Investigating short wavelength correlated errors on low-resolution mode altimetry

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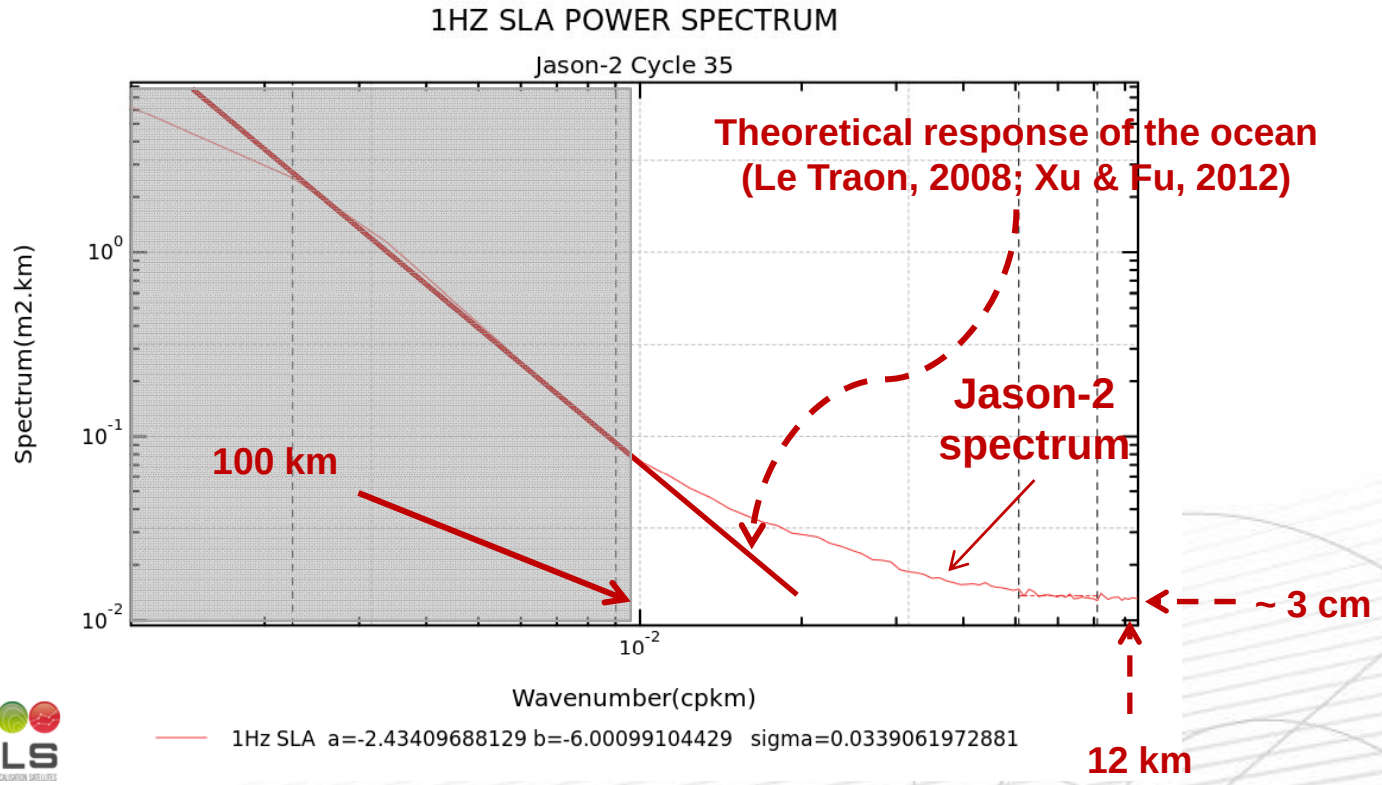
Introduction

- **Can we reach small spatial scales (typ. less than 100 km) with conventional altimetry in the along track direction ?**
- **What is the dominant error for small scale observation ? Can we reduce it ? Which data should be used for science at these scales ?**

- Brief overview of different results obtained with altimetry

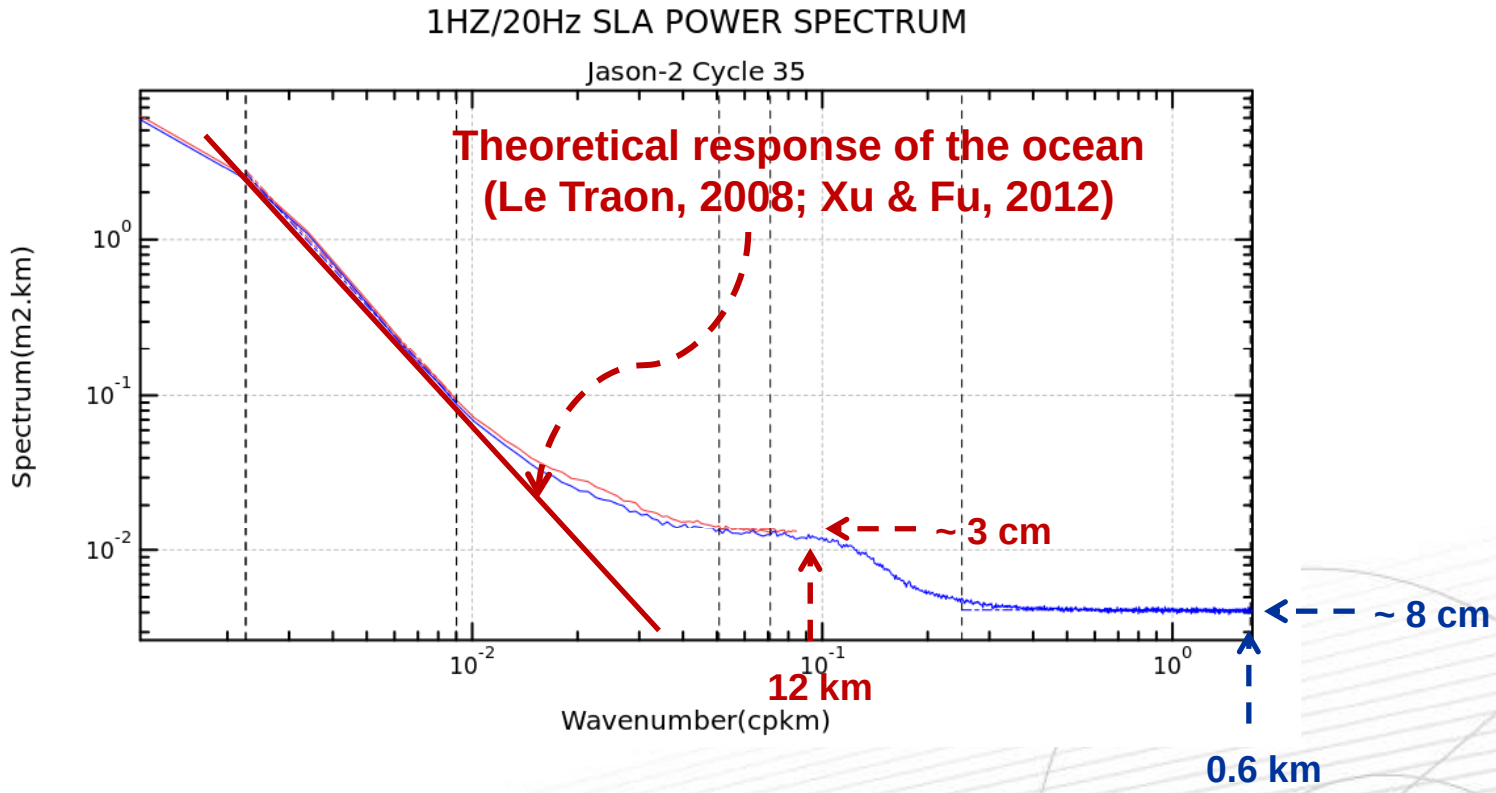
  Conventional altimetry data are provided at a high rate in the products (20 measurements per seconds for ERS, Envisat-RA2, Jason-1, Jason-2, LRM Cryosat-2, …; 40 for Saral/altika ; 10 for Topex)
- Outlooks to improve high resolution altimetry
- Insights and limits of Power Spectral Density analysis in this context
- Does delay/doppler SAR altimetry (Cryosat-2 and S-3) improves the observation at these scales?
- Conclusions

Jason-2 1Hz Sea Level Anomaly power spectral density (PSD)



❑ SLA PSD decreases with wavenumber but the 3 cm Gaussian noise can corrupt wavelengths as large as 100 km. This noise **is the main limitation to observe small mesoscale** with 1Hz GDR along-track products.

1Hz/20Hz Jason-2 SLA power spectral density (PSD)



- A hump-shaped artifact appears on the spectrum but is visible only with 20Hz rate
- A $\sqrt{20}$ factor is not found between 20Hz and 1Hz noise level (3 cm instead of 1.8 cm)

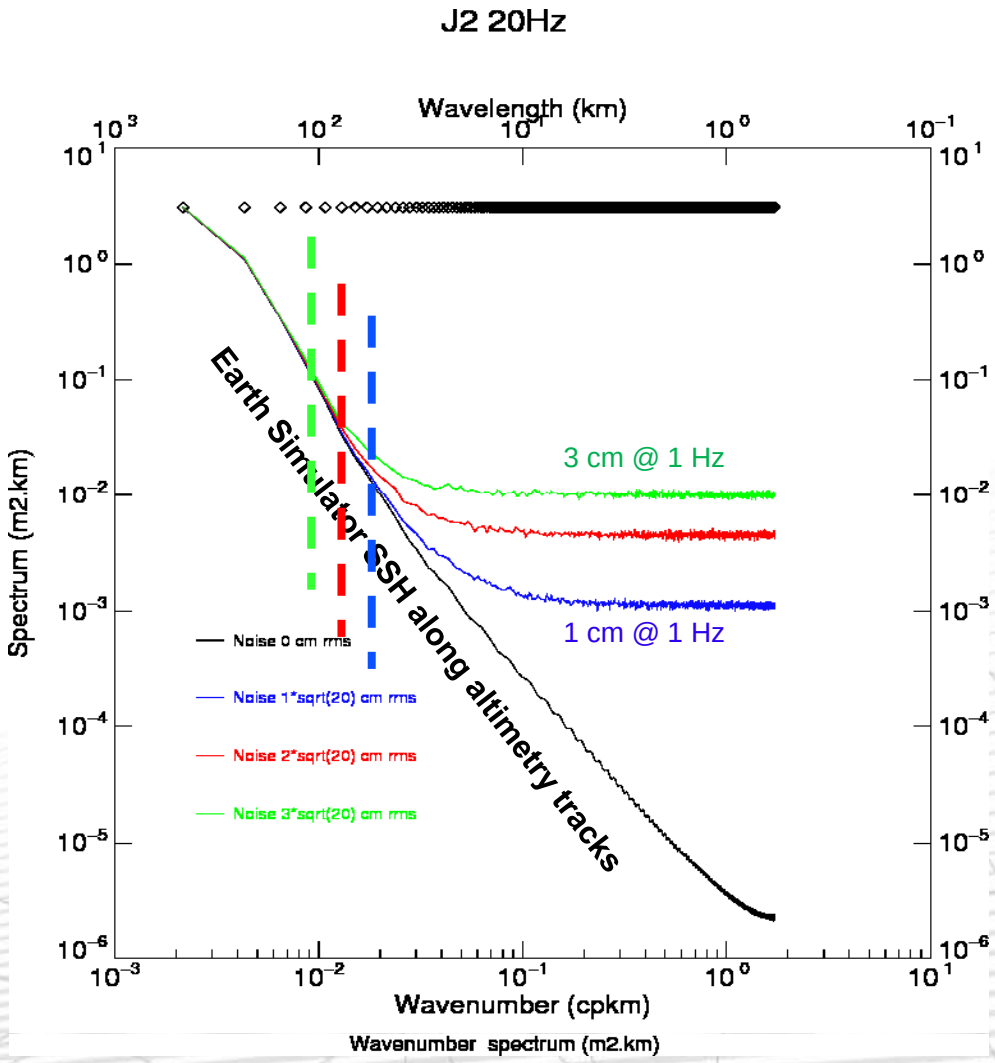
➔1 Hz noise is NOT ONLY instrumental noise !

Comparison with simulated data

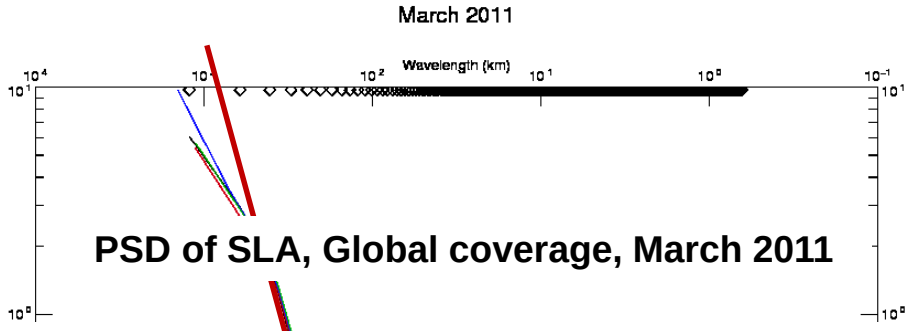
PSD of simulated SLA from Earth Simulator (P.Klein et al) + white noise

For comparison, we can plot the spectra obtained with simulated SLA on which different white noises have been added

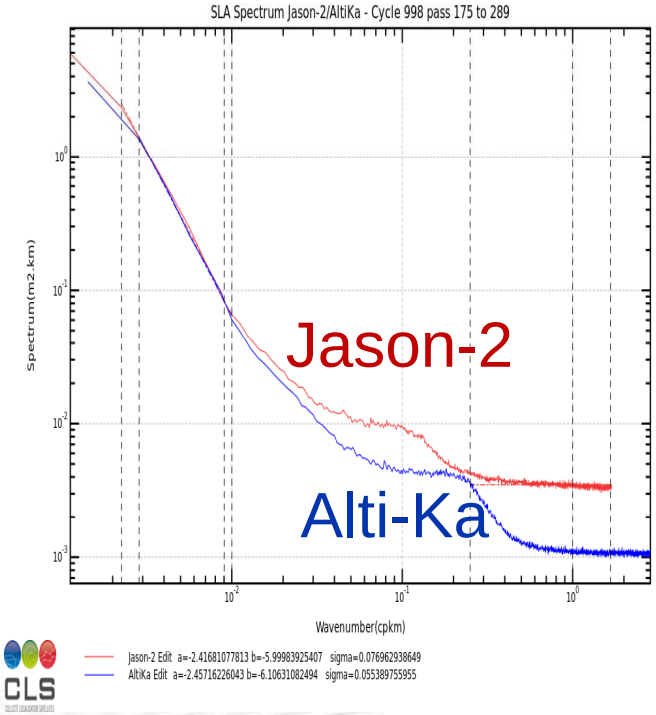
If we can reduce both the instrumental noise and spectral hump, we improve the observation of scales ranging from 15 to 100 km



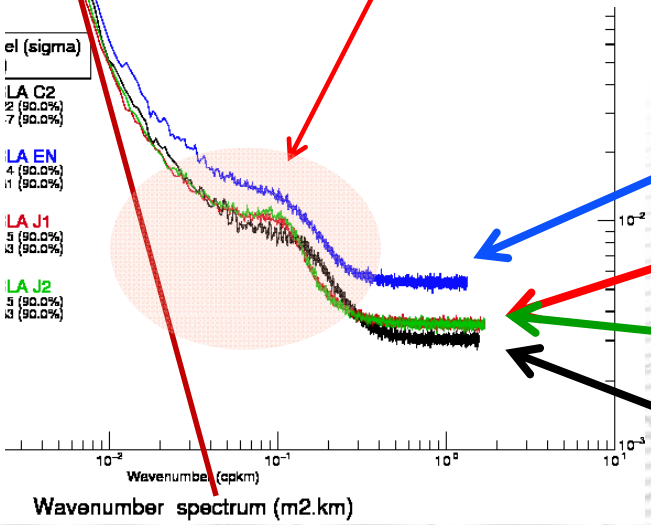
The spectral hump is present on all conventional altimeter PSD spectra



PSD of SLA, Global coverage, March 2011



Hump of energy observed on SLA between 10 and 60+ km



Wavenumber spectrum (m2.km)

Envisat

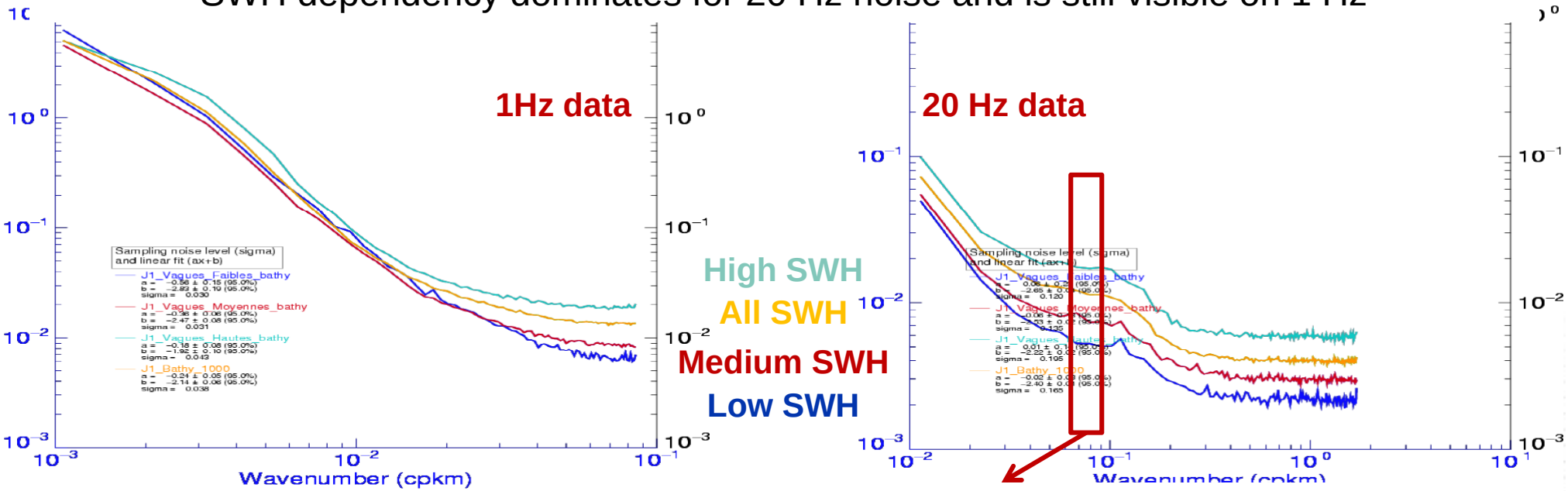
Jason-1

Jason-2

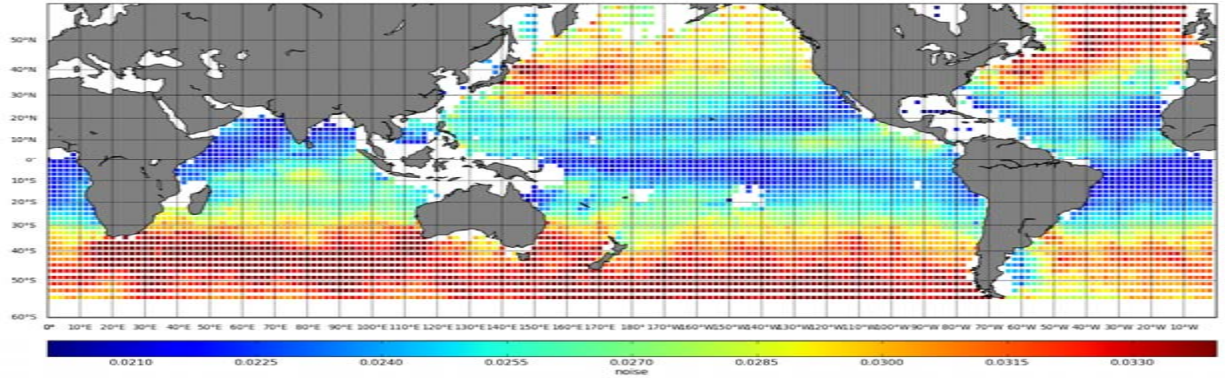
Cryosat-2

1Hz PSD energy as a function of SWH

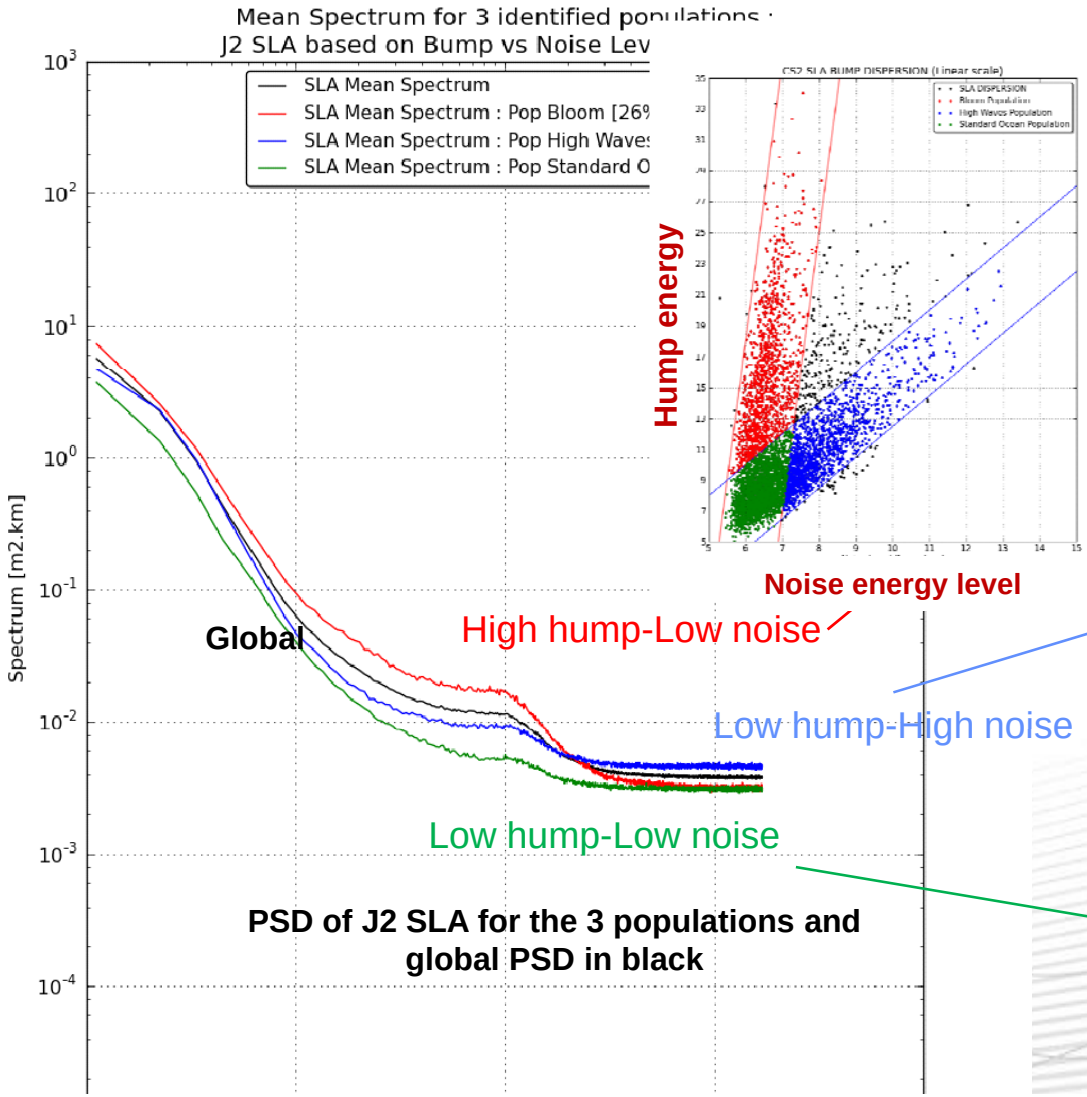
True instrumental noise increases with the waves, but hump artifact does not.
SWH dependency dominates for 20 Hz noise and is still visible on 1 Hz



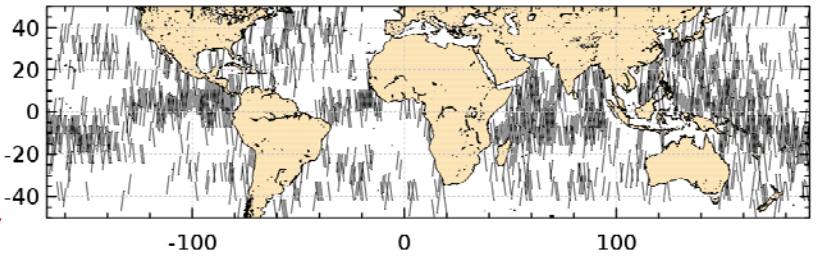
SLA energy between
14 and 25 km
(see poster from Dufau & al)



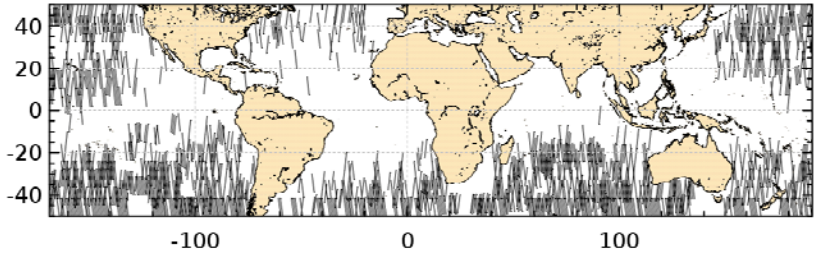
Understanding the spectral hump with 20Hz data



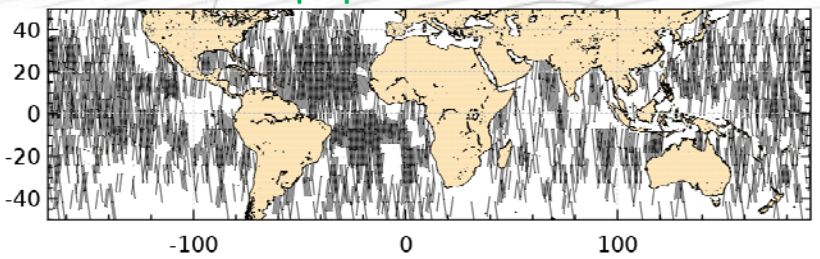
Red population = Rain and Bloom



Blue population = High waves



Green population = Brown ocean

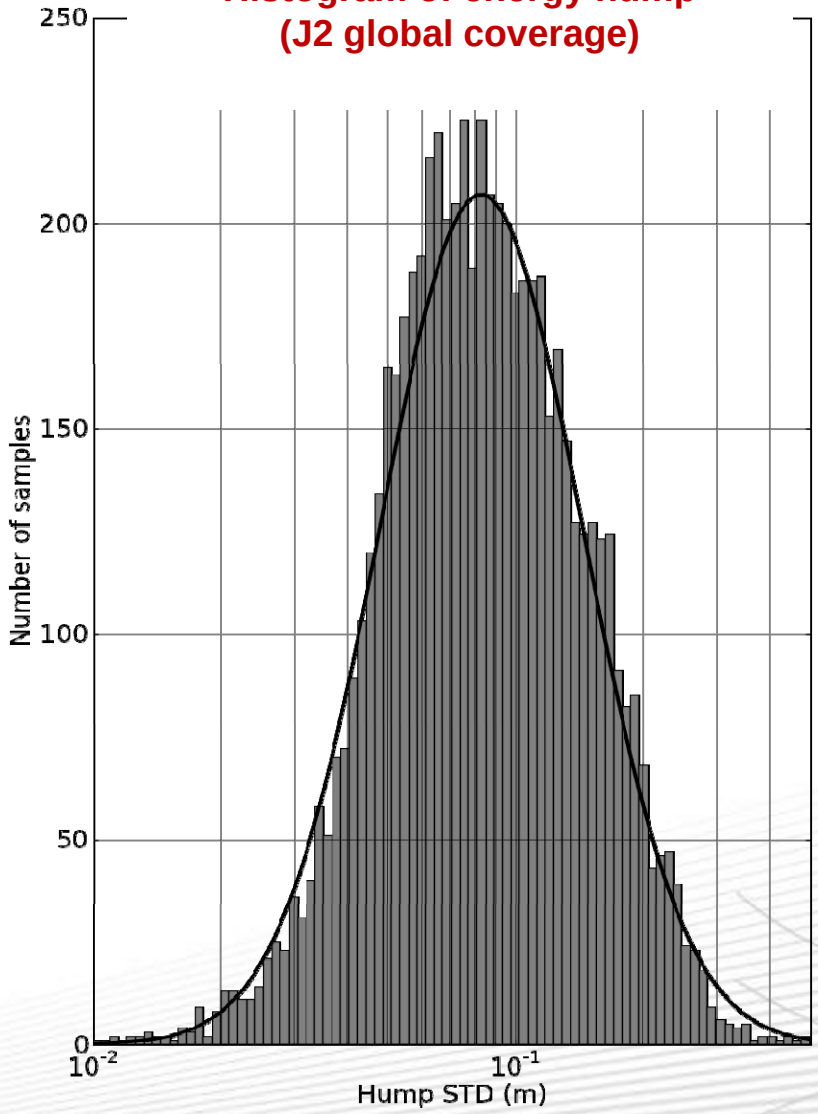


Geographic distribution for the 3 populations

Hump is more present in regions where the backscattering properties are not homogeneous in the waveform footprint (basic assumption of the Brown model)

Understanding the spectral hump with 20Hz data

Histogram of energy hump (J2 global coverage)



The distribution of the hump is relatively random for large samples:

- ❑ the hump exists on all 1000 km segments covering the globe albeit with a variable amplitude (geographical variations linked with occurrence of rain and sigma bloom events)
- ❑ not explained by a few isolated 1000 km segments that corrupt the mean spectrum

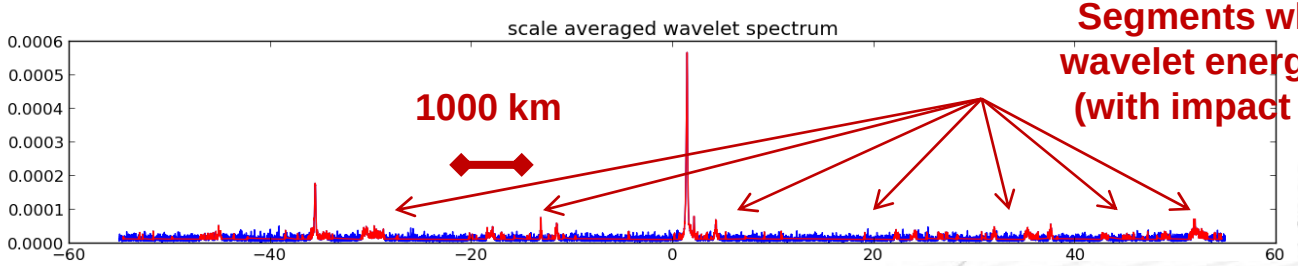
Is PSD the appropriate tool to determine the SLA content ? Wavelet analysis looks very promising

- PSD, based on Fourier analysis (averaging of hundred of long segments - 500 to 1000 km), is well designed for stationary signals

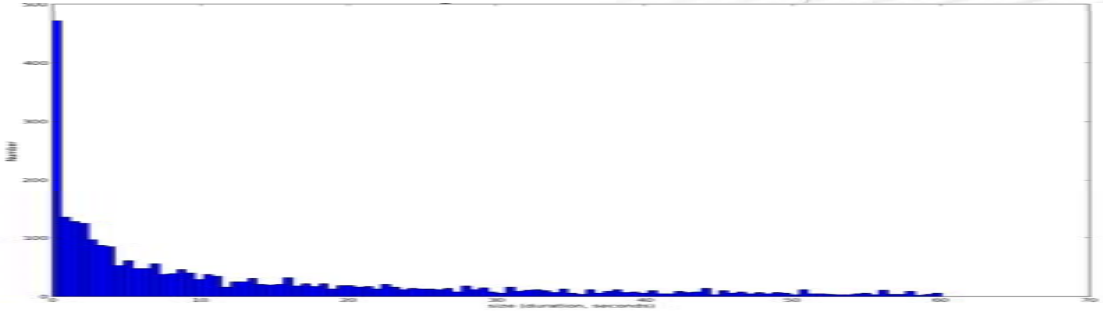
- **But SSH / SLA profiles cannot be considered as stationary signals**

The backscattering surface is affected by rain, bloom events, modification of the sea state …

Wavelets Energy (Morlet wavelet on WF trailing edge)



Histograms of segments without any corrupted data

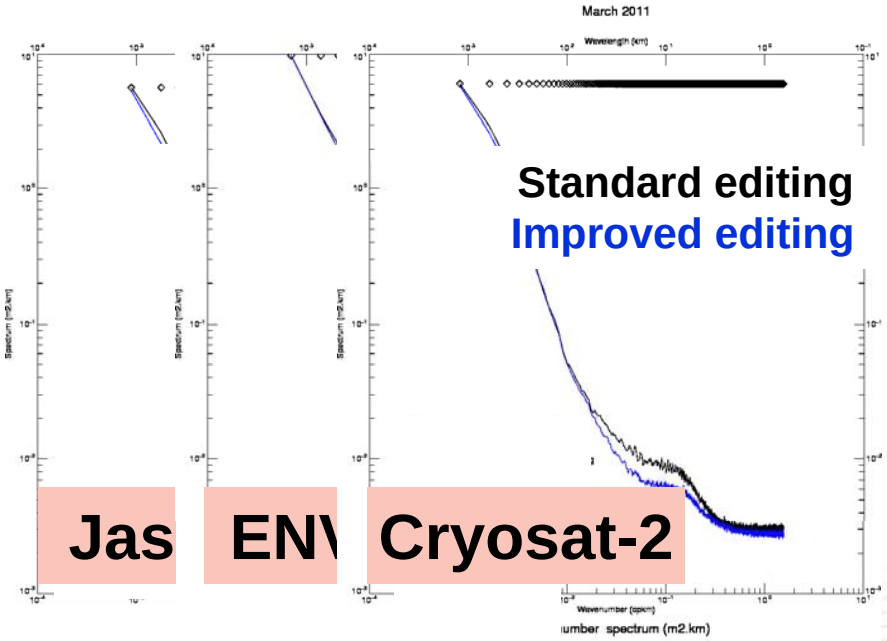


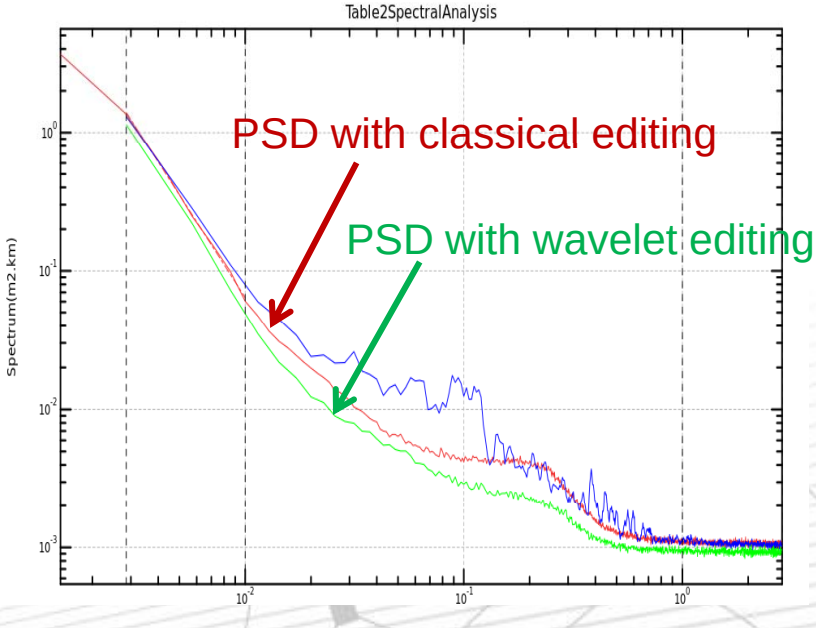
AltiKa data

Processing and post-processing methods to reduce the hump

❑ The spectral hump can be reduced by using an appropriate editing on 20 Hz data (including wavelet filtering)

➔ **Good trade off must be found between rejecting measurements and hump reduction**





AltiKa data

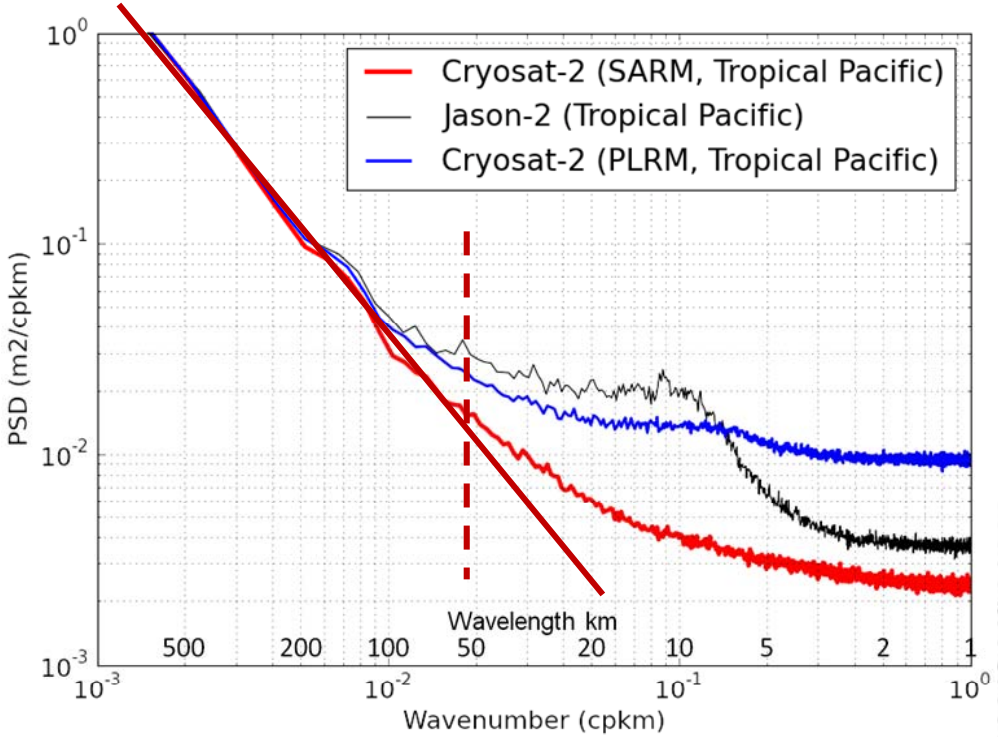
❑ Work needed on retracking algorithm (e.g. Sandwell & Smith 2013, 2-pass algorithm used to mitigate the spectral hump for bathymetry applications). (50 years of altimetry data)

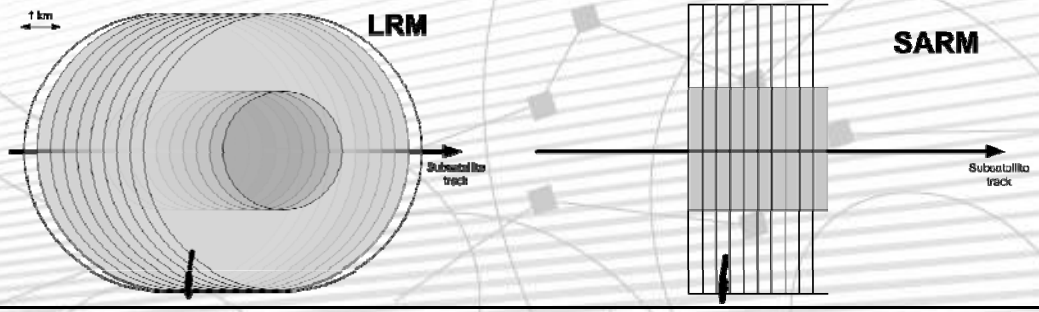
Outlook: SAR-Mode technology

- What is observed on SARM
  - Clean SSHA spectrum down to 50 km
  - Spatial limit (where error is 50% of the signal energy) might be closer to 30 km VS. 70 km with LRM processing

- Different size and shape of footprint (Circular 10 km / Rectangular 10 km * 300 m)

- SARM synthetic footprint no longer smoothes along-track error like LRM altimetry does.





Conclusions

- The spectral hump is not the result of a minority of outlier segments or sloppy processing
  - Exists on data from all LRM altimeters from TOPEX to AltiKa, and all retrackers
  - Long uncontaminated segments are very rare
  - Phenomenon is more intense in zones of major rain and bloom events, but it is also present for other ocean conditions (lower amplitude)
- Event triggered by surface heterogeneity (waveforms corrupted)
- Smarter post-processing & editing by end-users can mitigate the error
  - Usage of 20 Hz is strongly recommended for small scale studies
  - Work needed to develop better /smarter editing methods (lower artefact BUT good coverage)
- Work needed on the retracking algorithms and/or waveform pre-processing
- SARM technology is promising (thin synthetic footprint) in small zones from Cryosat-2 but technology and processors are still young w.r.t the long LRM record
- Needed for further investigation:
  - larger acquisitions from Sentinel-3
  - concurrent LRM/SARM data from interleaved mode of Jason-CS
  - SWOT/KaRIN images → to observe in 2D what nadir altimeters are integrating

Thank you for your attention