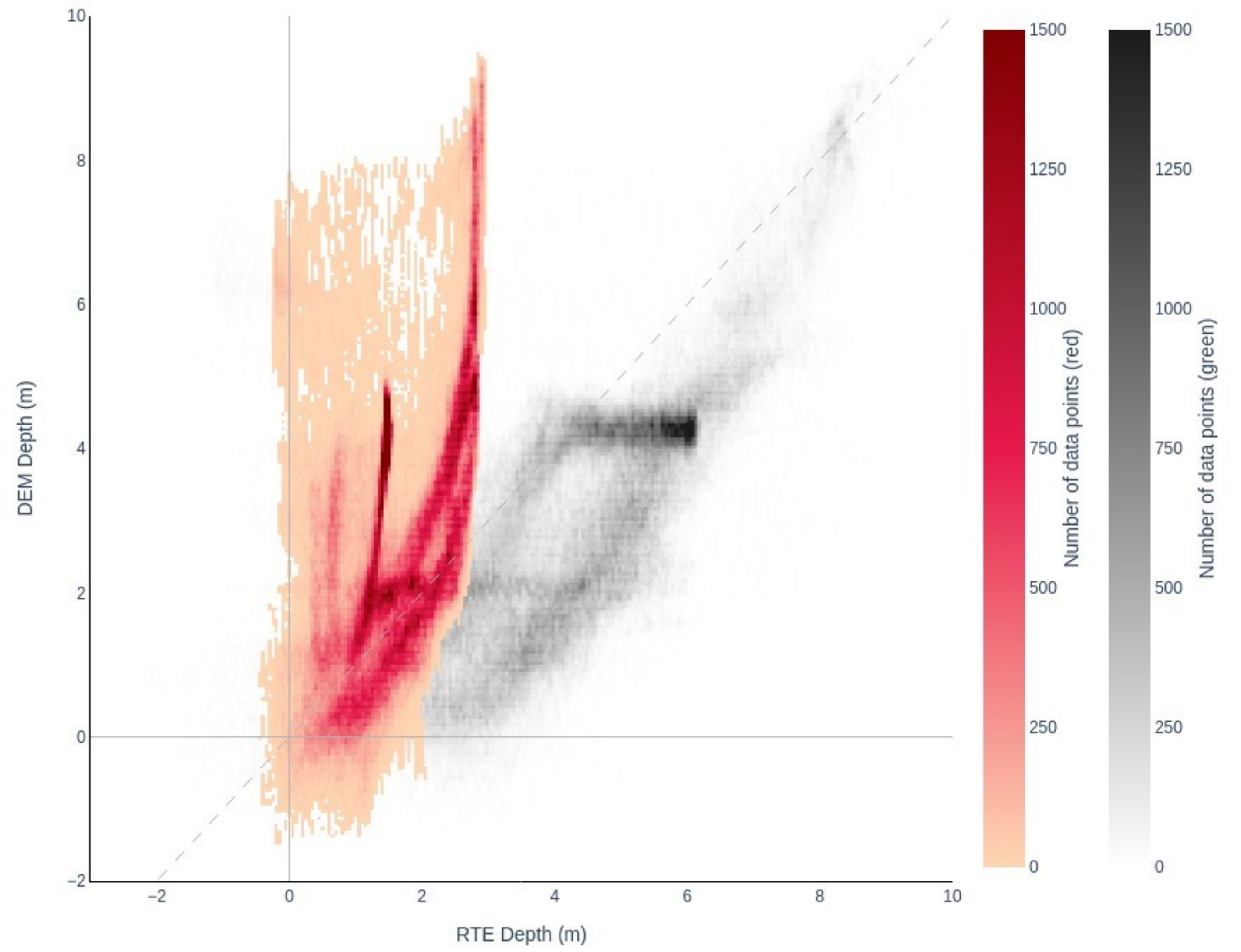
To the left are the depths achieved by each of the depth-detection techniques with associated uncertainties*. Depths were sampled along the ICESat-2 tracks (orange lines in the insets of the Panel 1 figure).

The RTE was calculated with both the red and green bands of S2 to determine their relative accuracy and reliability.

Our results show large variation between each of the methods, with green band RTE demonstrating a systematic overestimation of depth compared to the other methods. Compared to the DEM depths, the overestimation can be as high as 5.35 m. The red band RTE exhibits a plateau effect at ~1-3 m. The range of depths given by the green band RTE is largest, suggesting high uncertainty in the RTE calculation.

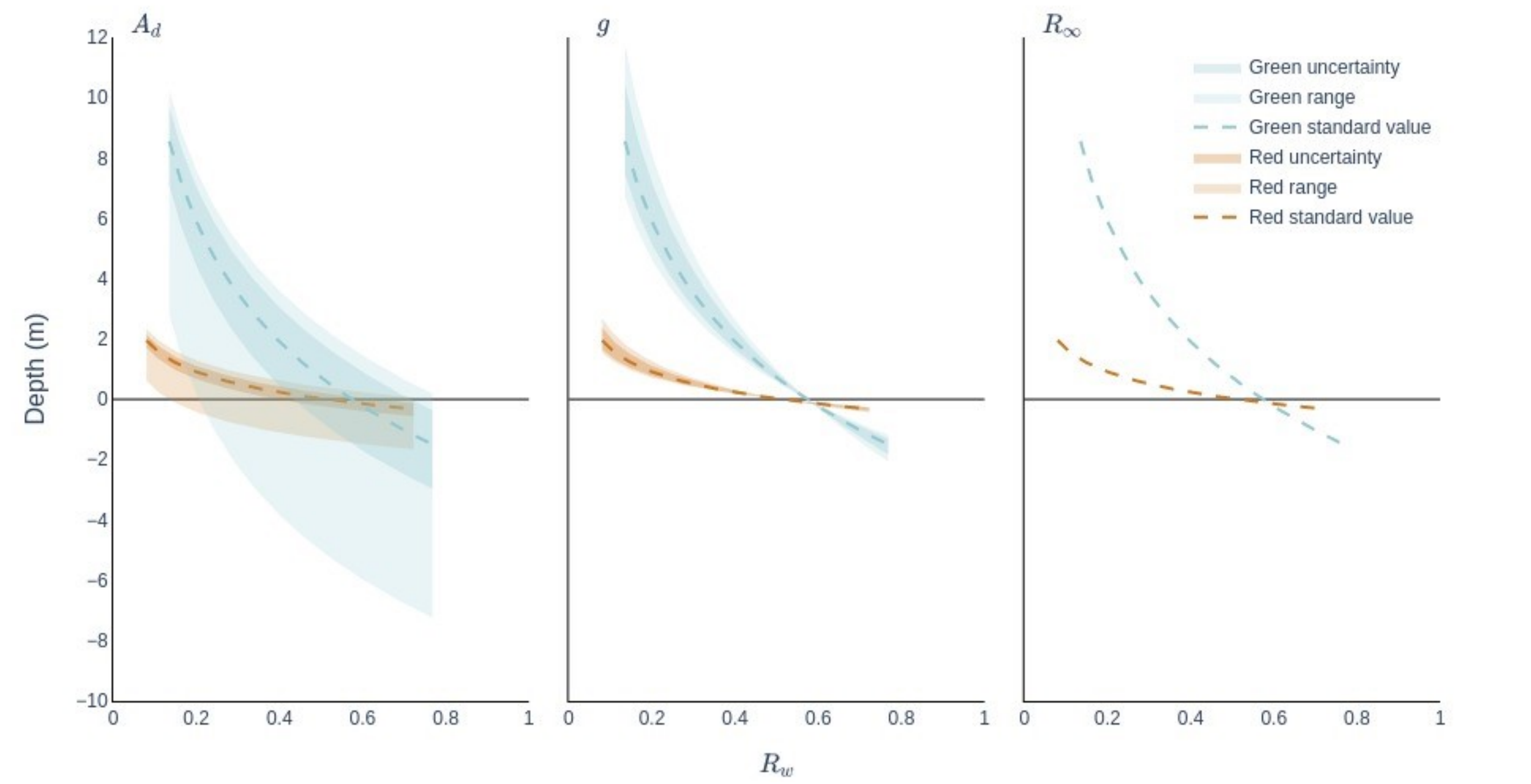
*Uncertainties are calculated as one σ. The ArcticDEM uncertainty is a constant 4 m in the vertical plane which is not represented on this figure to avoid overcrowding.

③ ArcticDEM vs the RTE



Above is the comparison of RTE depths to DEM depths. The darker spikes shown in the red band RTE cloud correlate with the plateauing effect seen in the figure in Panel 2. These plateaus are likely related to the depths achievable when A_d is varied (see Panel 4). The overestimation exhibited by the green RTE in Panel 2 is also shown here.

④ RTE Parameter Sensitivity



Above are the depths achieved by varying each of the tuneable parameters of the RTE. A_d exhibits the largest uncertainty and variation, followed by g and R_∞. The green band shows a larger uncertainty and range of depths than red.

The range of R_w and A_d are taken from the a 2019 SGL extent dataset of the study region (Glen et al., in prep). Uncertainties are calculated as one σ.

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