Accuracy and Resolution of SWOT Altimetry: Foundation Seamounts

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Introduction

The Foundation seamounts is a 1400-km long chain of approximately 40 large seamounts (2-4 km tall)) constructed on young seafloor discovered by a combination of spase ship soundings and satellite altimeter-derived gravity (Mammericks 1992). In January-February, 1997 an extensive multibeam and gravity survey was carried out by the L' Atalante using a dual multibeam sonar and shipboard gravimeter (Figure 1). These seamounts have some unique characteristics that make an ideal location for calibration and validation of SWOT measurements of sea surface height (MSS) and slope (SSS):

1) The seamounts formed on very young seafloor with age ranging from 0 to 9 Ma so the mean ocean depth varies from 2600 m to 3500 m.
2) Because the seafloor is young and far from sources of sediment supply, it is mostly barren rock having a relative uniform density 2550 to 2750 kg m^{-3} (Maia and Arkani-Hamed, 2002).
3) Within the areas of the 1-day SWOT coverage there are approximately 30 closely-spaced volcanoes having heights ranging from 1500 to 3500 m. These produce very large amplitude (20-120 mGal), short wavelength gravity peaks (Figure 2). The accuracy of the shipboard gravity is better than 1.5 mGal so the signal to noise ratio exceeds 100.
4) The short wavelength mesoscale (> 18 km) variability in the region is relatively low (e.g., sea surface slope varibility of >~2 microradians which corresponds to ~2 mGal). The uncertainty in the mean slope is between 0.5 and 2 microradian depending on the number of repeat altimeter profiles. This oceanographic "noise" is 50-100 times smaller than the gravity signal so can be largely ignored in our analysis of SWOT data.

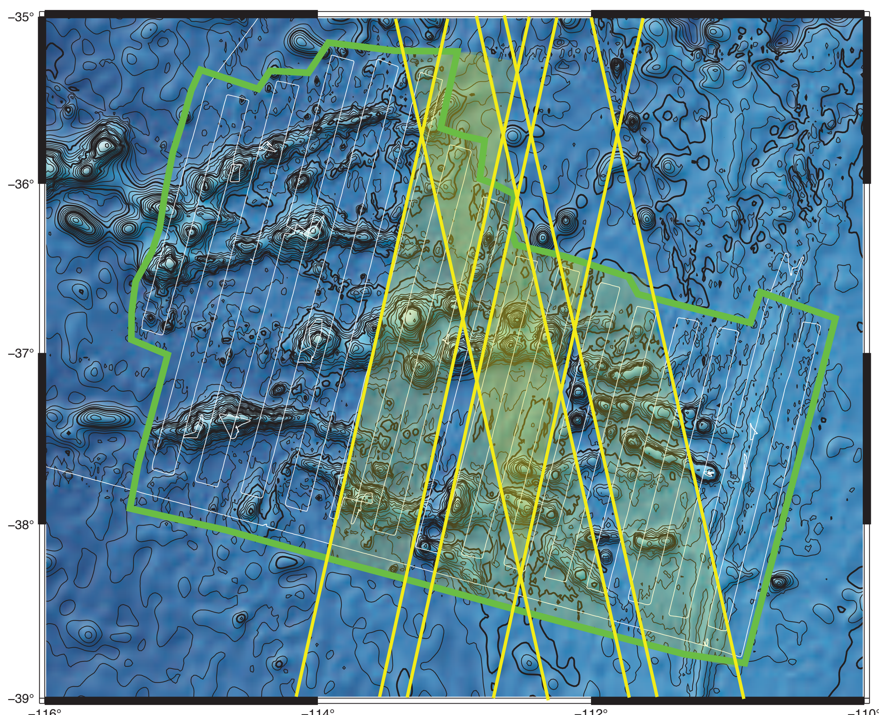

Figure 1. Contours of seafloor bathymetry of the Foundation seamounts. White lines show ship track where gravity and multibeam bathymetry was collected. Green line shows perimeter of multibeam coverage. Yellow polygons with shading mark the swaths of the SWOT altimeter.

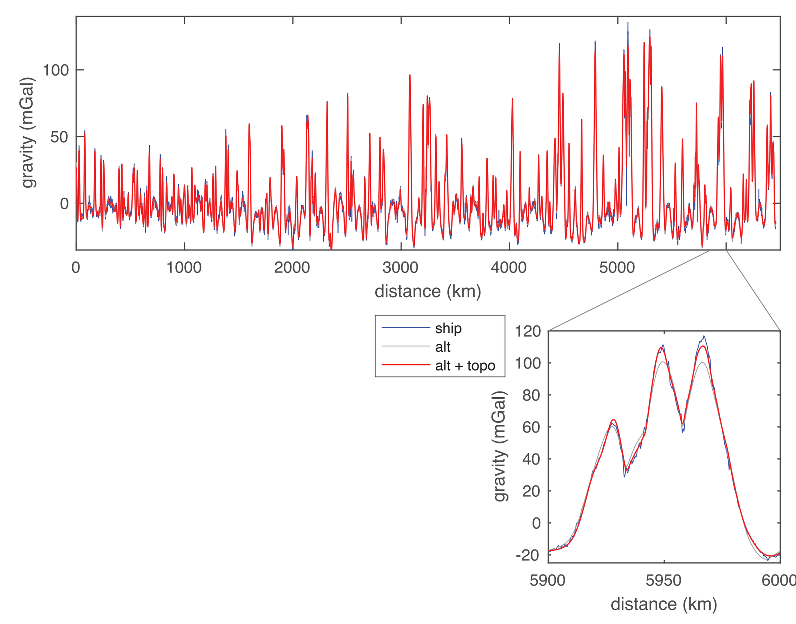

Figure 2. Gravity versus distance along the L' Atalante trackline shown in Figure 1, ship gravity (blue), altimeter gravity (grey), and combined altimeter/topography gravity (red). The median absolute deviation between the altimeter and ship gravity is 2.05 mGal and between the combined and ship gravity is 1.42 mGal (1 mGal ~ 0.98 microradian).

Construction of a 7 km resolution MSS

We need to construct mean sea surface height (MSS) or sea surface slope (SSS gradient) that is at least as accurate as the SWOT data. Current MSS and SSS slope grids are accurate to a few cm and a few microradian, respectively. Moreover, the altimeter-based grids cannot resolve wavelengths less than about 12 km because the data are filtered to reduce the noise from ocean waves and other environmental factors.

Higher accuracy and resolution MSS/SSS can be achieved at the Foundation seamounts using a combination of multibeam sonar and gravity collected over this area. The basic approach is to constrain the longer wavelength MSS/SSS (> 40 km) with the altimeter-derived products, and the shorter wavelength MSS/SSS (< 40 km) using the multibeam sonar bathymetry as input to a 3-D isostatically compensated gravity model. The important parameter is the crustal density and this is adjusted so the combined gravity model best matches the gravity profile observed by the ship.

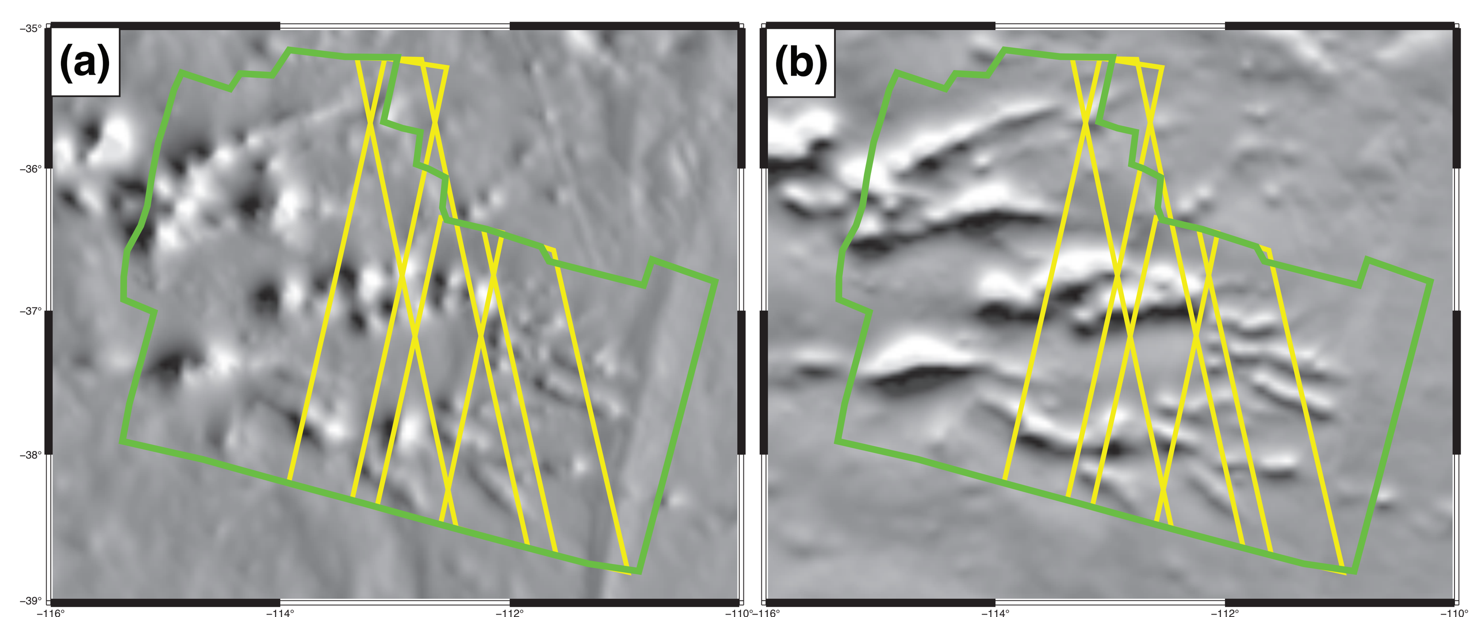

Figure 3. (a) East component of sea surface slope based on combined slopes from altimetry and multibeam topography (grey scale +/40 microradians). (b) North component.

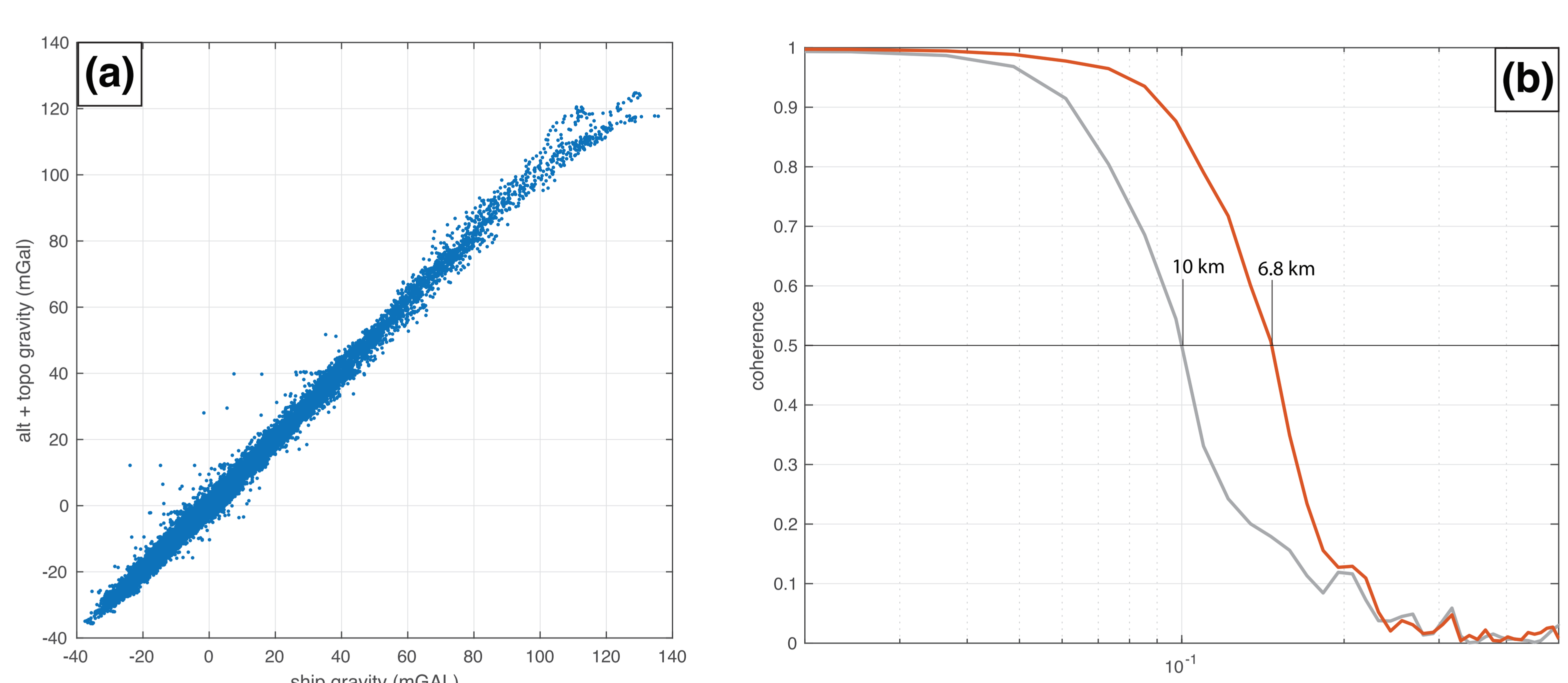

Figure 4. Combined gravity anomaly versus shipboard gravity (mean difference 0.215 mGal, rms difference 1.96 mGal). (b) (grey) Coherence between altimeter-only gravity and shipboard gravity falls to 0.5 at a wavelength of 10 km. (red) Coherence between combined gravity and ship gravity falls to 0.5 at a wavelength of 6.8 km. There is some coherent signal at 5.5 km wavelength so a sampling of 2.7 km will be the maximum spacing to resolve this wavelength.

References

Maia, M., & Arkani-Hamed, J. (2002). The support mechanism of the young Foundation Seamounts inferred from bathymetry and gravity. Geophysical Journal International, 149(1), 190-210.

Mammerickx, J. (1992). The Foundation Seamounts: tectonic setting of a newly discovered seamount chain in the South Pacific. Earth and planetary science letters, 113(3), 293-306.

Acknowledgments

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Evaluation of SWOT Data

We analyzed (30/28) repeat passes of L3 (V0.1 expert) data from path (11/26) over the Foundation seamounts (Figure 5). The data were provided by CNES/CLS/DATLAS in preparation for the September SWOT investigator's meeting. Data were processed using python in a jupyter notebook. We specifically analyzed the longitude, latitude, ssha, and mss fields to produce corrected ssh as well as the along-track and cross-track slopes as shown in Figure 5. The along-track slopes, single cycle and stacked, were compared with the corresponding along-track slopes derived from a combination of previous altimeters (V32) and enhanced as described on the left side of this poster (Figures 3 and 4).

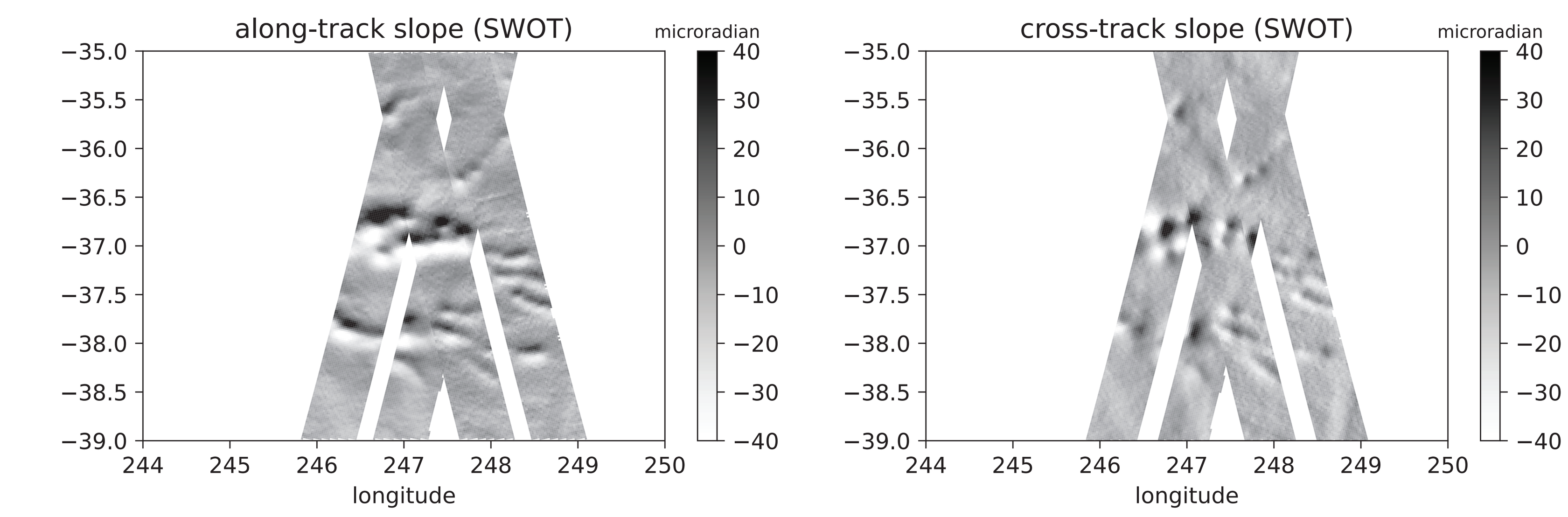

Figure 5. (left) Along-track slope for SWOT passes 11/26 is the average of the slope from 30/28 repeats (grey scale +/40 microradians). (right) Cross-track slope.

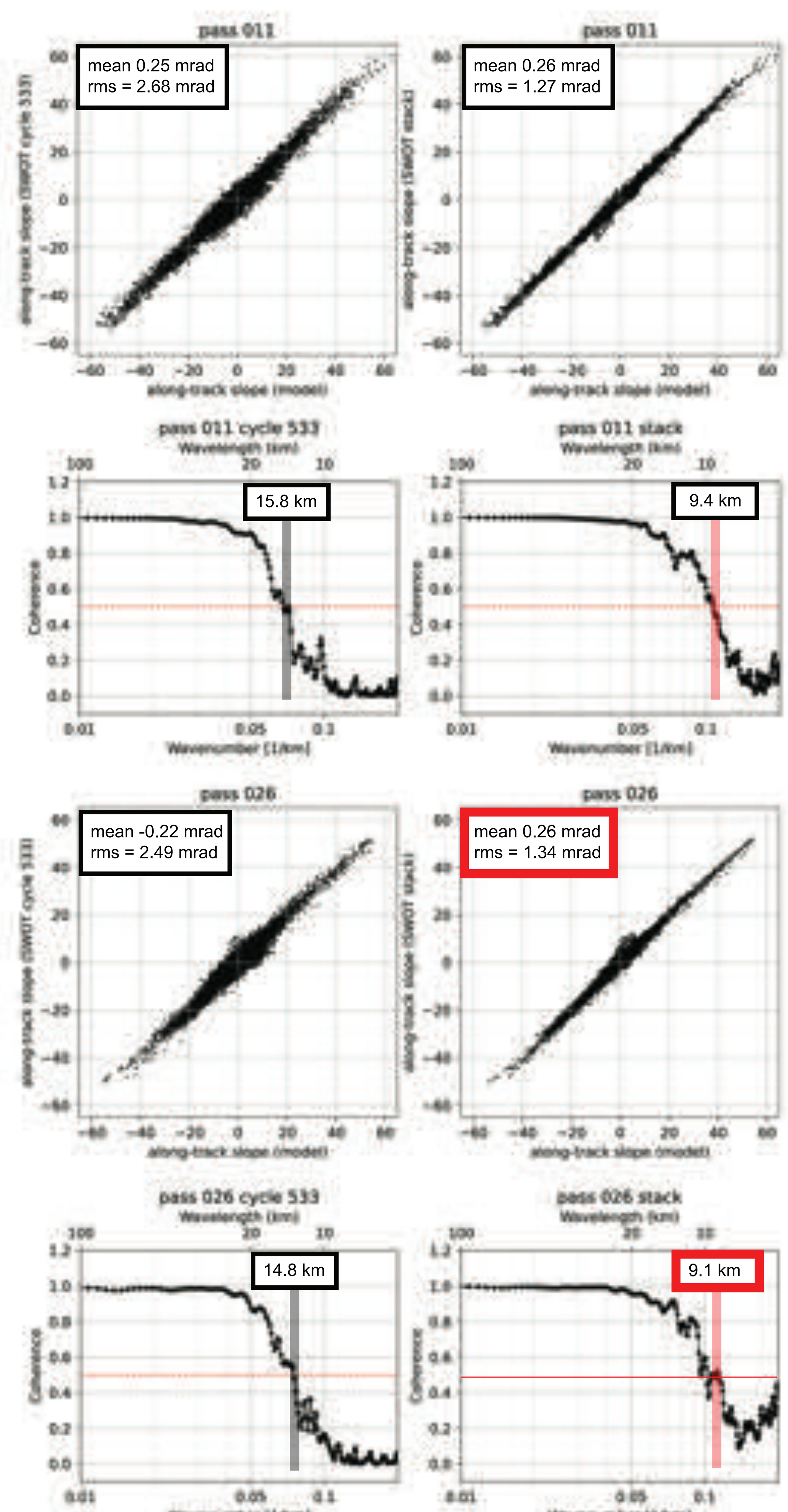

Figure 6.
(left) SWOT along-track slope for a single cycle of pass 11 versus the along-track slope from the combined altimeter and shipboard analysis. The rms scatter of 2.68 microradian is mainly due to noise in the SWOT data.

(right) SWOT along-track slope for the average of 30 cycles of pass 11 versus the along-track slope from the combined altimeter and shipboard analysis. The rms scatter of 1.27 microradian is due to both noise in the model and the SWOT data.

Figure 6.
(left) Spectral coherence between SWOT along-track slope for a single cycle of pass 11 versus the along-track slope from the combined altimeter and shipboard analysis. Coherence is high for wavelengths > 16 km and lower for shorter wavelengths.

(right) Spectral coherence between SWOT along-track for the average of 30 cycles of pass 11 versus the along-track slope from the combined altimeter and shipboard analysis. Coherence is high for wavelengths > 9.4 km and lower for shorter. wavelengths.

Very high accuracy!

Very high resolution!

Conclusions

SWOT L3 data are fully consistent with along-track slopes derived from all previous geodetic altimeter missions with **no** adjustments.

The rms difference between the individual SWOT slopes and the and the reference slopes based on shipboard data is 2.5 microradian which is 4 times lower than the best altimeter data from SARAL/Altika when filtered at 6.7 km wavelength (10.4 microradian).

The rms difference between the SWOT stacked slopes and the reference slopes is 1.3 microradian which is comparable to the best shipboard gravity data.

The coherence between the SWOT stacked slopes and the reference has a 0.5 value at a remarkably short wavelength of 9.2 km suggesting it is better than or equal to the best shipboard gravity data and superior to the spatial resolution of the latest altimeter-derived gravity models.

This is a very preliminary analysis and further improvements may come from a more careful weighting of the individual swaths in the stack as well as an analysis of the 250 m grid. We have not examined the accuracy and resolution of the cross-track slopes yet.