The Influence of Lake Morphology on the Accuracy of Satellite-Derived Water Level Measurements (SWOT)

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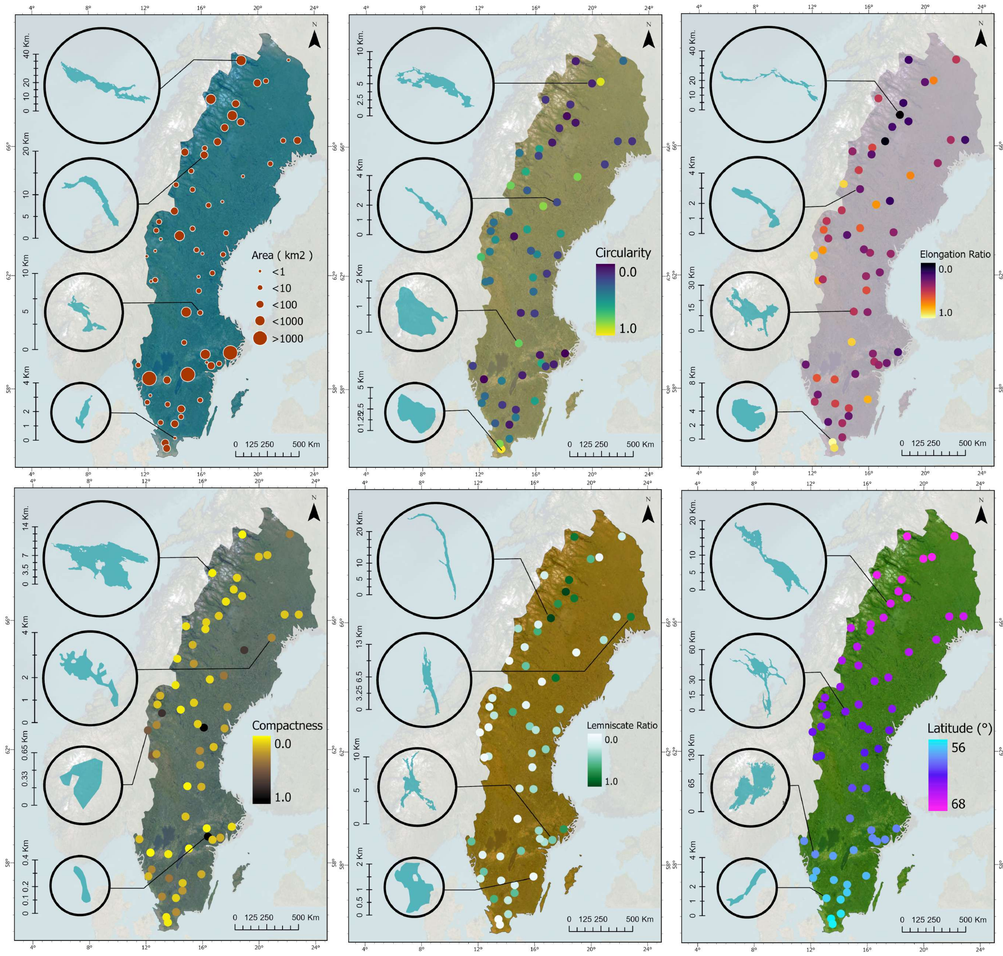
Introduction

Climate change, population growth and competing demands are tightening the pressure on freshwater resources. The new Surface Water and Ocean Topography (SWOT) mission provides global, 2-D water-surface elevations at an unprecedented resolution. Yet, the influence of lake morphology on SWOT accuracy remains largely untested. Here we evaluate 62 Swedish lakes that span two orders of magnitude in size and a wide range of shapes.



Objectives

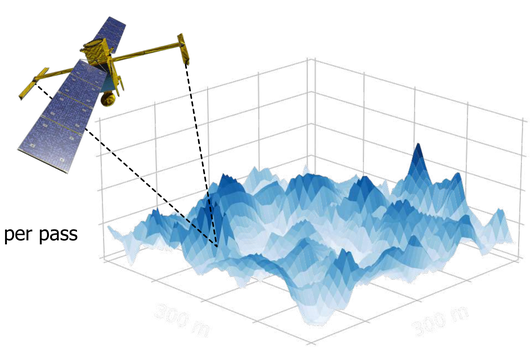
1.Verify that SWOT meets its 10 cm Root Mean Square Error (RMSE) design target for lake water-surface elevation (WSE).
2.Quantify how circularity, elongation, lemniscate index, compactness, area and latitude explain residual RMSE after accounting for area.

Data

- SWOT Hydrology L2_HR_PIXC (Aug 2023 – Mar 2025)
- Daily gauge data for 62 lakes from SMHI
- HydroLAKES polygons & static morphometry

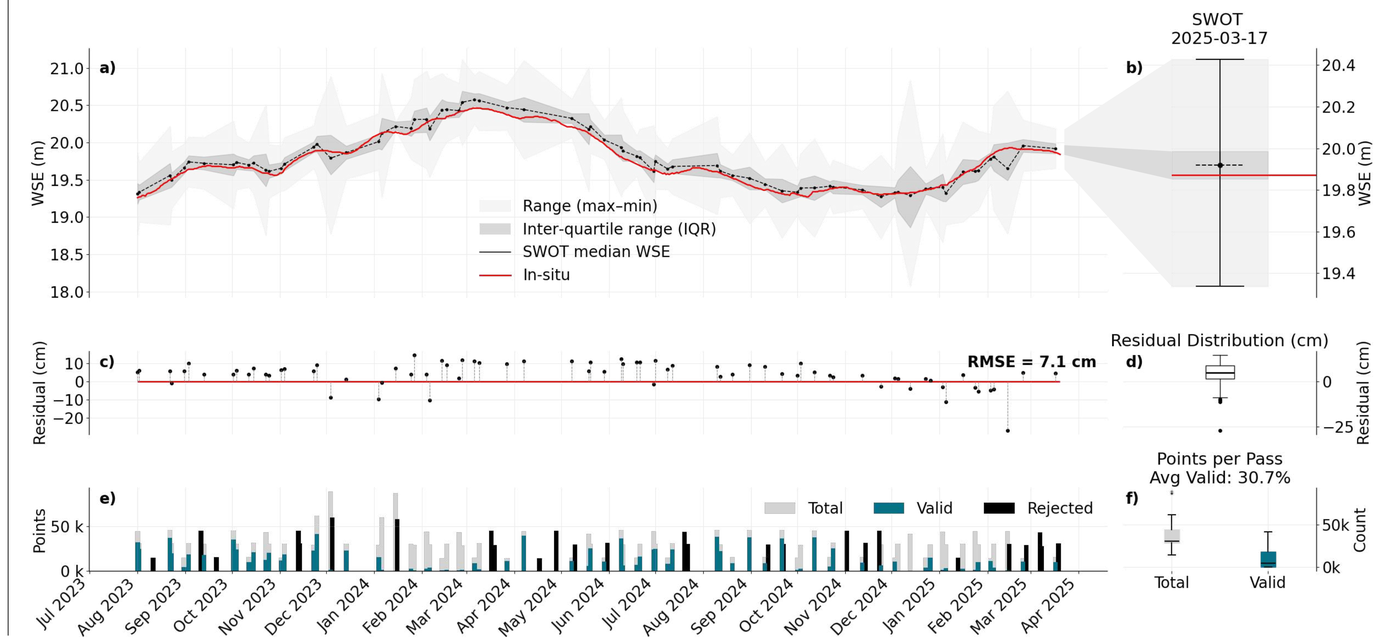
Methods

- Clip SWOT point-clouds with HydroLAKES outlines.
- Retain pixels flagged "good quality"; compute median WSE per pass
- Calculate RMSE against gauges.
- Test bivariate Pearson correlations.
- Fit multiple linear regression RMSE

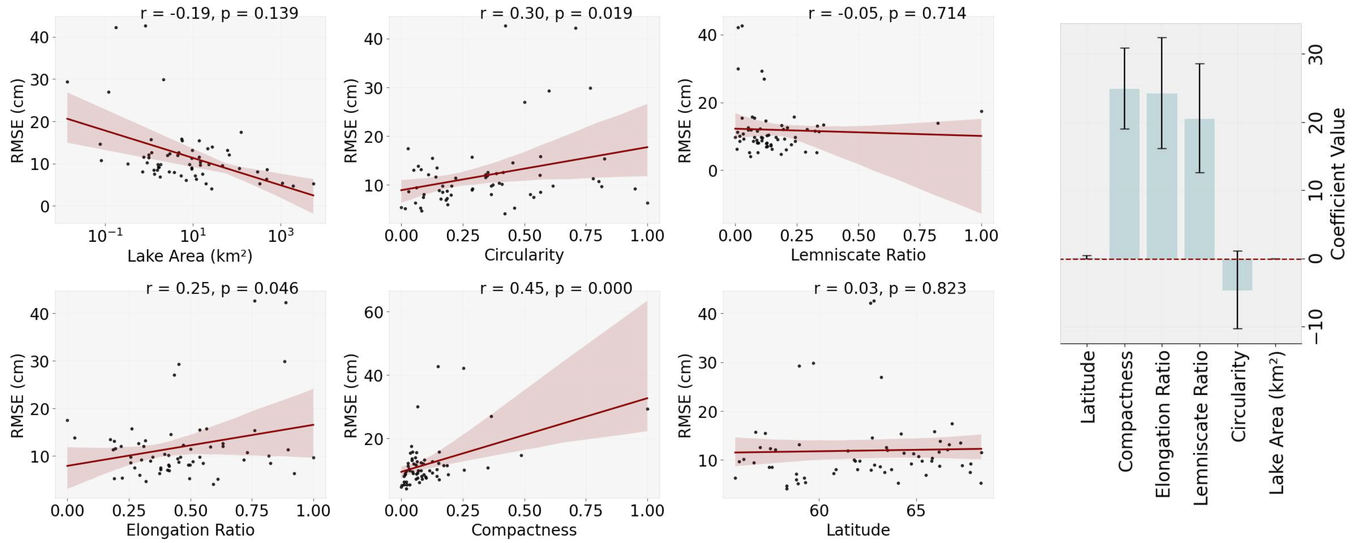


Results

- Design goal met for 94 % of passes and all lakes ≥ 1 km² (RMSE = 10.2 cm).
- Small lakes (< 1 km², n = 12) show higher error (19.1 cm) but still within 25 cm.



- Compactness is the dominant control (r = 0.45, p < 0.001), followed by circularity (r = 0.30) and elongation (r = 0.25).
- Together, shape metrics explain 38 % of RMSE variance; area, lemniscate index and latitude are not significant once shape is included.



Conclusion

Our evaluation demonstrates that SWOT reliably attains its design specification of ≤ 10 cm RMSE for lakes ≥ 1 km² and maintains acceptable performance (≤ 25 cm) even for smaller waterbodies. Multivariate analysis reveals that shoreline compactness, circularity and elongation collectively explain 38 % of residual error, whereas lake area, lemniscate index and latitude exert no significant influence once shape is accounted for. These findings underscore lake morphometry,rather than size,as the primary determinant of SWOT accuracy, highlighting the vulnerability of highly indented shorelines to phase-decorrelation and geolocation bias.