Retracking Jason-1 Altimeter Waveforms for Marine Gravity Recovery

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Key Ideas

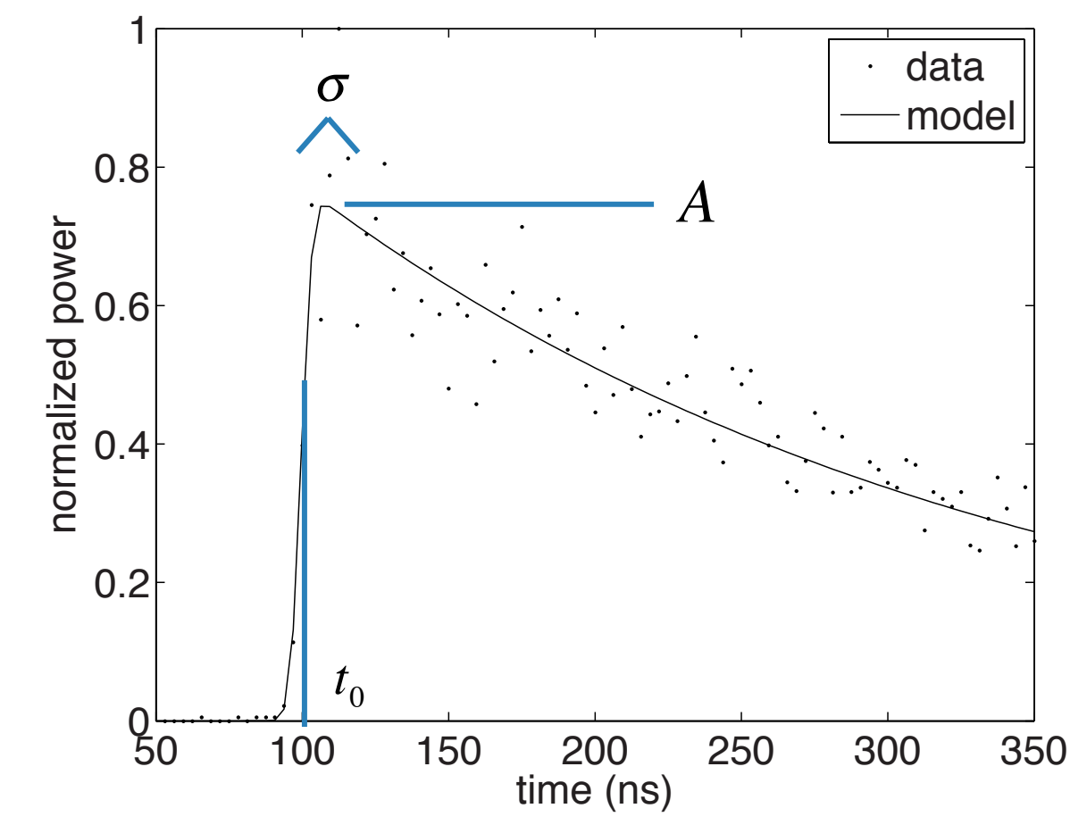
In order to construct improved maps of marine gravity anomalies, we have developed and tested retracking methods for determining sea surface slopes from radar altimeter return waveforms collected by the Jason-1 geodetic mission.

- To recover the gravity signal from sea surface slopes, we need to retrack the high rate waveforms.
- However, the range retrievals from retracking are correlated with the significant wave height (SWH).
- Double retracking addresses this correlation and is optimized for range precision, and hence better gravity.

1 Retracking Approach

A double retracking method originally developed for ERS-1 and Geosat data was also applied to the Jason-1 return waveforms. In this approach, the first step is to perform a least-squares fit of the altimeter waveform power to a mathematical model with three unknown parameters: arrival time, rise time, and amplitude. This model is a simplified version of the conventional pulse-limited altimeter waveform model (Brown, 1977).

Sample Waveform Data and Model Fit

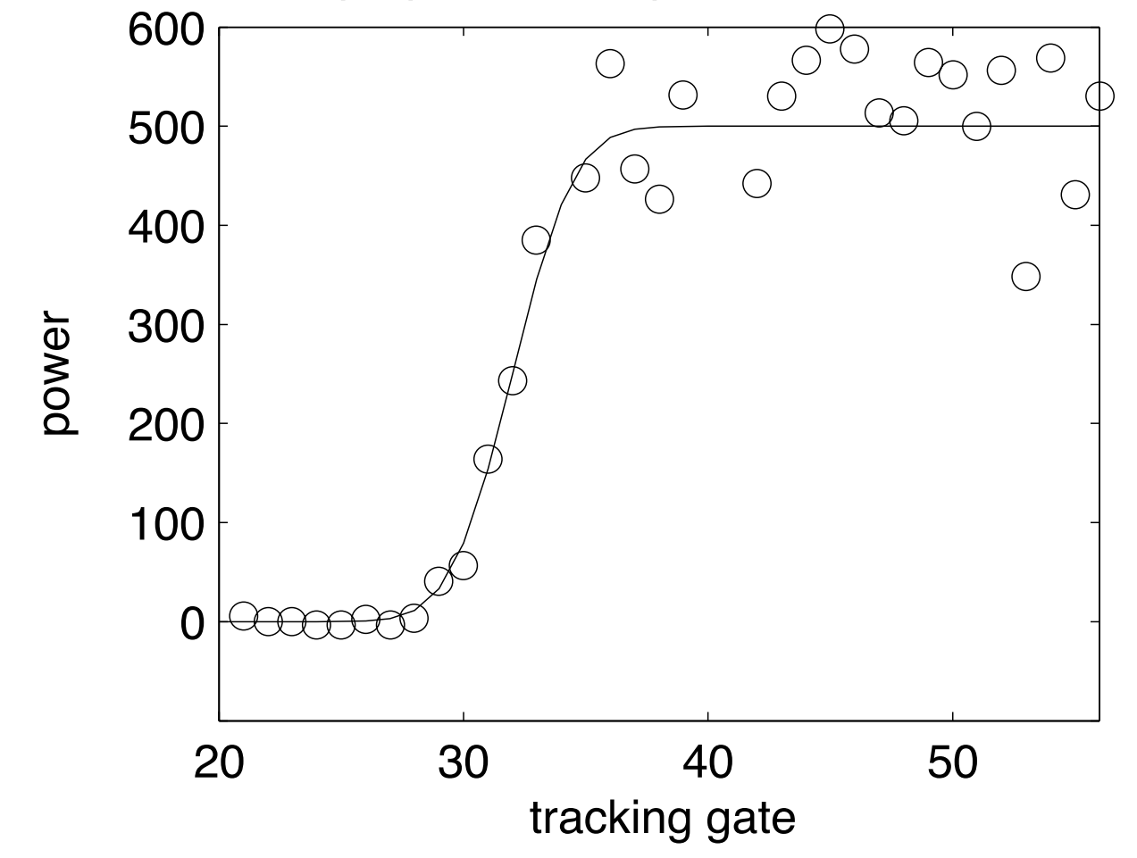


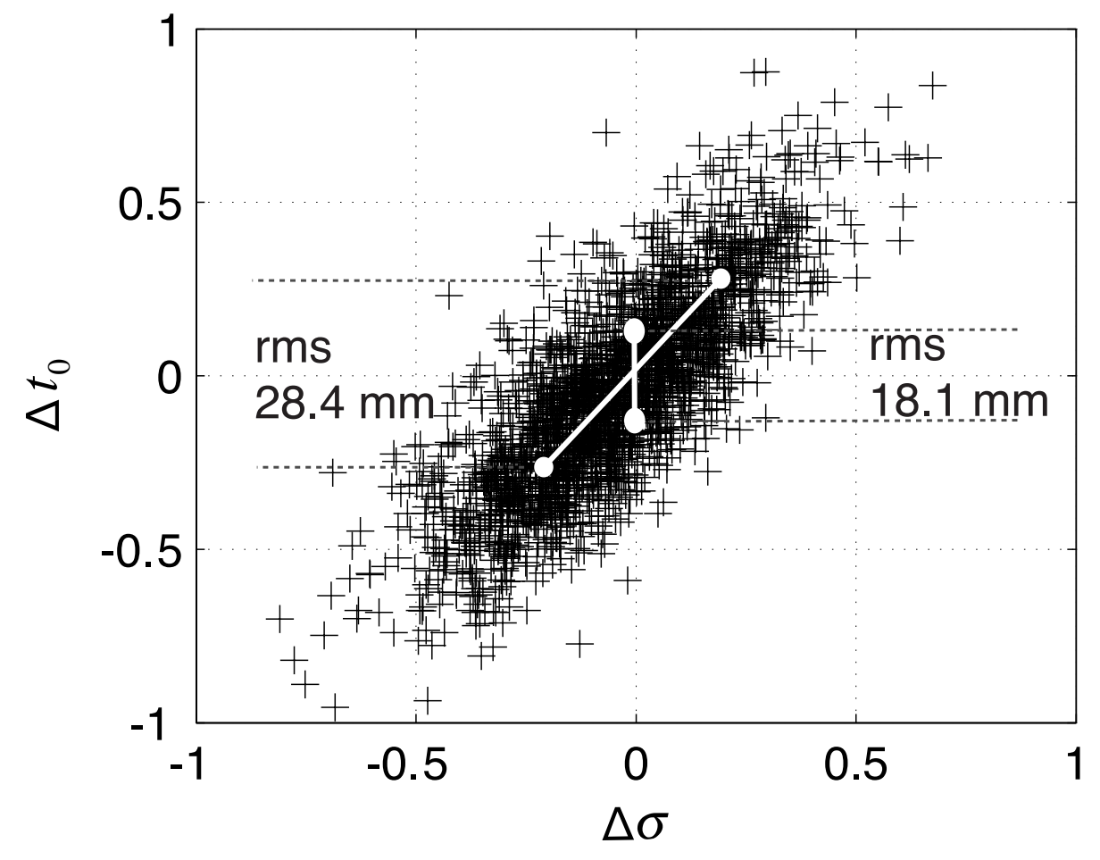
$$M(t) = \frac{A}{2}\left[1 + erf\left(\frac{t - t_0}{\sqrt{2}\sigma}\right)\right]\exp\left[-\alpha\left(t - t_0\right)\right]$$

where $erf(z)$ is the error function with argument z

t - time since pulse transmission
t_0 - arrival time of return signal, gives range to sea surface
σ - rise time parameter, related to significant wave height
A - waveform power amplitude
α - waveform power decay rate

noise proportional to power, non-uniform weight

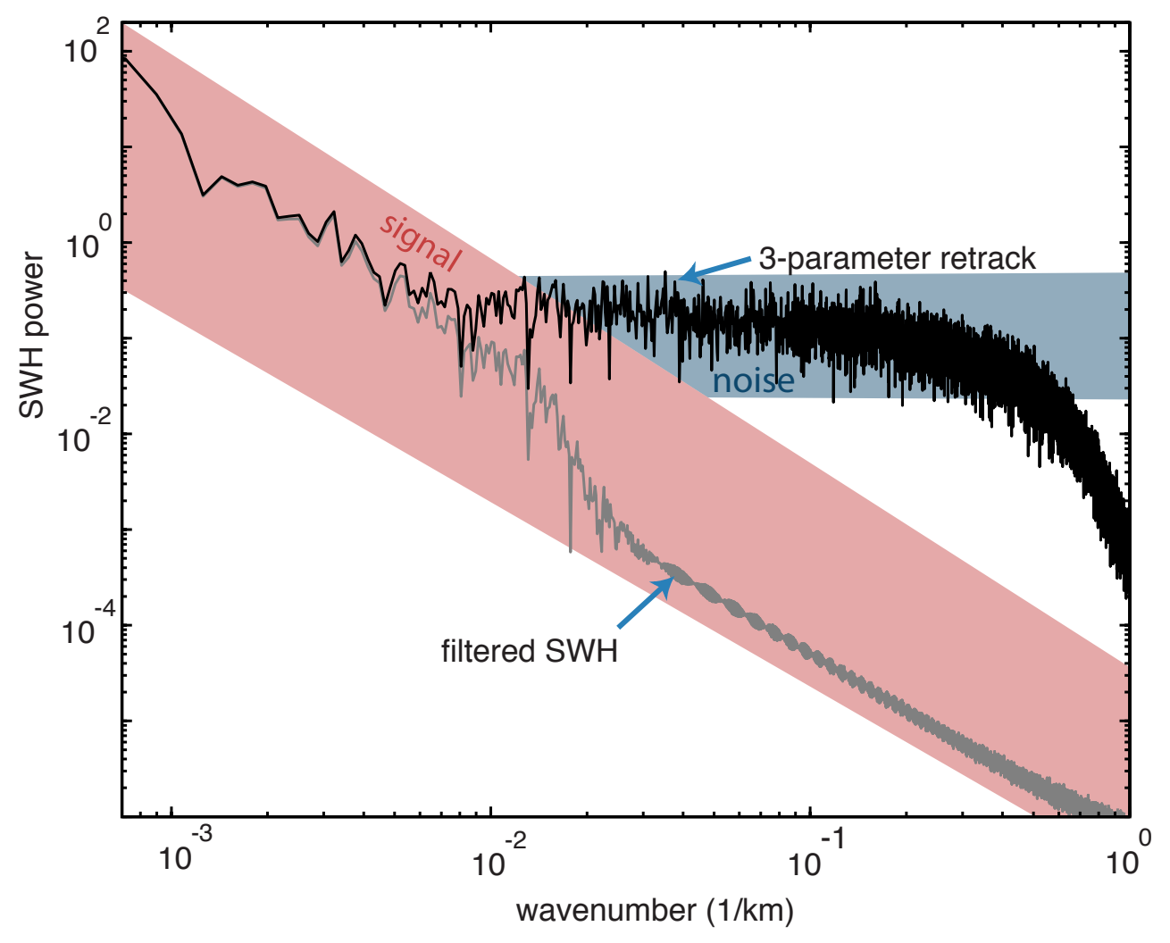




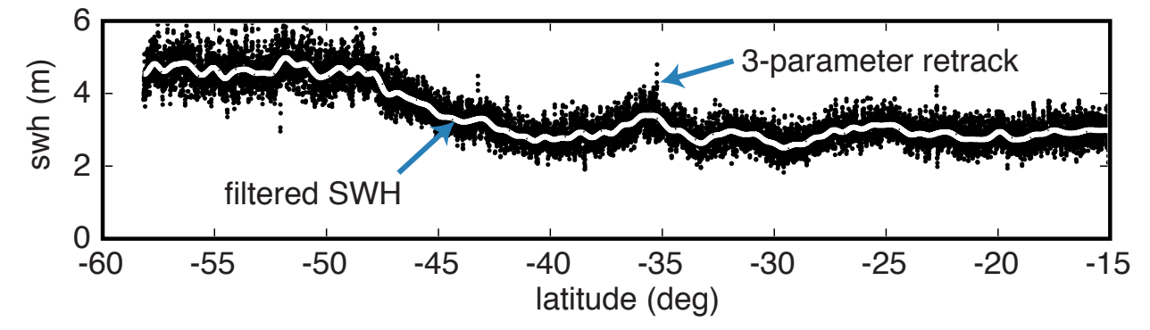
Previously, Monte Carlo simulations (Sandwell & Smith, 2005) showed that if non-uniform weights inversely proportional to the waveform power are used, there is high correlation between arrival time and rise time. In the double retracking approach, smoothing is performed on the rise time retrieved from the initial retracking with 3 parameters. The waveforms are then retracked again but with the smoothed rise time held fixed, reducing the problem to the recovery of 2 parameters: amplitude and arrival time (hence, range).

2 SWH Spectrum

Power Spectral Density of SWH from ERS-1



SWH from along an ERS-1 ground track



The SWH is estimated from the rise time recovered by the 3-parameter retracking. By calculating the power spectral density of the SWH along a track, the scale at which noise predominates may be identified. After the application of a low-pass filter, the spectral slope observed at shorter wavelengths becomes more similar to the red spectrum found at longer wavelengths.

Poster Guide

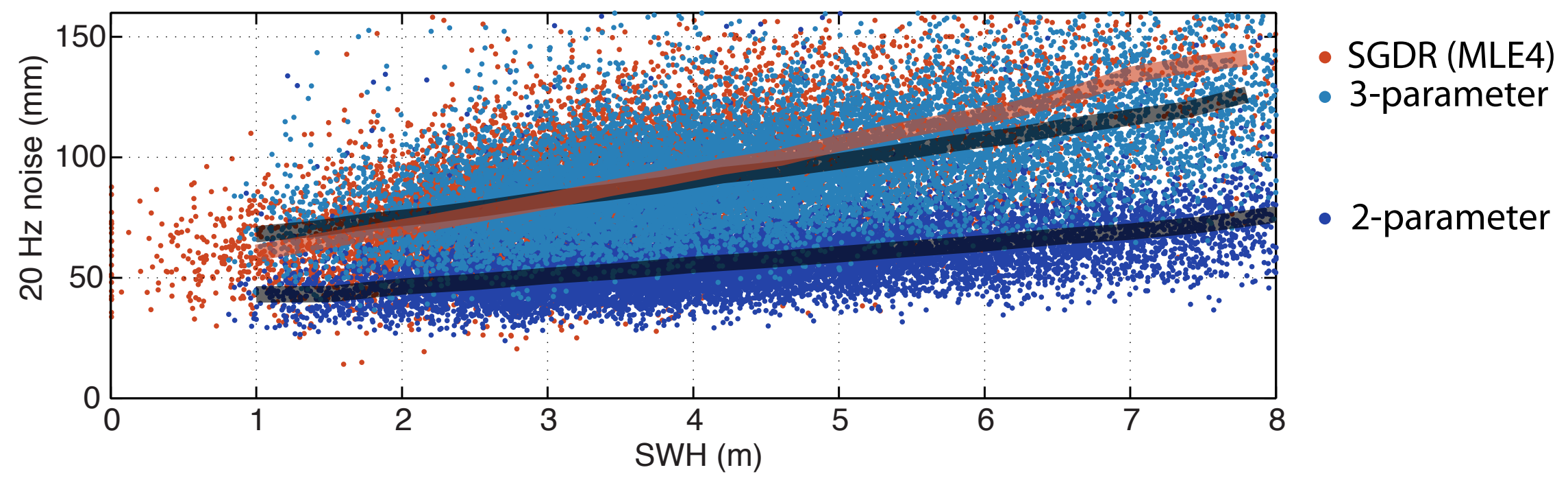
1 Least-squares estimation of range and SWH show that they are correlated parameters, and even more so when waveform weights are non-uniform [Sandwell and Smith, 2005]

2 We propose that the power spectrum of the recovered SWH has a long-wavelength (λ > 50 km) component with a red spectrum and a white noise floor. Moreover, the red spectrum of the SWH should continue over all wavelengths and therefore we apply a low-pass filter to achieve that.

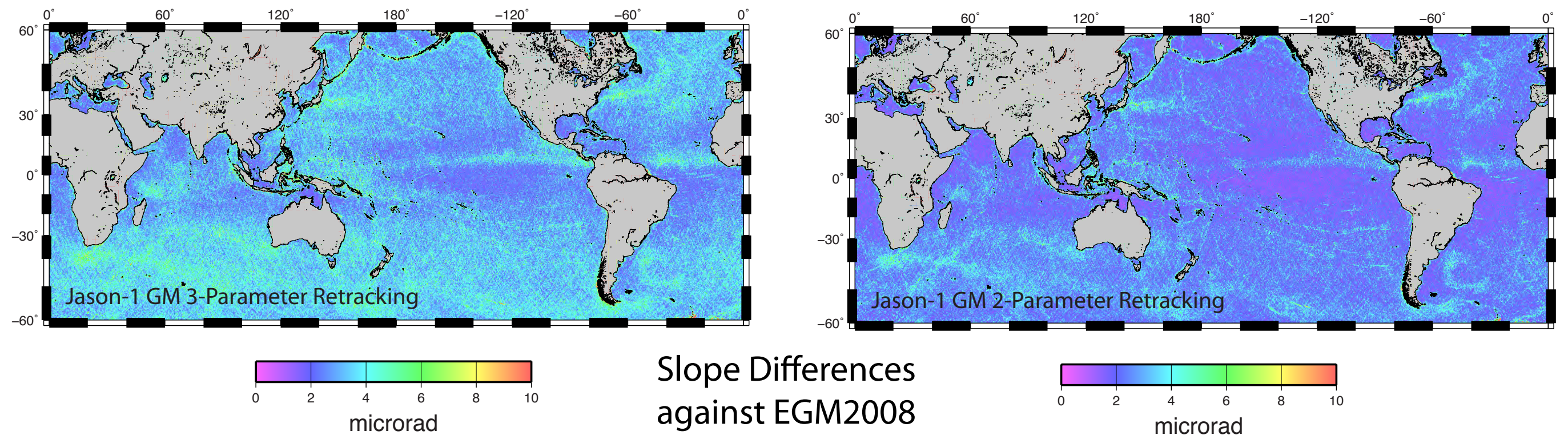
3 Double retracking by assuming a smoothed SWH has two effects:
a) it reduces the 20 Hz range noise by a factor of 1.5
b) it reduces the spectral "hump" in the 10-50 km wavelength band
(This noise reduction occurs for all data from conventional pulse-limited altimeters but not for Cryosat-2 in SAR mode [Garcia et al, 2013, submitted])

4 For both the MLE4 retracker and our 3-parameter retracker, we find higher coherence between SLA and SWH in the 10-50 km wavelength band, perhaps due to the above mentioned correlation between range and SWH. The sea state bias (ratio of SLA to SSB) is wavelength dependent with lower SSB (~6% or less) at longer wavelengths and higher SSB (~12% or more) at shorter wavelengths.

3 Noise Reduction from Retracking



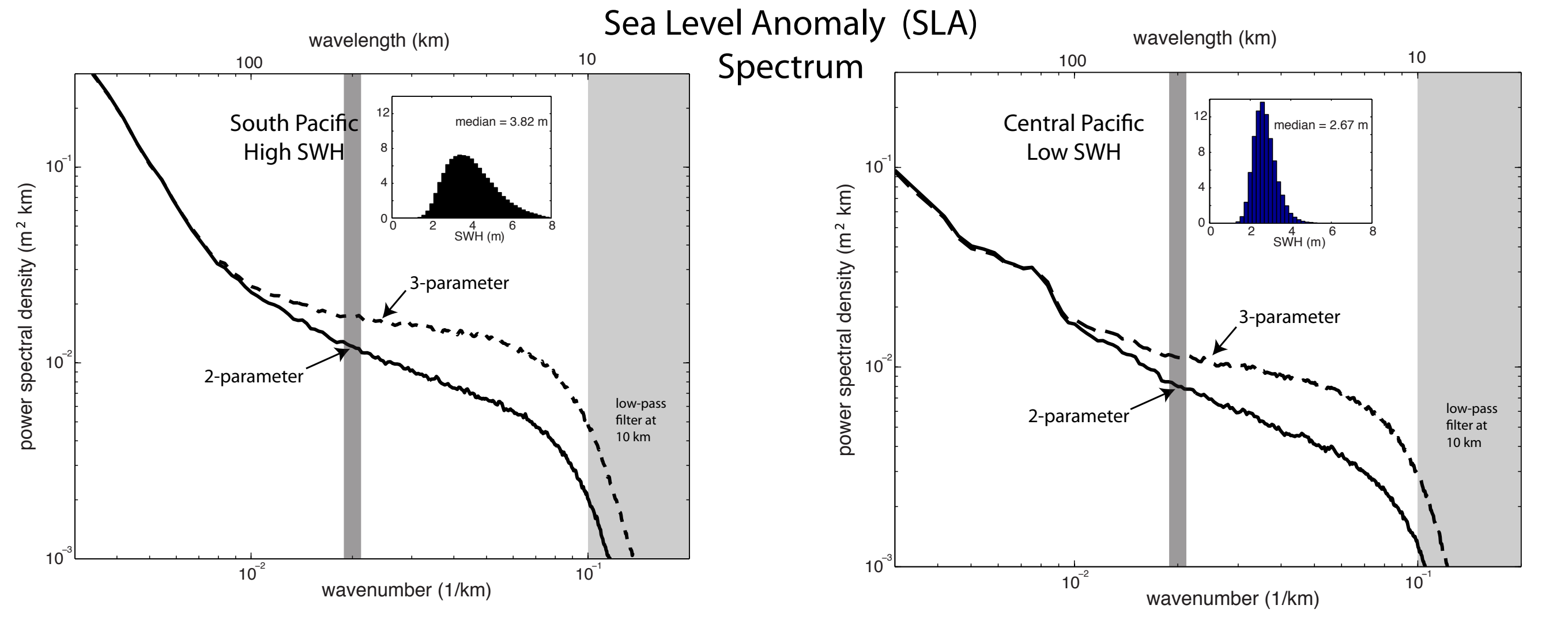
We estimated the noise levels in our range estimates by computing the RMS deviation of the 20 Hz samples (above). The range noise levels are ~1.5 times higher for 3-parameter retracking compared to 2-parameter retracking. We also compared the noise levels in our 3-parameter retracked data to the values of range provided in the official CNES and NASA Geophysical Data Record (GDR) product, which are processed using an MLE4 algorithm. The GDR noise levels are slightly lower for values of SWH less than 3 m, whereas at high SWH the GDR noise is higher than for our 3-parameter retracking.



Slope Differences against EGM2008

To assess the noise reduction in sea surface slopes, we mapped the differences between the results of 3-parameter retracking and the EGM2008 mean sea surface model, and did the same for the 2-parameter retracking results (above). The slope differences were decreased when double retracking was applied.

Jason-1 GM
Sea Level Anomaly (SLA)
Spectrum

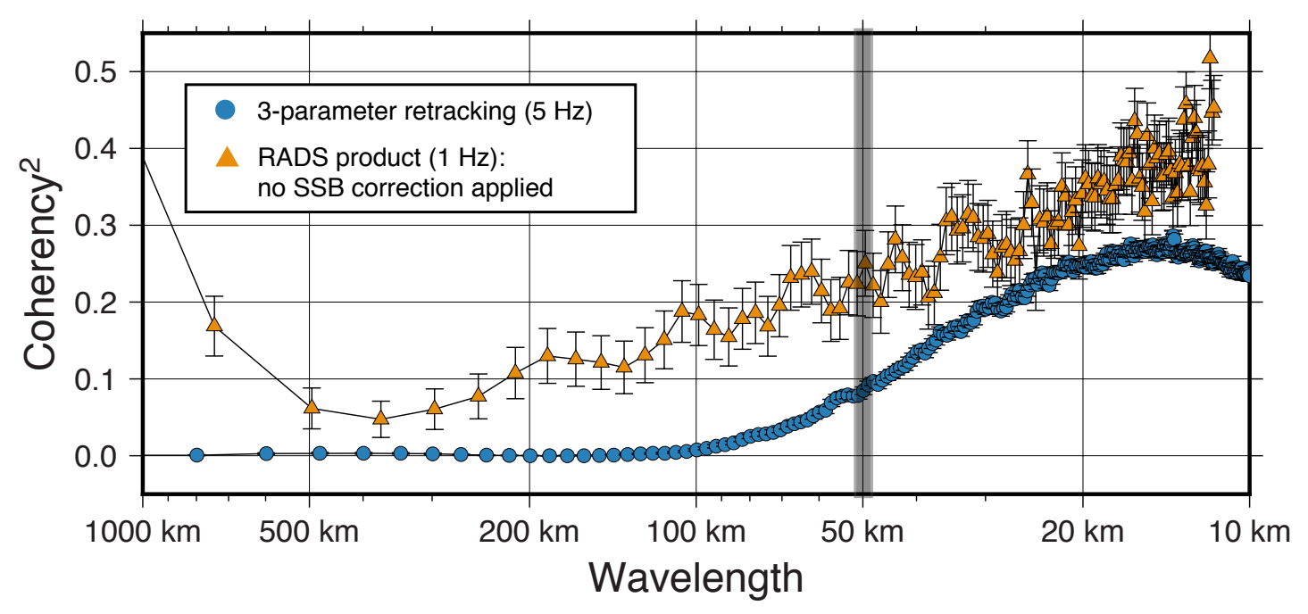


We computed spectra of SLA (above) for along-track Jason-1 data from two areas: one with typically low SWH in the Central Pacific and another with high SWH in the South Pacific (see outlines on gravity anomaly map). Upon double retracking, the noise in the 10-50 km wavelength band is reduced. These are the same scales over which the spectral "hump" has been previously described [Boy et al, 2012].

4 SWH and SLA Cross-Spectral Analysis

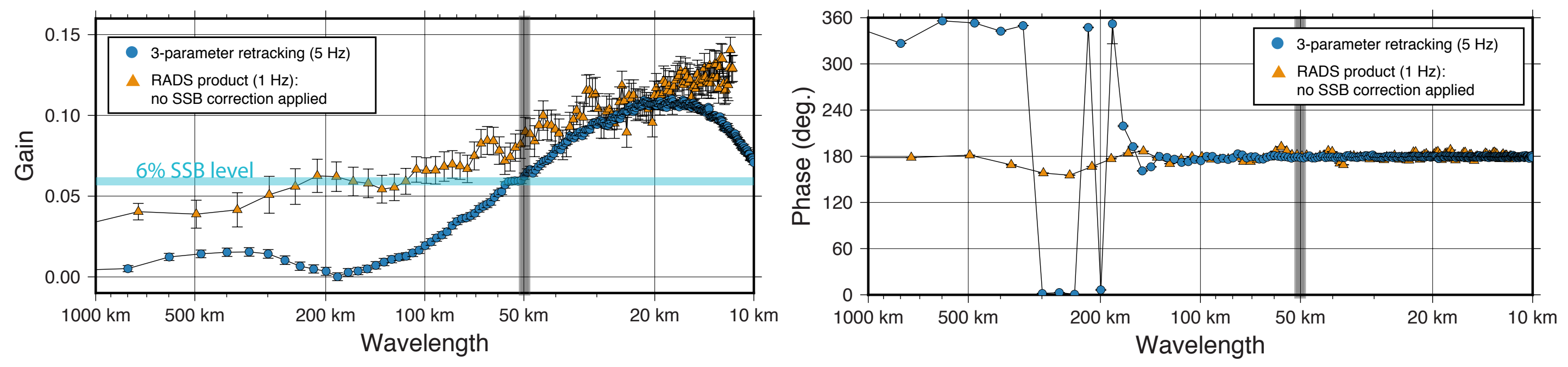
We sought to explore the cross-spectral relationship between sea level anomaly (SLA) and significant wave height(SWH) for Jason-1 geodetic mission ("Phase C") data. The passes we used for the analysis were taken from a region in the South Pacific with high sea state (see outlined box on gravity anomaly map, below). The results of our 3-parameter retracking sampled at 5 Hz were compared with the SLA as provided at 1 Hz through the Radar Altimetry Database System (RADS). For both data sets, the sea state bias (SSB) correction was not applied to the retracked range. Otherwise, all other usual calculations were done to obtain the SLA.

SWH-SLA Coherence



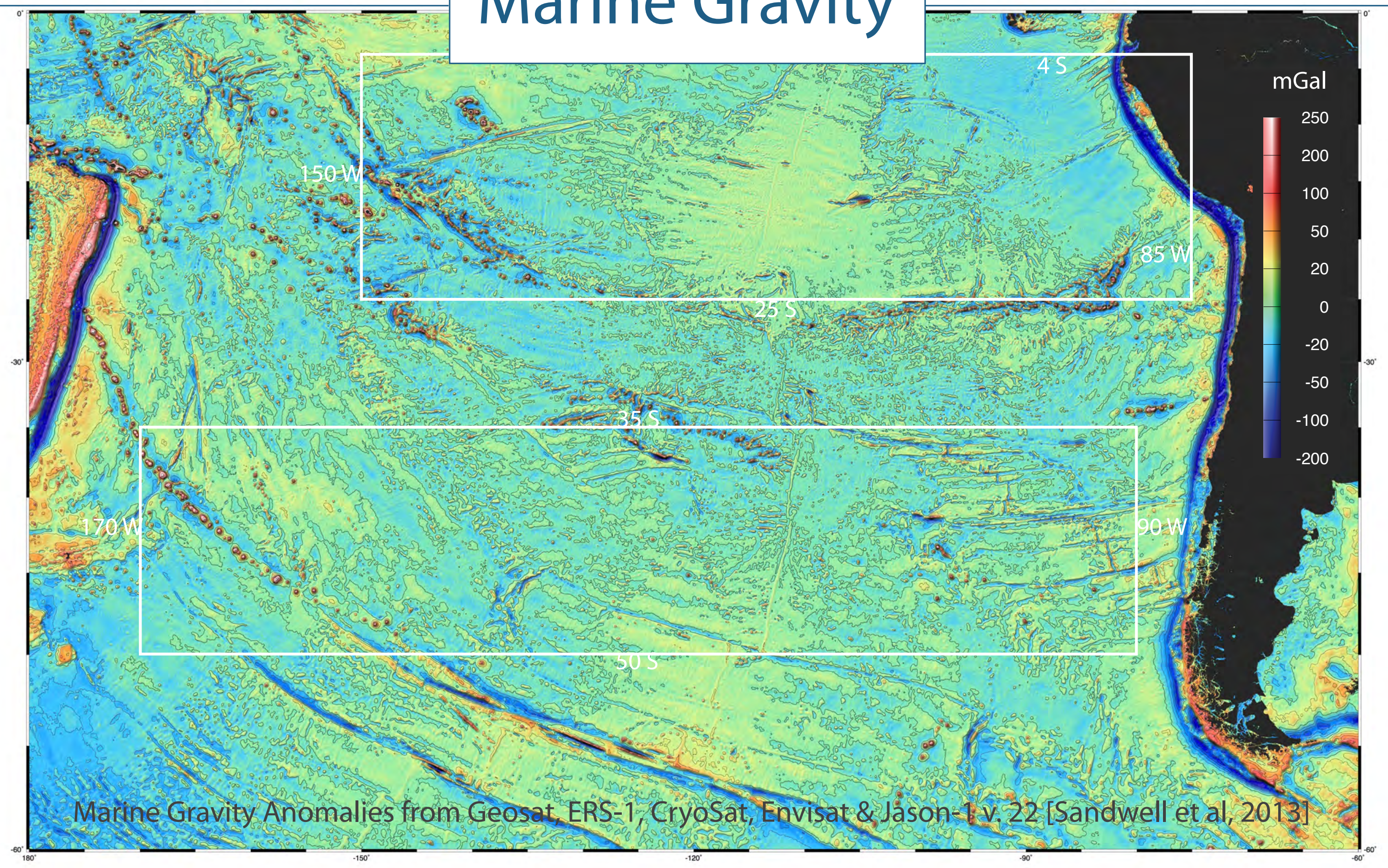
For both the 3-parameter and RADS results, there is an increase in coherence with decreasing wavelength. At longer wavelengths the coherence is low (left) because the SWH reflects true spatial variations that are largely uncorrelated with SLA. The ground tracks we used are about equivalent in length, but we note that the 5 Hz sampling output of the 3-parameter retracker results in a spacing of ~ 1.7 km along track, while it is ~5.8 km for the 1 Hz RADS product.

SWH-SLA Transfer Function



Similar to the behavior of the coherence, the gain of the transfer function increases at shorter wavelengths (above, left). Meanwhile, the phase at shorter wavelengths tends to be around 180°(above, right) because increasing SWH causes an increase in range, or a decrease in SLA. We speculate that these results have implications for the correlation between SLA and SWH, and therefore, the SSB correction. The typically assumed SSB value of ~6% seems suitable at longer wavelengths, but perhaps not at shorter wavelengths. In future work we hope to investigate how double retracking modifies the cross-spectra.

Marine Gravity



Marine Gravity Anomalies from Geosat, ERS-1, CryoSat, Envisat & Jason-1 v. 22 [Sandwell et al, 2013]

Conclusions

Double retracking reduces both the 20 Hz range noise and the "hump" in the SLA spectrum over the 10-50 km wavelength band. Therefore, the assumption that the SWH spectrum is red provides better results than a SWH spectrum with a white noise floor.

The factor of 1.5 reduction in noise is critical for improving the accuracy of the gravity field over the 10-50 km scale. We conjecture that physical oceanography applications would also benefit from this noise reduction.

The SSB is wavelength dependent with actual (~6% or less) SSB at wavelengths greater than 50 km and artificial (12% or more) SSB at shorter wavelengths.

References

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Acknowledgements

We thank M. Mazloff (SIO), E. Leuliette (NOAA), R. Scharroo (EUMETSAT) & E. Zaron (PSU) for their help. We appreciate the support from NSF, ONR, and NGA.