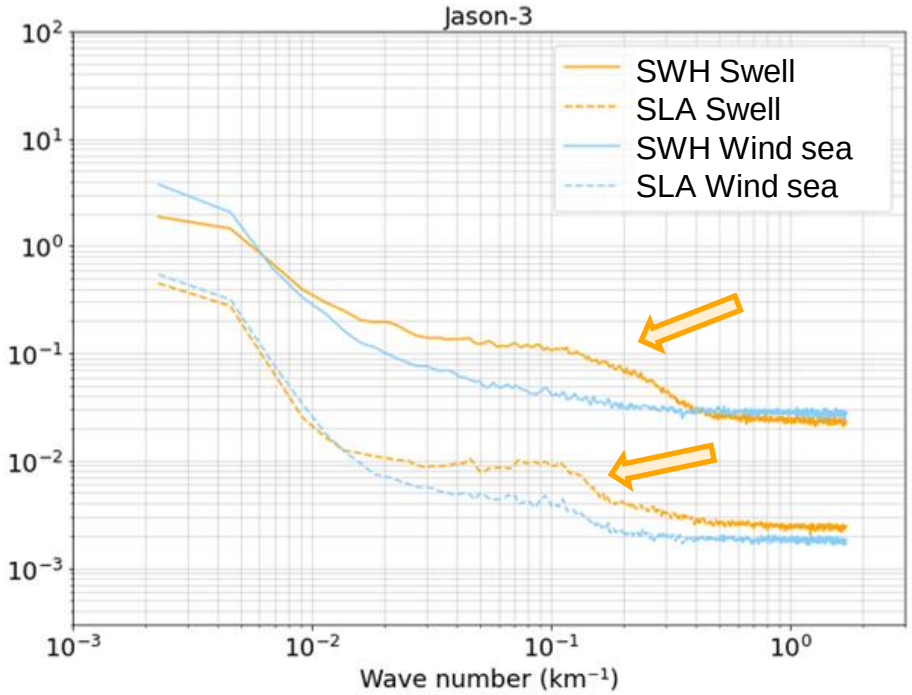
Small scale wave height variability and wave groups

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

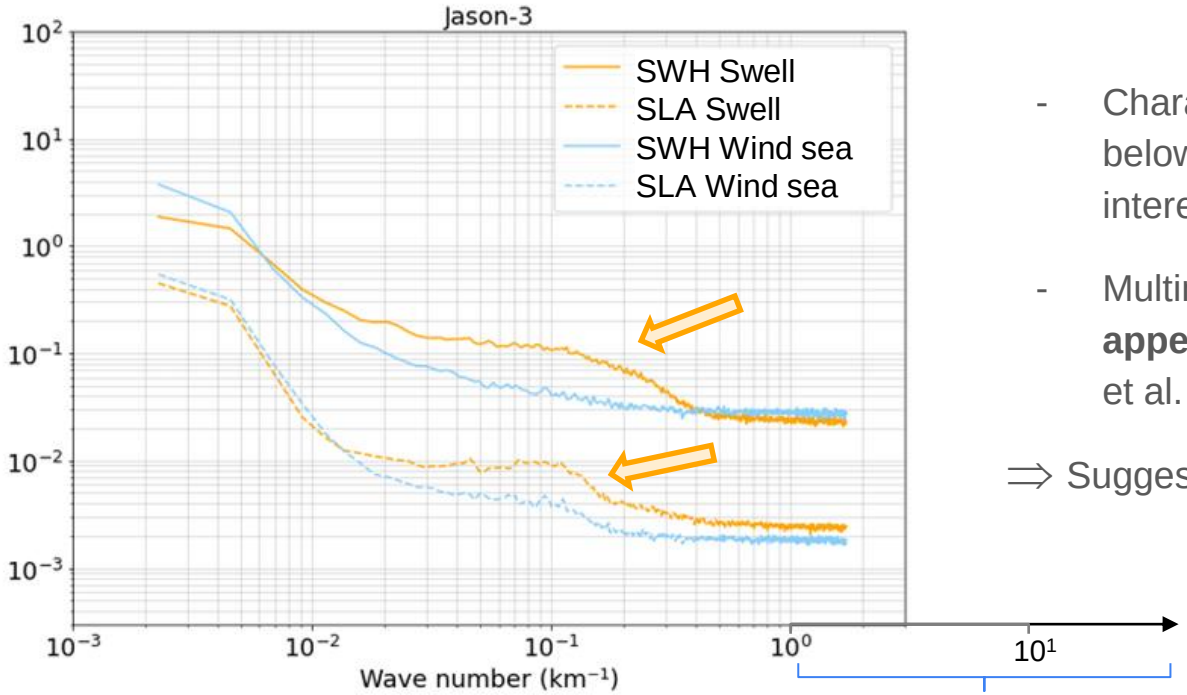
Bump on the SWH and SLA spectrum



- Characterization of the Hs variability below 100 km is an ongoing topic interesting the community (e.g. SWOT)
- Multimission analysis showing bump **appears in Swell conditions**. (Ollivier et al. 2022, LPS Poster)

⇒ Suggests **relationship with waves**

Bump on the SWH and SLA spectrum



- Characterization of the Hs variability below 100 km is an ongoing topic interesting the community (e.g. SWOT)
- Multimission analysis showing bump **appears in Swell conditions**. (Ollivier et al. 2022, LPS Poster)

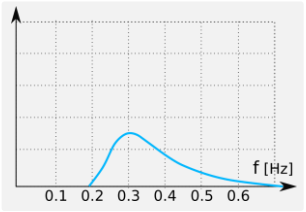
⇒ Suggests **relationship with waves**

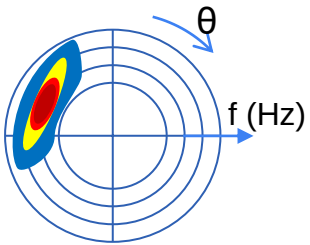
HOW ?

Sea states and spectrum

Wind Sea

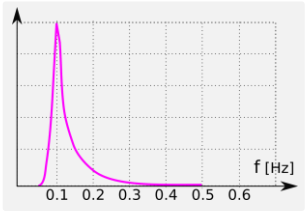
- Broad
- higher frequency

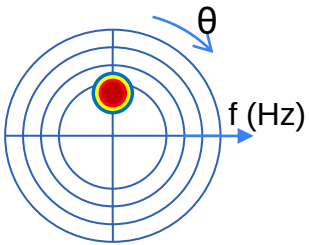




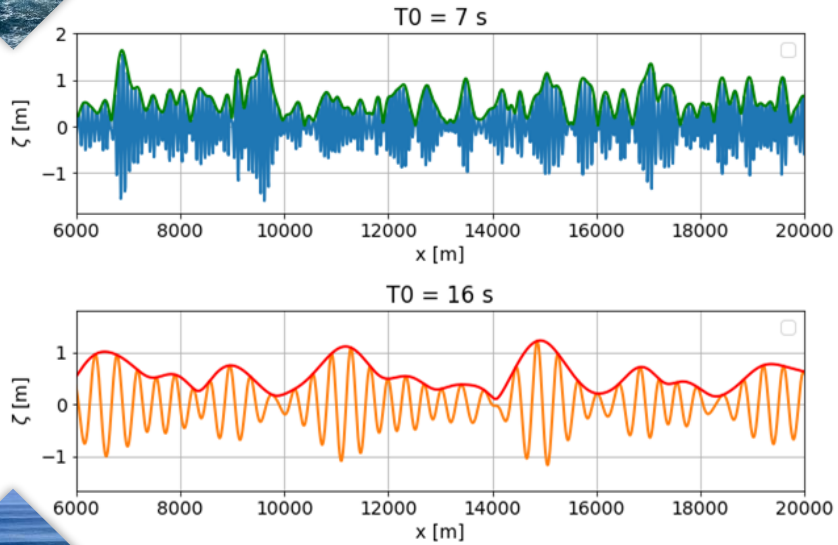
Swell

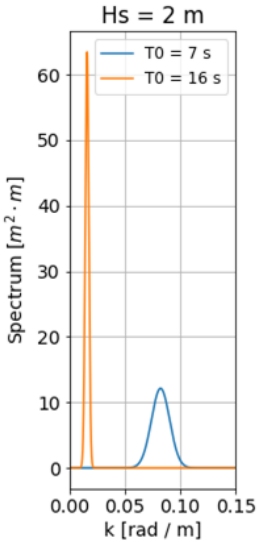
- Narrow
- low frequency

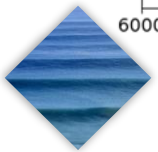




Modulation by wave groups

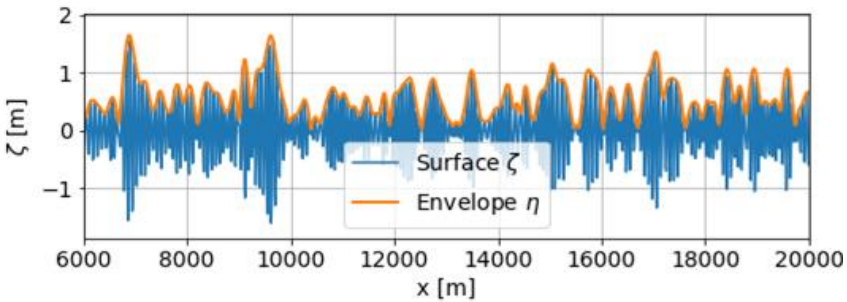






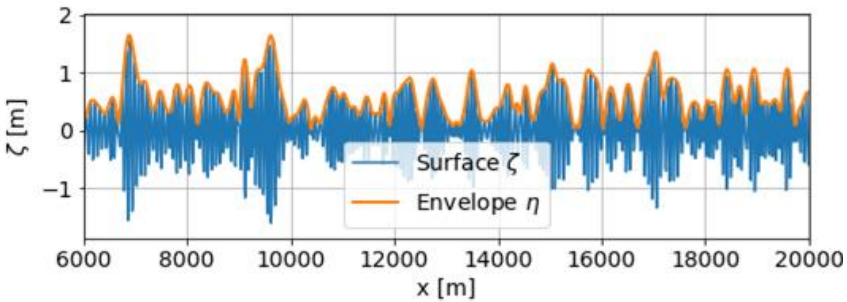
- Simulation of a surface from **broad** (blue) and **narrow** (orange) spectra (inverse FFT) /!\ homogeneous conditions
- Modulation resulting from **linear sum. of sinus**
- Free surface is **modulated by wave groups**
  → **envelope** is key !
- Depending on the **groups scale** and the size of the footprint → modulate Hs estimate

About the envelope

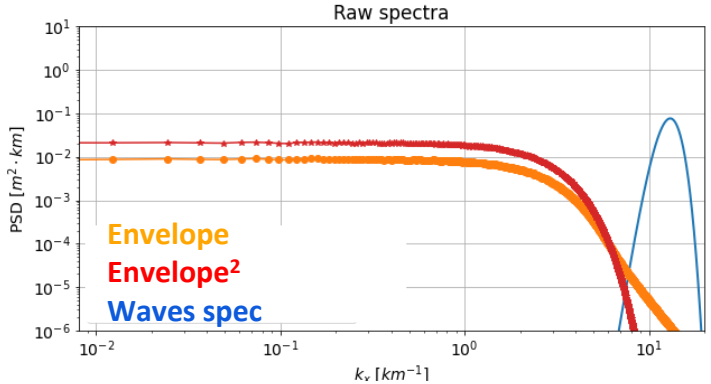


- Simulation of a **surface** from broad spectrum (real part of iFFT)
- **Envelope** is computed from surface (modulus of iFFT)

About the envelope

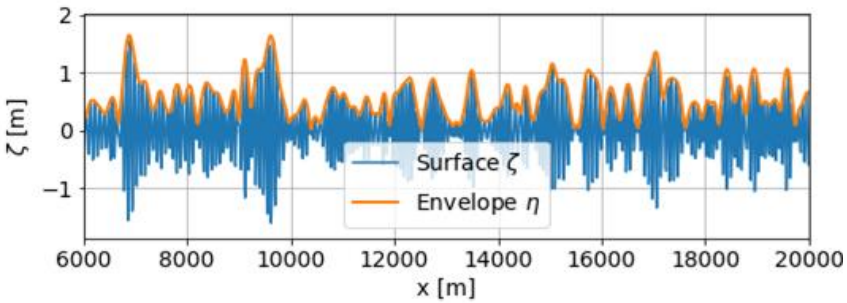


FFT

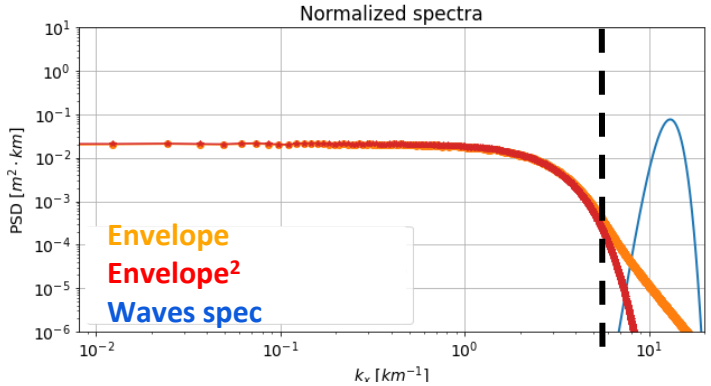


- Simulation of a **surface** from broad spectrum (real part of iFFT)
- **Envelope** is computed from surface (modulus of iFFT)
- From **FFT** :
  - **Envelope** spectrum
  - **Envelope²** spectrum
  - Waves spectrum

About the envelope

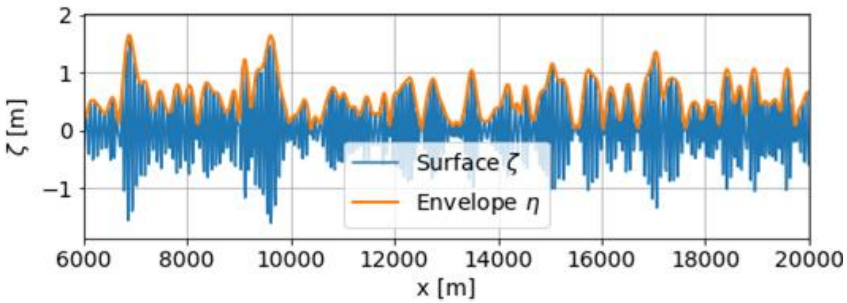


FFT

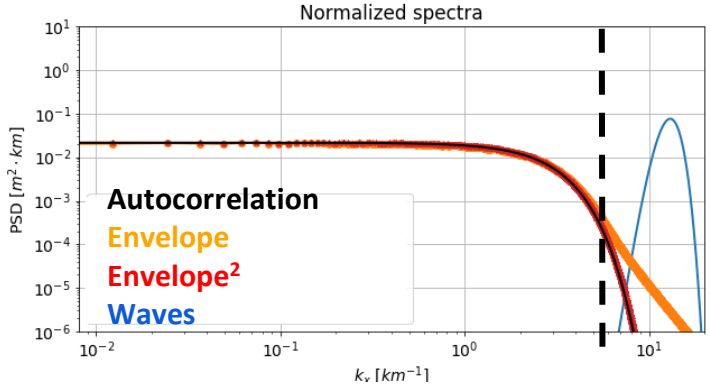


- Simulation of a **surface** from broad spectrum (real part of iFFT)
- **Envelope** is computed from surface (modulus of iFFT)
- From **FFT** :
  - **Envelope** spectrum
  - **Envelope²** spectrum
  - Waves spectrum
- From Rice 1944, Nolte & Hsu 1972 : Normalized spectra of env and env^2 are similar at low frequencies

About the envelope



FFT



- Simulation of a **surface** from broad spectrum (real part of iFFT)
- **Envelope** is computed from surface (modulus of iFFT)
- From **FFT** :
  - **Envelope** spectrum
  - **Envelope²** spectrum
  - Waves spectrum
- From Rice 1944, Nolte & Hsu 1972 : Normalized spectra of env and env^2 are similar at low frequencies
  +
  spectra env^2 = **autocorrelation** of wave spectra

And so what?

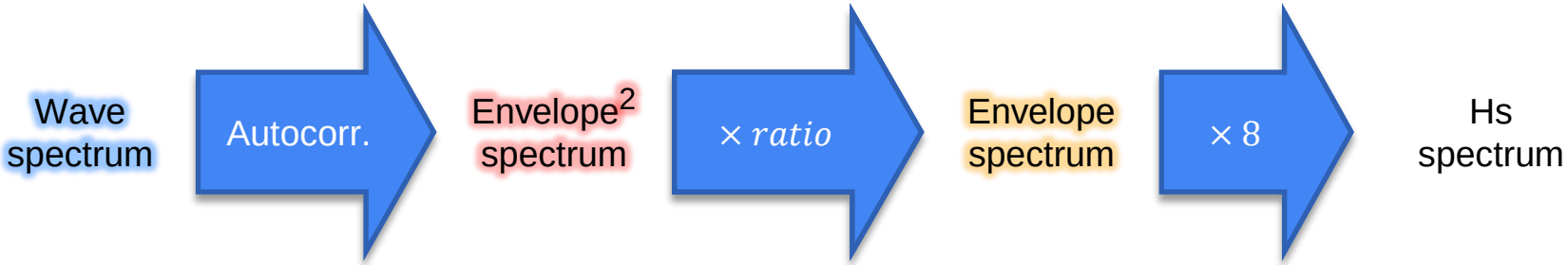

Wave spectrum
Autocorr.
Envelope^2 spectrum
$\times ratio$
Envelope spectrum
?
Hs spectrum

And so what?

Reminder :
Hs is an integrated value that can be linked to the Hrms value :

$$H_s = \sqrt{2}\, H_{rms} = \sqrt{8} < env >$$

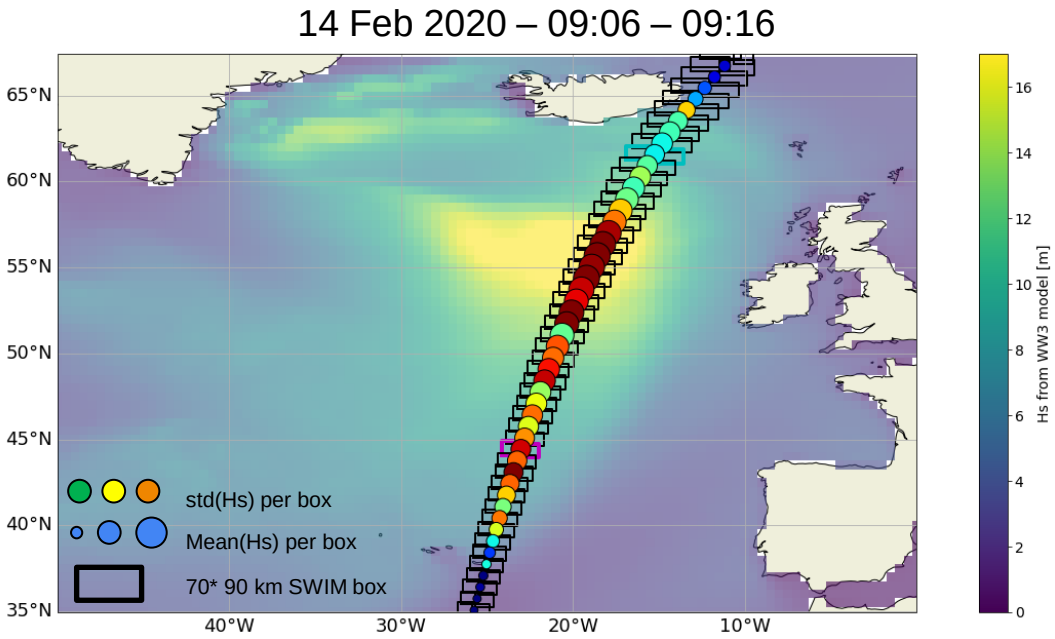
And so what?



Reminder :
Hs is an integrated value that can be linked to the Hrms value :

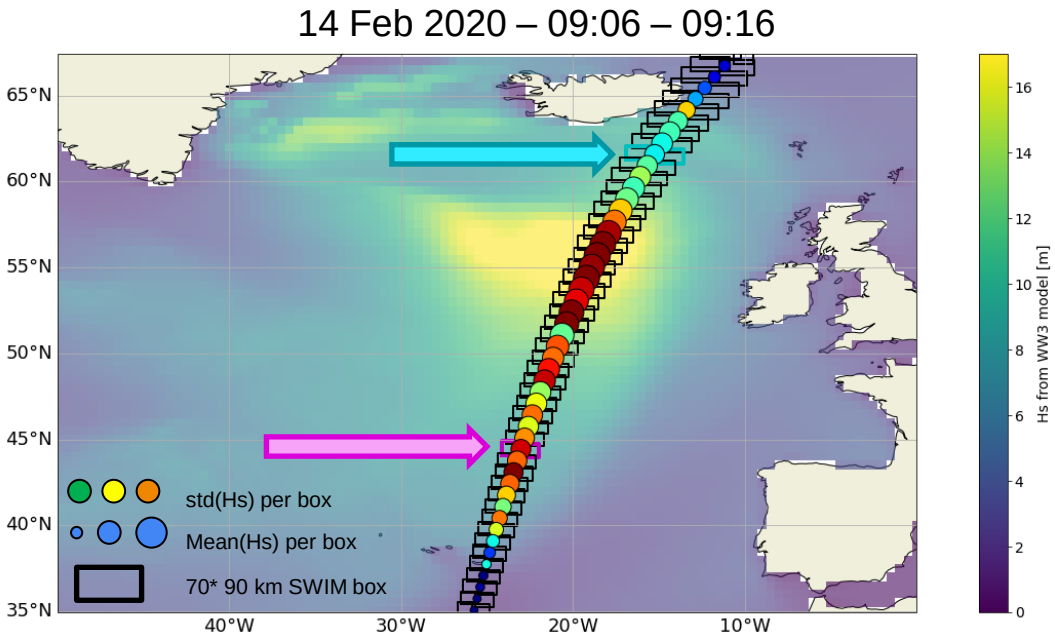
$$H_s = \sqrt{2}\, H_{rms} = \sqrt{8} < env >$$

Example with CFOSAT data



- Background color: Hs from WW3 model
- Colocalisation of nadir and spectral measurements
- Nadir measurements:
  - mean(Hs) per box
  - std(Hs) per box
- Off-nadir measurement :
  2D spectra in boxes

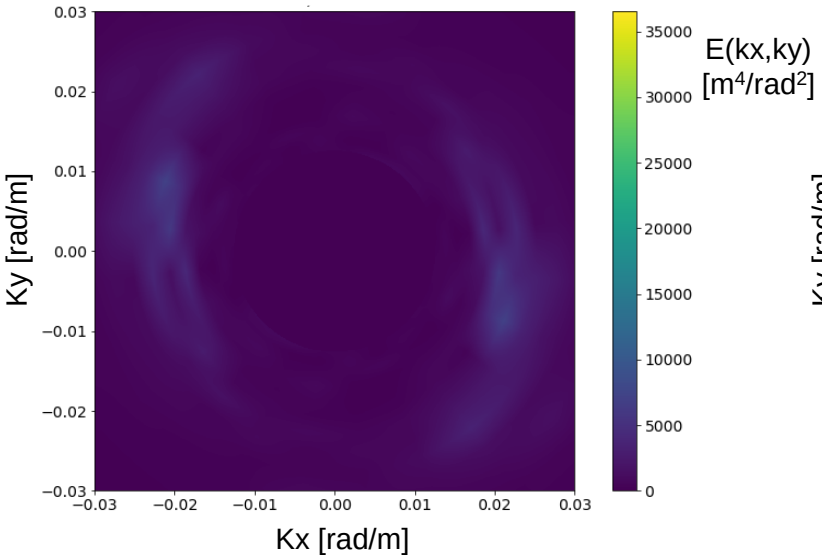
Example with CFOSAT data



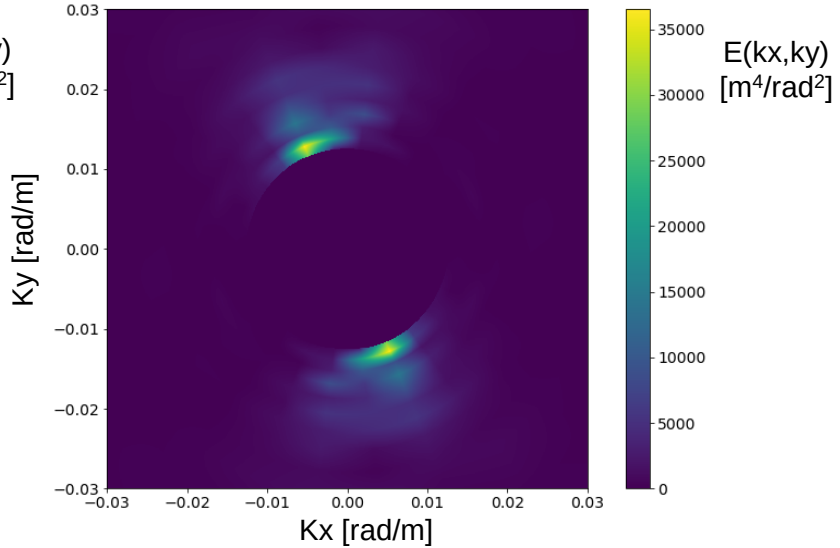
- Background color: Hs from WW3 model
- Colocalisation of nadir and spectral measurements
- Nadir measurements:
  - mean(Hs) per box
  - std(Hs) per box
- Off-nadir measurement :
  2D spectra in boxes
- Focus on 2 boxes :
  1) mean(Hs) = 9.3 m, std(Hs) = 0.49 m
  2) mean(Hs) = 9.3 m, std(Hs) = 0.88 m

Spectra from boxes

Box 1) mean(Hs) = 9.3m, std(Hs) = 0.49 m



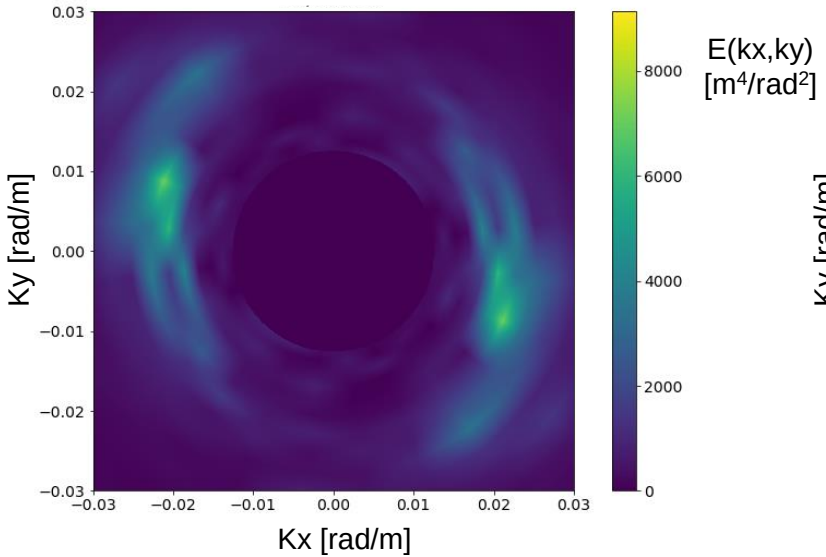
Box 2) mean(Hs) = 9.3m, std(Hs) = 0.88 m



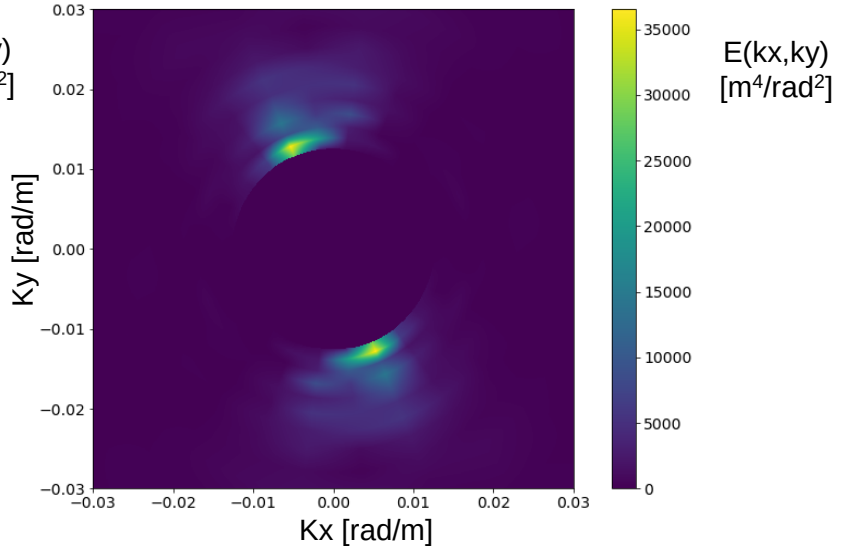
N.B. : same colorbar does not allow to see box 1/ spectrum

Spectra from boxes

Box 1) mean(Hs) = 9.3m, std(Hs) = 0.49 m



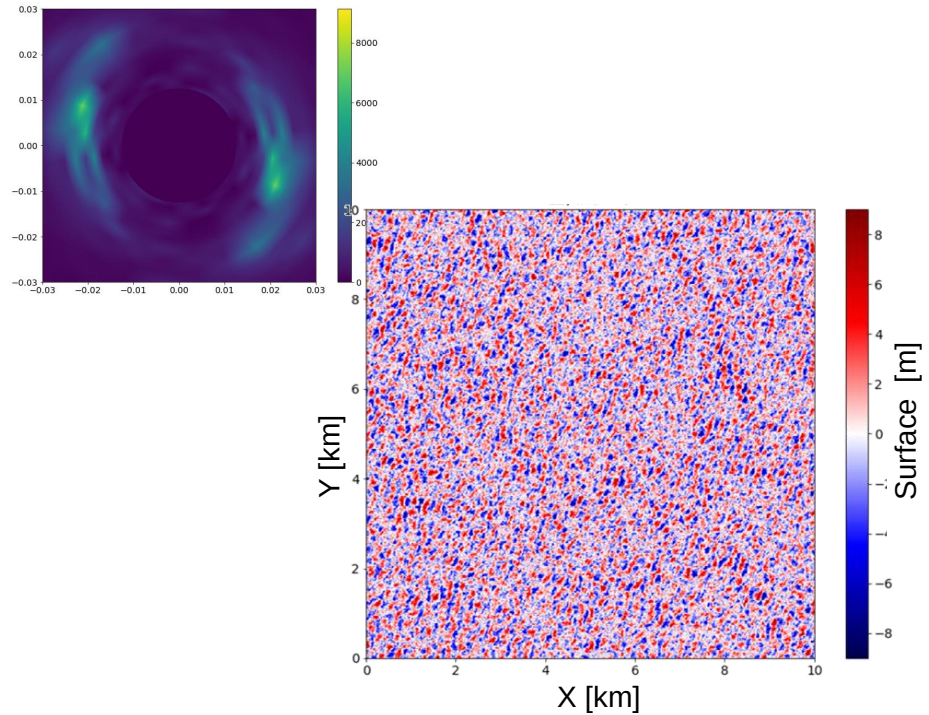
Box 2) mean(Hs) = 9.3m, std(Hs) = 0.88 m



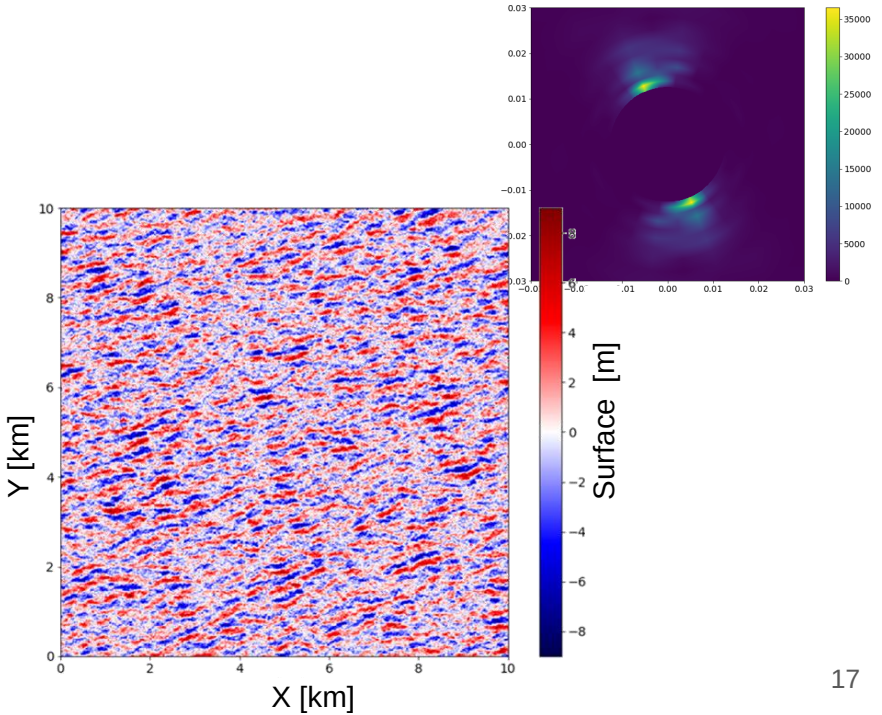
N.B. : colorbar for box 1) = colorbar for box 2) divided by 4

Simulated surface from spectrum

Box 1) mean(Hs) = 9.3m, std(Hs) = 0.49 m

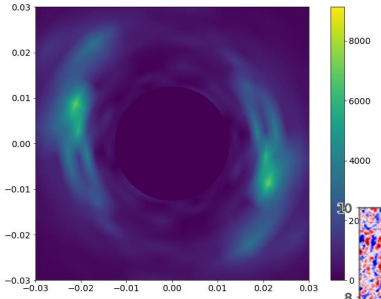


Box 2) mean(Hs) = 9.3m, std(Hs) = 0.88 m



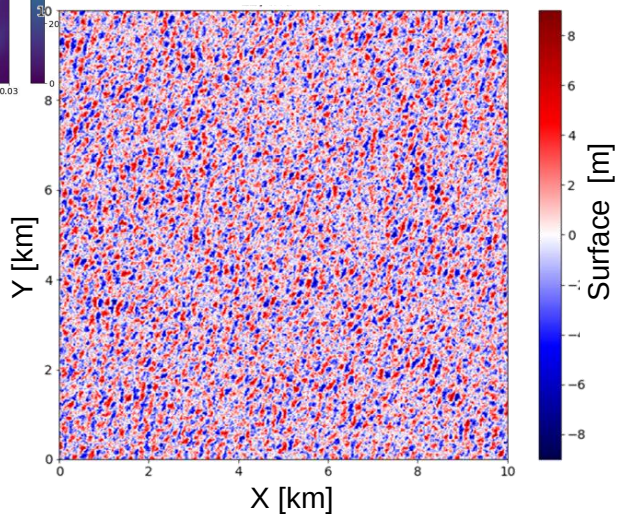
Simulated surface from spectrum

Box 1) mean(Hs) = 9.3m, std(Hs) = 0.49 m

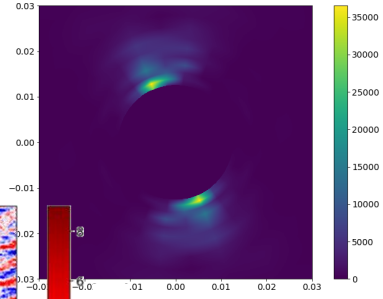


- Wide blurred spectrum
- Small and ‘random’ crests

⇒ **Wind sea**

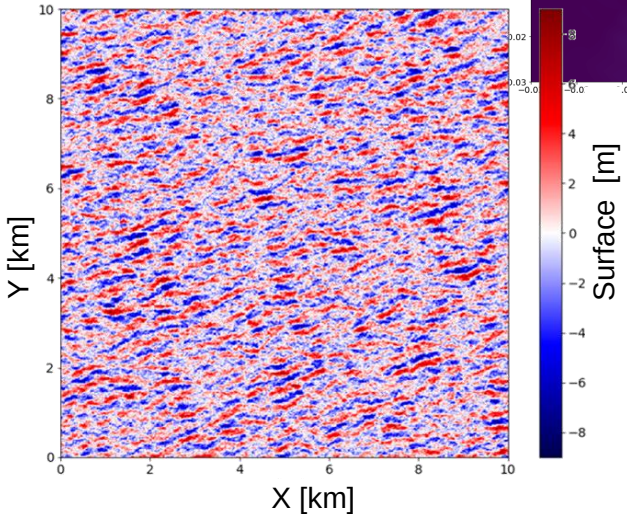


Box 2) mean(Hs) = 9.3m, std(Hs) = 0.88 m



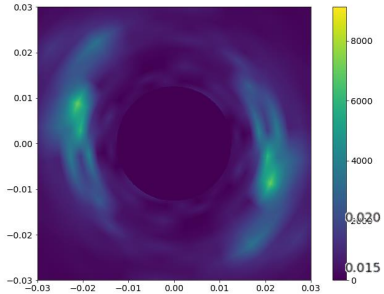
- Narrow spectrum
- Long and organised crests

⇒ **Swell**

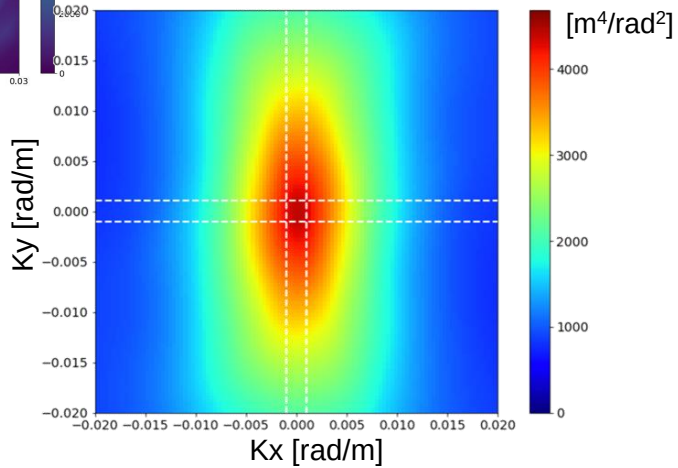


2D Hs spectra from autocorrelation

Box 1) mean(Hs) = 9.3m, std(Hs) = 0.49 m

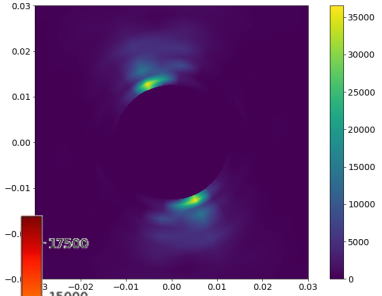


⇒ Energy of Hs is spread over a large range of scales

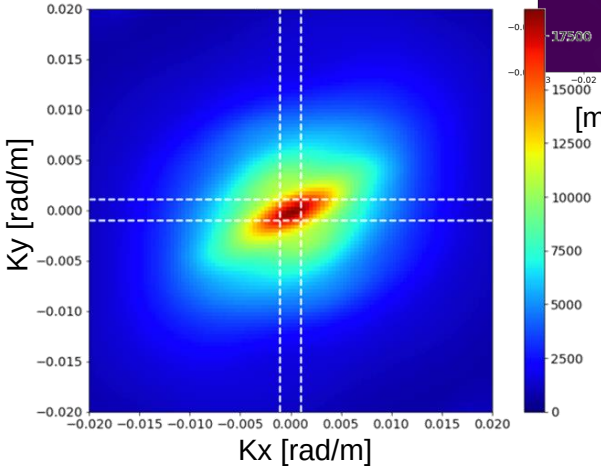


Hs spectrum *from autocorrelation*

Box 2) mean(Hs) = 9.3m, std(Hs) = 0.88 m



⇒ Hs energy concentrated to small k, i.e. long scales

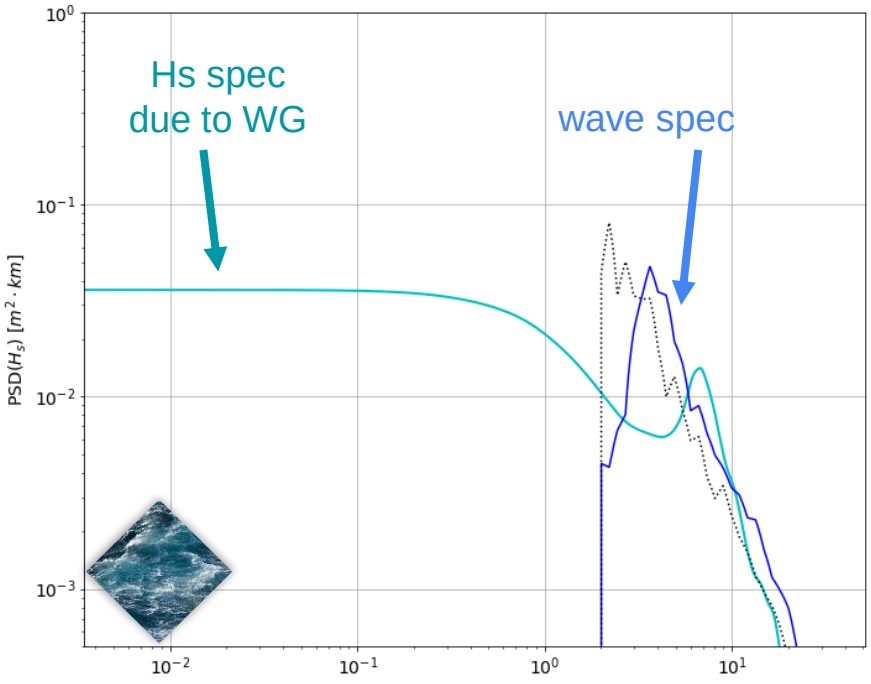


Hs spectrum *from autocorrelation*

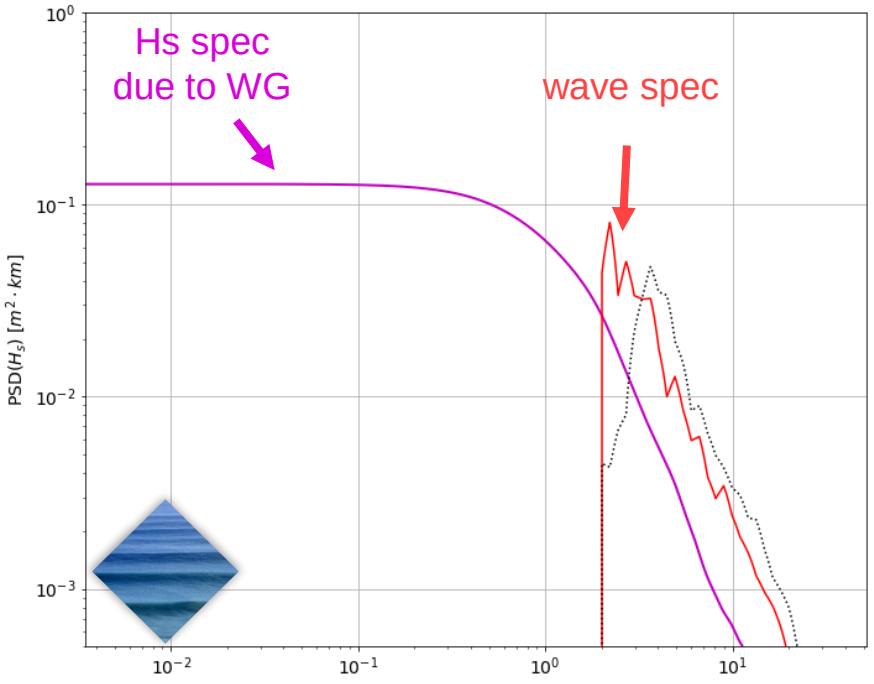
N.B. : colorbar for box 1) = colorbar for box 2) divided by 4

1D Hs spectra from autocorrelation

Box 1) mean(Hs) = 9.3m, std(Hs) = 0.49 m

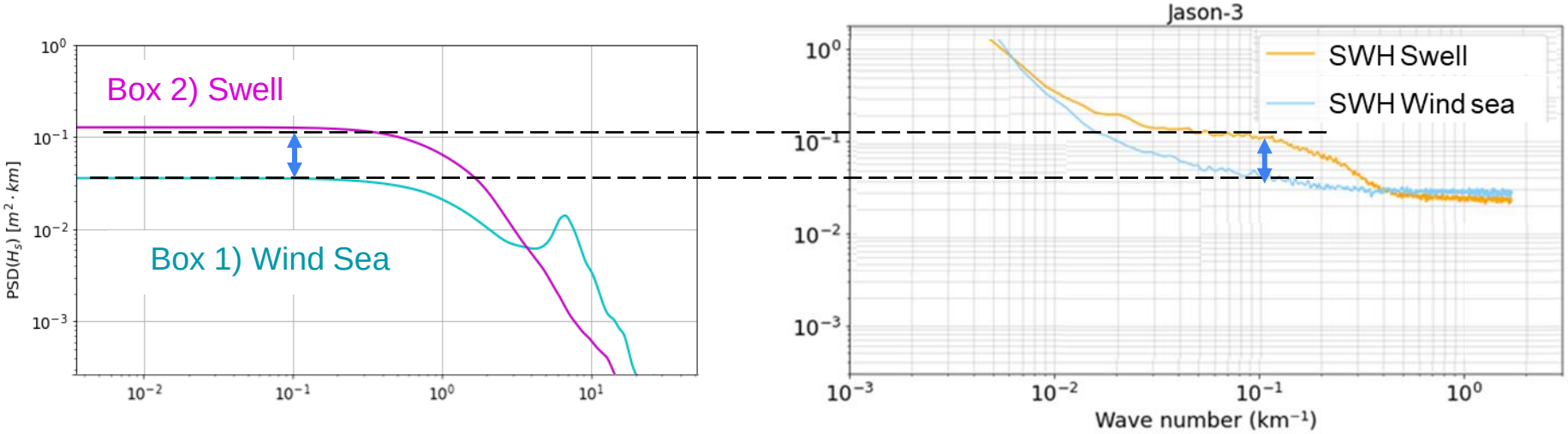


Box 2) mean(Hs) = 9.3m, std(Hs) = 0.88 m



Coming back to our SWH along track spectrum

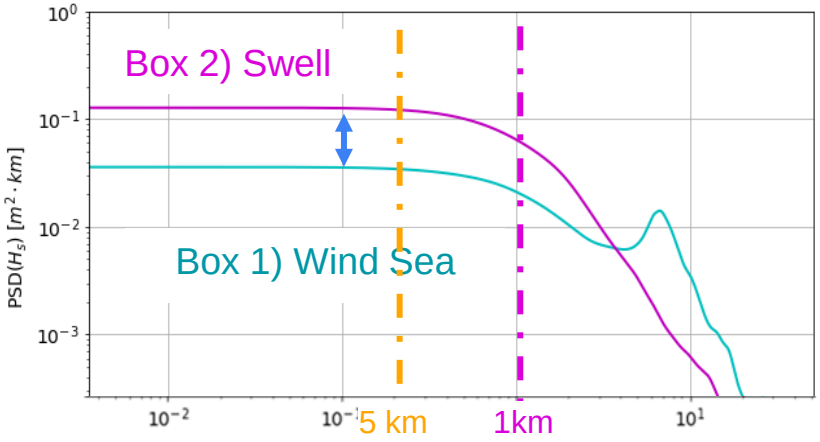
⇒ Similar order of magnitude for the ‘bump’ at 10 km

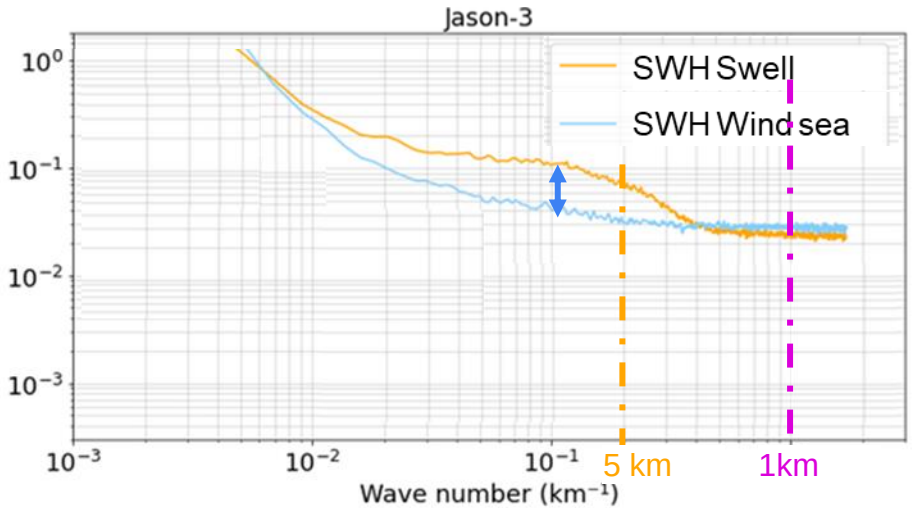


Coming back to our SWH along track spectrum

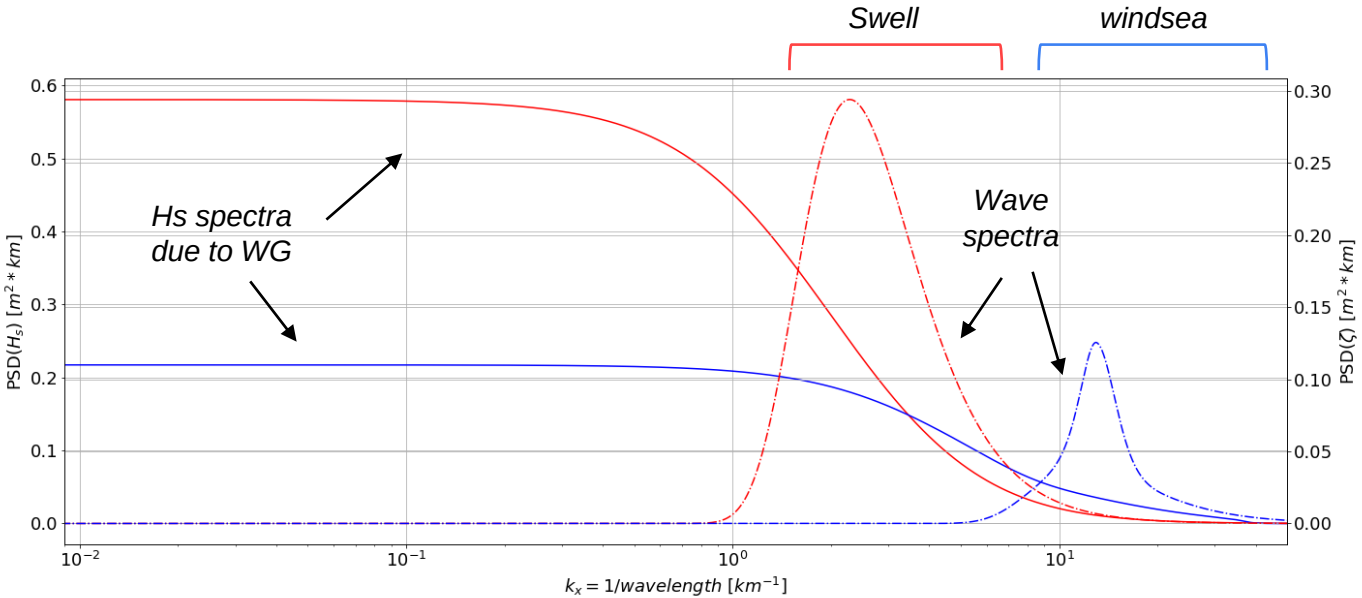
⇒ Similar order of magnitude for the ‘bump’ at 10 km

⇒ The **drop of energy** (towards small scales) happens before in **real data (J3)** than in the **model** : possible instrumental effect (antenna gain pattern TBC)

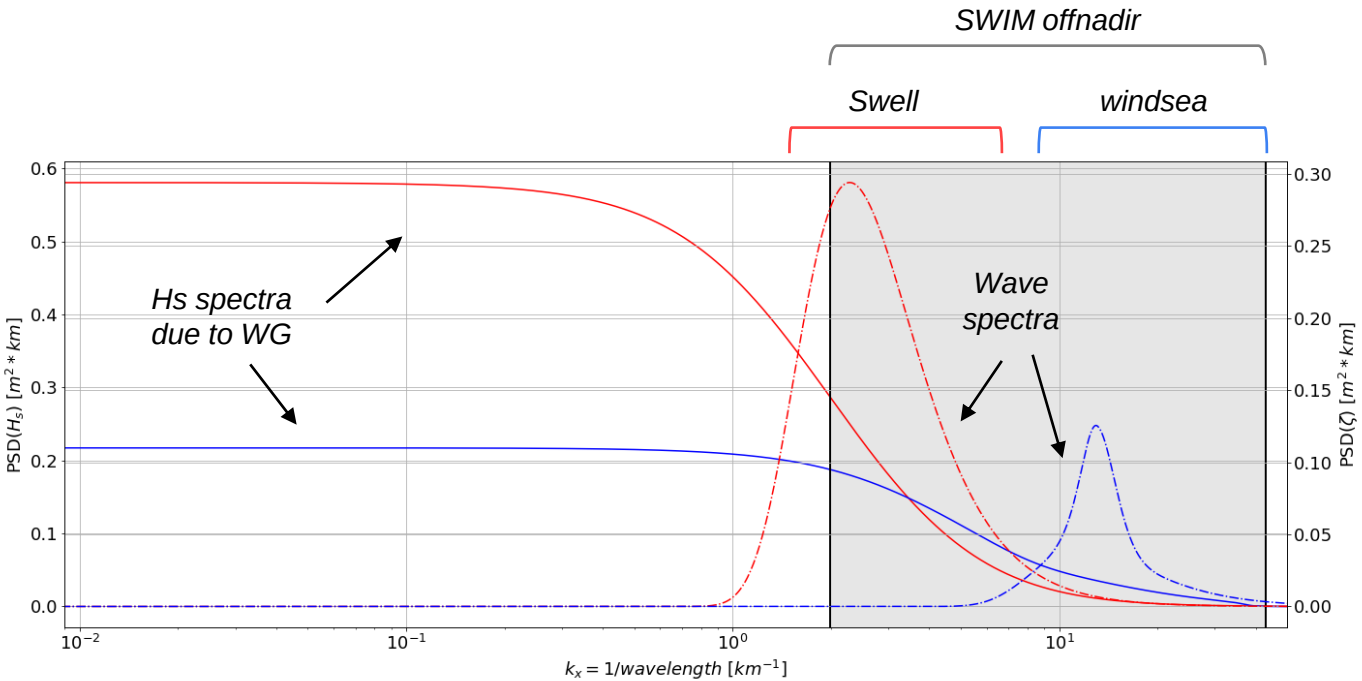




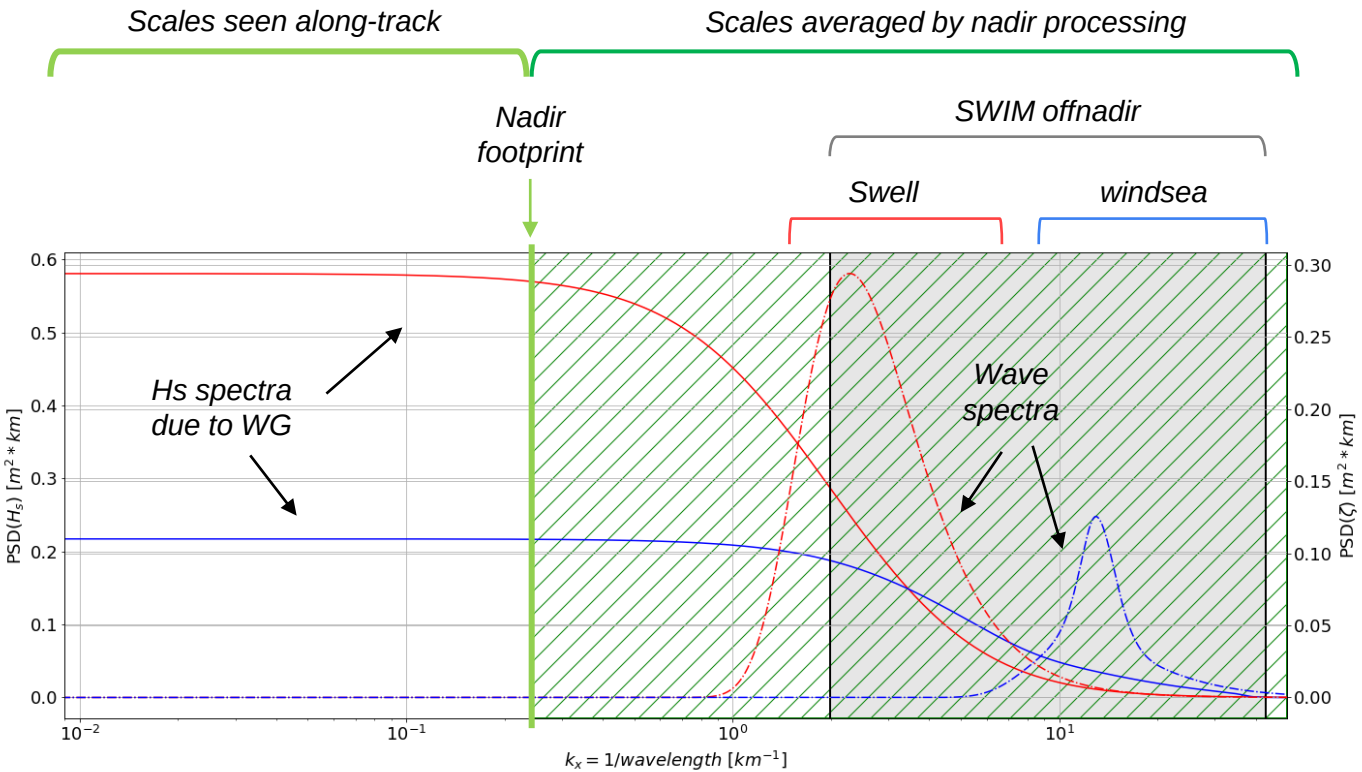
Conclusions – Schematic view on scales



Conclusions – Schematic view on scales



Conclusions – Schematic view on scales

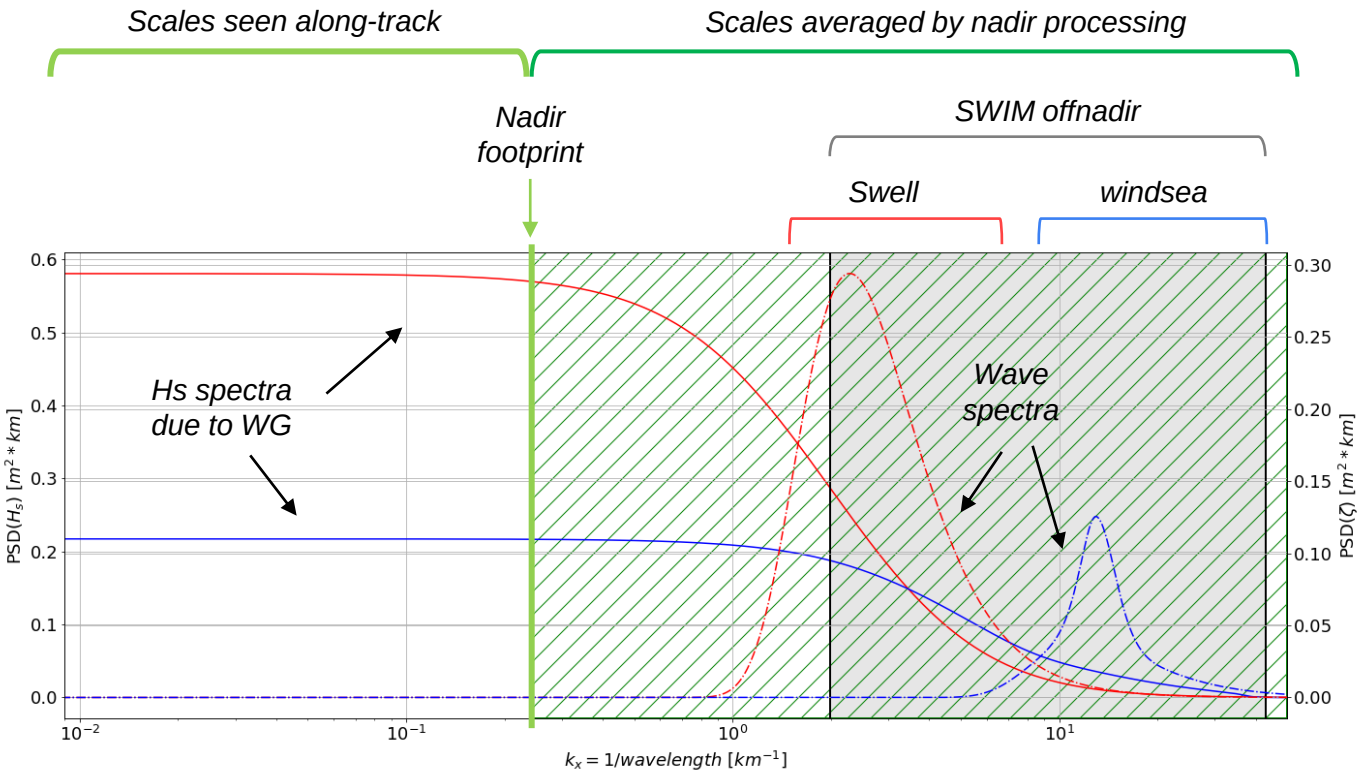


Nadir footprint scale

→ for LRM (isotropic)

→ to be updated for nadir doppler SAR mode

Conclusions – Schematic view on scales



Nadir footprint scale

→ for LRM (isotropic)

→ to be updated for nadir doppler SAR mode

⇒ **Waves** have **no signature** above the altimeter footprint

⇒ **Wave groups** may have a signature to larger scales, depending on wave conditions

Thank you for your attention !