Analysing the resolution of SWOT altimetry for geodetic applications

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Abstract:

The Surface Water and Ocean Topography (SWOT) mission uses advanced radar technology to measure global waters in wide-swath. We estimate the resolution and accuracy from SWOT altimetric observations in wide-swath along the Central Kerguelen Plateau in Southern Indian Ocean to derive marine gravity anomalies. In this region, the sea surface slopes (SSS) from a single cycle of SWOT has a standard deviation of~2 µrad with a resolution of 15 km at~4m significant wave height. Averaging 97 cycles of repeated measurements from SWOT in fast-sampling orbit has reduced the standard deviation of SSS to ~1.2 µrad. The spatial resolution of stacked data has improved to ~7 km resulting in >20% improvement compared to conventional altimetry. These enhanced resolution estimates help in the retrieval of high-resolution marine gravity field to better understand the plate tectonics and seafloor beneath the ocean surface.

Introduction:

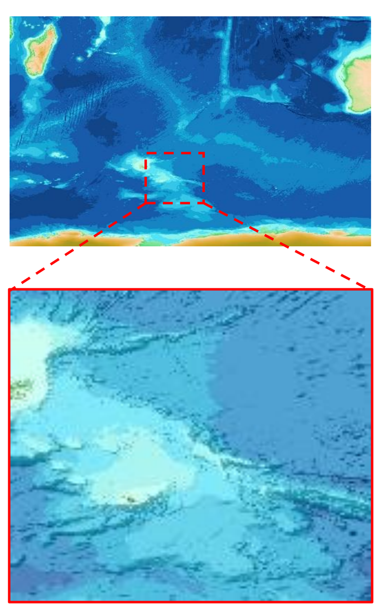
High-resolution ocean topography and gravity near to the coasts are very crucial to improve the understanding of many tectonic and volcanic processes. The Ka-band radar interferometer (KaRIn) on-board SWOT, provides the first ever wide-swath measurements on the elevation of global waters[1]. It provides an opportunity to measure the ocean surface in unprecedented details even in shallow waters and has the potential to improve the spatial resolution of geoid anomalies.

Data and Study Area:

We use the L2_LR_SSH Data Product (Version 2) from fast calibration and validation (CalVal) orbit with a repeat cycle of ~1 day. The ocean topography measurements are saved as 2 km x 2 km grids in along-track and cross-track directions. We compute the corrected SSH as:

$$cor\_SSH = ssha\_karin + height\_cor\_xover + mean\_sea\_surface\_cnescls$$

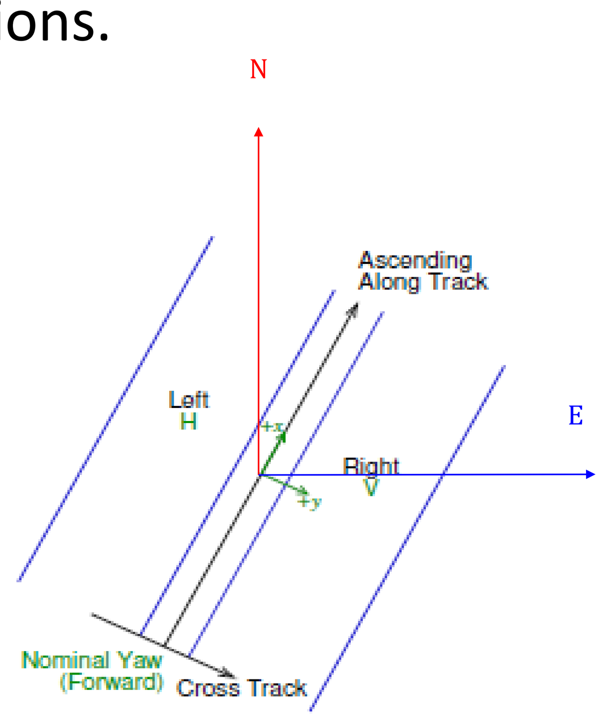
where, ssha_karin is the SSH anomaly corrected for solid earth tide, pole tide, ocean tide, coherent internal tide, and dynamic atmospheric correction, height_cor_xover is the built-in crossover calibration, and mean_sea_surface_cnescls is the mean SSH above the WGS84 reference ellipsoid given by CNES_CLS_22. Ice and land flags are applied to the SWOT data, and bad data (suspect/degraded) are eliminated using quality (ssha_karin_qual) flags to select only valid ocean observations.

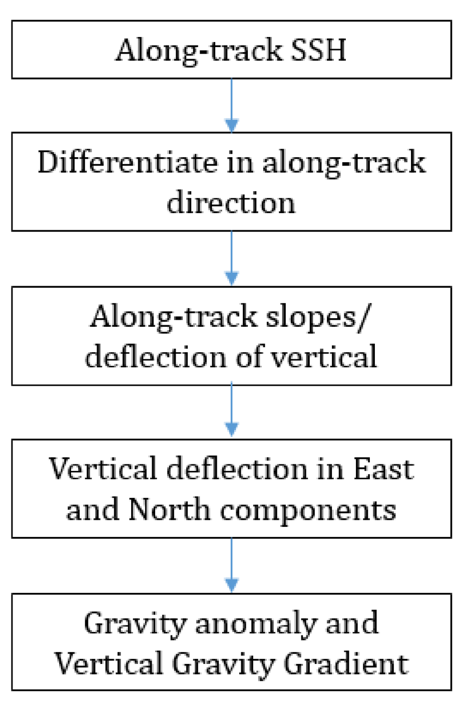


We choose the SWOT passes (from ascending and descending orbits) along the Central Kerguelen Plateau in Southern Indian Ocean to derive marine gravity anomalies.

Methodology:

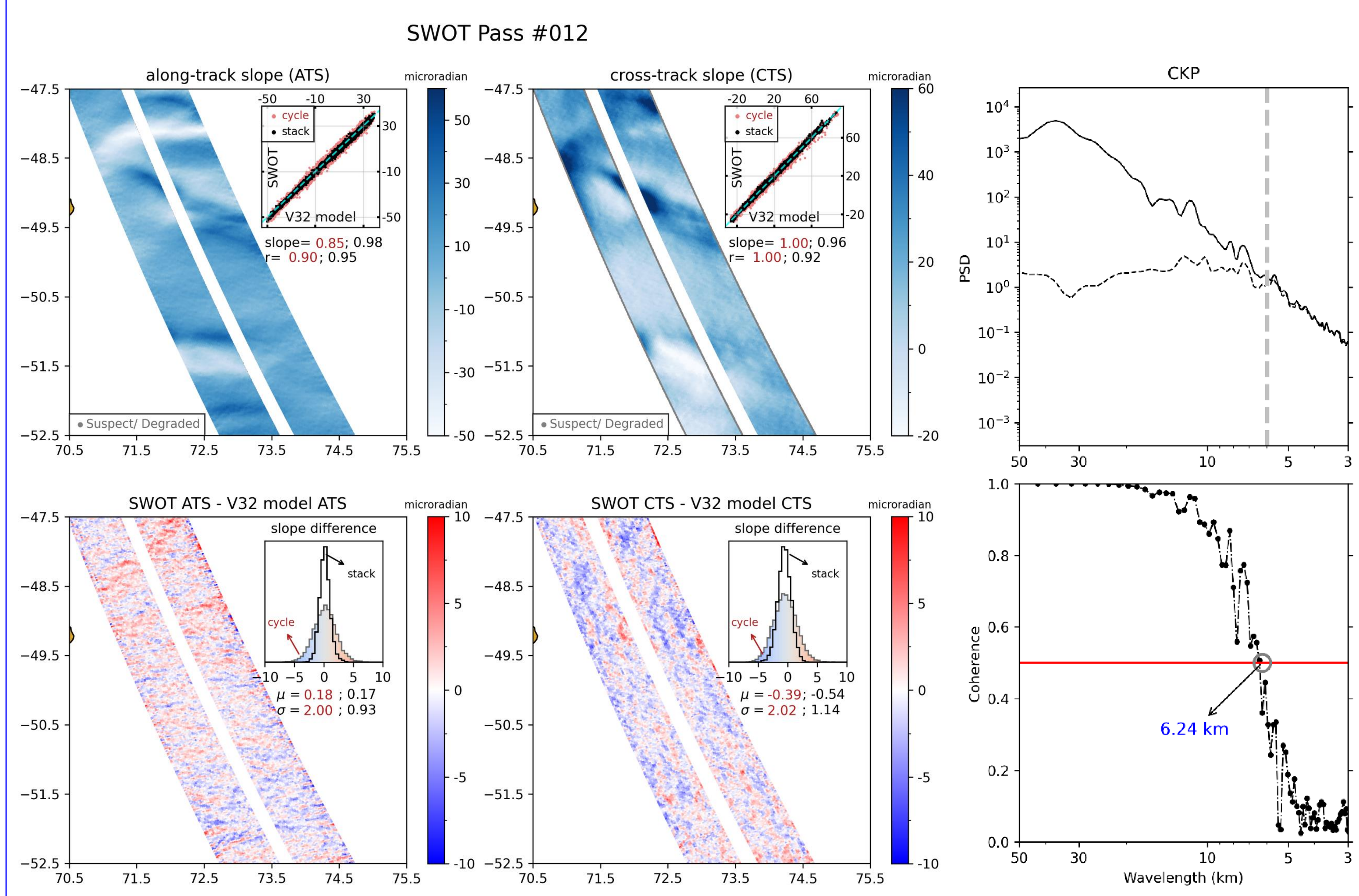
The horizontal gradient on the corrected SSH in the along-track and cross-track directions results in 2-D grids of along-track and cross track sea surface slopes (SSS) respectively. We average 97 cycles of repeated measurements from SWOT using PyReX[2] to derive stacked SSS. Similarly, we extract SSS from V32 model[3] in the along-track and cross-track directions of SWOT. Finally, we perform the power spectral and cross spectral analysis to the SWOT slopes and model slopes in order to assess the accuracy and resolution of SWOT data for geodetic applications.





Results and Discussions:

The accuracy of SSS from a single cycle of SWOT has a standard deviation of~2 µrad with a resolution of 15 km at~4m significant wave height. Stacking reduces the oceanographic signal and improves the accuracy of SSS from SWOT to ~1.2 µrad. The difference between stack slope and model slope is termed as 'noise'. The stack slope and noise are of the same order of magnitude for wavelengths less than 7 km. In addition, the minimum resolvable wavelength computed using the cross-spectral analysis of the noise and single cycle of SWOT is 15 km. However, stacked slopes are resolved at ~7km wavelength.



Conclusions:

We estimate the resolution and accuracy from SWOT altimetric observations in wide-swath along the Central Kerguelen Plateau in Southern Indian Ocean to derive marine gravity anomalies. The major conclusions are as follows:

i. A single cycle of SWOT SSS measurements are accurate up to ~2 µrad with a resolution of 15 km.
ii. Stacked slopes have improved estimates with an accuracy of ~1.2 µrad at spatial resolution of ~7km.
iii. This results in an improvement of >20% compared to the V32 gravity model derived from conventional nadir altimetry.
iv. These enhanced resolution estimates from SWOT measurements help in the retrieval of high-resolution marine gravity field to better understand the plate tectonics and seafloor beneath the ocean surface.
v. In addition, SWOT data has the potential to improve the spatial resolution of geoid anomalies along the continental margins.

References:

1. Fu et al., 2024. GRL
2. Vikram et al., 2024. Under review in ESS
3. Sandwell et al., 2021. ASR
4. Krishna and Sreejith. 2020. IJRS

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