WAVELET ANALYSIS OF ALTIMETER MEASUREMENTS
APPLICATION TO SARAL/ALTIKA

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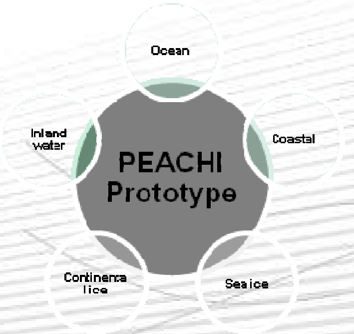
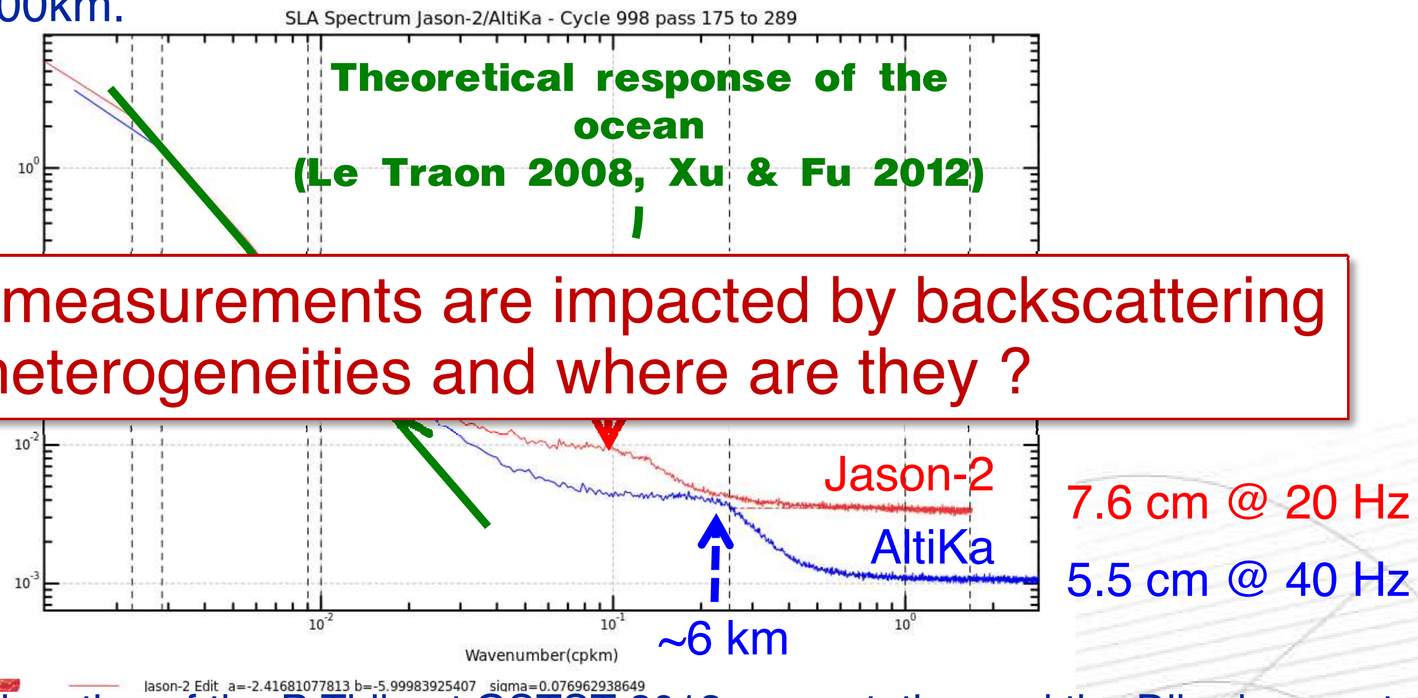


Summary

1. SLA Spectrum computed from LRM measurements
2. The Continuous Wavelet Transform (CWT) applied to AltiKa measurements
3. Validation on strong event detection : rain cells and sigma bloom events
4. Investigating the spectral hump using CWT
5. Conclusions and perspectives

The SLA Spectrum and the spectral hump

- It has been shown several times that **a spectral hump is present on all conventional altimeter** SLA spectra preventing from correctly observe ocean signal at scales below 100km.



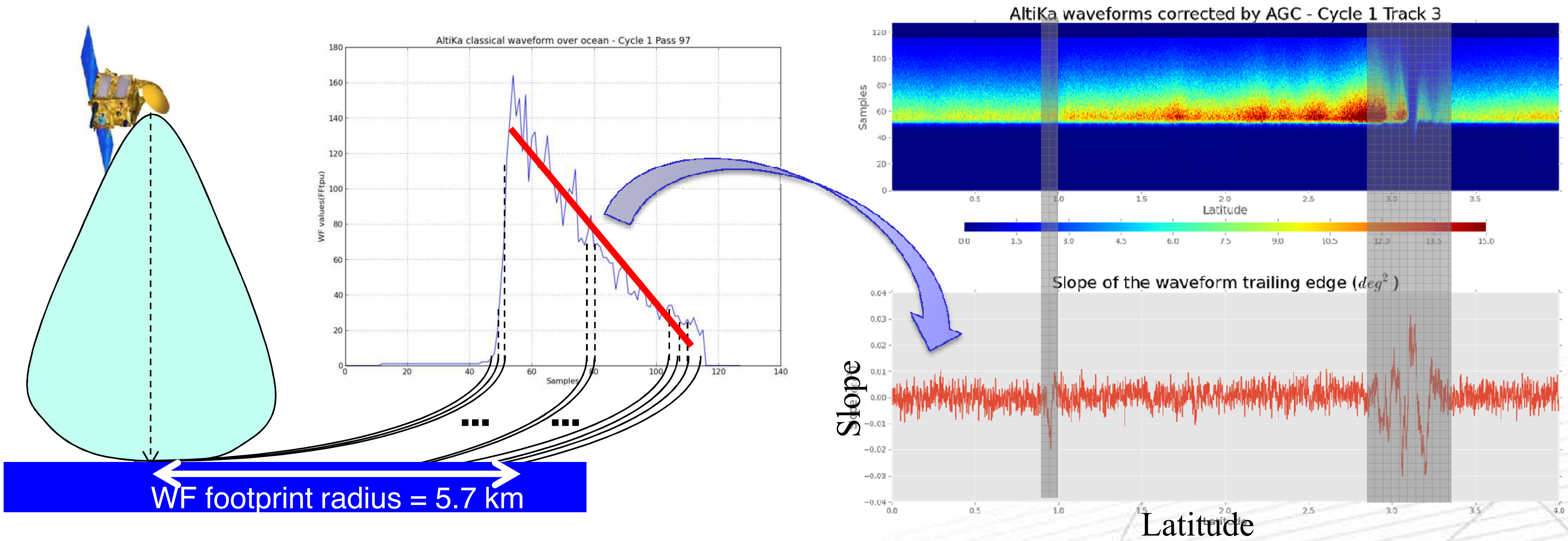
How many measurements are impacted by backscattering heterogeneities and where are they ?

- This study is a continuation of the P.Thibaut OSTST 2013 presentation and the Dibarboure et al. paper named "Investigating short wavelength correlated errors on low-resolution mode altimetry"

➔ The spectral hump is mainly due to backscattering heterogeneities in the waveform footprint with direct impacts on the MLE4 outputs.

➔ PSD analysis is an efficient tool for stationary signal analysis but not for the observation of transient signals.

The Continuous Wavelet Transform (CWT) applied to AltiKa measurements



- Backscatter heterogeneities present in the waveform footprint directly impact the waveform on its trailing edge.

  ➔ Local oscillations of the trailing edge slope are visible : strong oscillations for rain cells or sigma blooms, smaller for sea state modifications

The Continuous Wavelet Transform (CWT) applied to AltiKa measurements

- Based on a Torrence & Compo (1998) paper, the scale-averaged wavelet power spectrum is computed from the slope of the waveform trailing edge to analyze localized variations of this particular parameter.

Wavelet

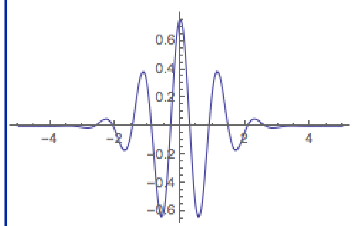
$$\Psi$$

CWT

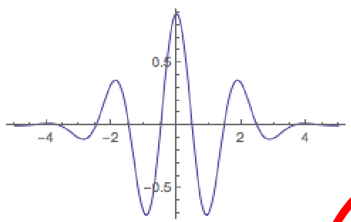
$$W_n(s) = \sum_{n'=0}^{N-1} \chi_{n'} \Psi^* \left[\frac{(n'-n)\delta t}{s} \right]$$

Scale-averaged wavelet power spectrum

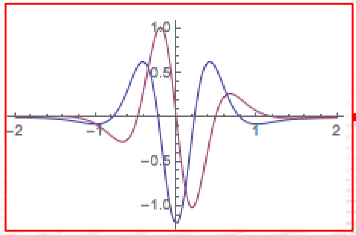
$$\overline{W_n^{\,2}} = \frac{\delta_t \delta_s}{C_\delta} \sum_{j=j_1}^{j_2} \frac{|W_n(s_j)|^2}{s_j}$$



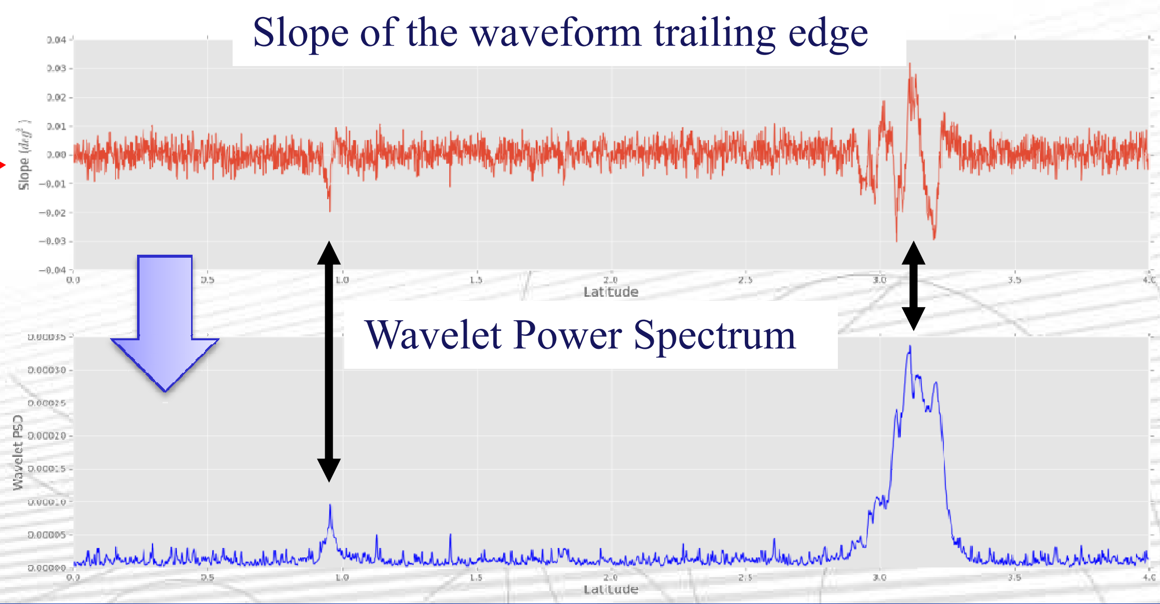
Morlet



DOG

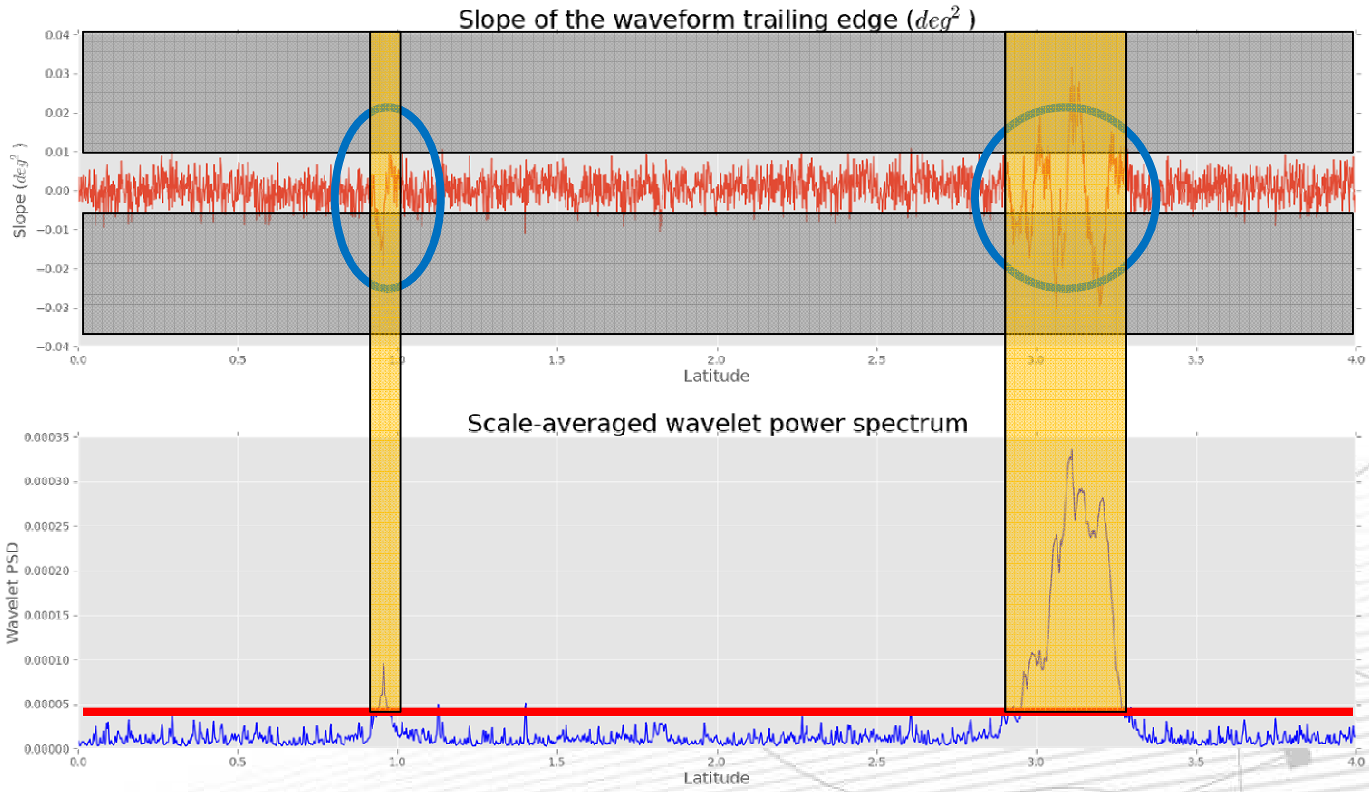


Paul



The Continuous Wavelet Transform (CWT) applied to AltiKa measurements

The CWT is a powerful tool to perform an efficient data editing removing **coherent structures** at 40Hz



➔ A classical threshold editing (as used in Calval processing) keeps data inside events

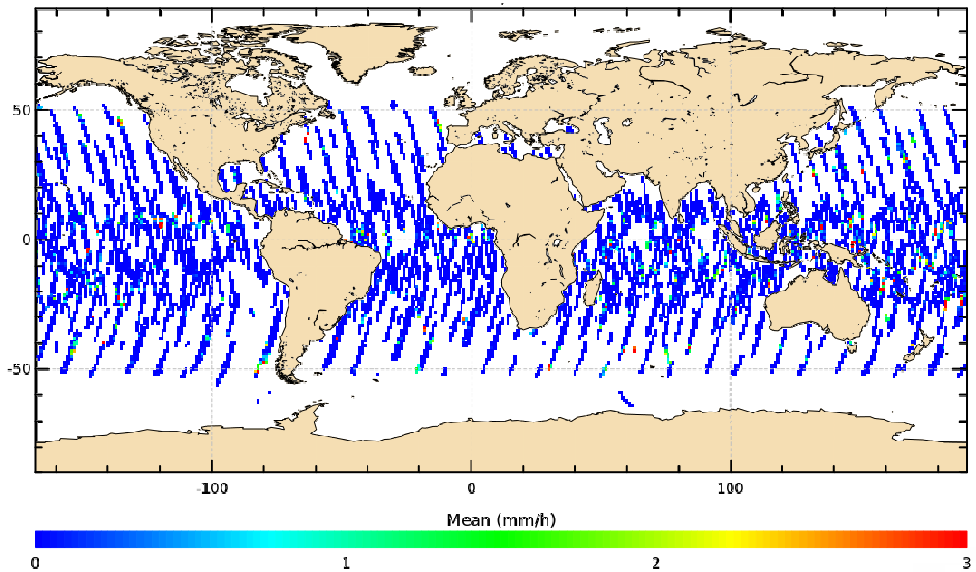
➔ A threshold on the scale-averaged wavelet power spectrum edits entire events

- The CWT is used in this study to detect backscatter events exceeding a threshold of the wavelet power spectrum during at least a second.

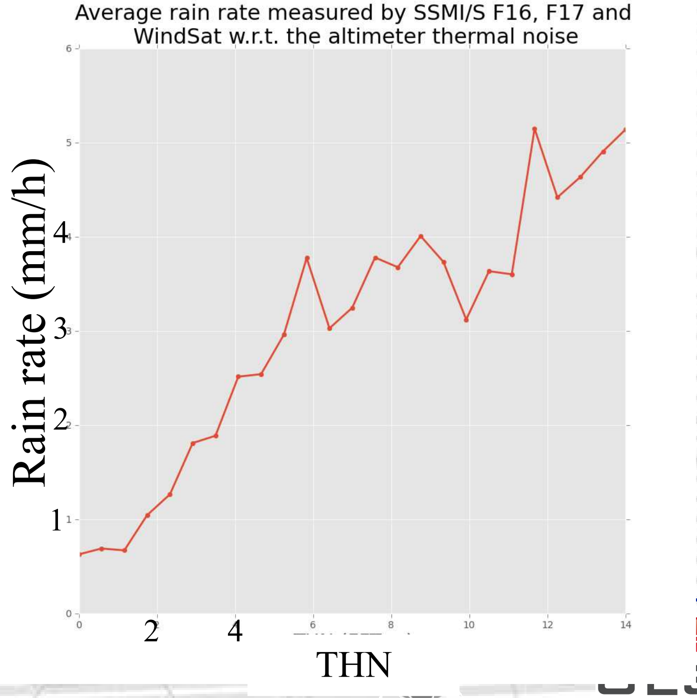
Validation on strong event detection : Rain cells and Sigma blooms

- As the matching pursuit algorithm (developed by J. Tournadre), the CWT can detect variations of the slope of the trailing edge due to rain cells and sigma blooms.

Collocated rain rate measurements for $\Delta t < 5$ min



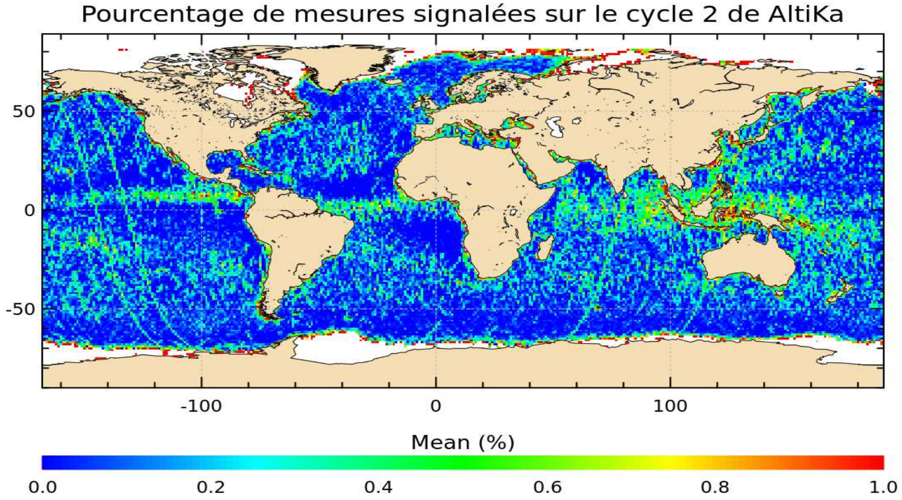
➢ To validate the rain detection, SSMI/S F16, F17 and WindSat rain rate measurements are collocated with AltiKa measurements with a time lag < 5 min .



➢ The CWT alone cannot separate rain cells from other perturbations:

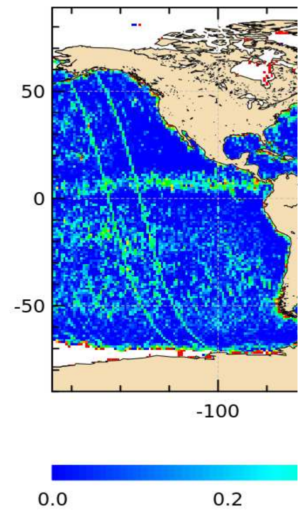
➔During rain cells, the Ka band returned signal is attenuated as a function of the rain rate →The tracking loop mitigates this attenuation impacting the waveform thermal noise level

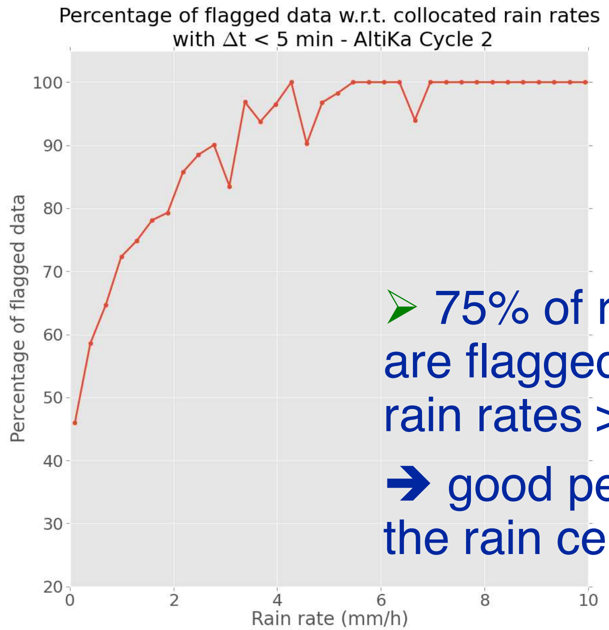
Validation on strong event detection : rain cells and Sigma blooms



- With a threshold of 1e-5 on the wavelet power spectrum, **15%** of ocean data are flagged (no identification of rain or blooms)

- The association of the THN criterion and the CWT flag allows to identify that 10% of the data are affected by rain ➔ similar to the Matching Pursuit (cf J. Tournadre's talk)





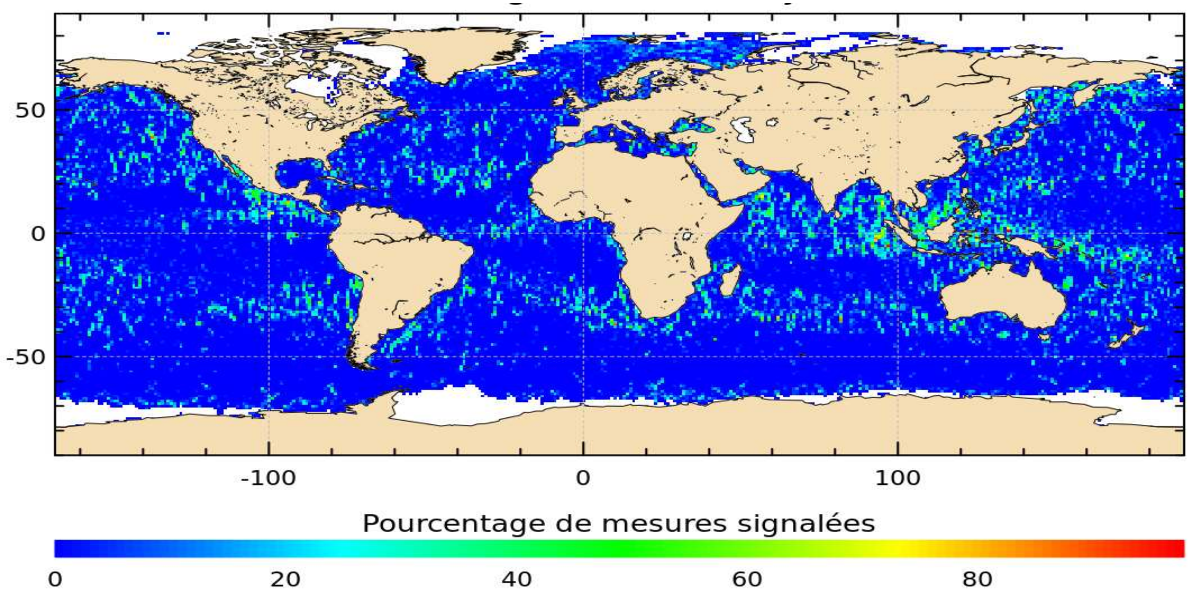
- 75% of rain rate ~1mm/h are flagged and ~ 100% of rain rates > 5 mm/h

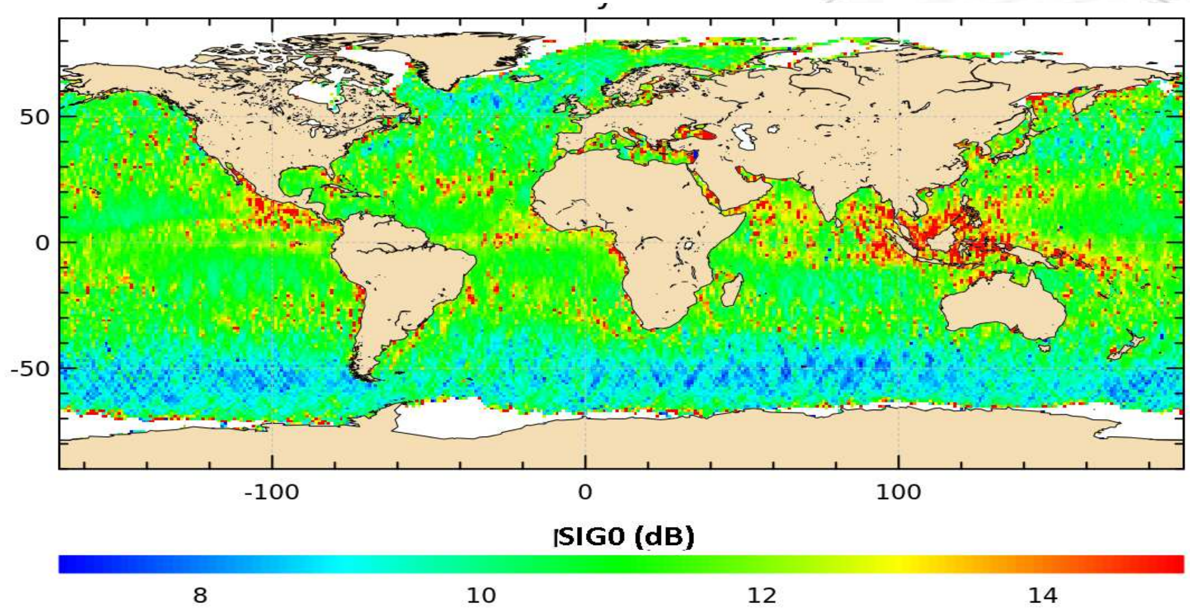
➔ good performances of the rain cells detection

Validation on strong event detection : rain cells and Sigma blooms

➢ 5% of data are flagged by the CWT but do not satisfy the THN Criterion

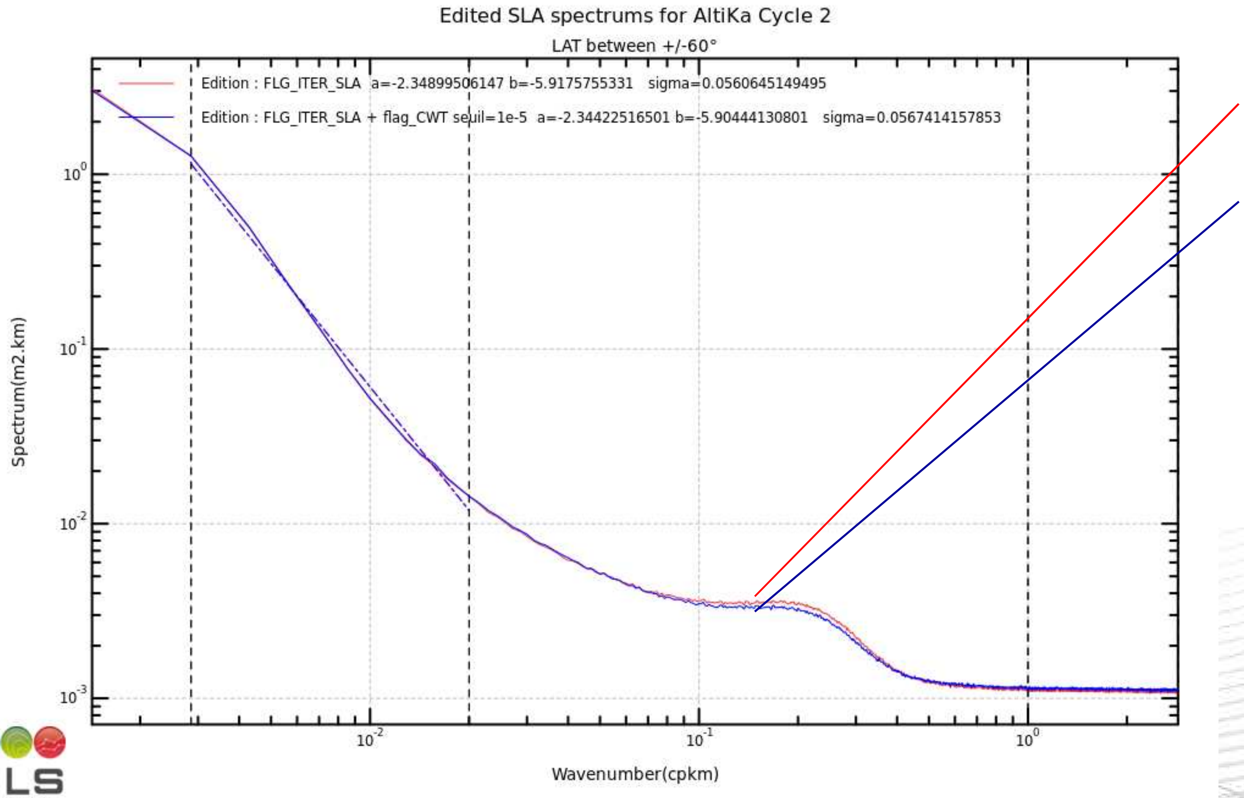
➔ These data mainly correspond to strong values of Sigma0 (Sigma blooms ?)





Investigating the spectral hump through the CWT

➢ Does the removal of 15% of the measurements identified as rain and sigma bloom sufficient to reduce the spectral hump ?



Reference SLA spectrum

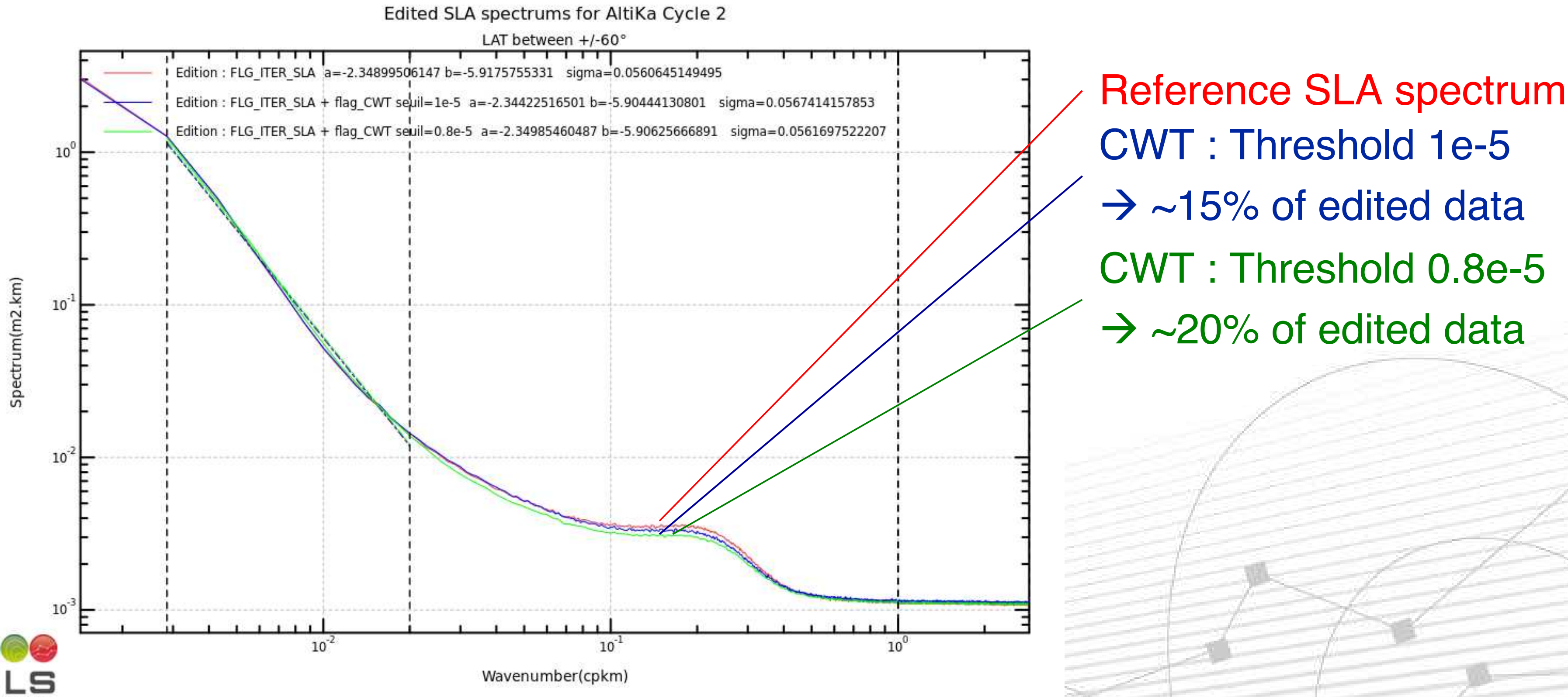
CWT : Threshold 1e-5

→ ~15% of edited data

➢ Does the spectral hump can be reduced with a more drastic editing ?

Investigating the spectral hump through the CWT

➢ Does the removal of the 15% of measurements identified as rain and sigma bloom sufficient to reduce the spectral hump ?



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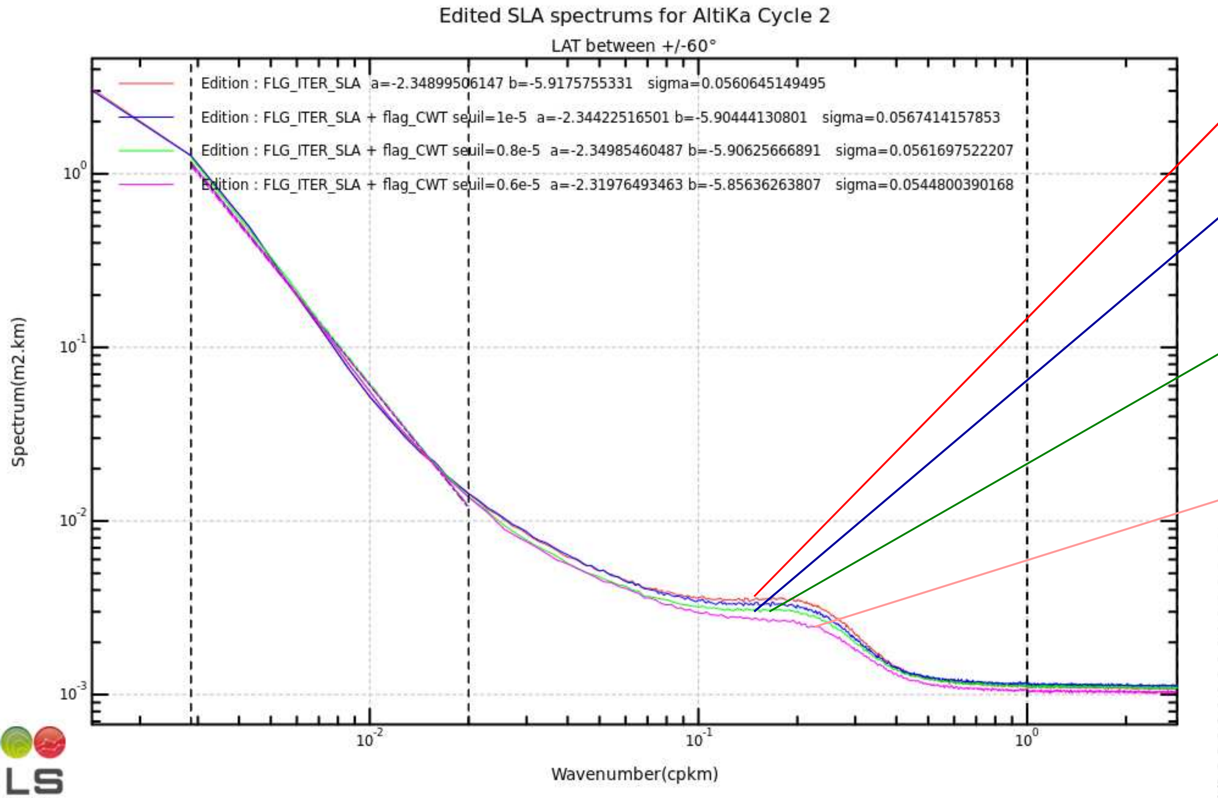


Reference SLA spectrum

CWT : Threshold 1e-5

→ ~15% of edited data

CWT : Threshold 0.8e-5

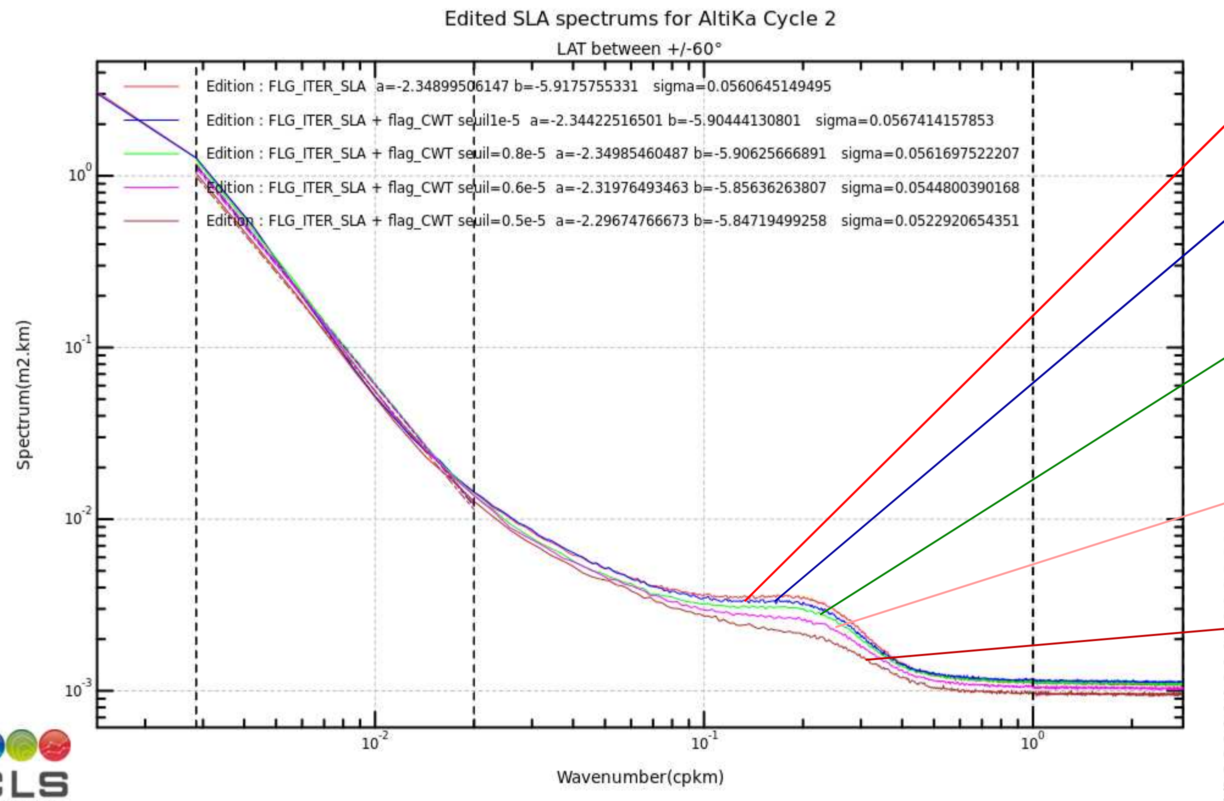
→ ~20% of edited data

CWT : Threshold 0.6e-5

→ ~30% of edited data

Investigating the spectral hump through the CWT

➢ Does the removal of the 15% of measurements identified as rain and sigma bloom sufficient to reduce the spectral hump ?



Reference SLA spectrum

CWT : Threshold 1e-5

→ ~15% of edited data

CWT : Threshold 0.8e-5

→ ~20% of edited data

CWT : Threshold 0.6e-5

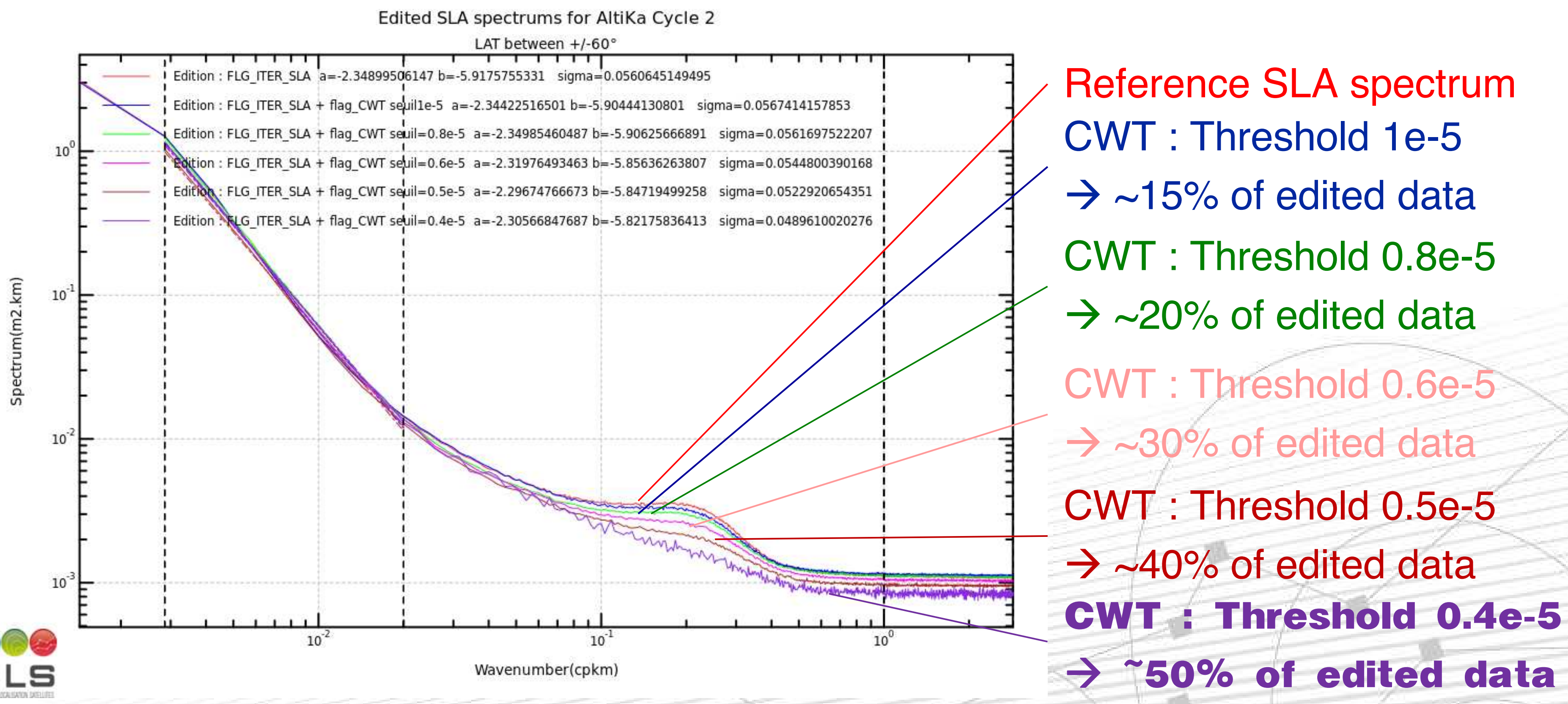
→ ~30% of edited data

CWT : Threshold 0.5e-5

→ ~40% of edited data

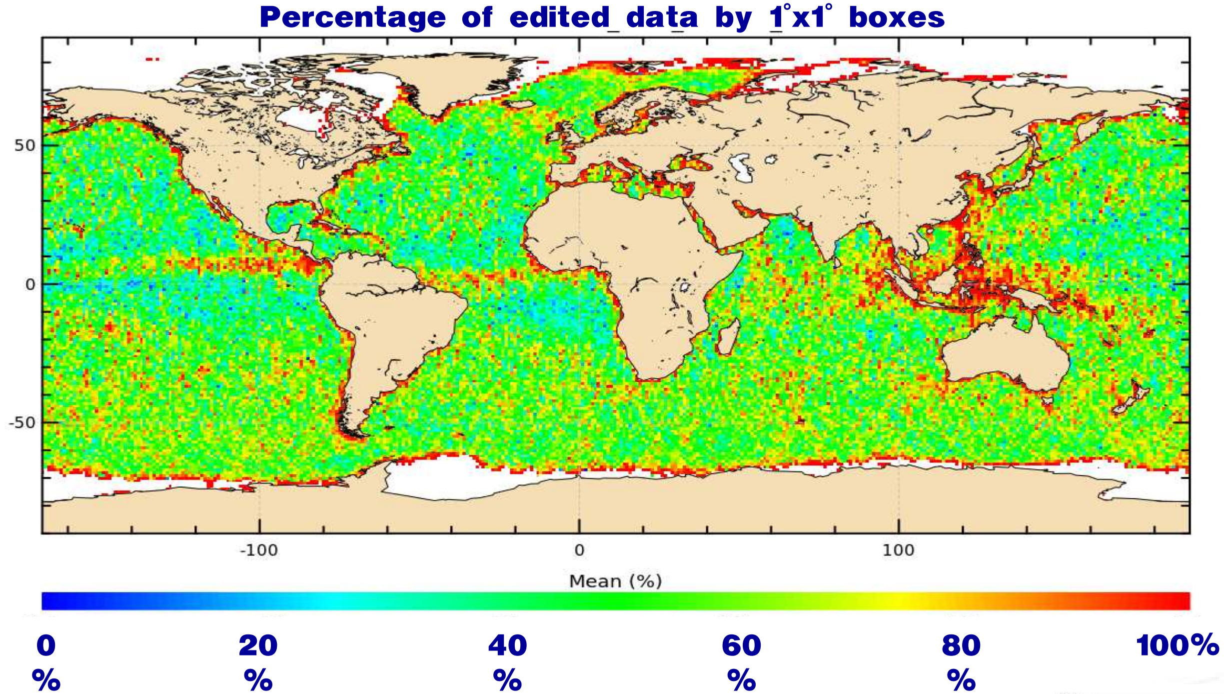
Investigating the spectral hump through the CWT

➢ Does the removal of the 15% of measurements identified as rain and sigma bloom sufficient to reduce the spectral hump ?



➢ When using the CWT method, the spectral hump is greatly reduced without any change of the PSD slope for scales higher than 100 km… **BUT WITH 50% OF EDITED DATA !!**

Investigating the spectral hump through the CWT



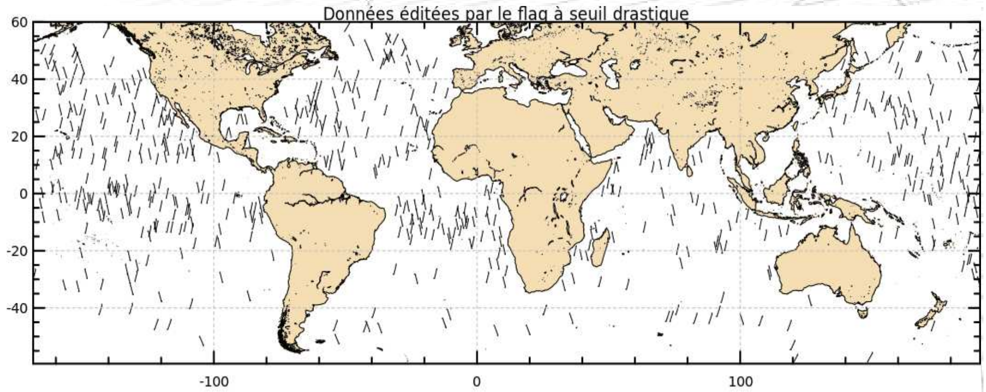
- With the last drastic threshold on the wavelet spectrum, even if some regions are highlighted with near 100% of edited data, measurements are edited all over the globe

➔Backscatter heterogeneities are present in a quasi ubiquitous way.

➔ New waveform processing/retracking is needed to account for these features (DCORE is an attempt to tackle this issue)

- After drastic CWT editting, it becomes hard to find segments without any edited data :

➔ 587 segments of 350 km have been used to compute the last SLA spectrum



Conclusions and perspectives

- The CWT is a powerful tool to detect short scale coherent variations in a time series. Applied to the slope of the waveform trailing edge, it allows to flag backscattering variations in the waveform footprint like rain cells, sigma blooms or modifications of the sea state.

- Rain and bloom measurements (~15%) don't explain alone the SLA spectral hump.

- The spectral hump is greatly reduced by a drastic threshold on the wavelet power spectrum which leads to edit almost 50% of data all over the globe

➔ New retracking algorithms are needed to decorellate backscattering heterogeneities in the footprint from the range estimation (cf L. Amarouche's talk about the DCORE retracking) and be able to reach smaller scales.

- It could be interesting to reiterate this study in Ku-Band.

- It could be interesting to use the CWT to compare SAR and LRM (PLRM) measurements.

Thank you for your attention