Global spectral characteristics from 1Hz along-track altimetry

Oscar Vergara[1,2]*, Rosemary Morrow[1], Isabelle Pujol[2], Gérald Dibarboure[3], Clément Ubelmann[2]

[1]LEGOS, IRD/CNES/CNRS/University Toulouse, Toulouse, France.
[2]CLS Space Oceanography, Toulouse, France.
[3]CNES, Toulouse, France.

*oscar.vergara@legos.obs-mip.fr

In one line: SSHa variability is analyzed considering the observations' uncertainty. The spectral slope break that marks a regime shift is observed over most of the global ocean.

1. Context and Motivations

Recent evidence from along-track Sea Surface Height observations (1Hz) highlights the capabilities of current generation altimeters to characterize the ocean variability at wavelengths below 100km[1,2].

Recent analyses of models and in-situ data show that **internal gravity waves (IGW)** dominate the small-scale SSH spectrum, particularly in the tropics and low mesoscale energy regions[3,4]. These IGWs are not in geostrophic balance. Defining the "Transition Scale" where balanced motions become dominated by IGWs is important for calculating geostrophic currents from sea surface slopes.

Observability in the meso to submesoscale wavelength range is limited by instrumental noise in current generation altimeters. De-noising the along-track data can allow us to study the sub-100 km wavelength variability.

Meso- and small-scale spectral slopes (Sentinel-3)

Mesoscale Slope:
Reflect the known regions of intense eddy activity.
Values close to QG/sQG in the extra-tropics.

Small-scale Slope:
Values between k^{-1} and k^{-2} globally, increasing towards the tropics.

Blanks in the tropics: observed spectra do not show two distinct slopes.

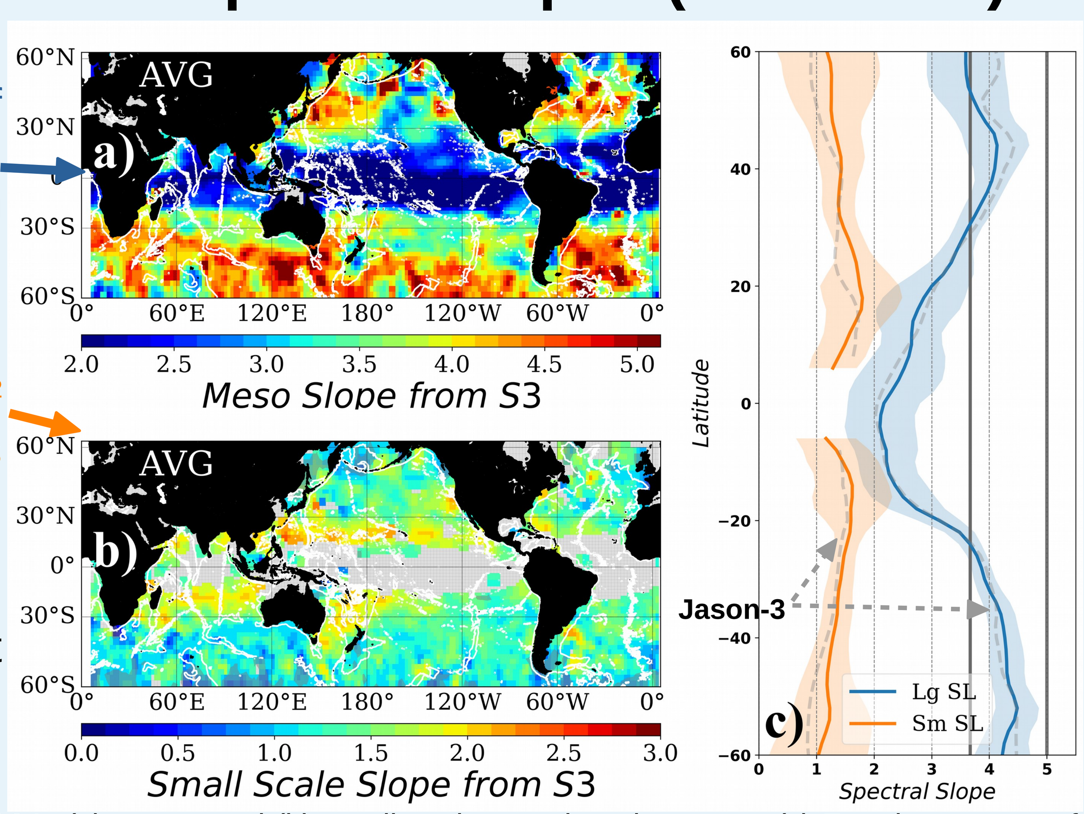


Figure 1. Spectral slope estimates for S3A: (a) meso- and (b) small scale wavelength ranges. (c) Zonal averages of (a) and (b); Jason-3 data is also included.

2. Spectral estimates and slope rupture

1. Along-track SSH anomalies (**SSHa**) are subsampled inside 15°by 15° boxes.

2. Average spectra are obtained for all tracks and cycles within each box.

3. Noise levels is estimated for **λ < 30 km** wavelength[5].

4. Spectral slopes are fitted on the **denoised spectrum**, over a variable λ range[2].

5. We then use an optimized bi-linear fit to compute the mesoscale spectral slope, a small-scale spectral slope, the observational wavelength range (**SNR > 1**) and the intercept wavelength.
This wavelength corresponds to the change in the spectral shape.

Fit of a simple linear model with two spectral slopes weighed by the observations' uncertainty

$$f(x) = \underbrace{x^{a_1}/10^{-b_1}}_{\text{Mesoscale}} + \underbrace{x^{a_2}/10^{-b_2}}_{\text{Small-scale}}$$

The intercept wavelength (Lt) is only interpreted if:
1. Lt > observability wavelength.
2. Error in small-scale slope is less than 40%.

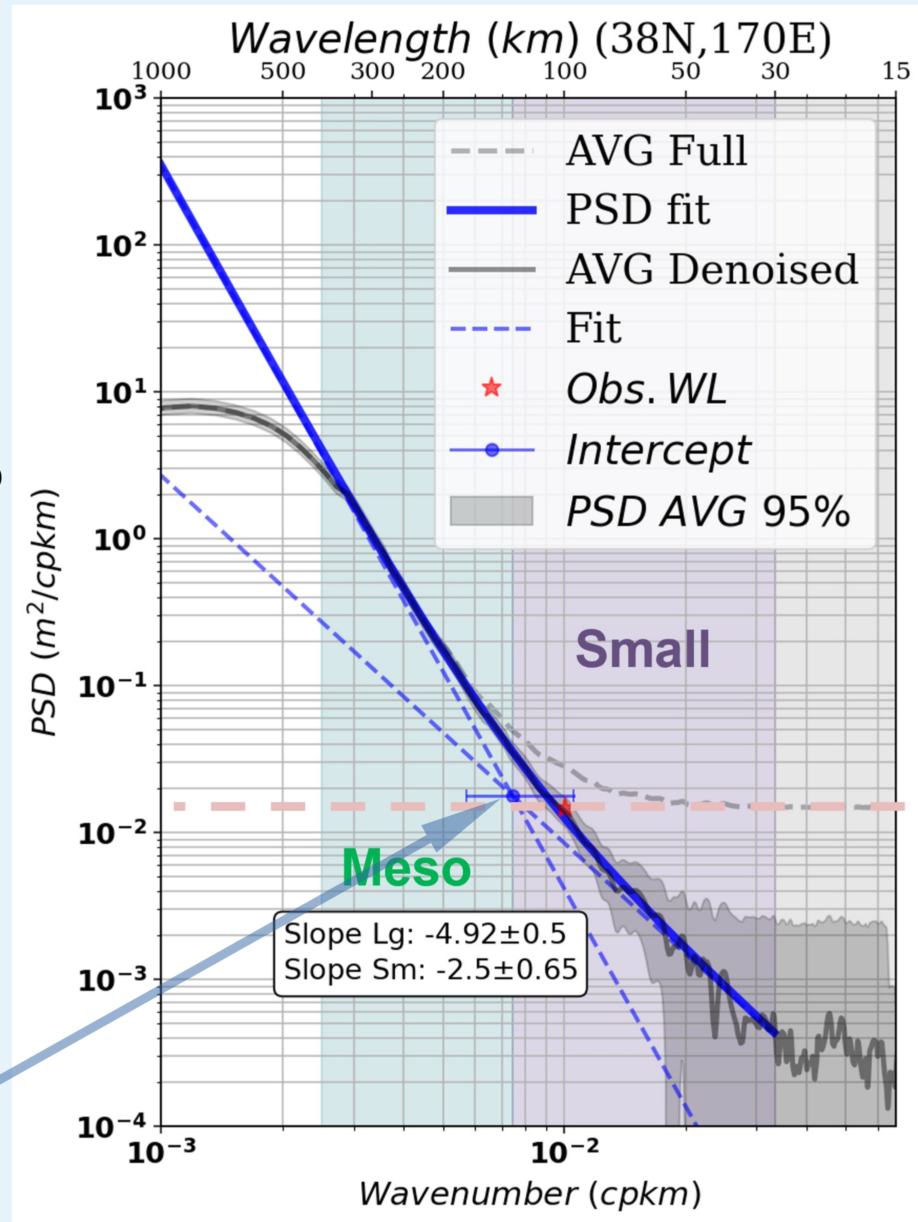


Figure 2. SSH spectral estimates (gray lines; 95% CI is indicated in gray shading) inside a 15x15 box located at the Northeastern Pacific. Result of the bi-linear model is plotted in blue. Intercept between the meso and small-scale slopes and the observability are also plotted.

3. Mesoscale to small-scale slope intercept

Intercept Wavelength

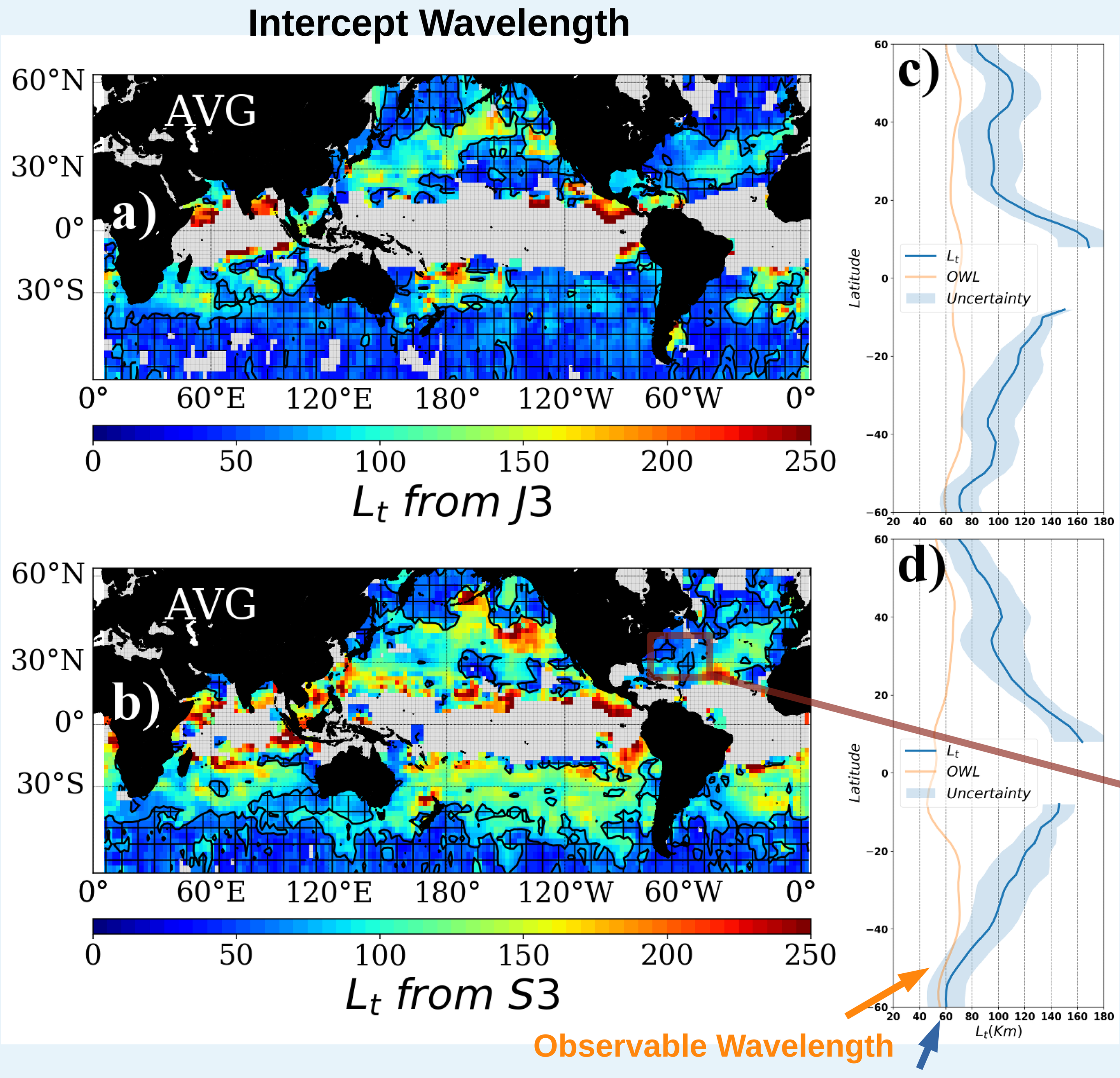


Figure 3. Intercept scale (in Km) between the meso and small-scale spectral slopes for Jason-3 and Sentinel-3. Shaded/hatched areas correspond to regions where the intercept scale is less than the local observable wavelength or the uncertainty in the small-scale spectral slope is more than 40%.

Basin scale averages

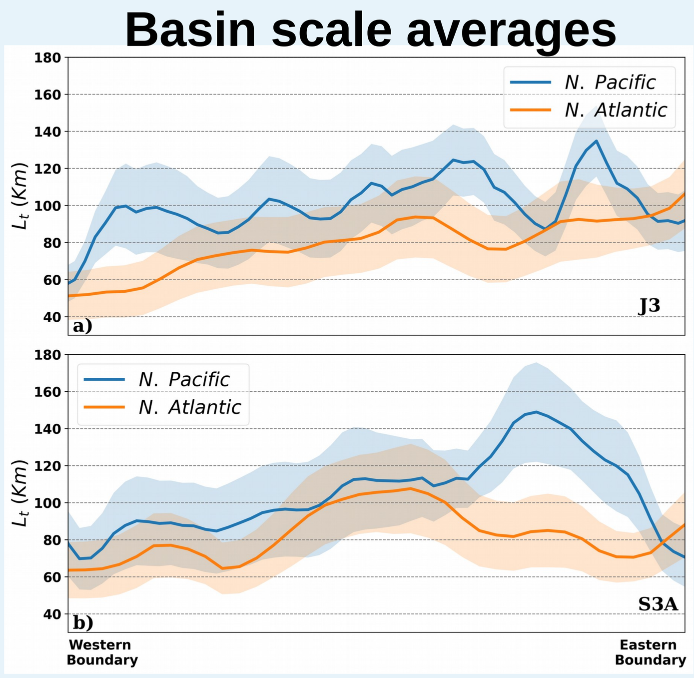
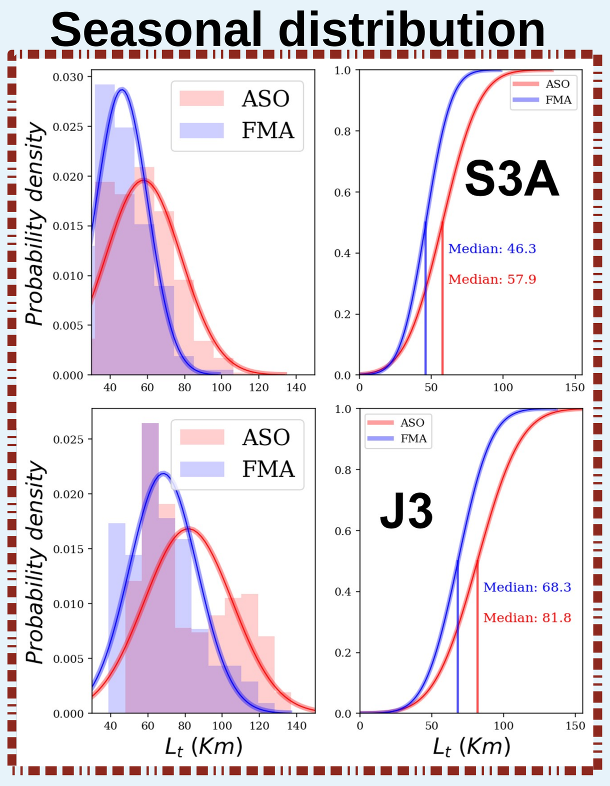


Figure 4. Average intercept wavelength in the North Atlantic and North Pacific.

Seasonal distribution



- Short intercept wavelength values are found in the energetic western boundary current regions and longer values over the eastern part of the basins.

- General trend shows an increase towards the tropics (> 150 km) compared to higher latitudes (around 100 km).

- Values observed in the Southern Ocean are non-interpretable: high noise levels related to sea-state yield a relatively high observable wavelength compared to the relatively short intercept values (high energy region).

- Overall, these results agree with the most recent modeling results that include tidal forcing[4].

- Intercept values during summer are longer than during winter, which is consistent with the current interpretation of the IGW field / small mesoscale variability relates to the seasonal changes in atmospheric forcing and stratification.

- The SWOT mission will observe essentially the same structures in the tropics but its reduced noise should give better coverage at higher latitudes.

5. Conclusions

- The bi-linear fit results are consistent with previous modeling and in situ results: shallow slopes due to large internal tides/IGW in the tropics, close to sQG/QG in the extra-tropics and small-scale slopes between 1.5 and 2 in the tropical regions.

- It is possible to estimate the meso- to small-scale intercept wavelength from alongtrack altimetry. The spatial coverage is limited due to uncertainties associated with the observations (SNR>1) and low mesoscale slopes in the tropics.
- Intercept wavelengths have the lowest values in the high mesoscale energy regions, growing towards the regions where IGW are more energetic than mesoscale eddies (inter-tropical band and equatorial region, eastern boundaries).

References

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