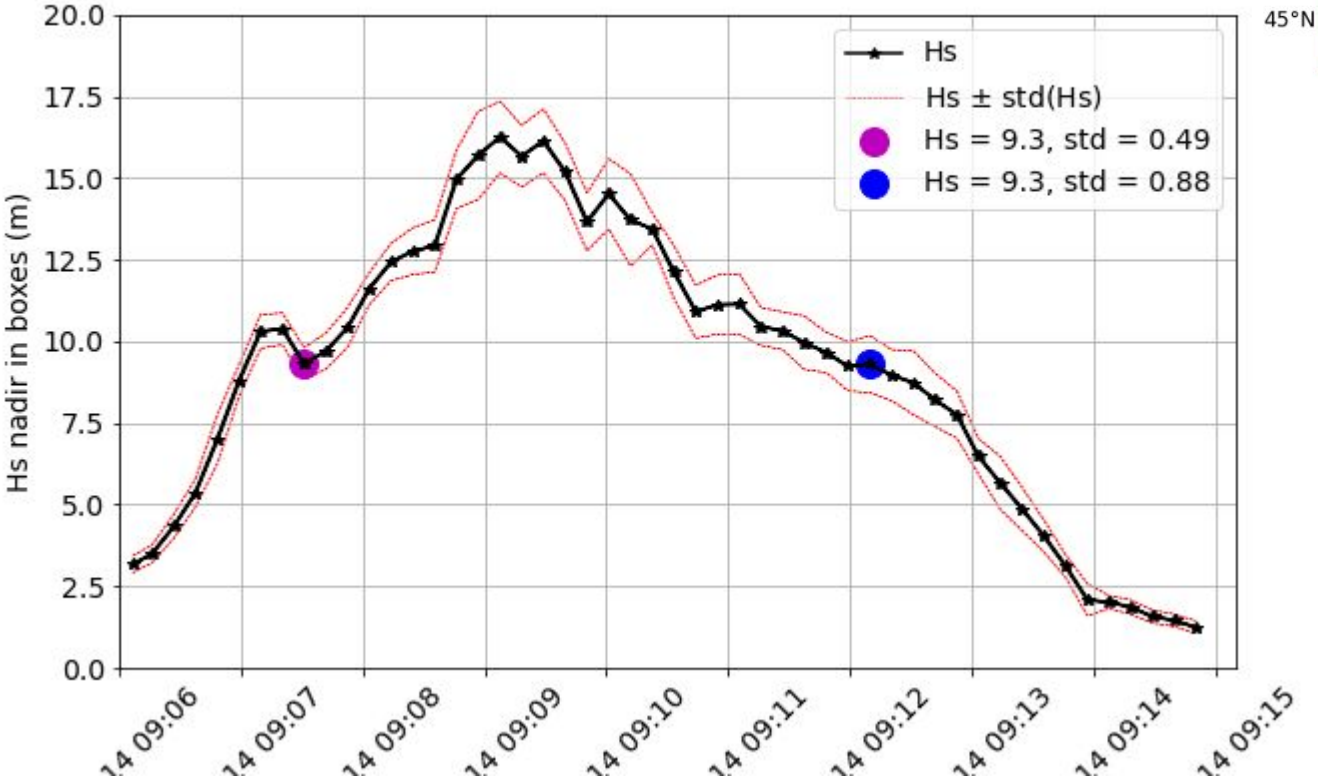
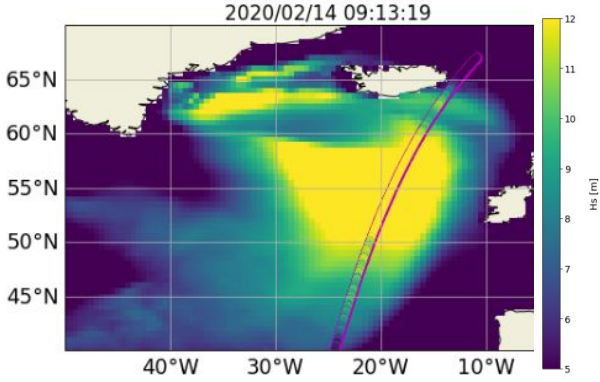
Small scale wave height variability and wave groups

M. De Carlo *(LOPS/CNES)*, F. Ardhuin *(LOPS/CNRS)*, A. Ollivier *(CLS)*

While looking for extreme Hs event …



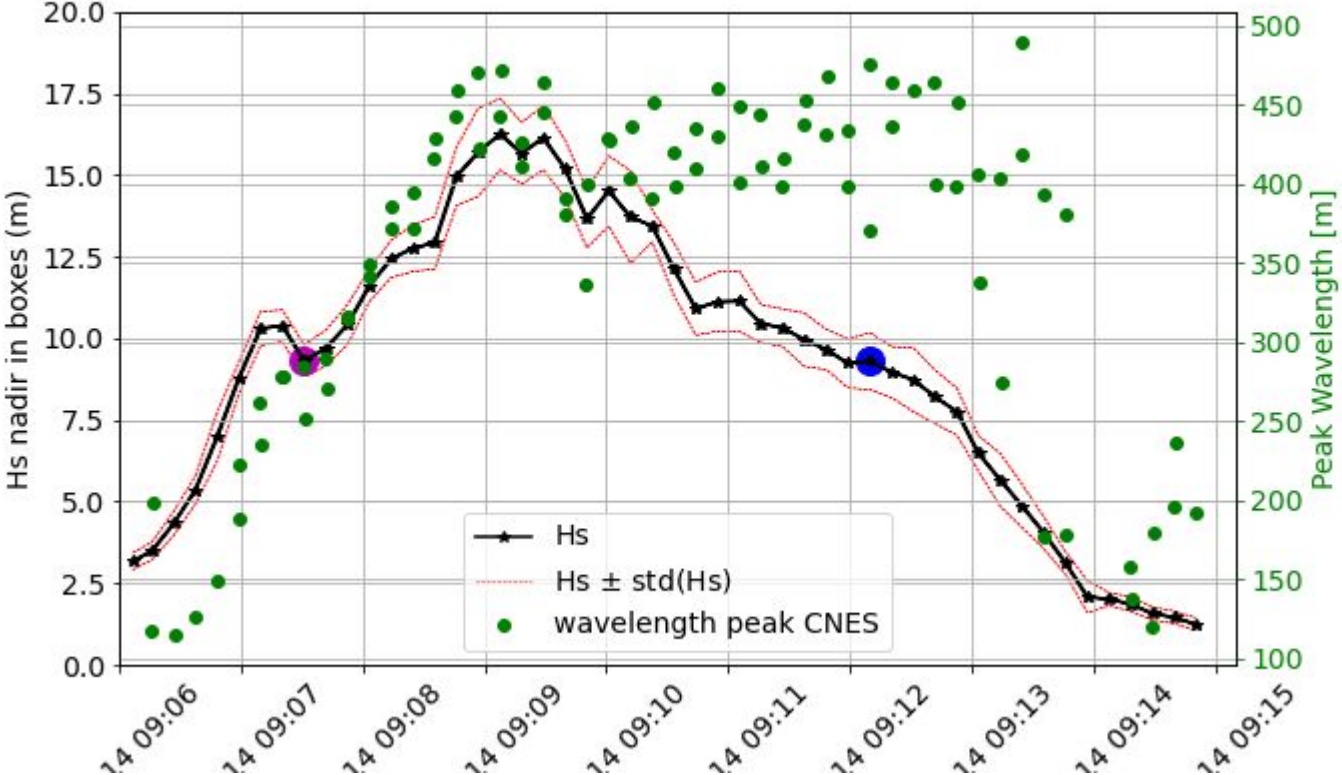


↥ WW3 model Hs with CFOSAT track, swim nadir value

↤ SWIM nadir track (box scale) + std(Hs)

●● Same Hs, different std ratio ~ 2

While looking for extreme Hs event …



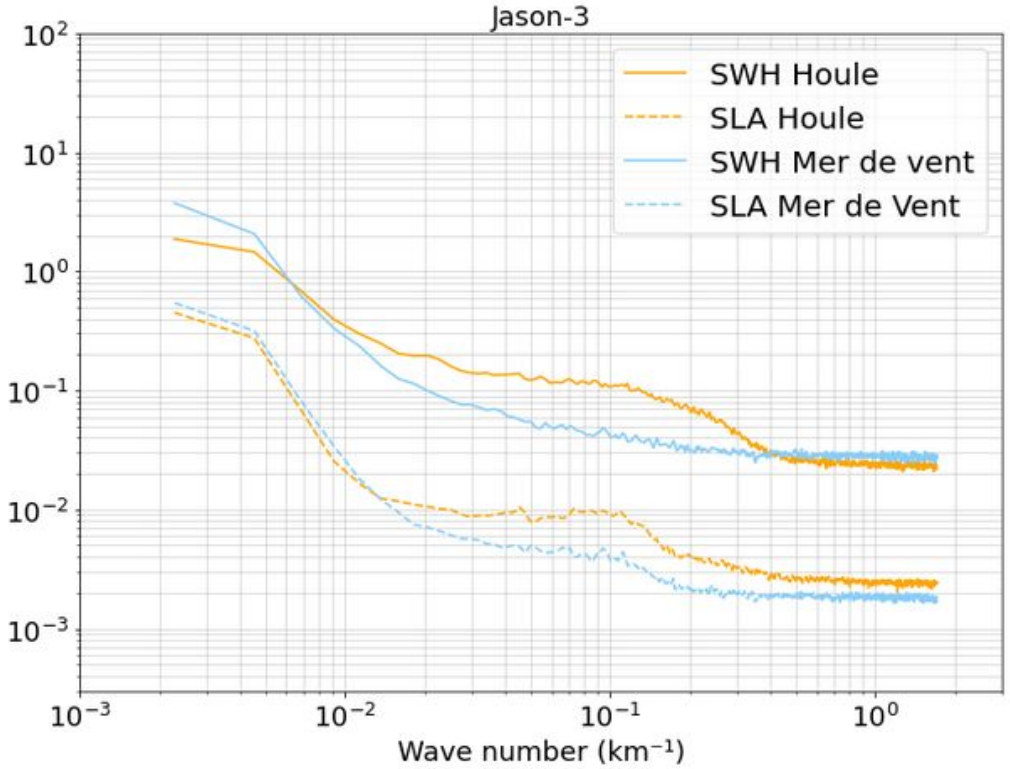
↤ SWIM nadir track (box scale) + std(Hs)

●● Same Hs, different std ratio ~ 2

Difference seems linked to peak wavelength

=> impact of wave groups

… Related to SWH spectrum bump



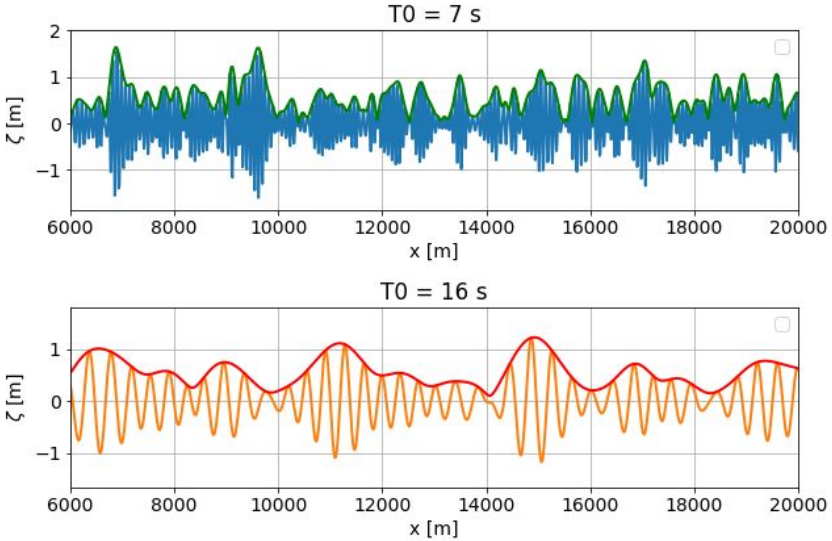
- CNES/CLS Team (A. OLLIVIER et al.) working on characterization of the Hs variability below 100 km.
- Multimission analysis showing bump appears in Swell conditions. (Ollivier et al. 2022, LPS Poster)

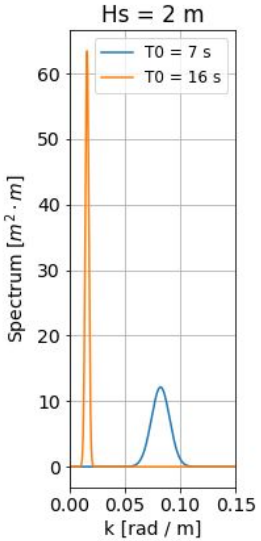
Outline

1) 1D theory about wave groups and Hs variations

2) Use of CFOSAT data to quantify part of std(Hs) due to waves (1st try)

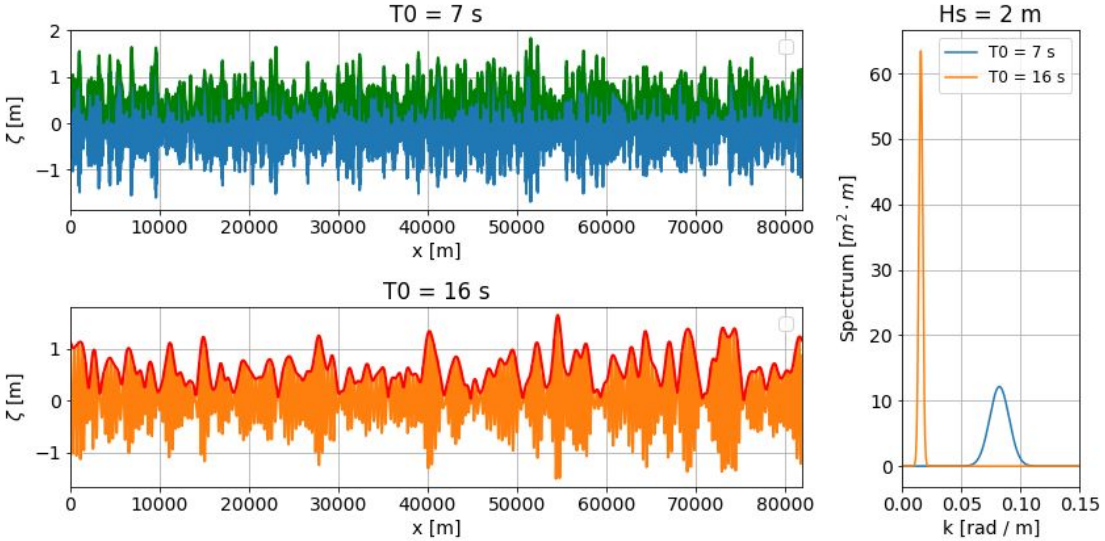
1D Theory





- Simulations of 1D surface based on Spectrum
- blue : T0 = 7s, orange : T0 = 16s

1D Theory



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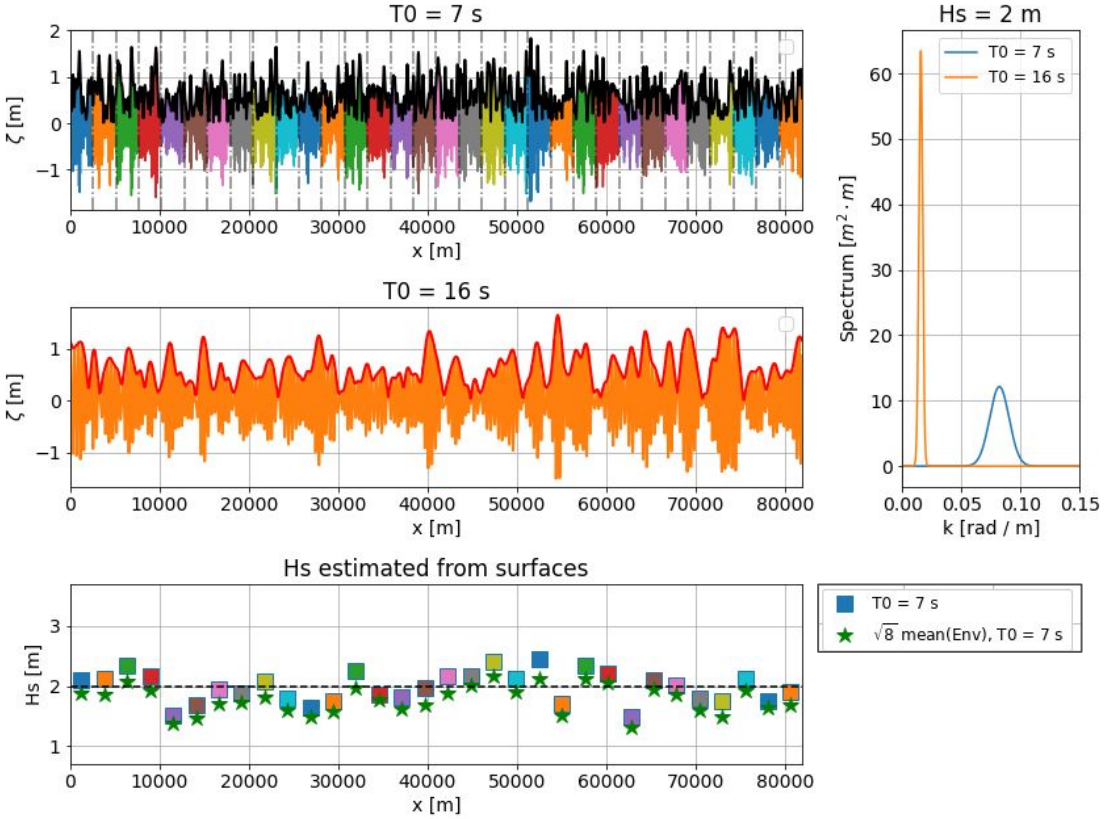
1D Theory



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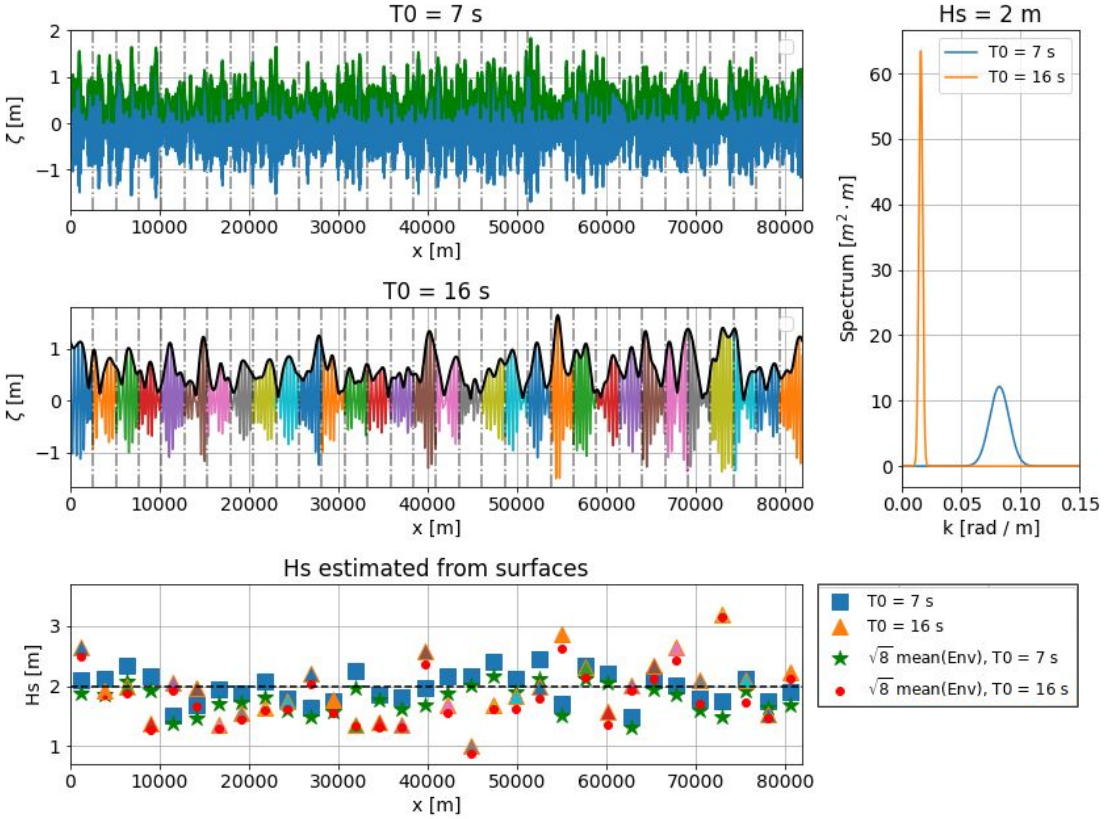
- computation of std(surface) on small windows -> Hs (as an altimeter)

1D Theory



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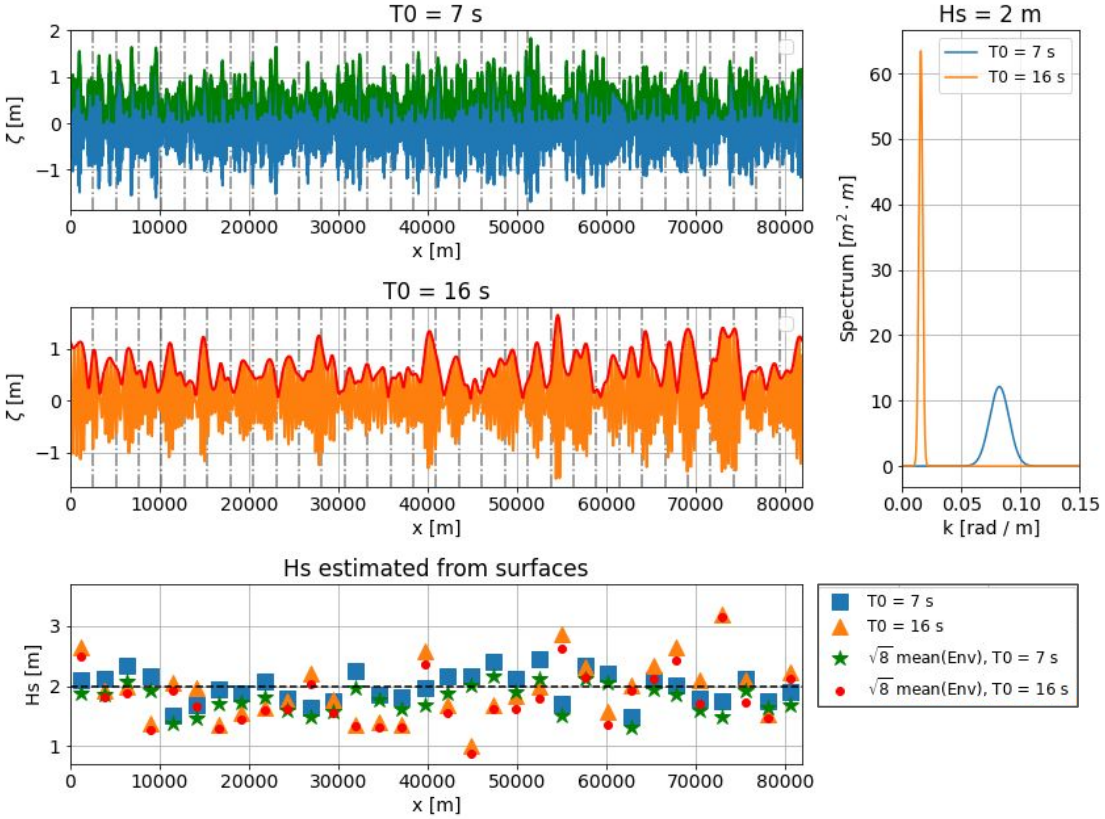
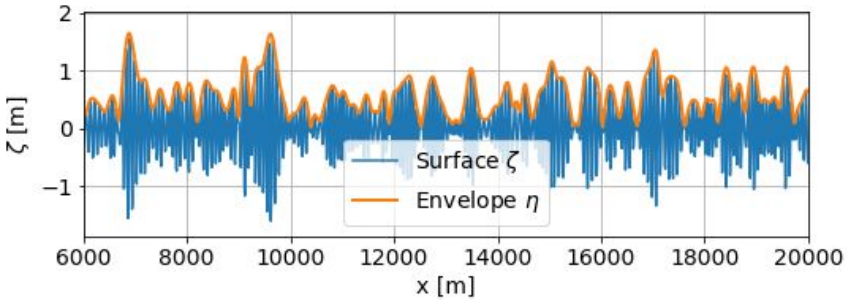
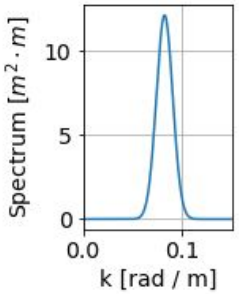


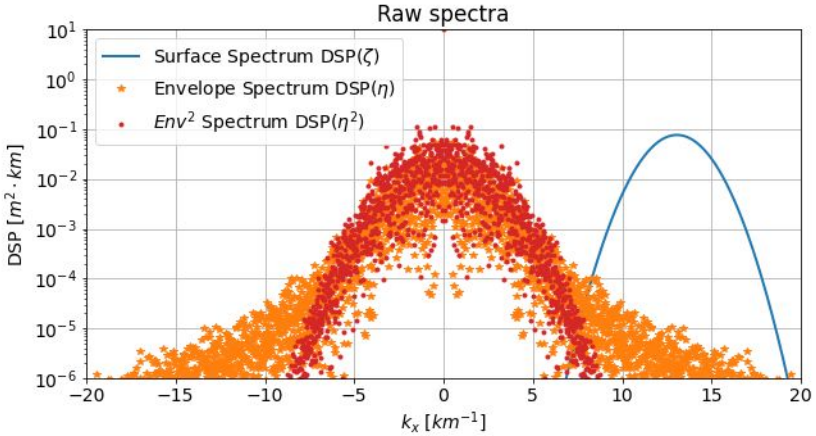
- Simulations of 1D surface based on Spectrum
- computation of std(surface) on small windows -> Hs (as an altimeter)
- Spectrum shape may generate wave groups and generate Hs variations.
- Std(Hs) = std(mean(Env))

std(Hs) = 0.25 (T0=7s)
std(Hs) = 0.49 (T0=16s)

1D Theory

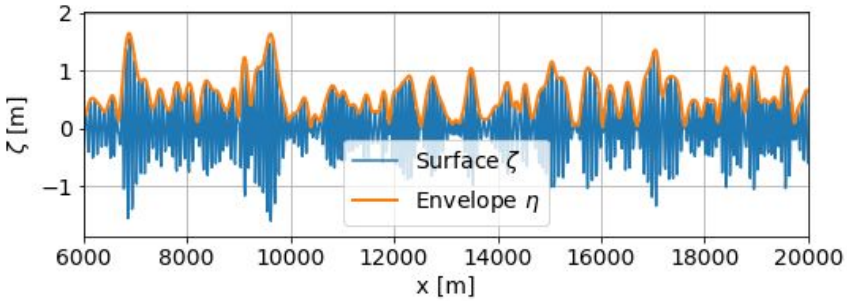


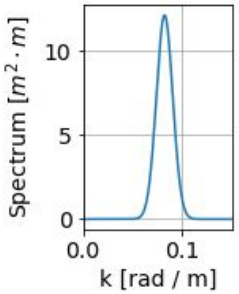


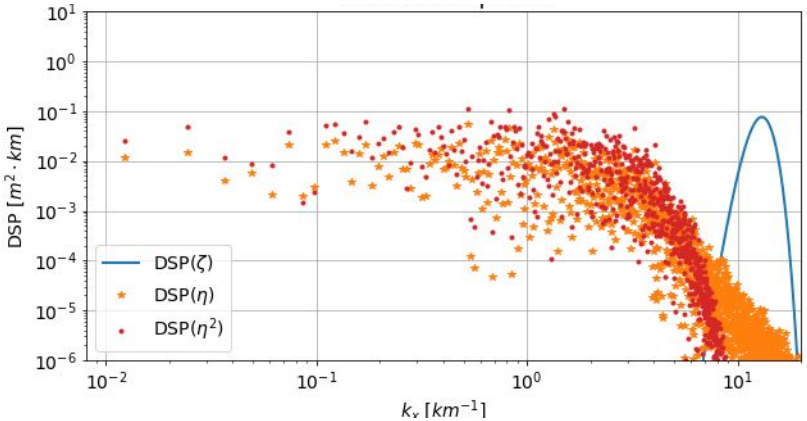


- Zoom on the T0=7s spectrum
- FFT(envelope) - orange - and FFT(envelope^2) - red.

1D Theory

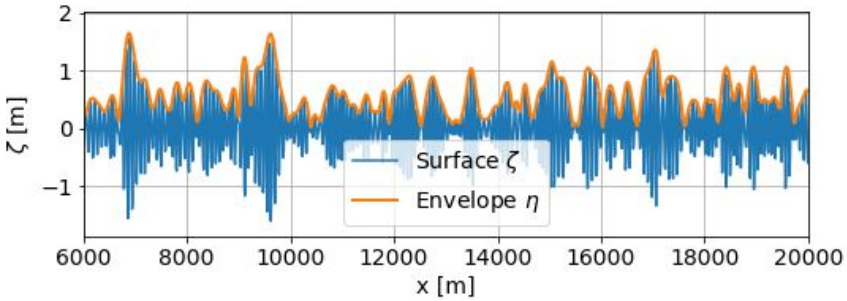


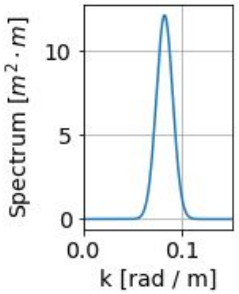


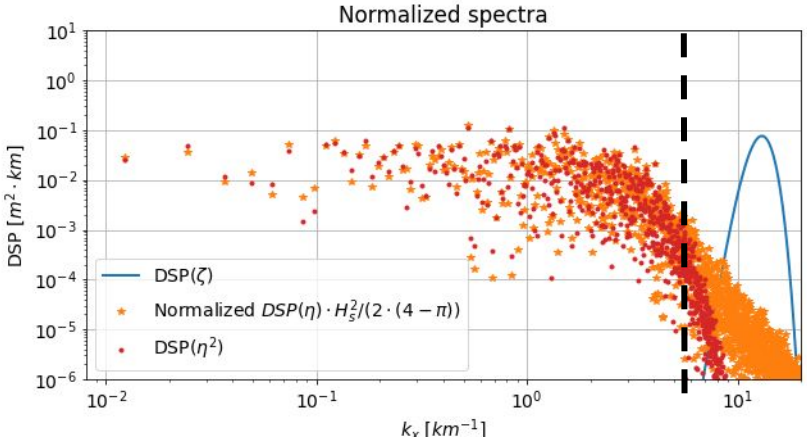


- Zoom on the T0=7s spectrum
- FFT(envelope) - orange - and FFT(envelope^2) - red -, logscale.

1D Theory

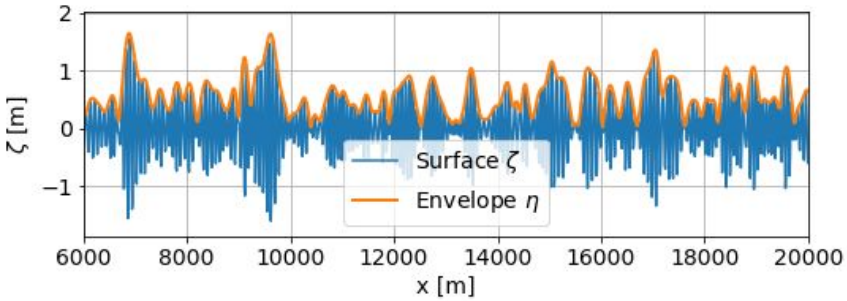


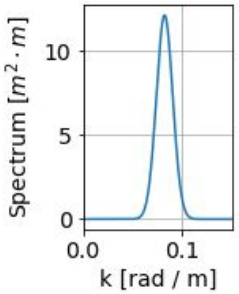


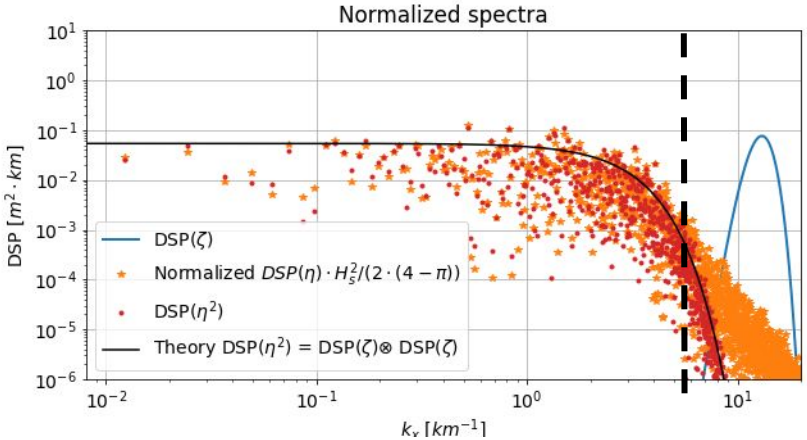


- Zoom on the T0=7s spectrum
- FFT(envelope) - orange - and FFT(envelope^2) - red -, logscale.
- *Rice 1944, Nolte & Hsu, 1972* : Power Spectrum Density (PSD) of envelope ≃ PSD of envelope^2 (up to k = 1/500 m)

1D Theory





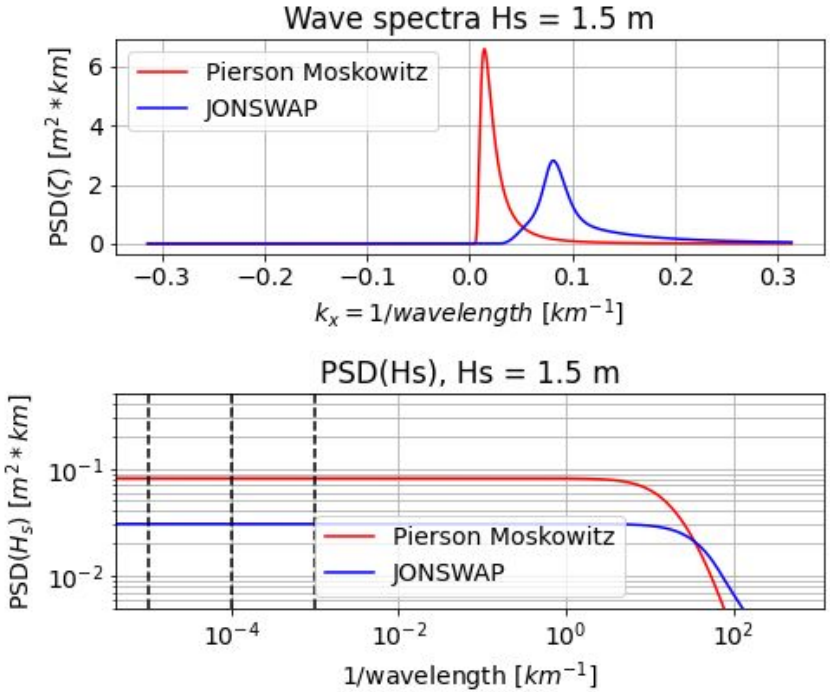


- Rice 1944, Nolte et al 1972 : Power Spectrum Density (PSD) of envelope ≃ PSD of envelope^2
  = convolution of PSD of surface

=> Amplitude of “Plateau” :

$\propto H_s^2 / \sigma_k$

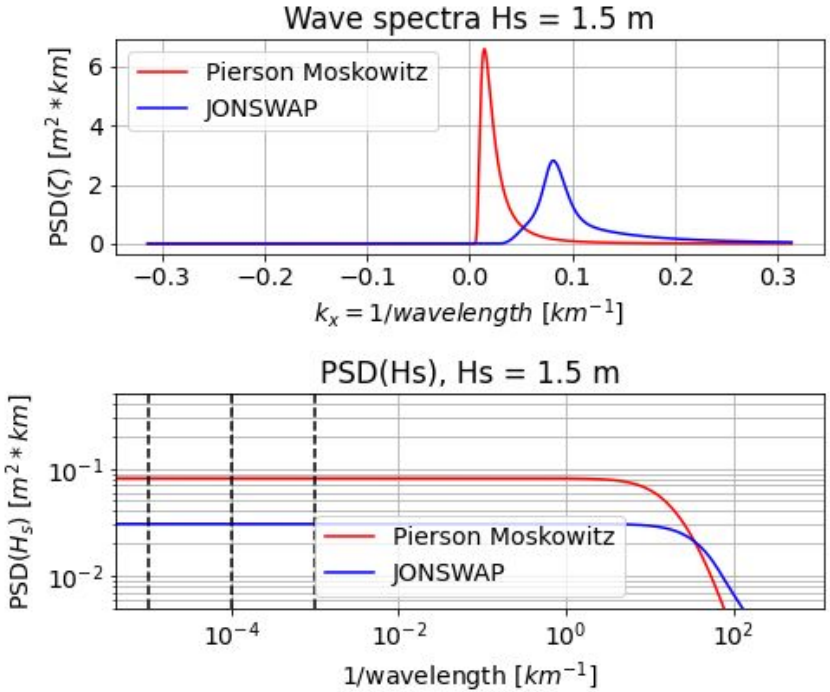
1D Theory



Example with “more realistic” spectra :

- Jonswap : windsea
- Pierson Moskowitz : Swell

1D Theory


Wave spectra Hs = 1.5 m
Pierson Moskowitz
JONSWAP
PSD(ζ) [m² * km]
$k_x = 1/wavelength\ [km^{-1}]$
PSD(Hs), Hs = 1.5 m
PSD(Hs) [m² * km]
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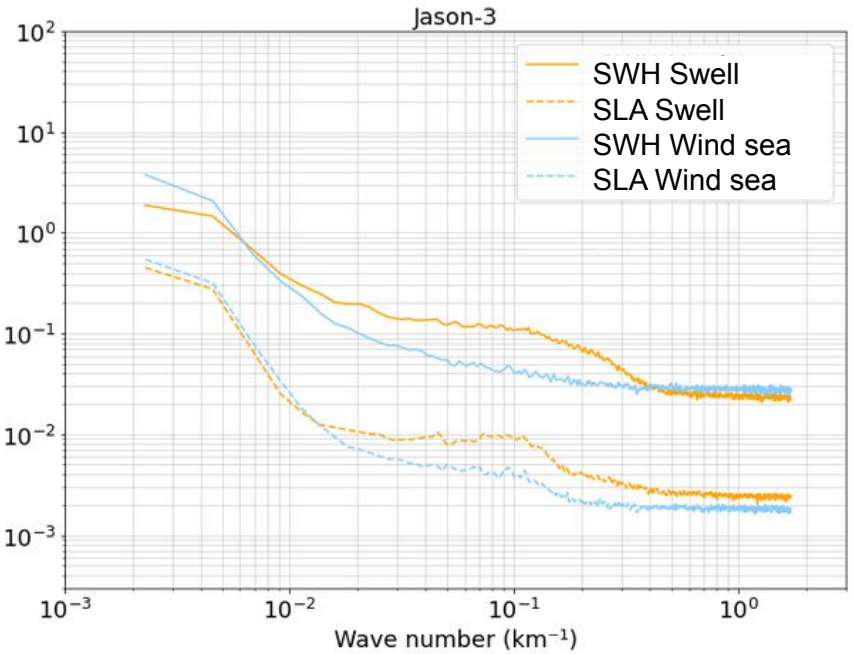
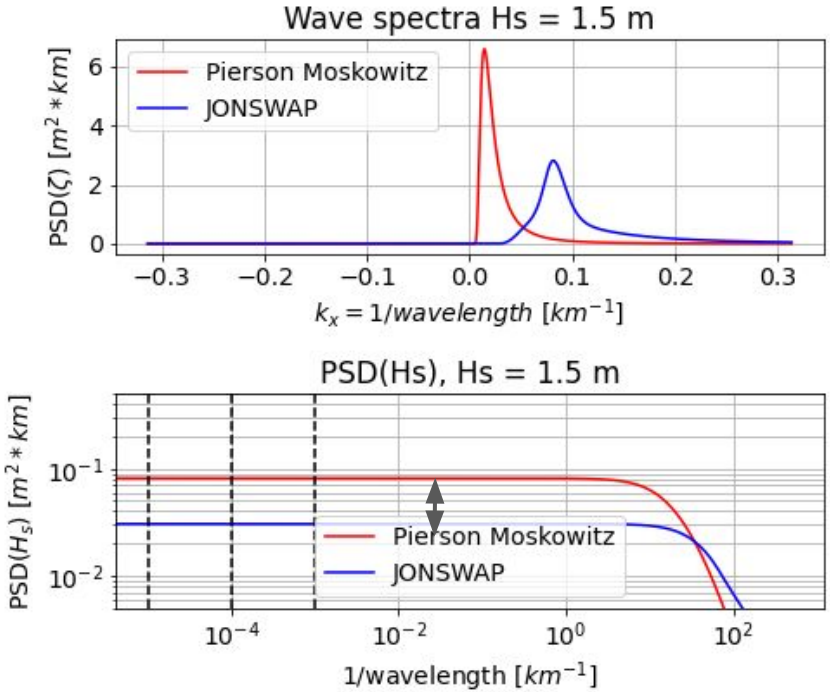
1/wavelength [km⁻¹]


Jason-3
SWH Swell
SLA Swell
SWH Wind sea
SLA Wind sea
Wave number (km⁻¹)

1D Theory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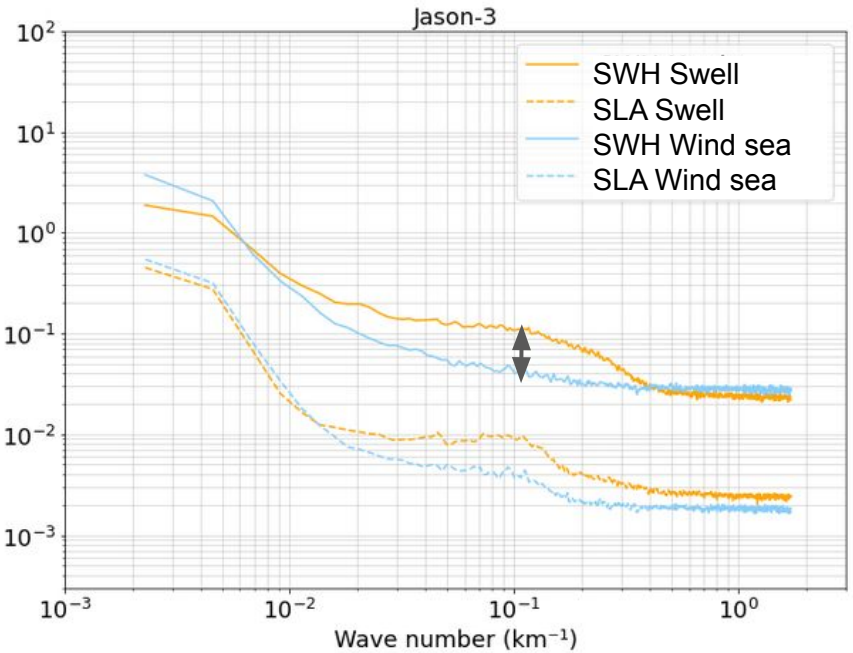
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Std(Hs) and CFOSAT/SWIM

- $std(Hs)_{tot}$ is calculated (L2 product) from nadir measurements of Hs

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- $std(Hs)_{tot} = std(Hs)_{wave\_groups} + std(Hs)_{geophysics\_bigger\_scales} + std(Hs)_{noise} + \ldots$

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- SWIM offnadir spectra => convolution => estimate of the $std(Hs)_{wave\_groups}$ by integration over the scale of interest (= size of footprint)

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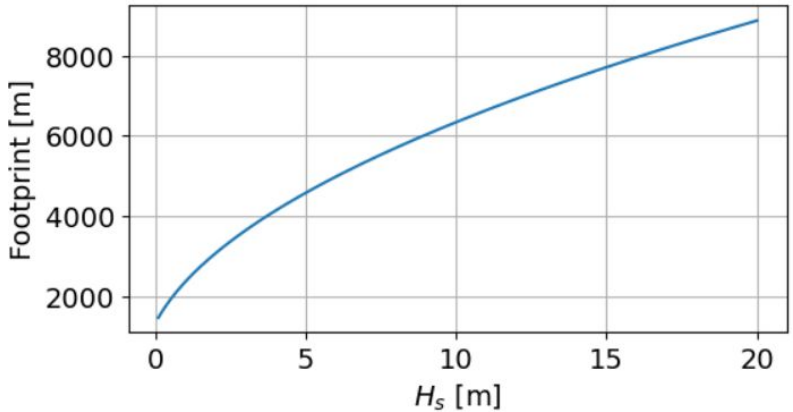

Based on Chelton et al (1989).

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=> Comparison of :
std(Hs) / Hs (from nadir)
vs
estimated std(Hs) / Hs

estimations from:
- std(Hs) : L2P omni spectra
- Hs : nadir

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vs

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estimations from:

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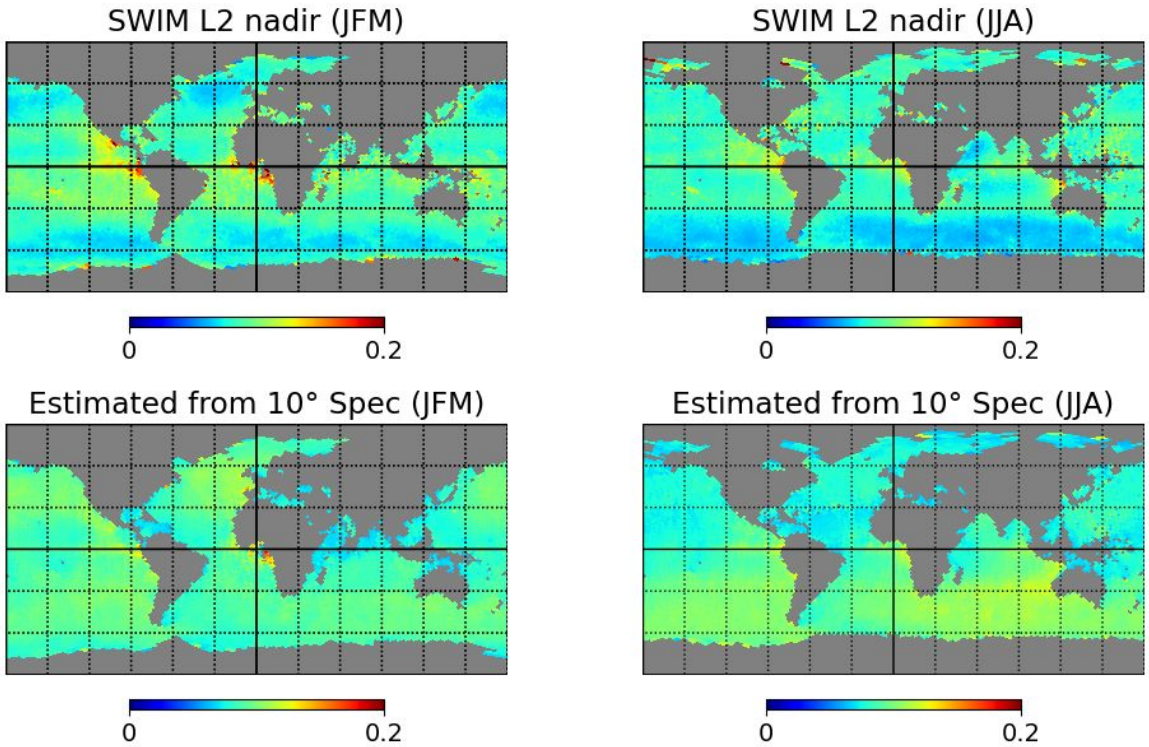
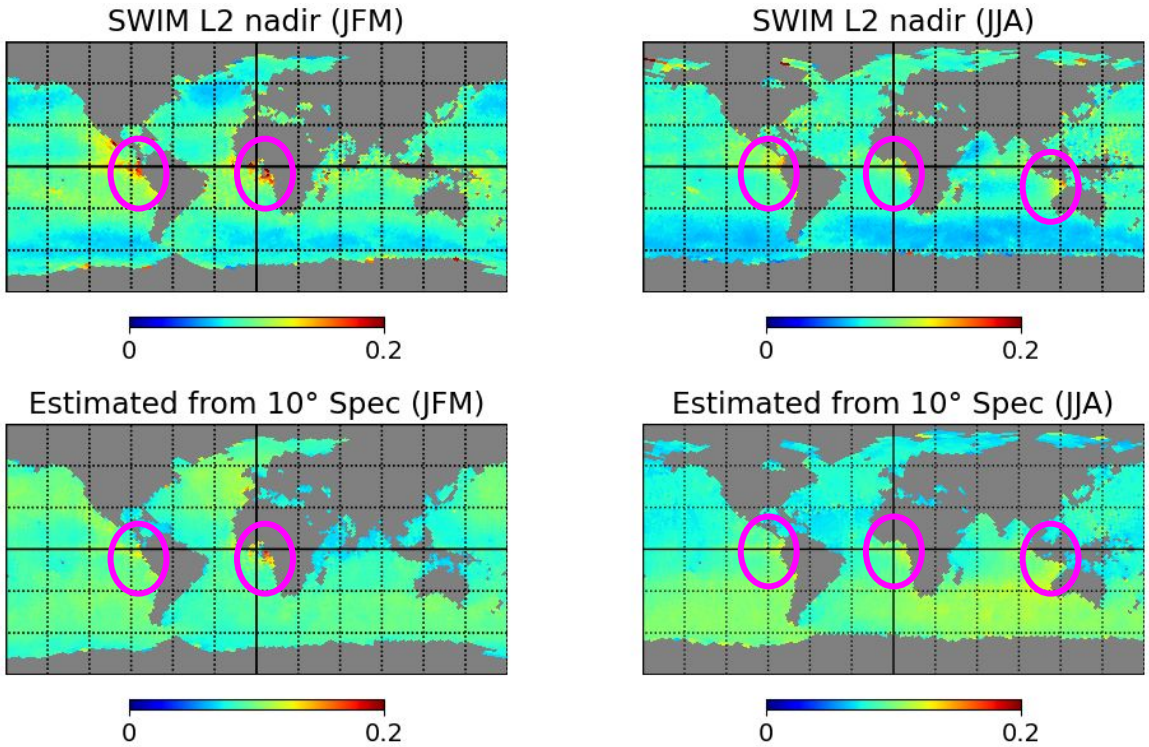
=> Purpose :
Quantifying to part of Hs variations due to wave groups

Std(Hs) and CFOSAT/SWIM



- From September 2019 to April 2022
- incidence = 10° (L2P product)
- For January-February-March (JFM) and June-July-August (JJA).

Std(Hs) and CFOSAT/SWIM



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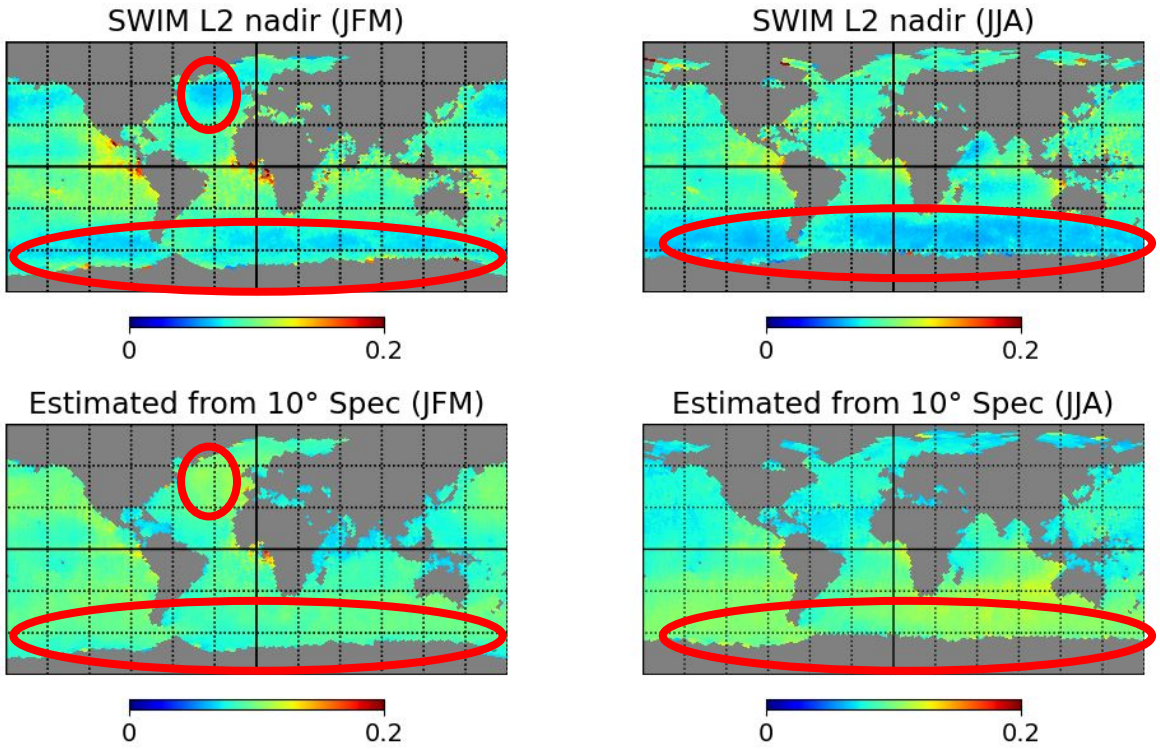

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Std(Hs) and CFOSAT/SWIM

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  => the 2D spectrum directional width may have a strong impact too.

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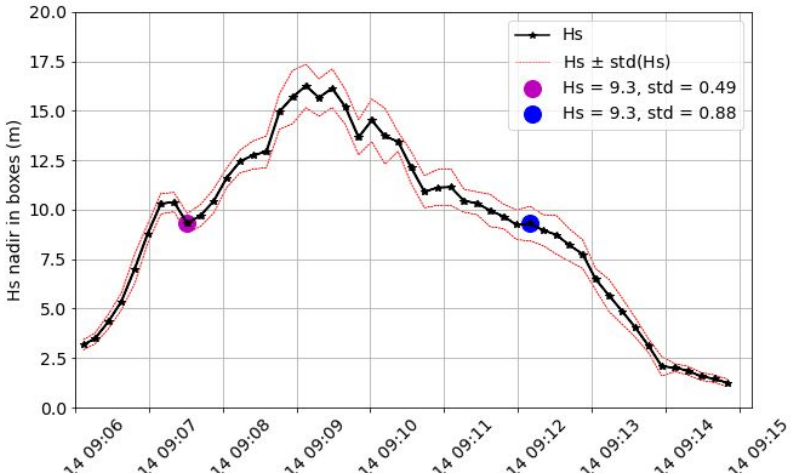
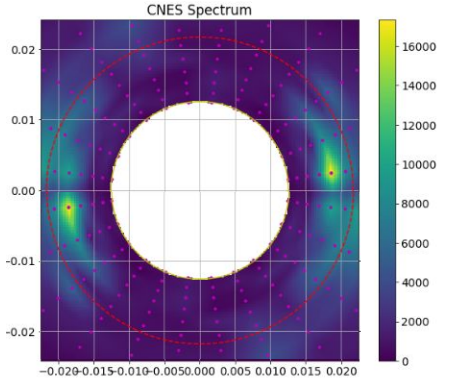
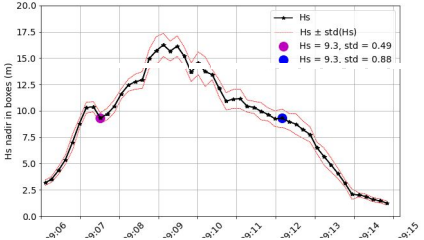
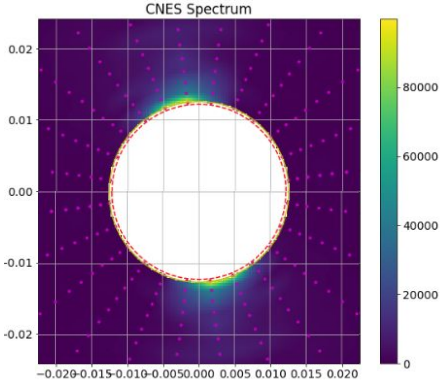
  e.g. with previous case :



L2 spectra


CNES Spectrum


Hs
Hs ± std(Hs)
Hs = 9.3, std = 0.49
Hs = 9.3, std = 0.88
Hs nadir in boxes (m)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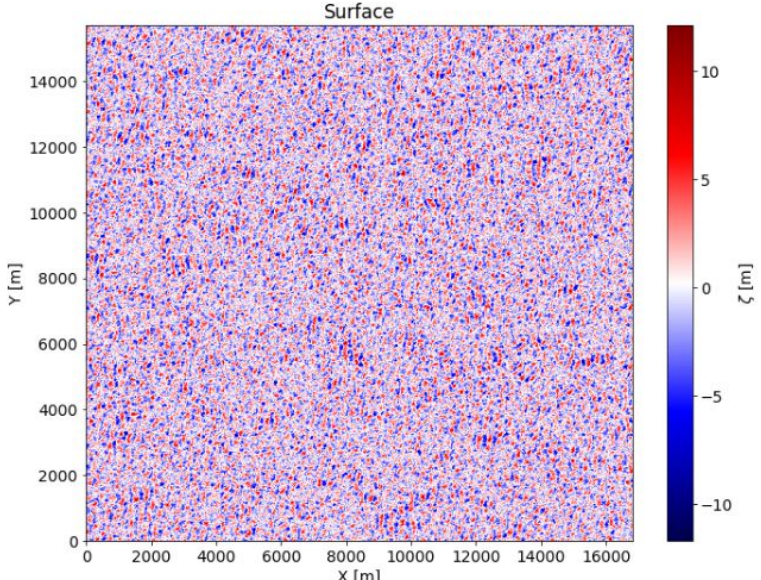
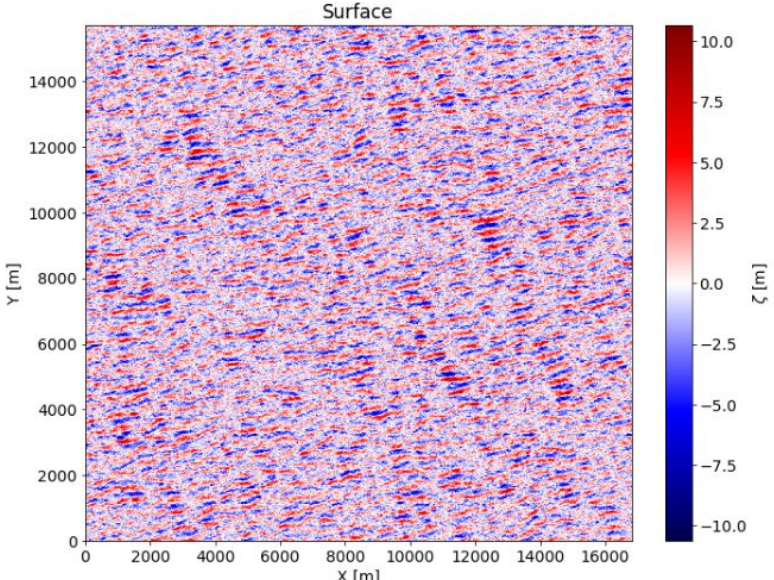

Surface
Y [m]
X [m]
ζ [m]

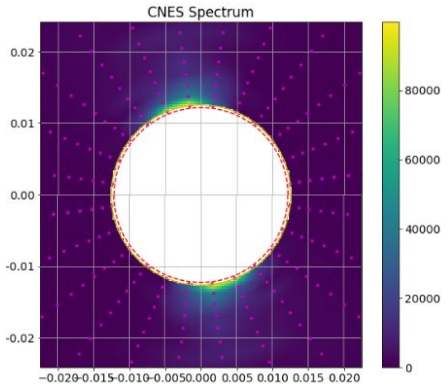

Surface
Y [m]
X [m]
ζ [m]

Std(Hs) and CFOSAT/SWIM

- Discrepancies that can be related to the use of the 1D omni spectrum

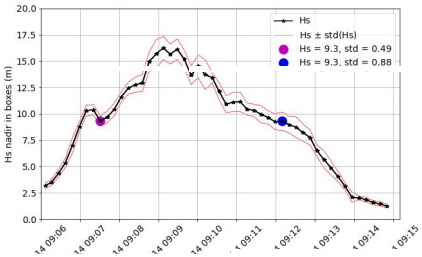
  => the 2D spectrum directional width may have a strong impact too.

- The 500 m wavelength cut may also impact the expected wave groups in High Hs conditions.

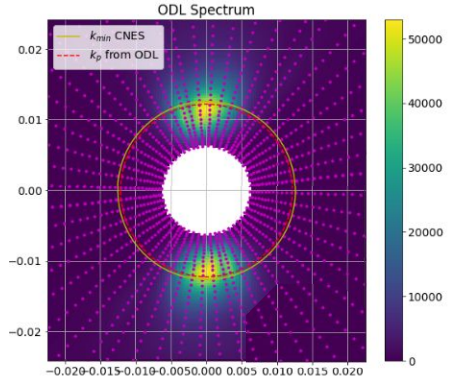


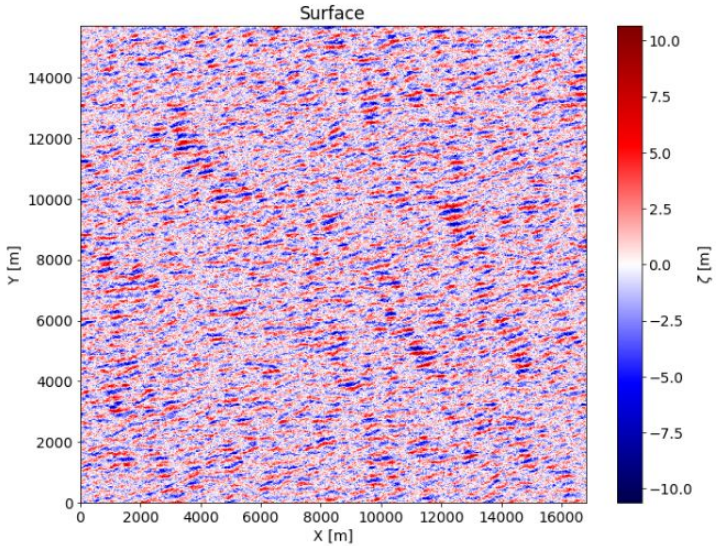
↤ L2

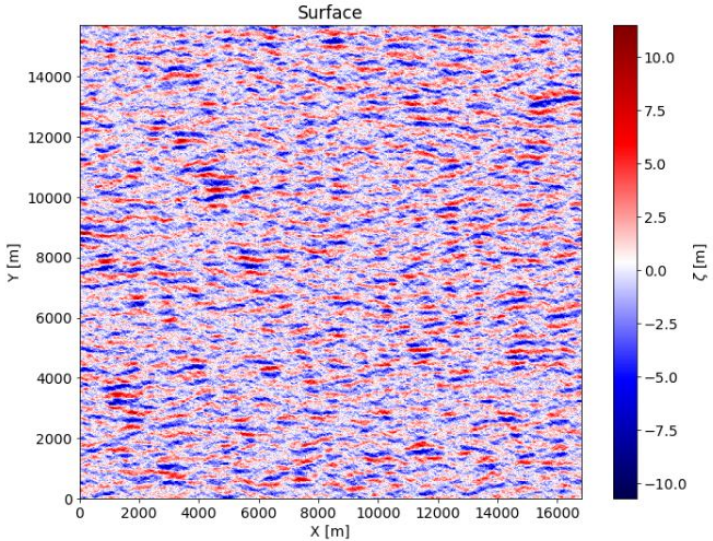
spectra



L2S ↦







Conclusion and perspectives

- 1D theory works and gives good order of magnitude
- A certain part of std is due to wavegroups

On going work :

- Work on the 2D: both theory and obs.
- Compute envelope and Hs variations from L2S
- Check how the nadir std(Hs) is computed for the box.
- ….

Thank you for your attention !