A Physics-Based Parameterization of Mean Melt Lake Depth and Area Fraction of Supraglacial Melt Lakes

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Full details of this work are in the following pre-print:

This presentation participates in OSPP

Outstanding Student & PhD candidate Presentation contest

Motivation

- Supraglacial melt lakes (SGLs) are features largely unrepresented in large-scale ice sheet modeling
- Use the statistical characteristics of glacier surface roughness to predict statistical average depth and areal coverage of supraglacial melt lakes

Statistical Roughness of the Antarctic Ice Sheet

We analyze Icesat -2 Elevation tracks in 10 km subtracks. We quantify the statistical surface roughness of Antarctica by:

1. **Hurst Exponent (H)**
2. **Roughness Amplitude (σ)**

Hurst is computed via Power Spectral Density analysis. Roughness amplitude is the standard deviation of the subtrack elevation.

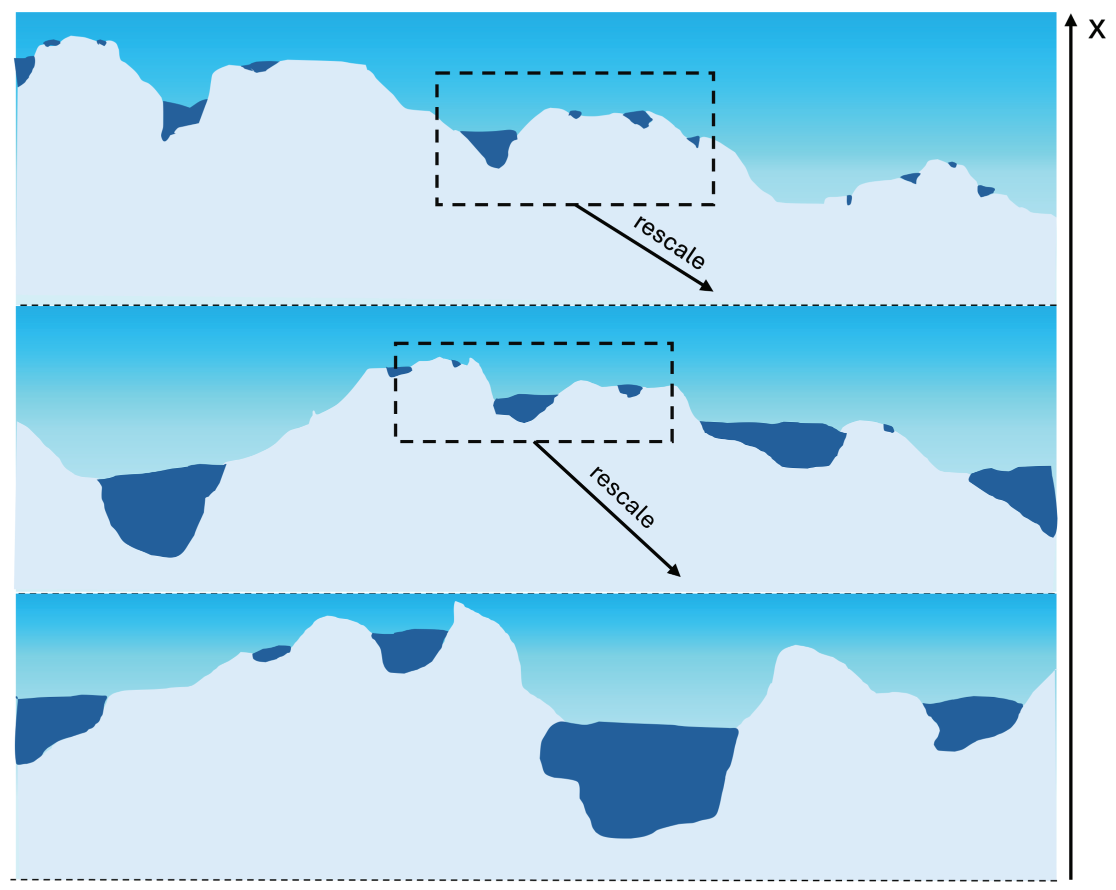

Figure 1: An example of the self-affinity on a glacial surface where the vertical pattern of topography is self-repeating at different horizontal length scales.

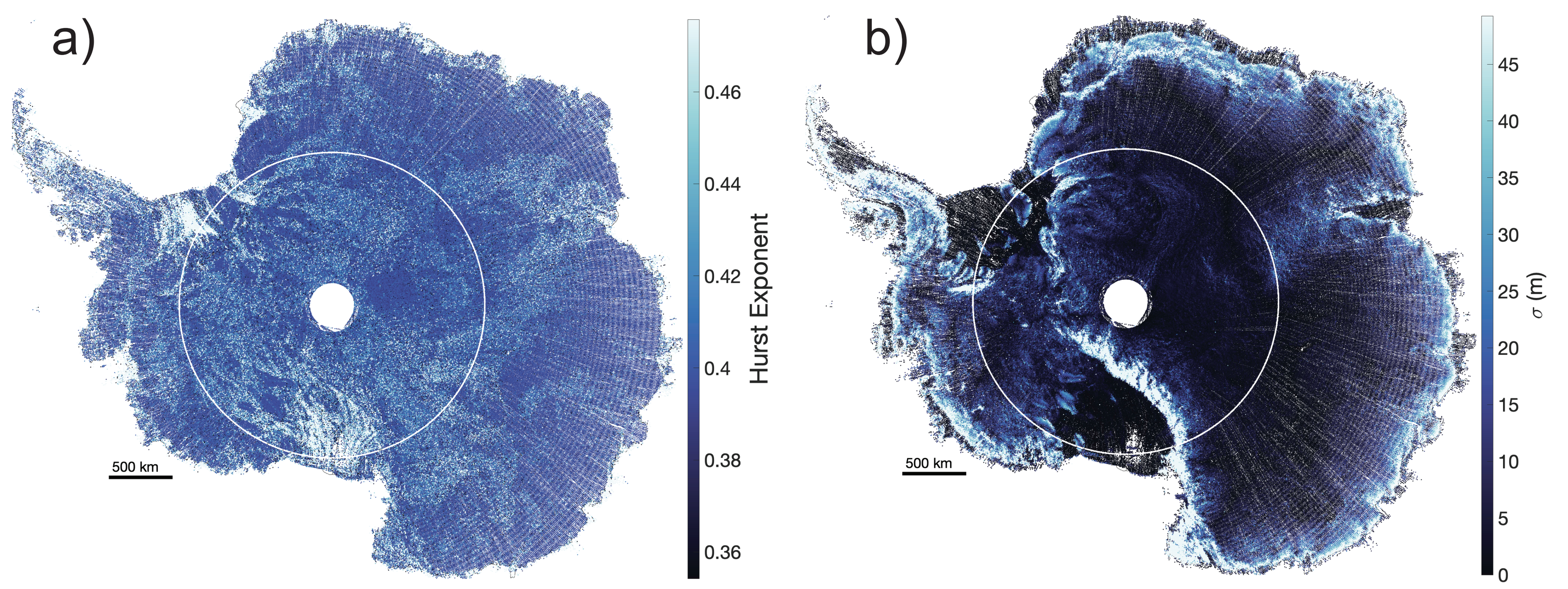

Figure 3a) Displays the computed Hurst exponent across the Antarctic Ice Sheet (AIS). Figure 3b) Displays the computed roughness amplitude across the (AIS).

The Antarctic Ice Sheet is self-affine in nature and has a mean Hurst exponent value of ~0.4.

Developing SGL Parameterizations

Monte Carlo Numerical Simulation Workflow

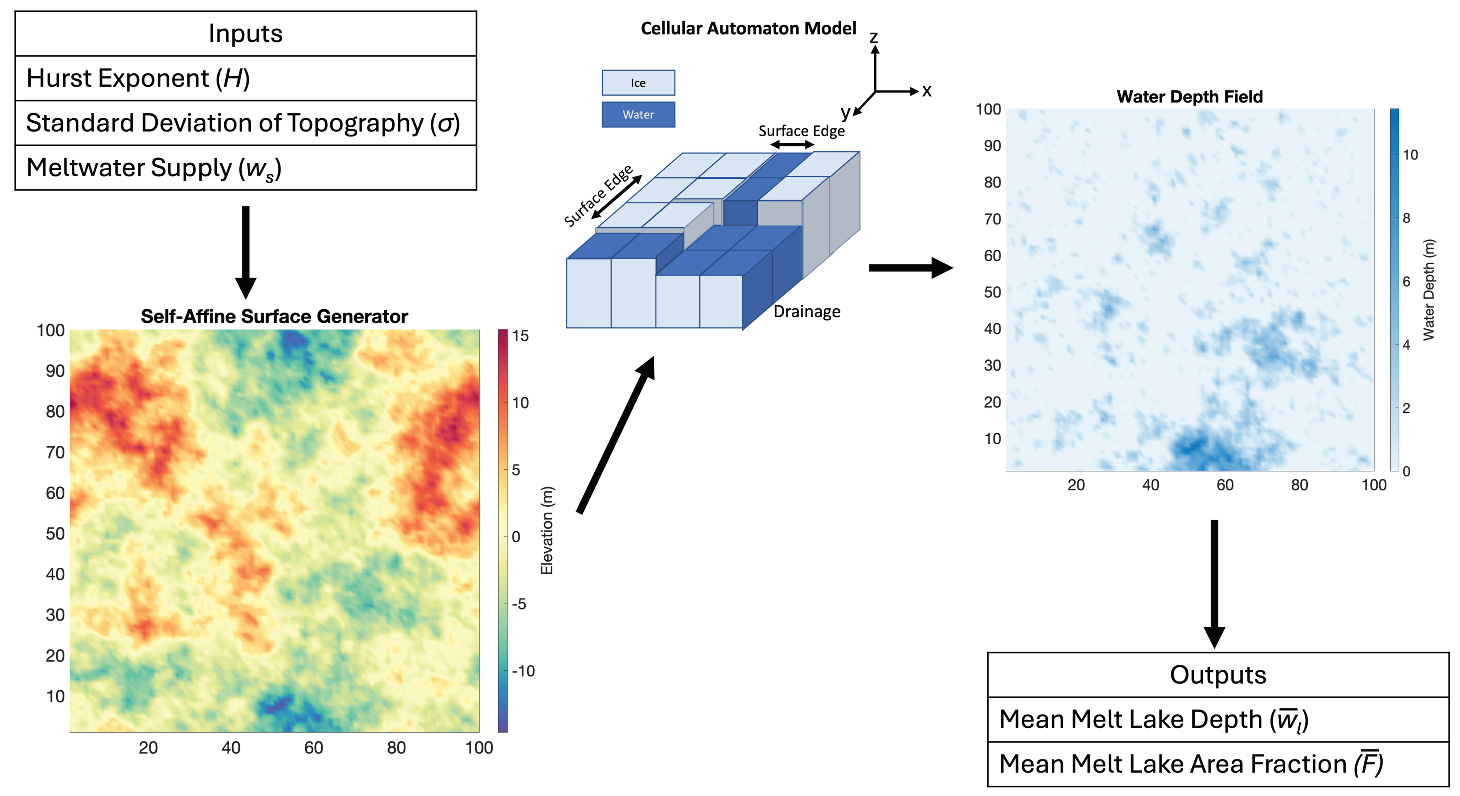

Figure 3: Monte-Carlo workflow of simluations used to develop the parameterizations.

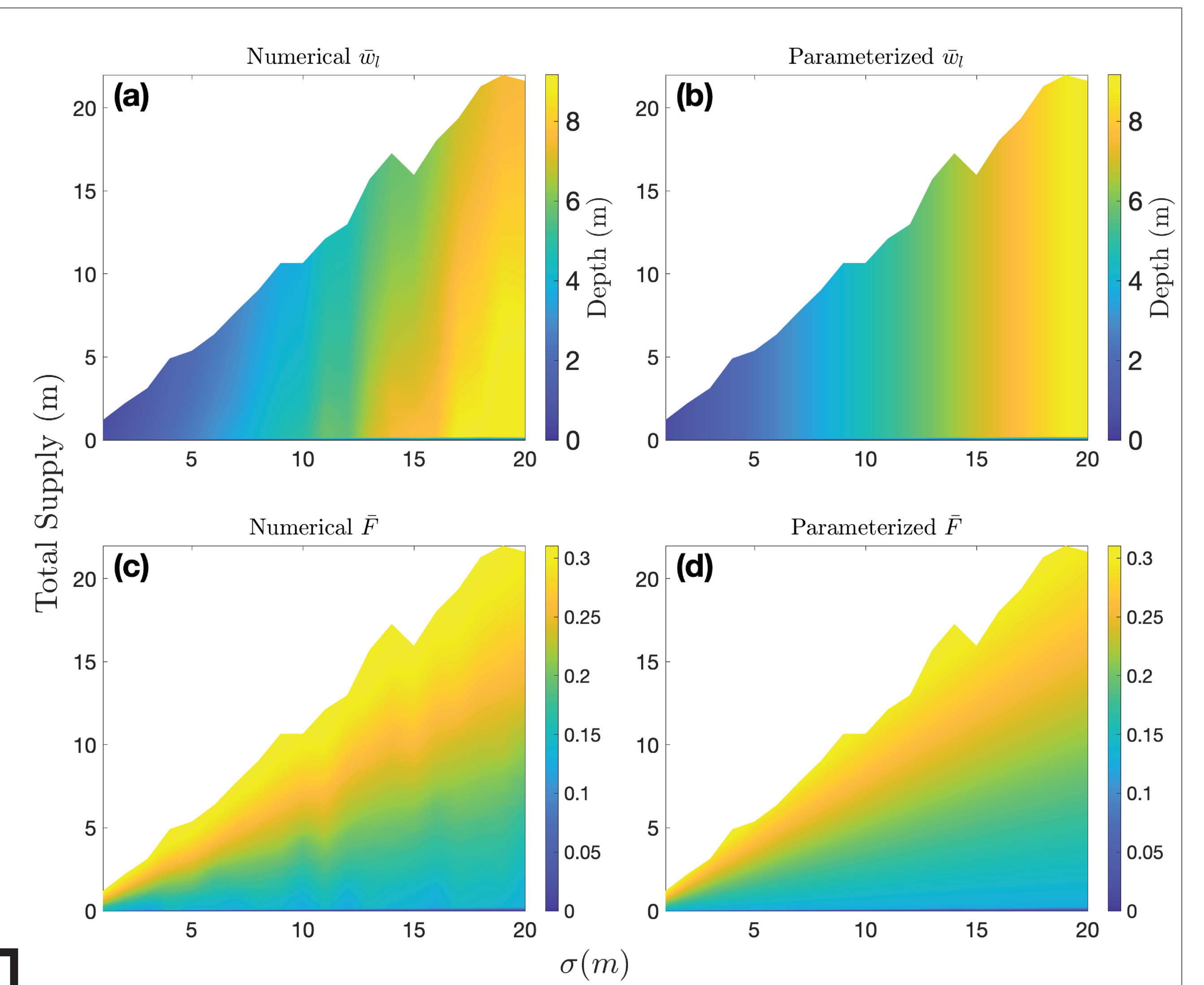

Figure 3a) and 3c) show the numerical results from the Monte Carlo simulations of SGL mean lake depth and area fraction for H = 0.4. Figure 3b) and 3d) show the estimatations of these characteristics when feeding the parameterizations the same numerical inputs.

Statistical SGL Parameterizations

Maximum Mean Water Depth of a Self Affine Surface

$$\bar{w}_d^*(H,\sigma) = \sigma(0.2 - 0.12H^{0.6})$$

Nondimensional Supply

$$S(H,\sigma) = w_s/\bar{w}_d^*(H,\sigma)$$

Mean Melt Lake Depth

$$\bar{w}_l(H,\sigma,S) = 0.6\sigma\,\mathrm{erf}\,(67S)\cdot(1 - 0.41H^{0.6})$$

Mean Area Fraction

$$\bar{F}(H,S) = 0.13\,\mathrm{erf}\,(55S)\cdot(1 - 0.13H^{1.3} + 2\,\mathrm{erf}\,(0.08S))$$

The parameterizations capture the overall pattern from the numerical simulations

Validation

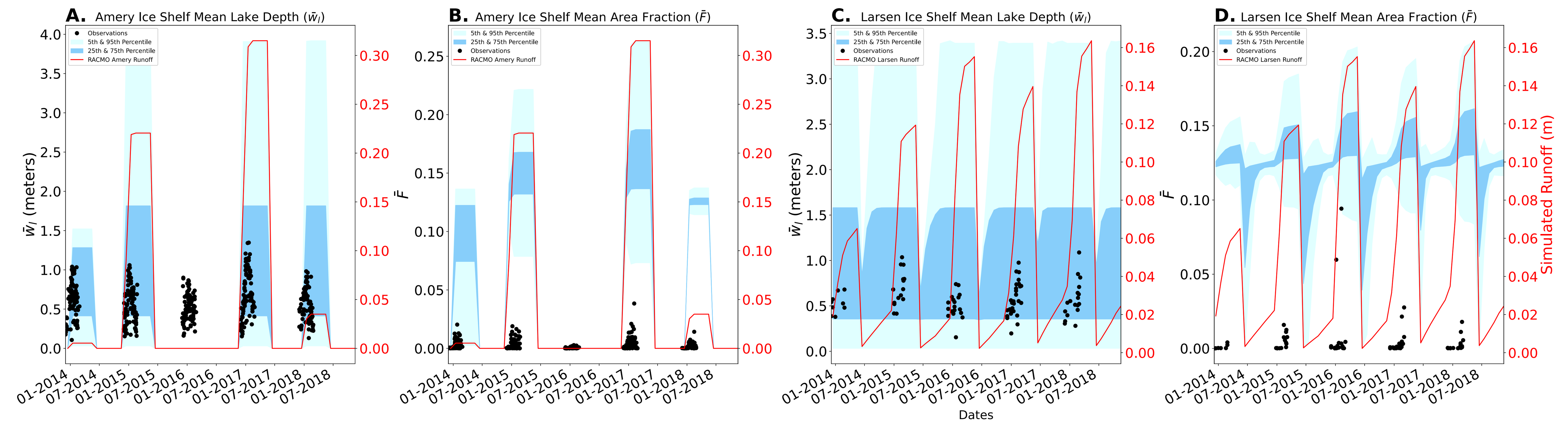

Figure 5: Displays the quartile (darker blue), 5th, and 95th percentile predictions of SGL mean lake depth and area coverage for Amery and Larsen C ice shelf, using RACMO runoff as the input supply (red line). Observations (black dots) of these parameters are from Moussavi et al., (2020).

Conclusion & Future Work

The parameterizations excel in determining SGL mean lake depth, but overestimates area fraction. Future work includes the implementation of these parameterizations in Ice-Sheet and Sea-Level System Model (ISSM).