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Monitoring the Arctic Ocean with SWOT - A comparison with conventional altimeter measurements in the ice-covered ocean

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Motivation:

- **SWOT:** Provides 500m (effective) resolution sea surface height (SSH) data in Arctic peripheral seas up to 78°N, enabling improved lead detection and comprehensive Arctic Ocean circulation analysis
- **Objective:** Initial assessment of SWOT's suitability for polar ocean research through Arctic-wide evaluation of 2D swath SSH observations from March 2023 until April 2024
- **Validation approach:** Comparison of SWOT with ICESat-2 laser altimetry at ~550 crossover locations within 30-minute time gaps during sea ice conditions
- **Analysis focus:** Quantification of differences between SWOT and ICESat-2; investigation of causes of discrepancies, including small-scale effects, SWOT calibration issues, seasonal and regional impacts

Input datasets:

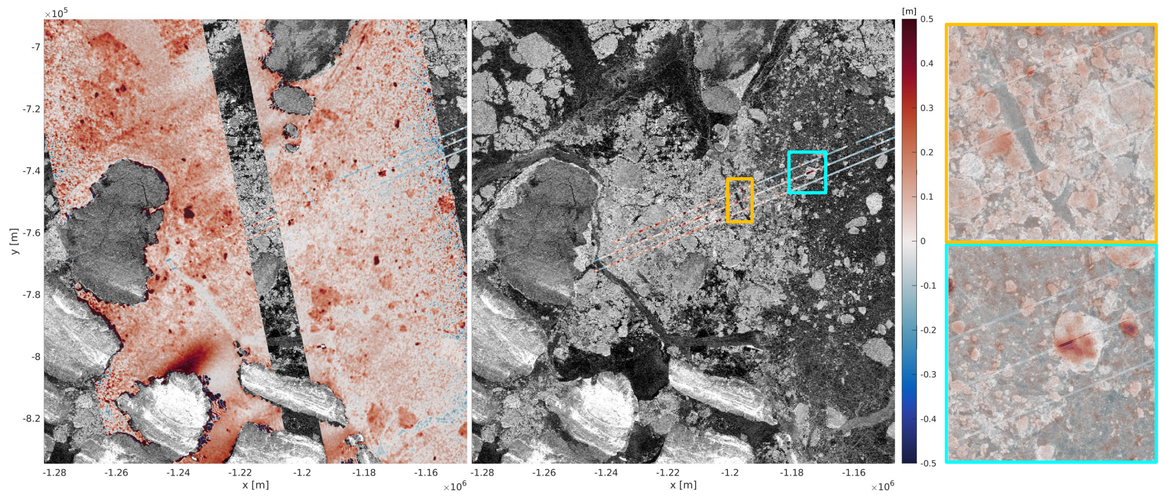
- SWOT Level 2 KaRIn LR SSH Unsmoothed and Expert products from cal/val and science orbit phase (Version C)
- ICESat-2 Level-3A ATL07 Version 6 sea ice product
- Sentinel-1A SAR images to support visual comparisons

Pre-processing:

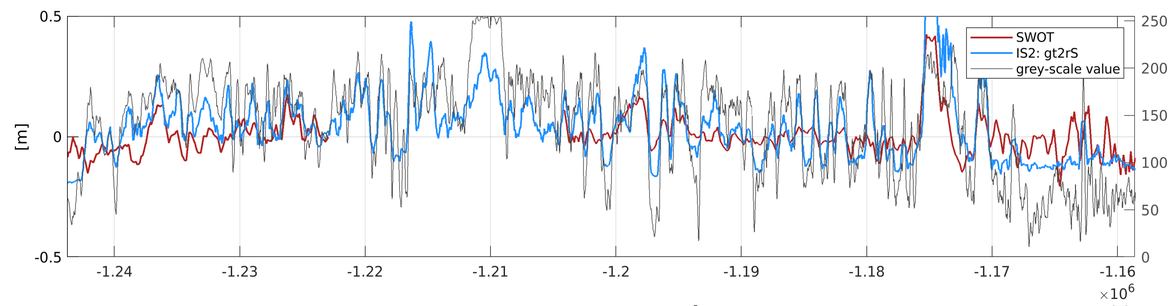
- Height calibration correction interpolated from Expert product
- Datasets are modified to be as consistent as possible (same reference and geophysical corrections applied)
- ±5 km of the outer and inner swath boundaries are cut off due to large noise and artefacts
- Smoothing of ICESat-2 elevations and Sentinel-1 grey values to match the 500-meter resolution of SWOT
- Interpolation of SWOT wide-swath data to ICESat-2 beam locations to enable point-by-point comparisons

Comparison:

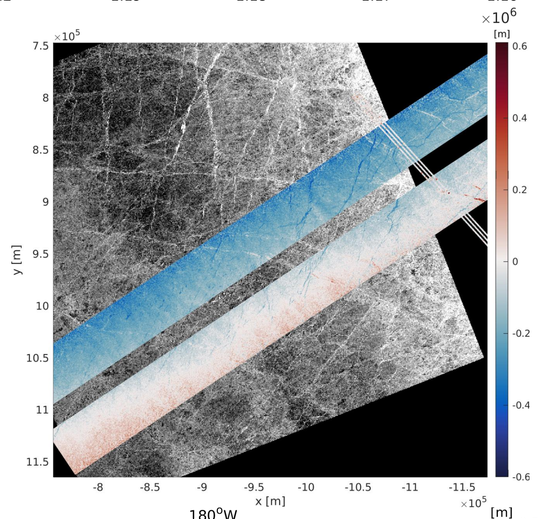
- Visual comparisons show coherence between dark SAR pixels and low heights of SWOT and ICESat-2 (i.e. leads)
- Analysis of absolute SLA differences shows differences between left and right swath (around 5 to 50 cm)
- Analysis of the standard deviation (STD) of the differences between ICESat-2 and SWOT shows an average of 8 cm for all surface types, and 6 cm for ICESat-2-detected leads
- Seasonal analysis of STD shows higher values during melting period between May and June



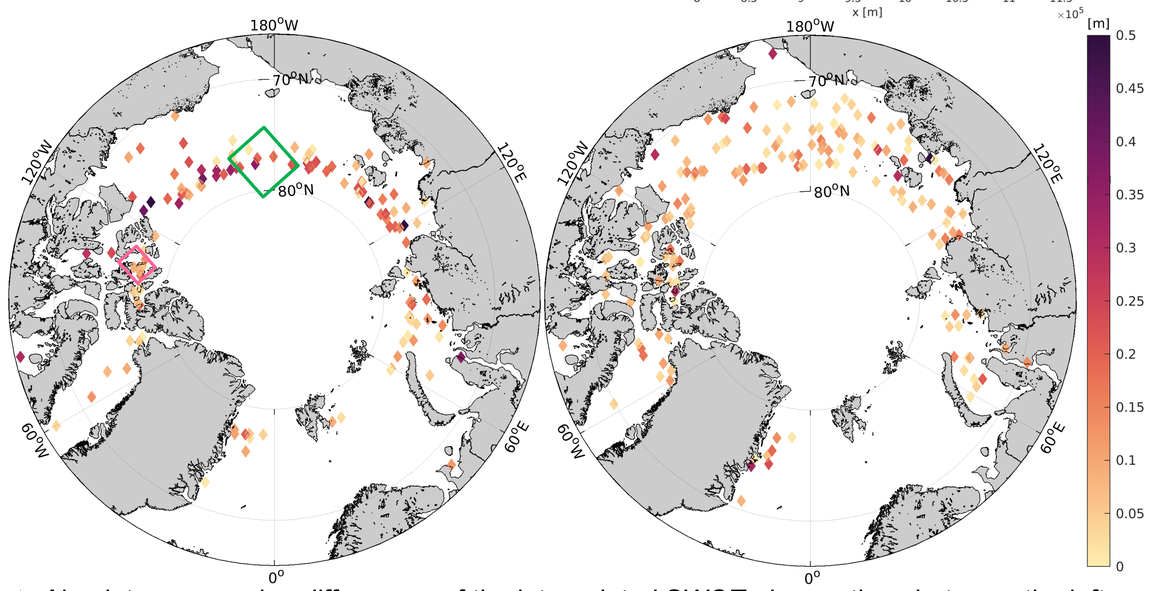
▲ *SWOT SLA swath, ICESat-2 profiles and Sentinel-1 image on 2024-01-25 in the Canadian Archipelago with and without SWOT (left/middle). Right side shows two zooms with backgrounded SAR grey-scale value information. Acquisition time differences: SWOT vs. ICESat-2, 5~min.; SWOT vs. Sentinel-1, 60~min.*



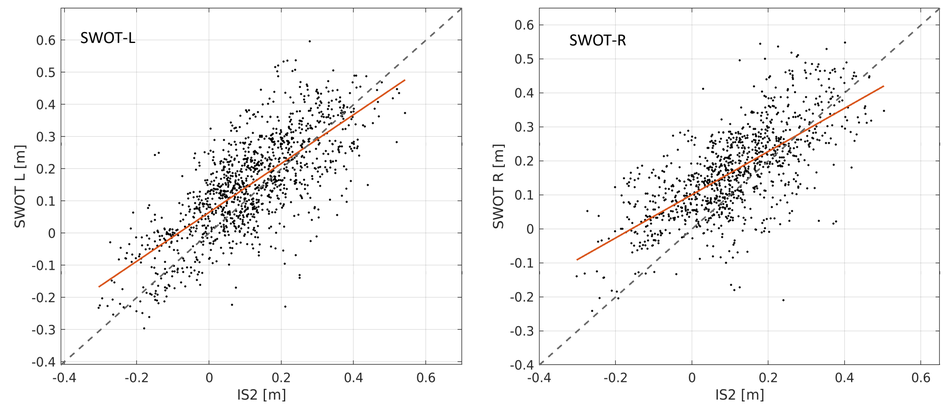
▲ *Along-track height comparisons in the Canadian Archipelago for the middle strong beam of ICESat-2 (blue). Interpolated SWOT heights in red and Sentinel-1 grey-scale values (right axis). Along-track elevations are zero-centered.*



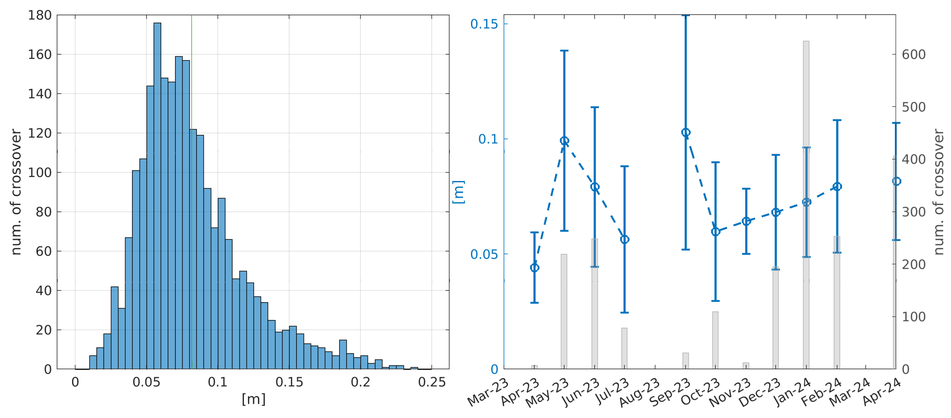
► *SWOT SLA swath, ICESat-2 profiles with underlying Sentinel-1 image on 2024-01-21 in the Chukchi Sea (projection: EPSG:3413). Acquisition time differences: SWOT vs. ICESat-2, 20~min.; SWOT vs. Sentinel-1, 38~min.*



▲ *Absolute mean value differences of the interpolated SWOT observations between the left and right swath for January/February 2024 (left) and other months (right). Different laser beams are averaged per swath side. Rectangles indicate SAR image position of the upper figures*



▲ *Scatter plots of ICESat-2 against interpolated SWOT SLAs per crossover for all three beams with regression line (red) and bisectrix (dashed)*



▲ *Histogram (left) and monthly averaged time series (right) of standard deviations of point-by-point differences between SWOT swath and strong ICESat-2 laser beams. The green line indicates a mean value of 0.08 m*

Outcomes:

- Clear visual coherence between SWOT, ICESat-2 and Sentinel-1 over open water patches and sea-ice surfaces
- SWOT shows limitations in detecting small-scale features compared to ICESat-2 laser profiles
- Significant swath side-dependent differences, especially in winter and in fully ice-covered regions, possibly indicating problems in the computation of the crossover calibration correction
- Figures shown and more info can be found in: **Müller F. L., Dettmering D., Seitz F., First Arctic-wide assessment of SWOT swath altimetry with ICESat-2 over sea ice (submitted, The Cryosphere) -→ preprint at EGUsphere**

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