Evidence of Altimetric SSH spectral slope changes potentially induced by IGW

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Context and motivations

- IGW energy dominates the mesoscale to submesoscale range in the tropical band, also showing a seasonal regime shift. Corroborated by *in situ* observations and modeling studies.

- Recent modelling studies highlight a transition length where dominant mesoscale energy changes to dominant IGWs (*e.g. Qiu et al.* 2018).

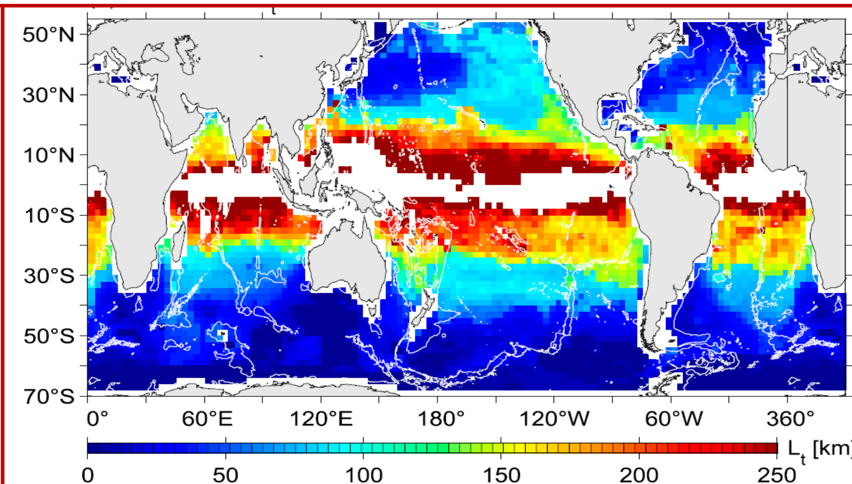
- **Is this observable with today's along-track altimetry?**

- Several questions remain: observability in the mesoscale to submesoscale wavelength range is limited by noise with the current generation altimeters. This has prevented the validation of modeling results at global scale.

Goals:

- To have a precise estimate of the mesoscale spectral slopes.
- To estimate a second k^{-2} spectral slopes for IGWs
- Compare against the results of recent works at global scale (*e.g. Qiu et al.* 2018).

Transition scale from balanced to unbalanced motions



Qiu et al., 2018

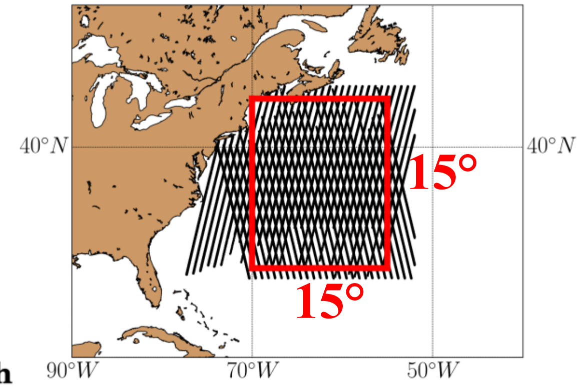
Spectral estimates in mesoscale range

- Spectra computed on along-track measurements:
  1. Tracks sub-sampled at fixed length, inside the region of interest.
  2. Individual spectral estimations for each sample (FFT*).
  3. Sample averaging yields regional spectrum.
  4. Spectral slope is fitted on the **denoised** spectrum, for a **variable λ range**.

*FFTs: 1000km samples, and overlapping of 500km, verified with decorrelation scales.

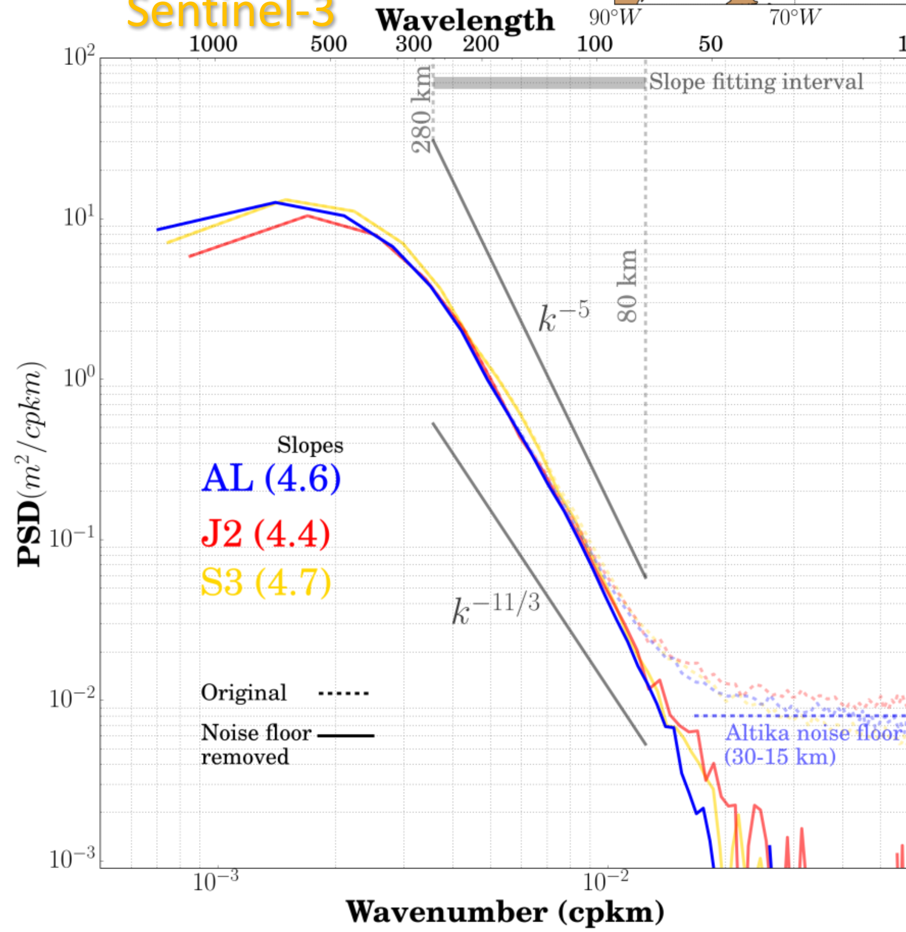
Wavelength range: based on the local eddy length scale *(Eden, 2007)*. **->** depends on local dynamics.

Track selection

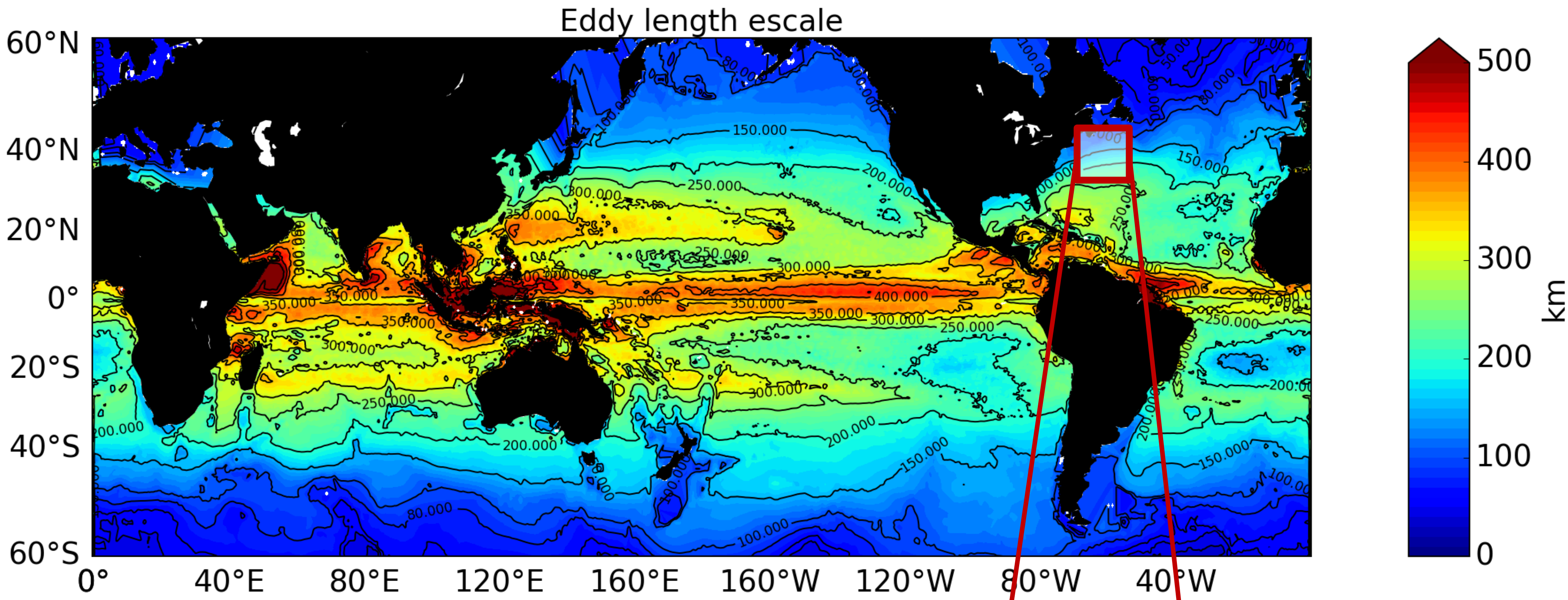


SSHa spectra

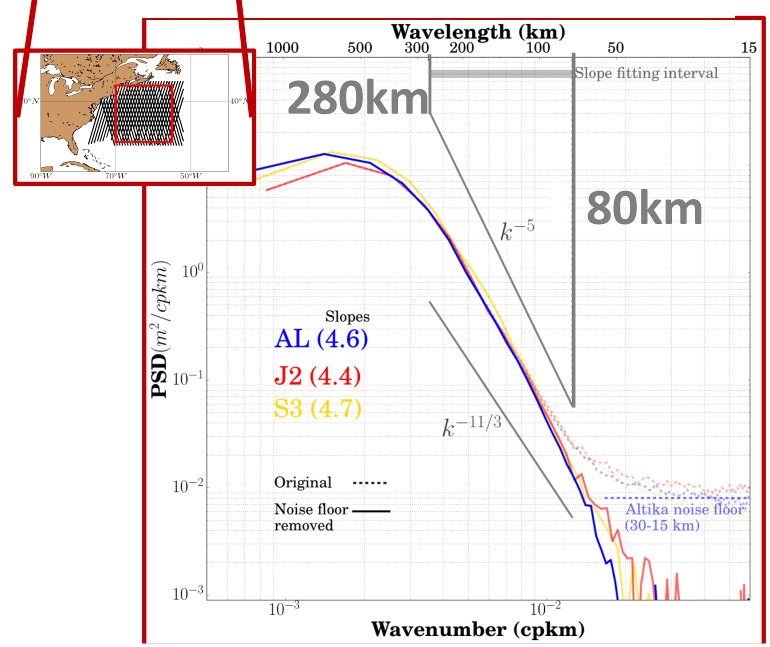
Jason-2, **Saral**, **Sentinel-3**



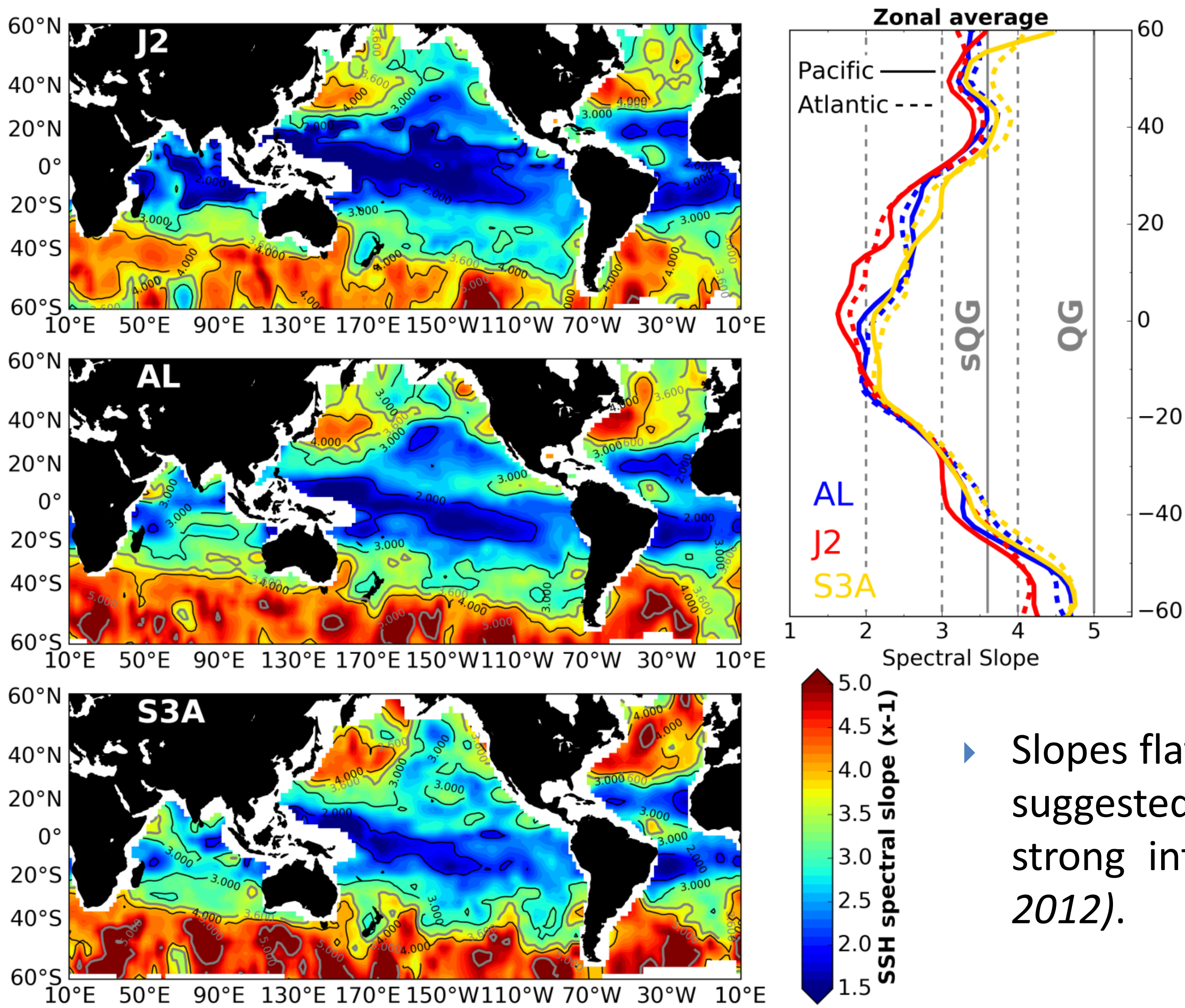
Spectral estimates in mesoscale range



- Using a variable wavelength range to fit the slope seems more appropriate (tied to local dynamics).
- Accounts for variations on stratification and the Rossby radius of deformation -> “Dynamical equivalence” across different latitudes.

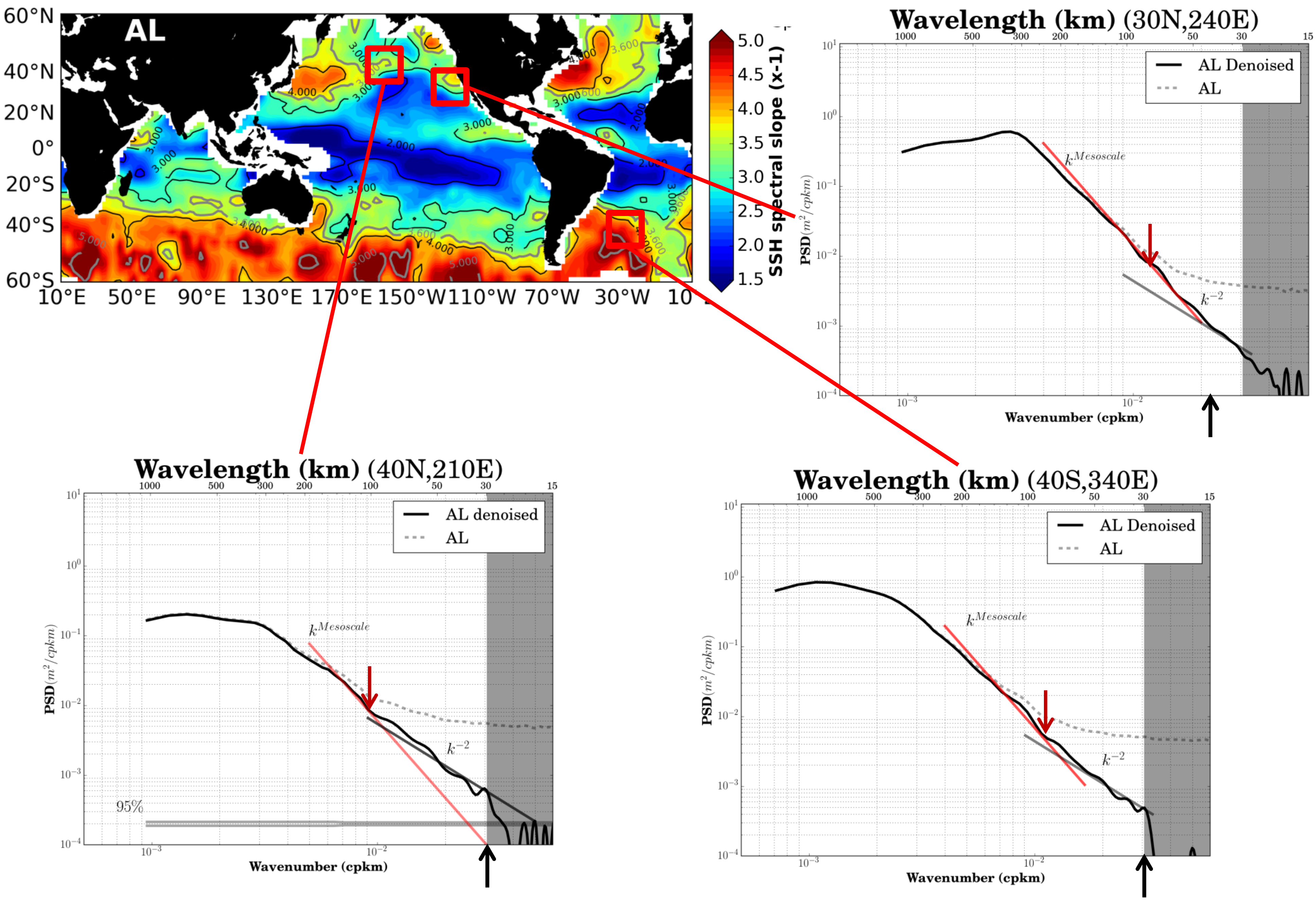


Spectral slopes from different missions



- Results are consistent for the different missions.
- Close to sQG/QG predictions in the extra-tropics.
- Flat slope are obtained in the inter-tropical band.
- Slopes flatter than QG/sQG have been suggested to arise in presence of strong internal tides *(Richman et al 2012)*.

AVG spectral slope form AL 13-15

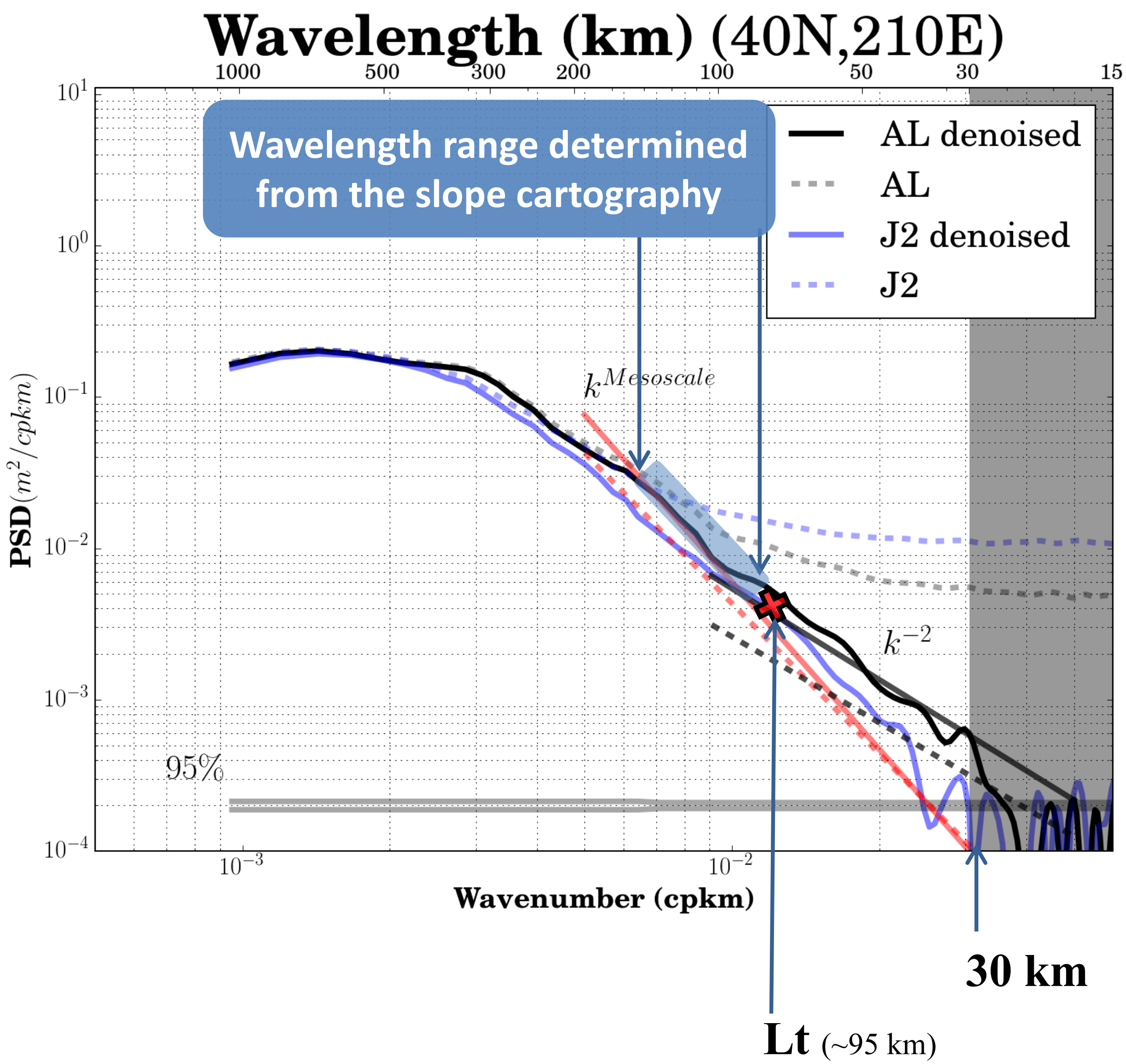


Estimation of transition scale from meso-to-submesoscale

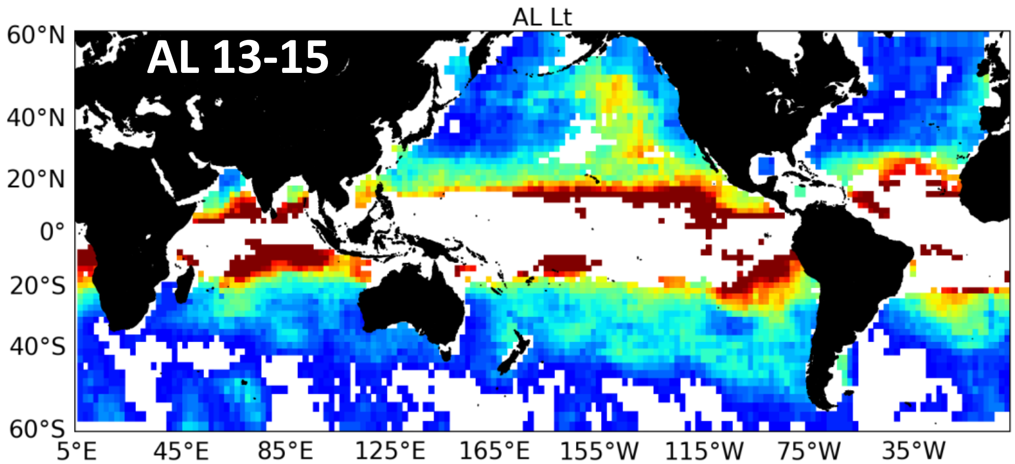
- In addition to the mesoscale slope previously found, we often find a k^{-2} slope in the high wavenumber range of the spectrum.
- Which is interpreted as the result of superposition of random linear IGWs.

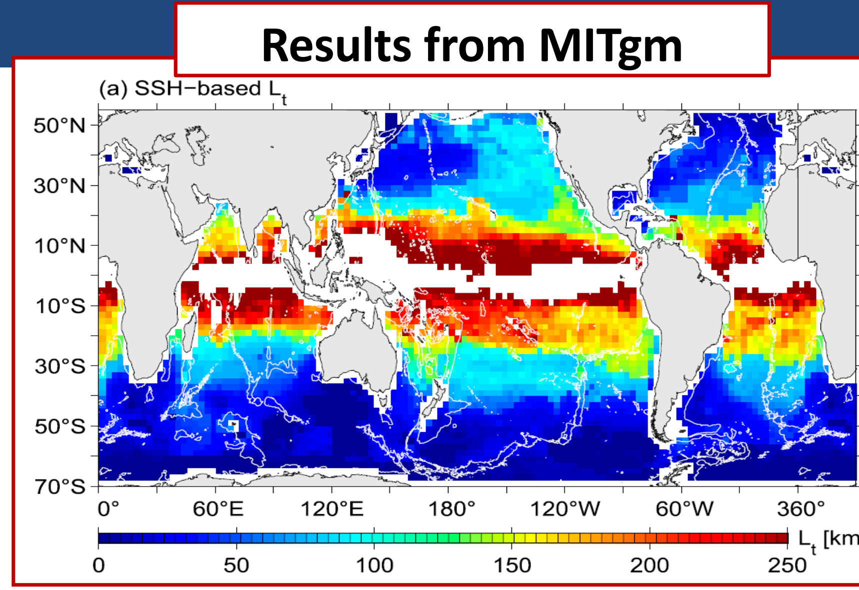
=>***We fit a k^{-2} slope here - imposing an IGW-type spectrum in this wavelength range*****.**

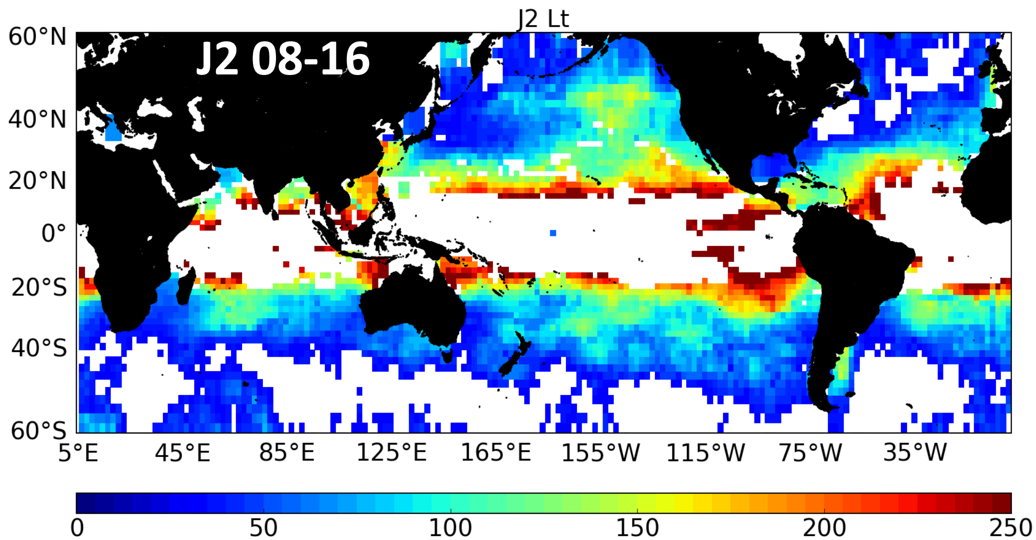
- We then define **Lt** as the intercep between the two slopes ($k^{Mesoscale}$ and k^{-2}).

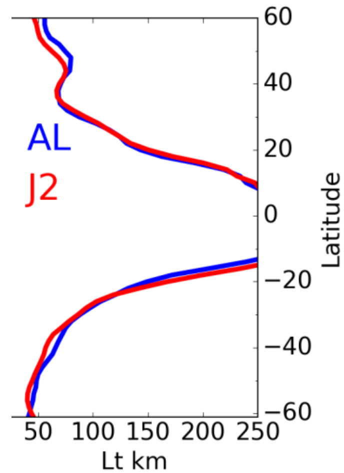


SSH-based Lt









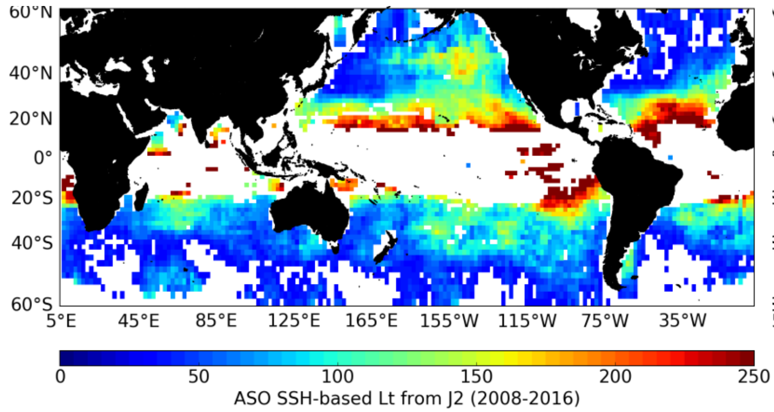
Qiu et al., 2018.

- Blanked values:
  - **Lt** > local eddy length scale
  - **Lt** < 30km (noise limit)

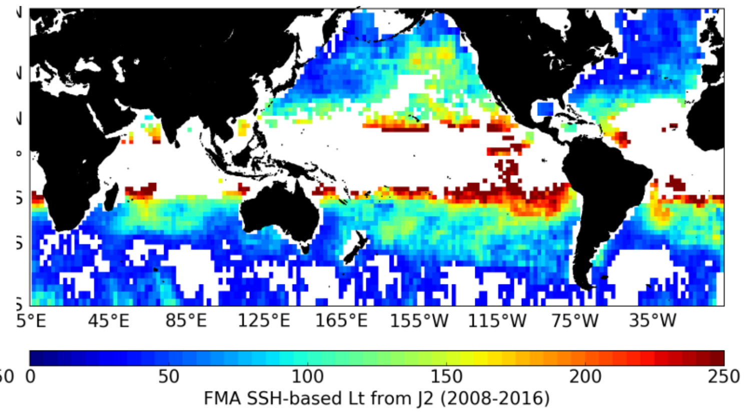
- Despite discrepancies (that could be related to methodology), the general distribution of **Lt estimations from current altimetry missions is consistent with recent literature**.

SSH-based Lt –seasonality

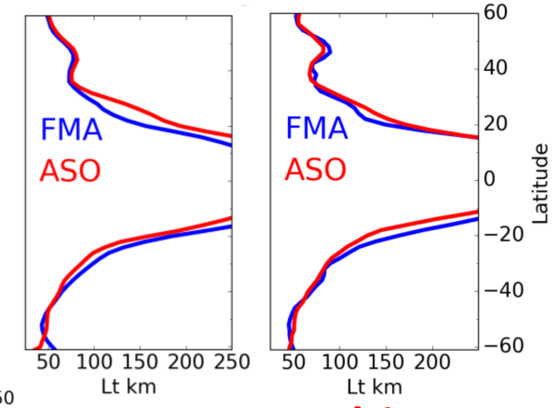
ASO



FMA



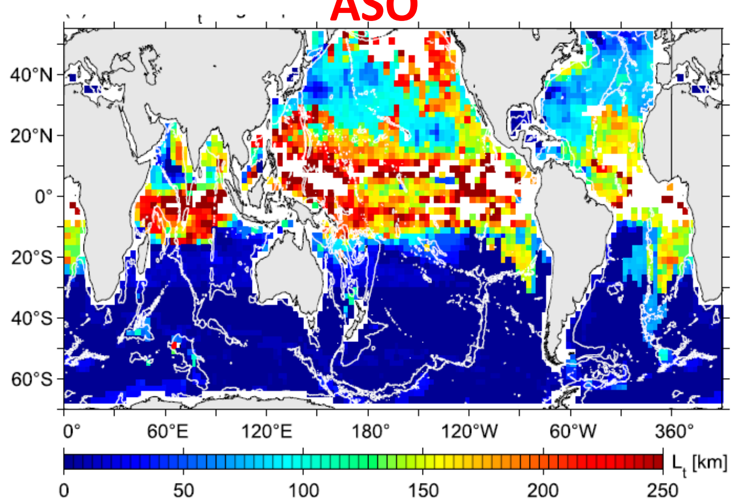
Zonal Average



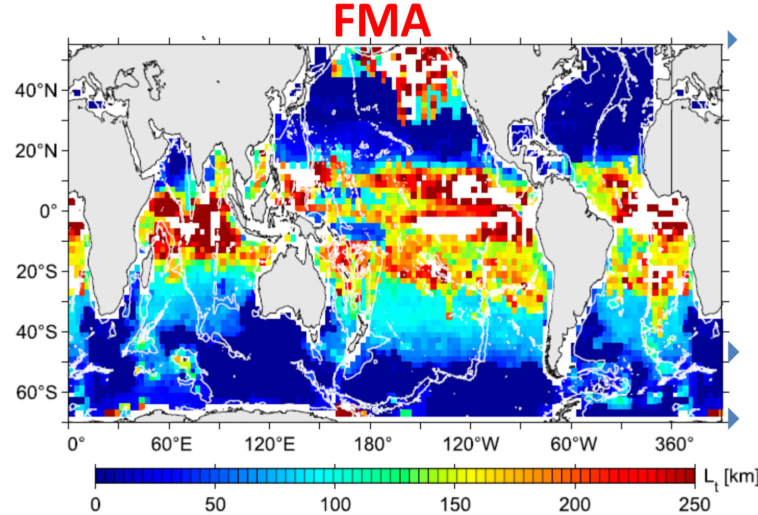
Jason-2 **AltiKa**

KE-based Lt from MITgcm

ASO



FMA



Qiu et al., 2018.

- Despite differences in global maps, zonal average reveals same seasonality in the observations and the modeling results:
- **ASO-Lt > FMA-Lt** in N.H.
- **FMA-Lt > ASO-Lt** in S.H.

Conclusions and current work

- Assuming a white-type noise in the 30-15km wavelength range for AL and J2, **it is possible to estimate Lt from de-noised along-track data** (1Hz).

- Estimations of **Lt** show the lowest values in western boundary current systems (around 50km or less), consistent with a high eddy energy in these regions.

- **Lt** values increase inside the inter-tropical band (>150km) towards the equator (>250 km) and at the eastern boundary current systems (100-150km).

=> IWs more energetic than mesoscale eddies. Consistent with recent studies.

- Although the amplitude of observed seasonal cycle is below that of the simulation, it shows the same trends.

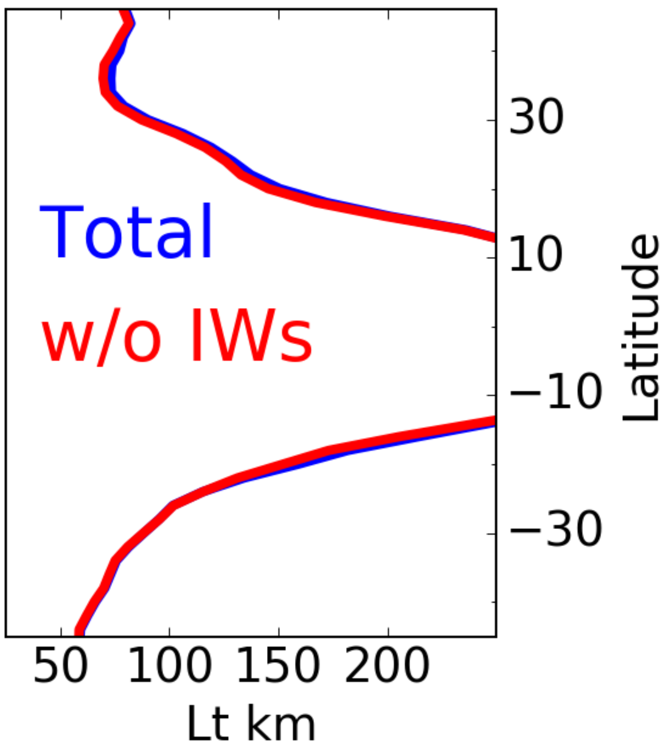
On-going:

- What exactly does the k^{-2} slope represent? Incoherent internal tides, IGWs, any remaining altimeter errors ?
- Current efforts in reprocessing S3A data (lower noise than AltiKa) are being carried out.

Backup

Small impact of correcting for coherent IWs

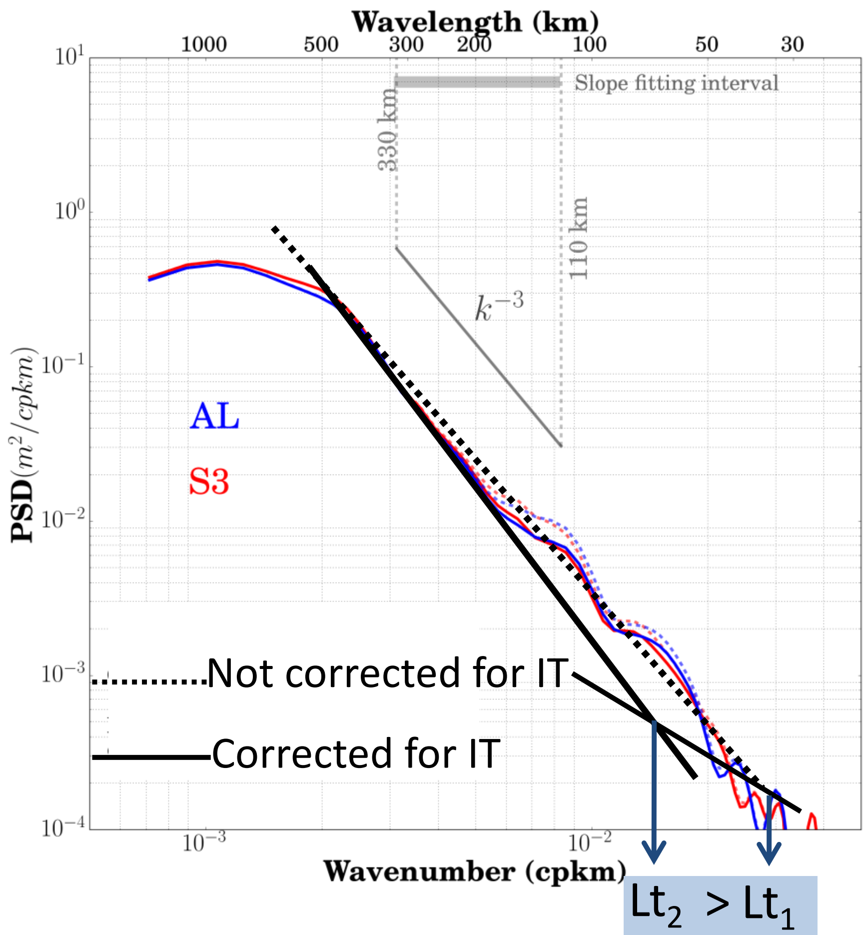
Impact on Lt of the Ray and Zaron (2016) coherent internal tide correction

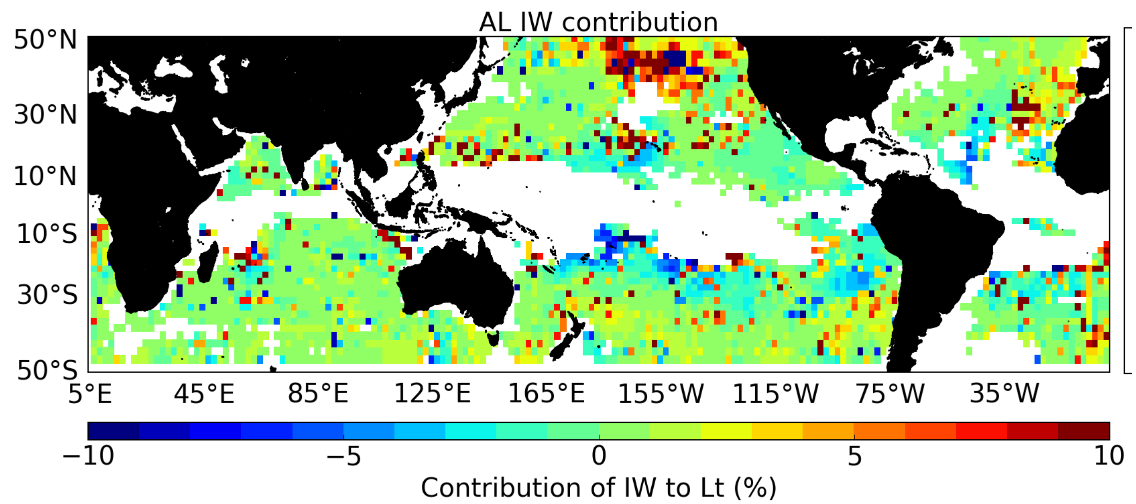


- The contribution of the coherent internal Tide to Lt is generally low (around 2%), inducing **lower Lt** values in the tropics. **Higher Lt** values (as expected) are found poleward of the intertropical band. And particularly in the N. Pacific.
- This does not fully agree with reported modeling results (Qiu et al., 2018) **Consistently higher Lt** values related to IT.

Small impact of correcting for coherent IWs

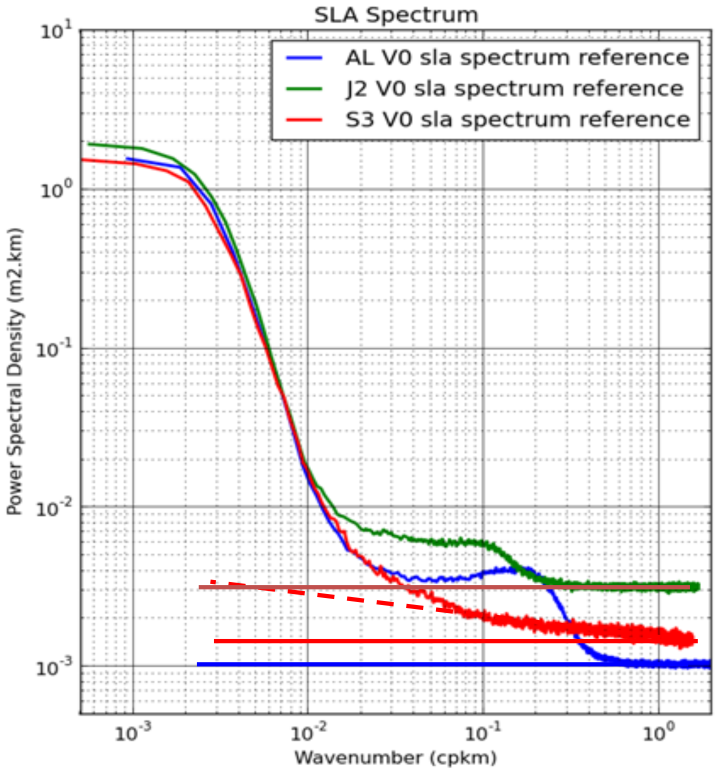
Impact on Lt of the Ray and Zaron (2016) coherent internal tide correction

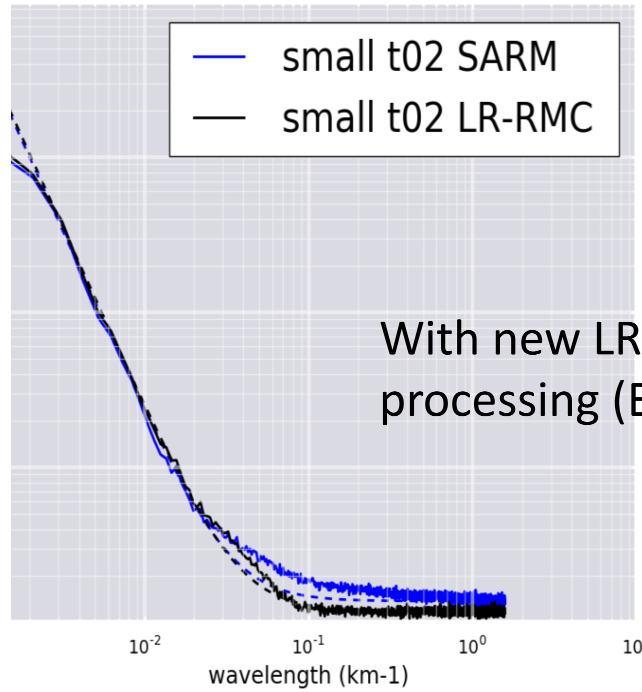




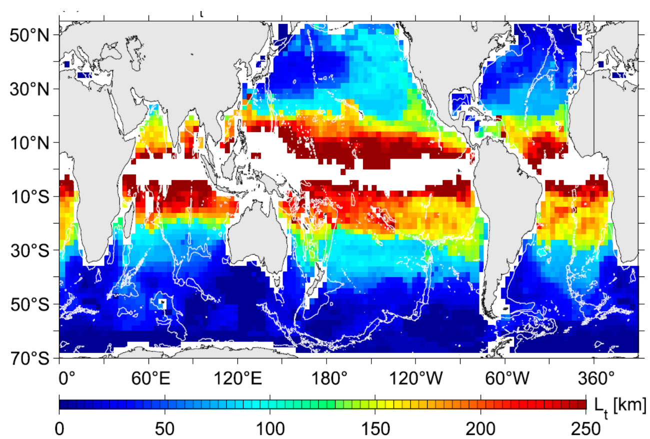
Negative values indicate that the coherent tides would act to decrease Lt -> likely to result from their impact on the spectral slope fitting procedure.

Perspective S3A processing



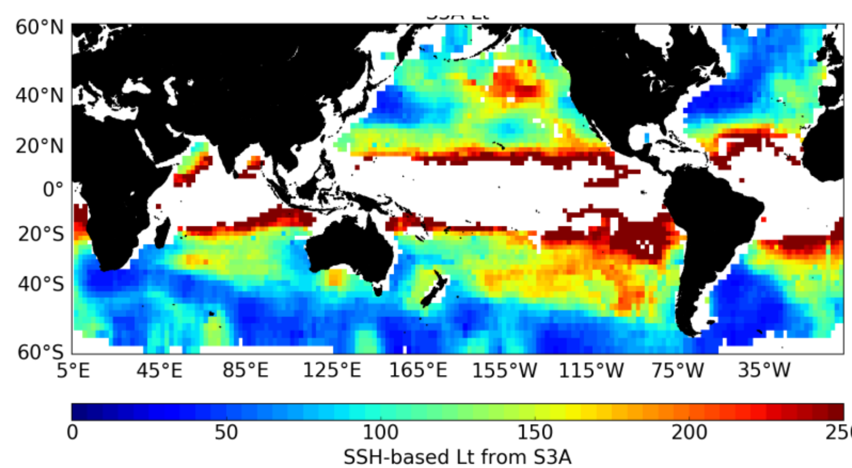


Lt from MITgcm (Qiu et al., 2018)

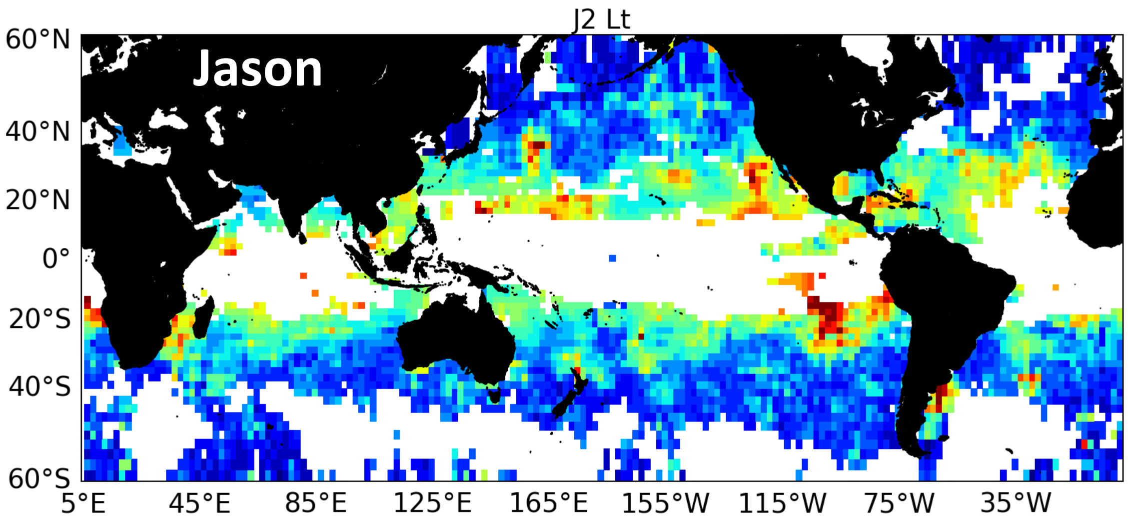


Qiu et al., 2018.

SSH-based Lt from S3A (difficult to interpret!)

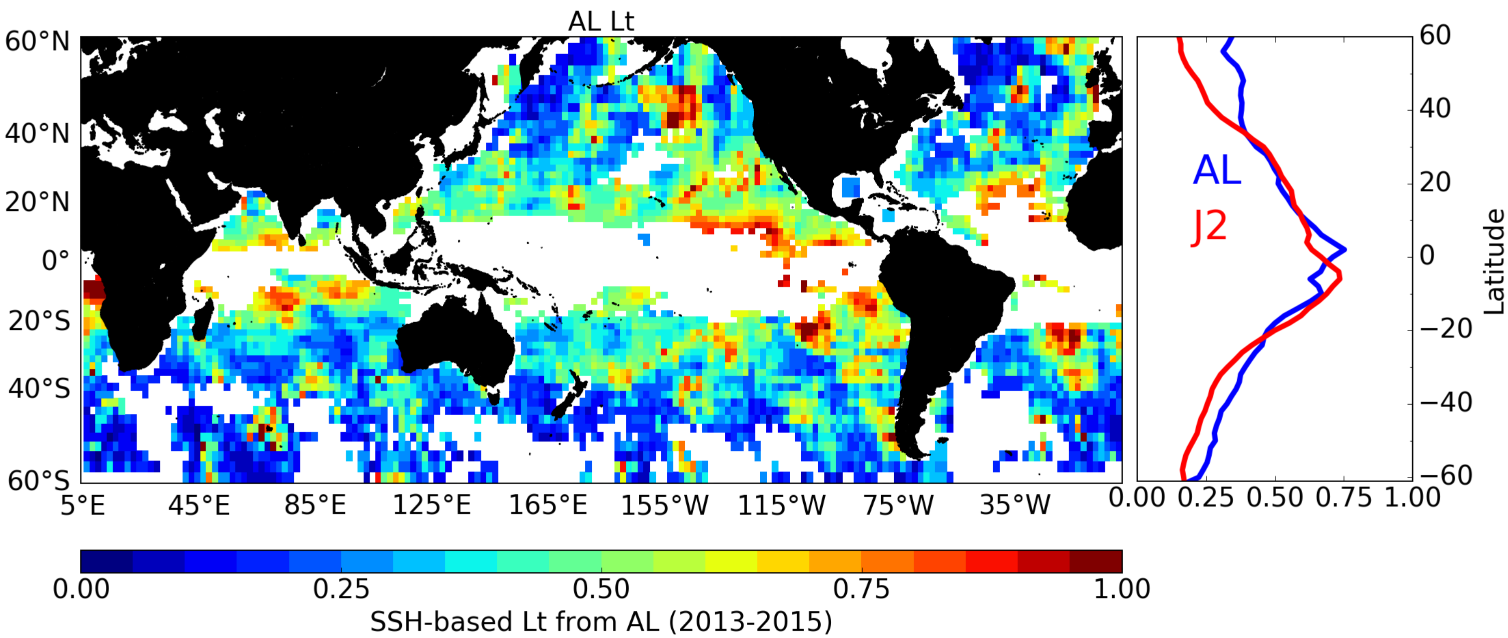


Submesoscale k^{-2} - goodness of fit



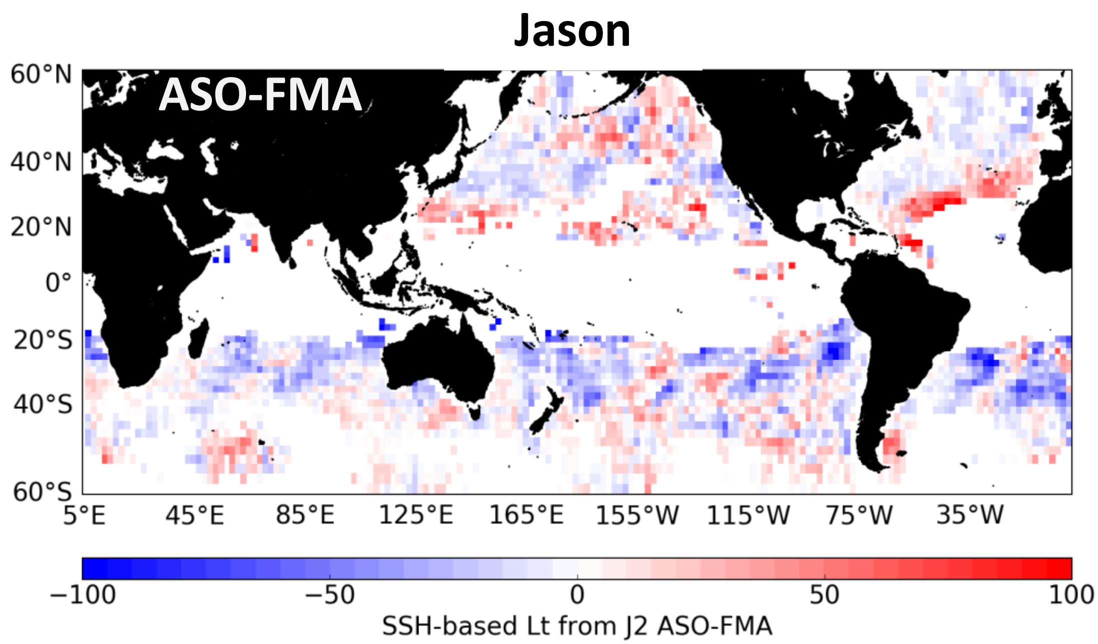
•The spectral slope in submesoscale range deviates from k^{-2} in highly energetic regions.

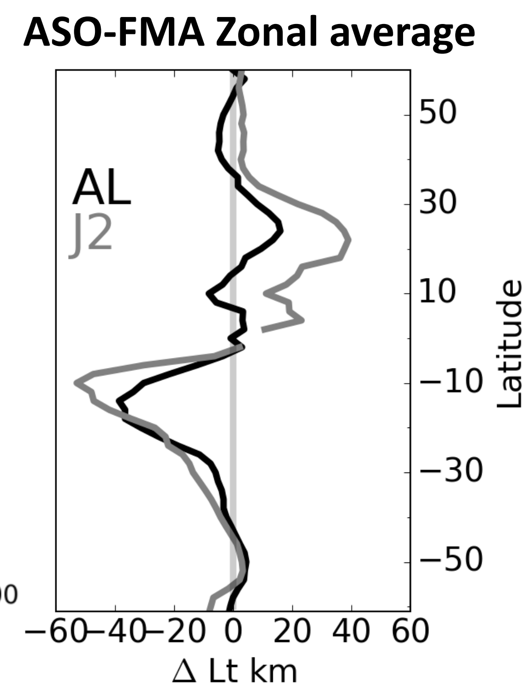
•This could be due to the very small Lt found here (near to instrumental noise range), hard to diagnose in the along-track data.

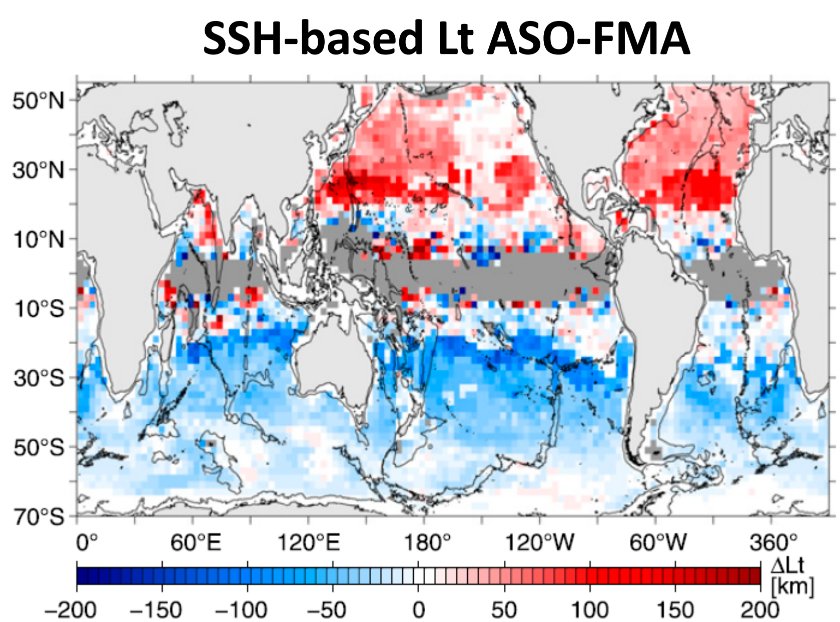


R^2 for the k^{-2} linear fit in the submesoscale range

SSH-based Lt –seasonality







Qiu et al., 2018.