

Continued,
enhanced ocean altimetry
and climate monitoring
from space

31 October > 4 November 2022

IDS workshop
OSTST meeting

Venice - Italy

<https://ostst-altimetry-2022.com/>



5Hz (1km) nadir wave products for coastal approach... and elsewhere!

Annabelle OLLIVIER, Adrien NIGOU, Victor QUET,
Charles PEREUX, Beatriz Molero, François SOULAT,
Fanny PIRAS (CLS)

Marine DE CARLO, Fabrice ARDHUIN (Ifremer)

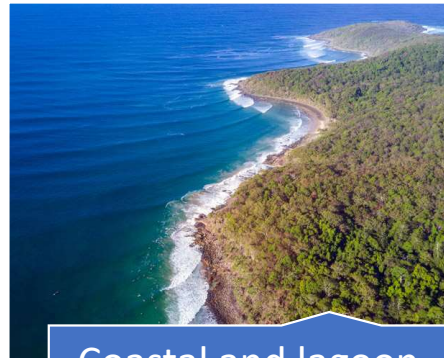
Alice DALPHINET (Meteo France)

Gérald DIBARBOURE, Cédric TOURAIN (CNES)

Pierre FEMENIAS (ESA)



High Frequency Wave products... what for?

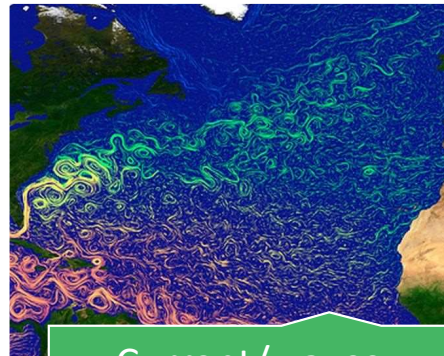


Coastal and lagoon studies

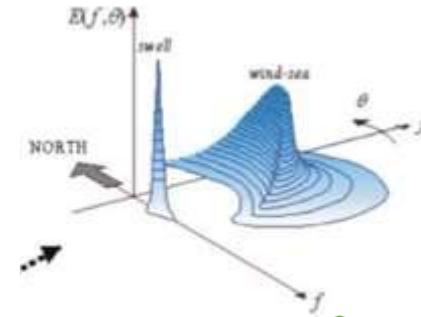
uragan Danielle : un emballement médiatique ?
rdi 6 septembre 2022



Extreme events



Current/waves interactions



Mixed seas understanding

2021 CMEMS Wave-TAC User Survey

Users first!

Survey sent by CMEMS Wave TAC in 2021:
3 main needs identified for operational data



1 - 91% Additionnal variables from wave spectra (direction and period):

CFOSAT full spectrum now available in CMEMS *see presentation CFOSAT session on CFOSAT/SENTINEL-1*

2- 79% Increase the resolution for along track products near coasts and high variability areas

3- 79% Uncertainty metrics associated to data

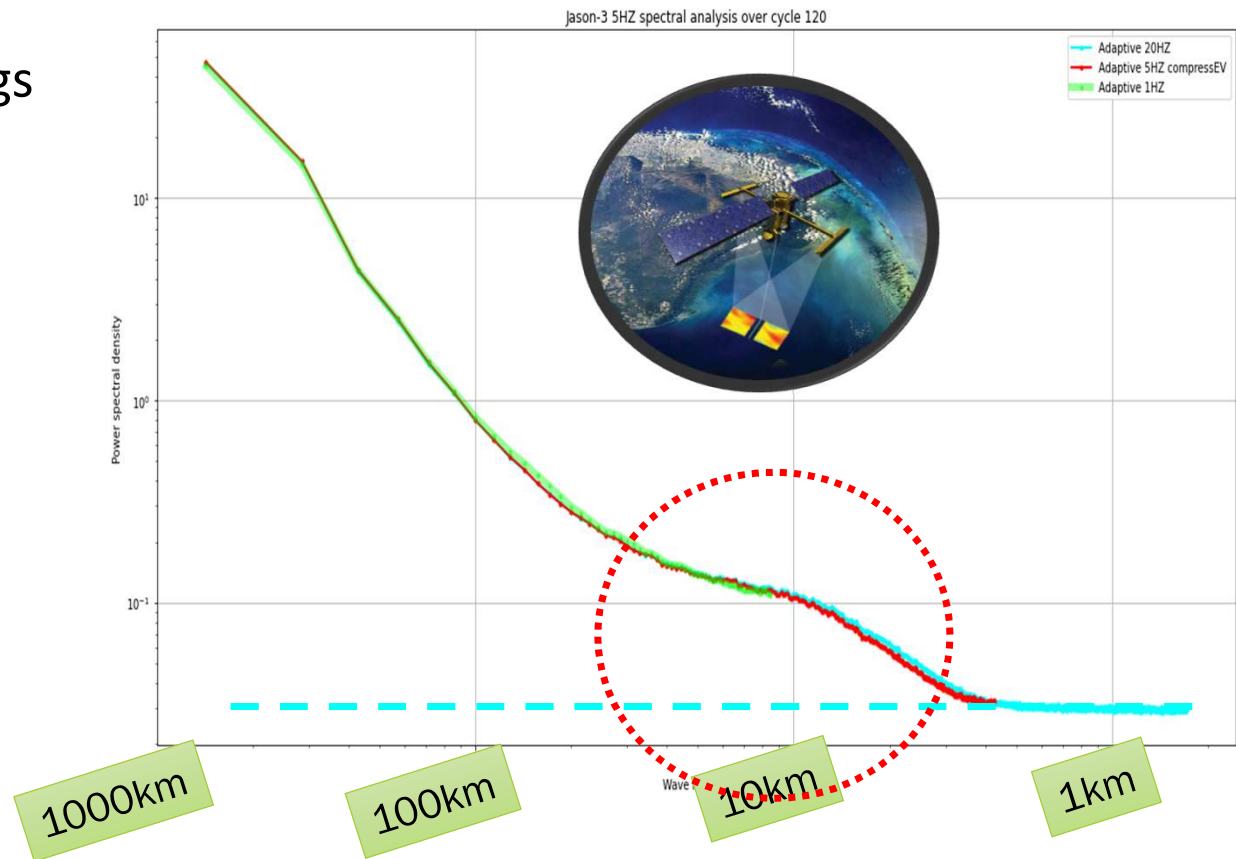
HF Wave product at 5Hz (1km along track), why this choice?



Because:

- Although retrackings, post processings keep improving...
- Below 1km: white noise plateau (speckle) dominates
- Between 1km- 50km: bump to:
 - Better resolve (unlike 1Hz)
 - Filter (or not?)
 - Understand!!!

Preparation for SWOT era...



Overview



- ☐ Availability of products: for which missions?
- ☐ Resolution skills near coasts
- ☐ Processing step
- ☐ Discussion around the bump on SWH spectrum
- ☐ Perspectives for altimetry

5Hz L3 WAVE Demo product are made available



4 missions provided as demo products over one year: 2021

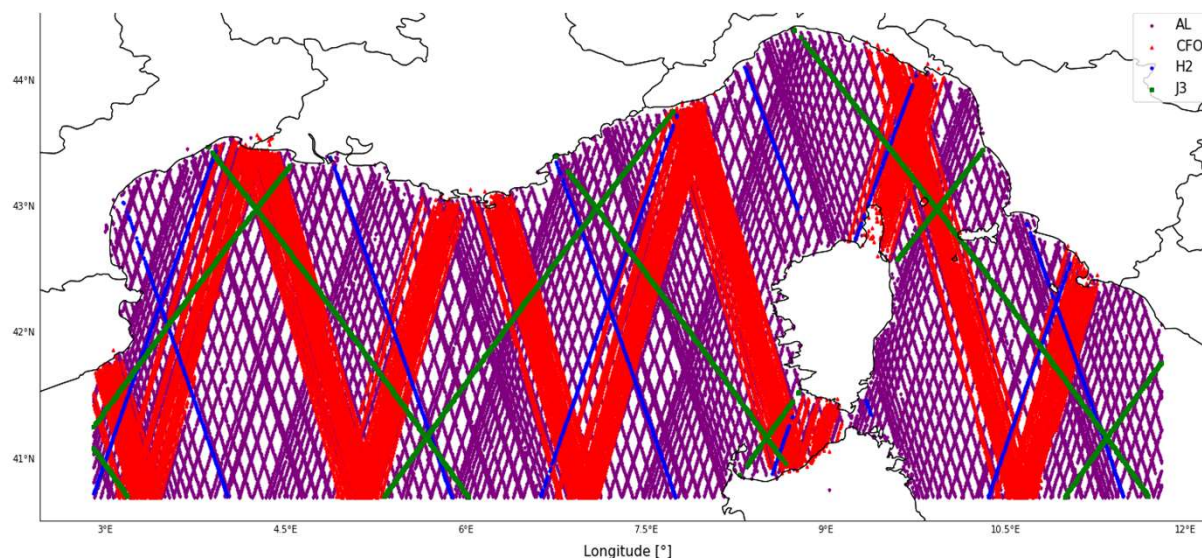
CFOSAT nadir

JASON3

ALTIKA

HY2

→ + soon, ENVISAT 11 years : on ESA portal, FDR4ALT project (see Fanny Piras poster)



Data are here:

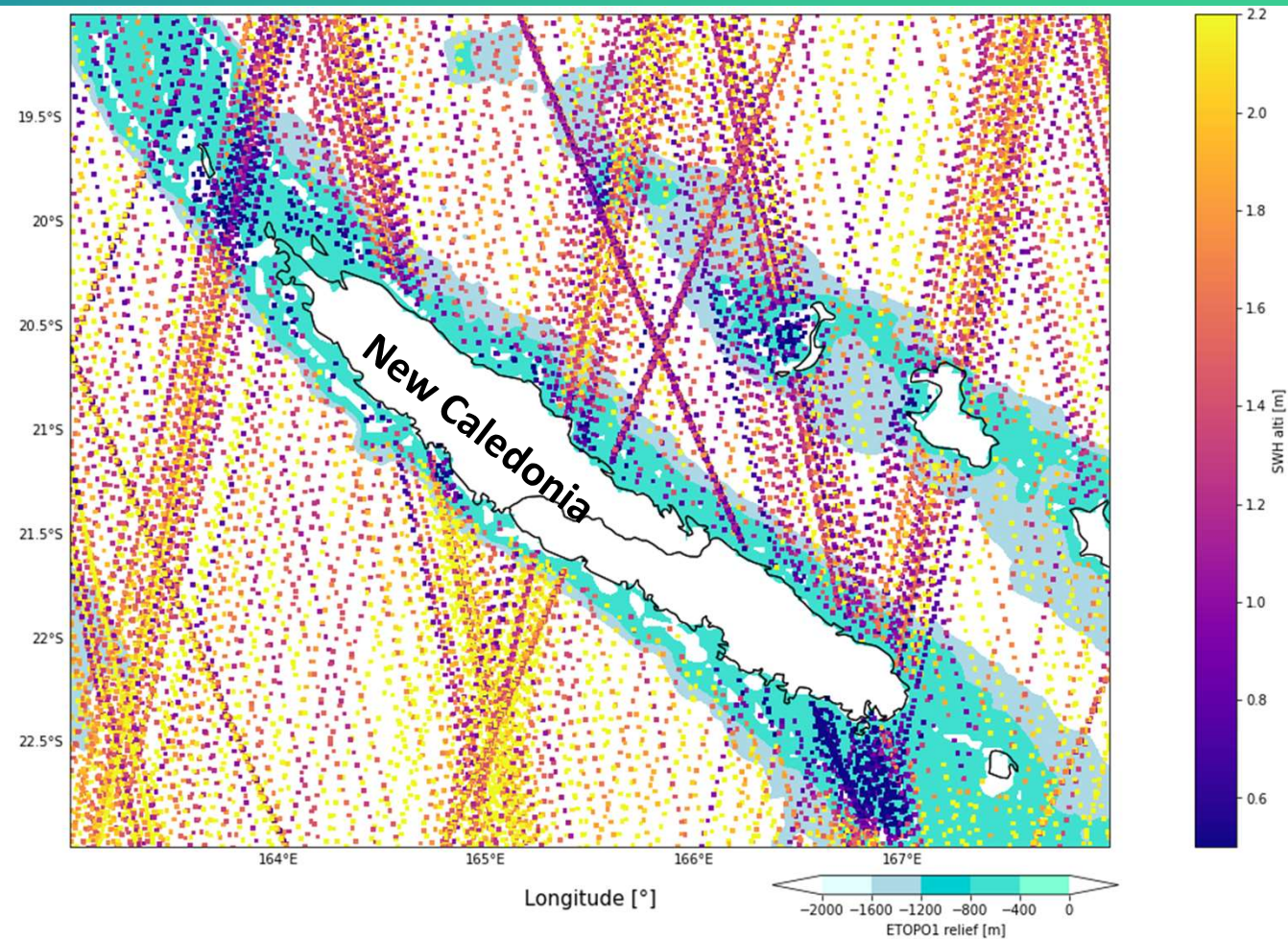
<https://www.aviso.altimetry.fr/en/data/products/windwave-products/wave-experimental-products.html>



Better coverage near coasts / inside lagoons



Operational 1Hz CMEMS/ CCI
along track SWH
over 2021



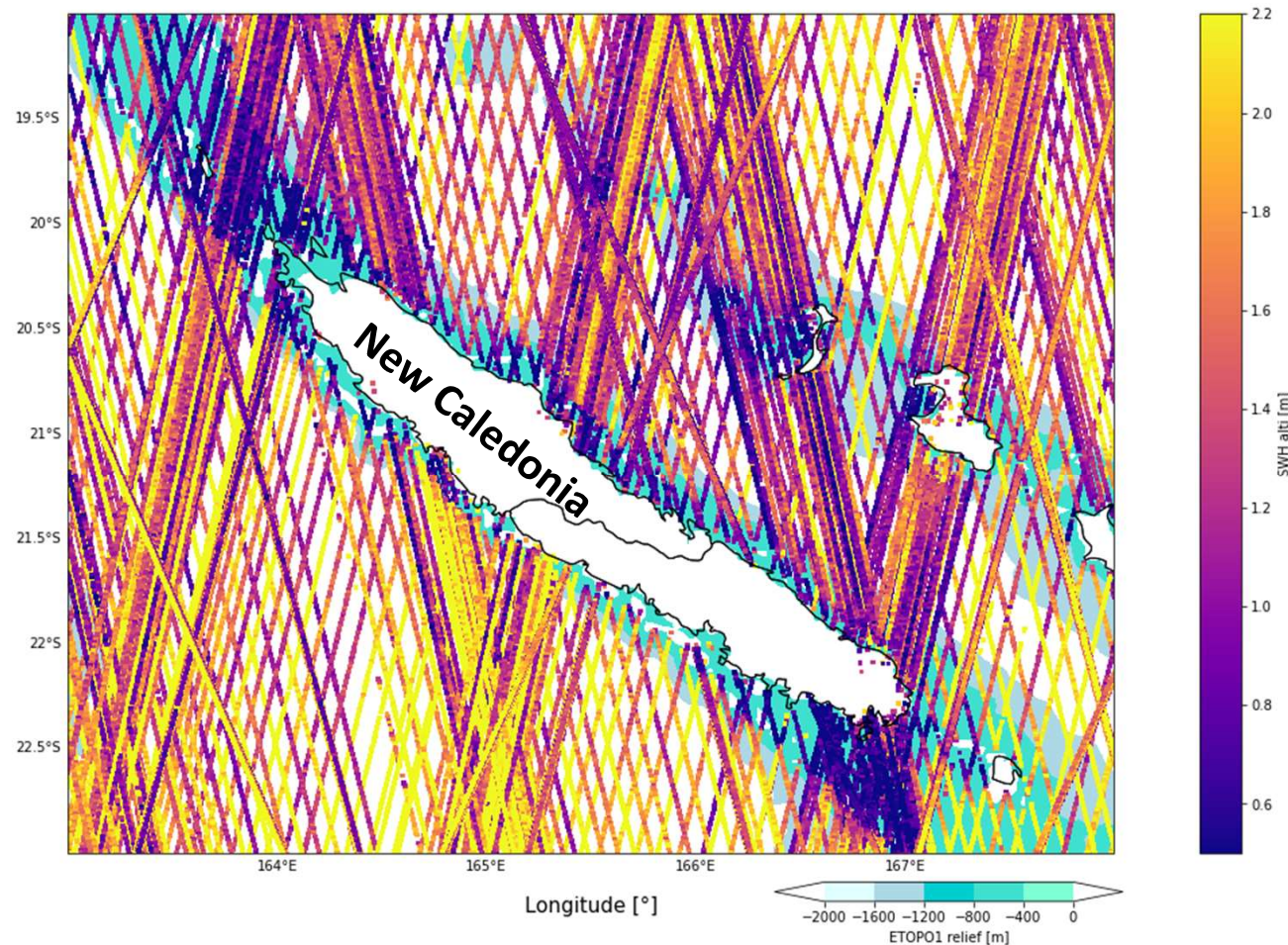
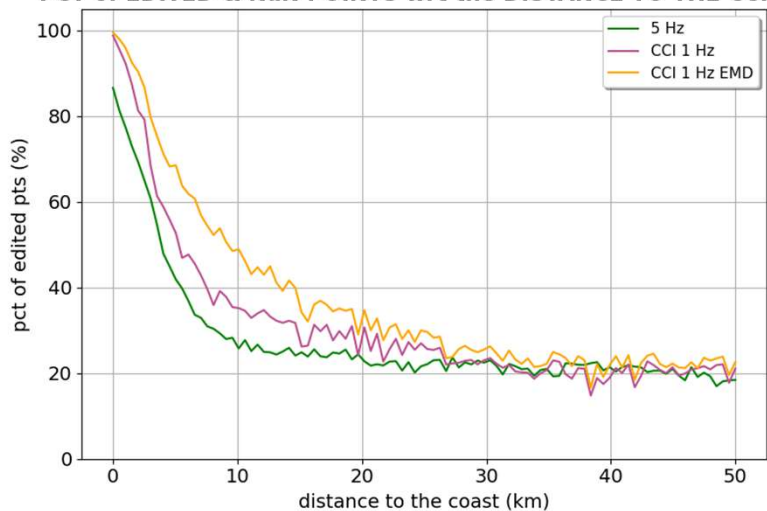
Better coverage near coasts / inside lagoons



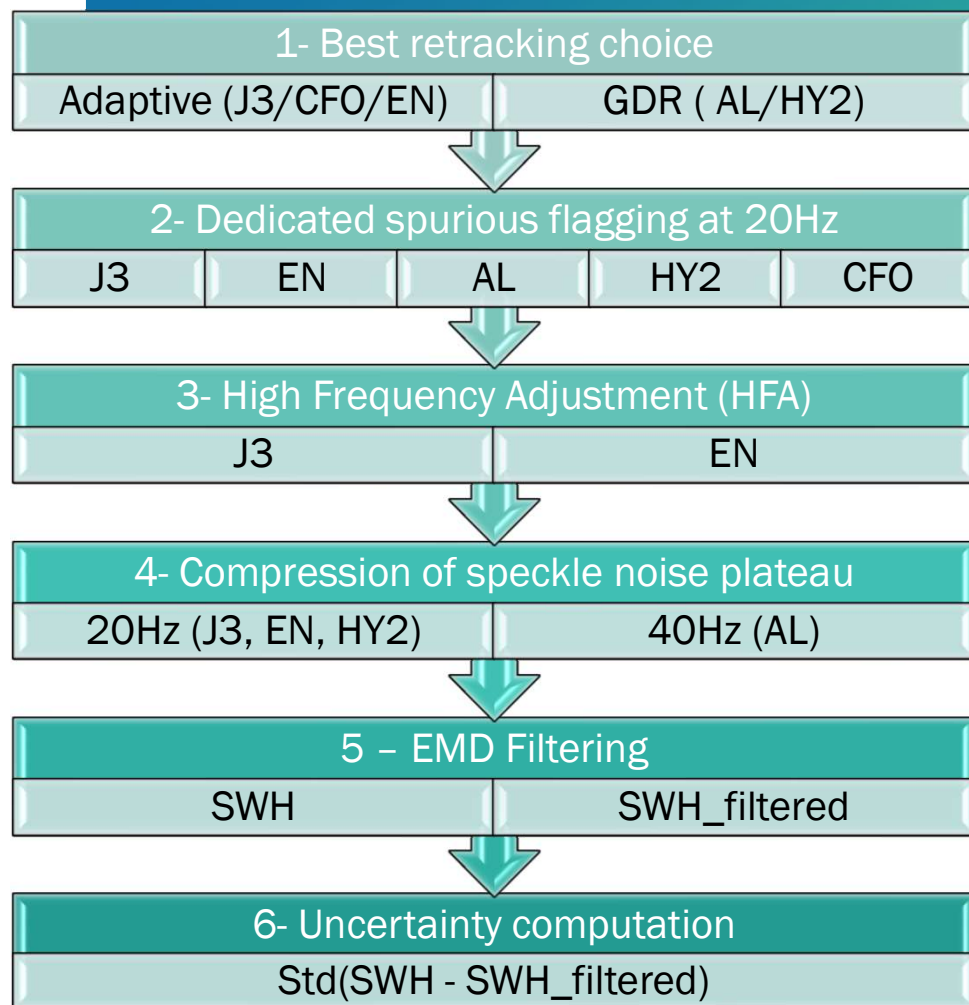
Demo product 5Hz along track SWH over 2021

In global: + 20% more valid data below 20km!

PCT of EDITED & NaN POINTS wrt the DISTANCE TO THE COAST



The 5Hz processing recipe (CMEMS L3 like products)



Adaptive retracking: Tourain et al. 2021, + Fanny Piras's talk, Dodet et al. 2021

Dedicated to each mission

High Frequency Adjustment (HFA): Noise reduction based on Zaron method Tran et al. 2021

Same algo as for 1Hz GDR compression

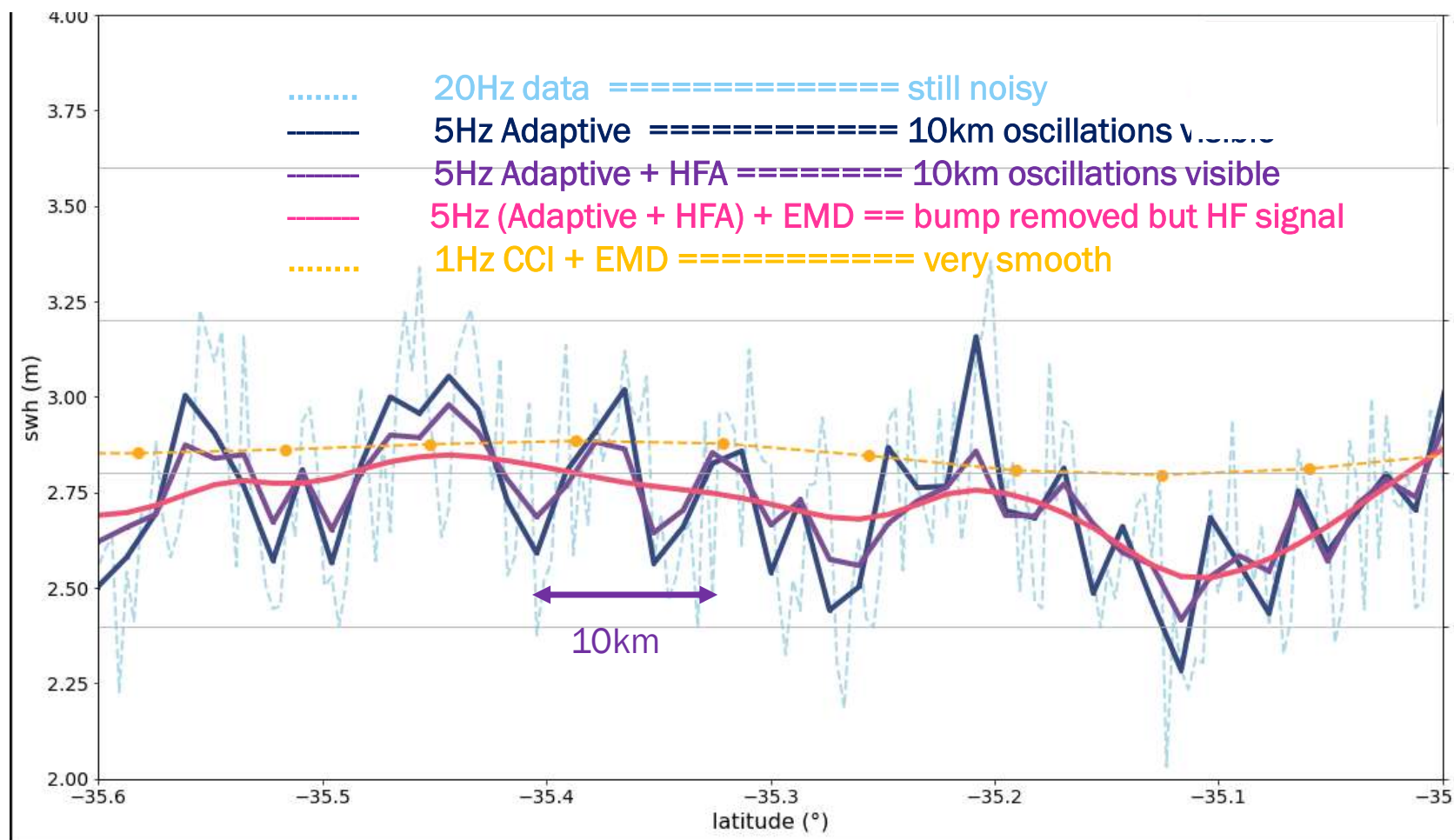
Quilfen et al. 2018

Exact definition still TBD with users

Different resolution waves along track content (exemple of Jason-3)



Along track spatial zoom of SWH near Agulas current signature expected (Quilfen et al. 2019)

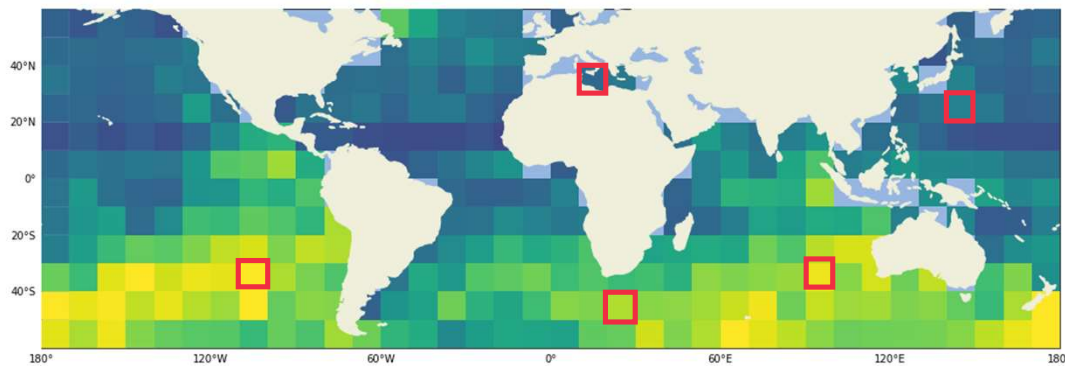


Regional spectral analysis in $10^\circ \times 10^\circ$ boxes

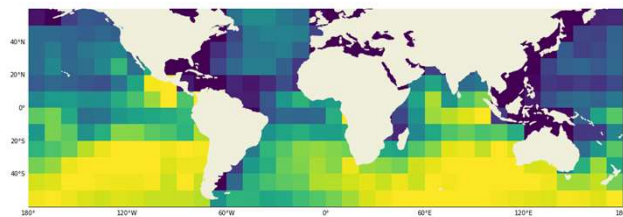
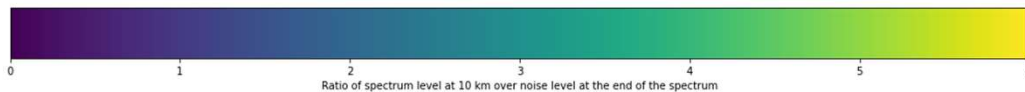
cycles 118 to 124 =

7 cycles = 2.5 months 

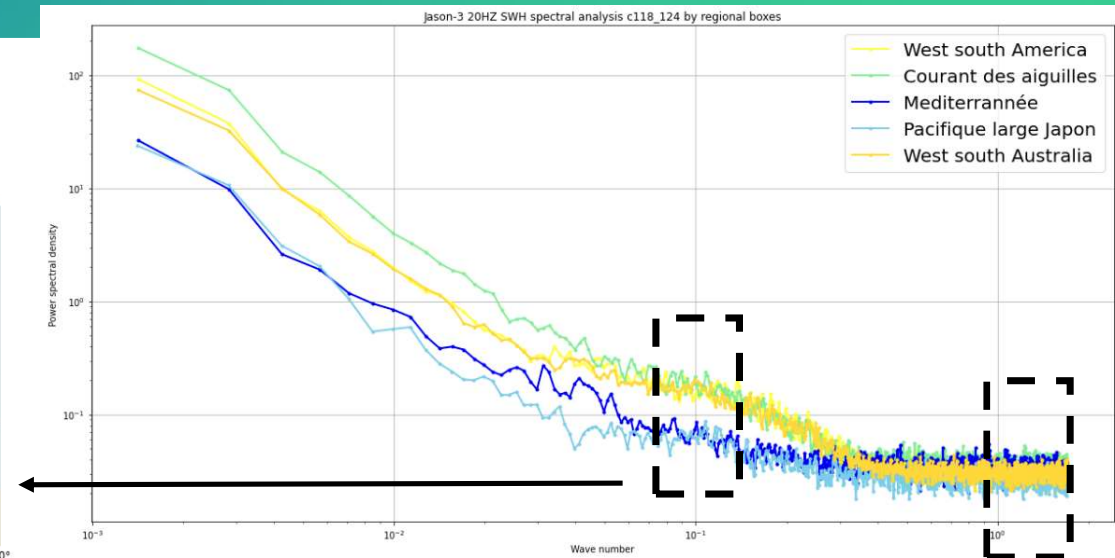
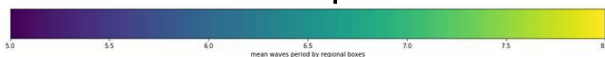
Ratio of mean spectrum energy at $\sim 10\text{km}$ over mean energy spectrum of the speckle plateau by regional box :



Ratio 10km/ speckle



WAM period



Regional spectral analysis : $10^\circ \times 10^\circ$ boxes

The 10km bump is directly related to the swell period
The speckle plateau is very stable

Spectral information and wave types

How do ocean waves develop?



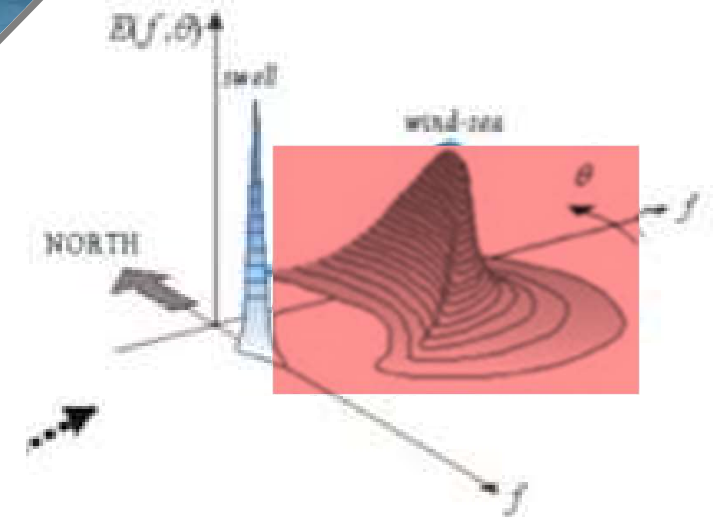
Wind sea



Large swell



Nadir SWH only gives the total energy

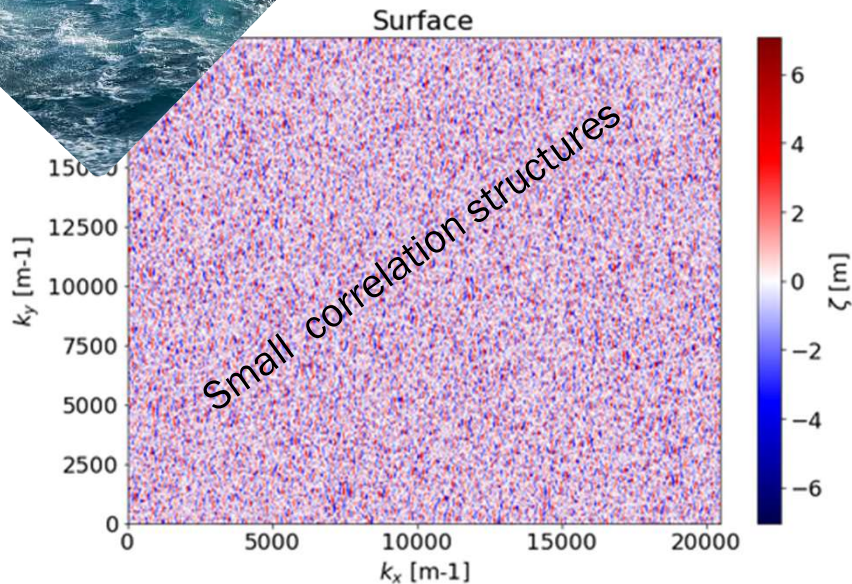


Surface elevation models for 2 different wavelengths (same H_s)



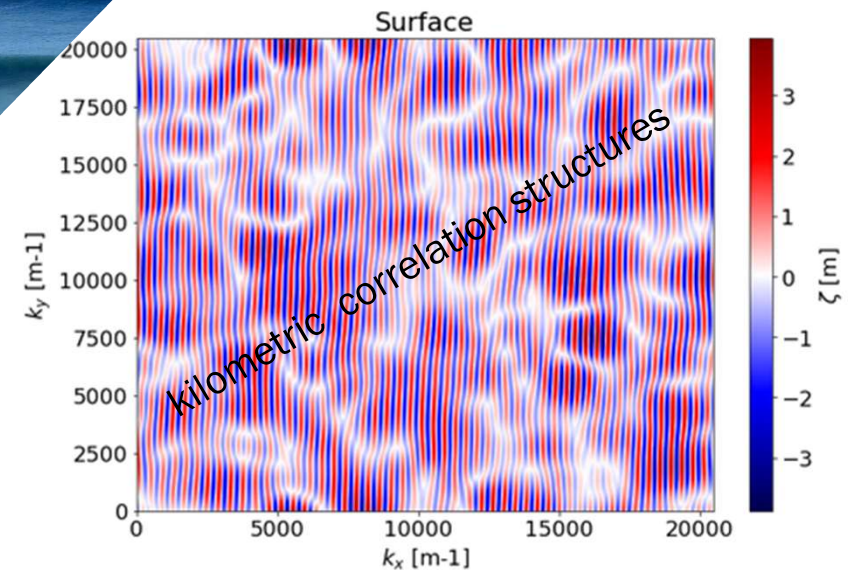
- Wind wave:

Wavelength < 90 m



- Long swell:

Wavelength > 200 m



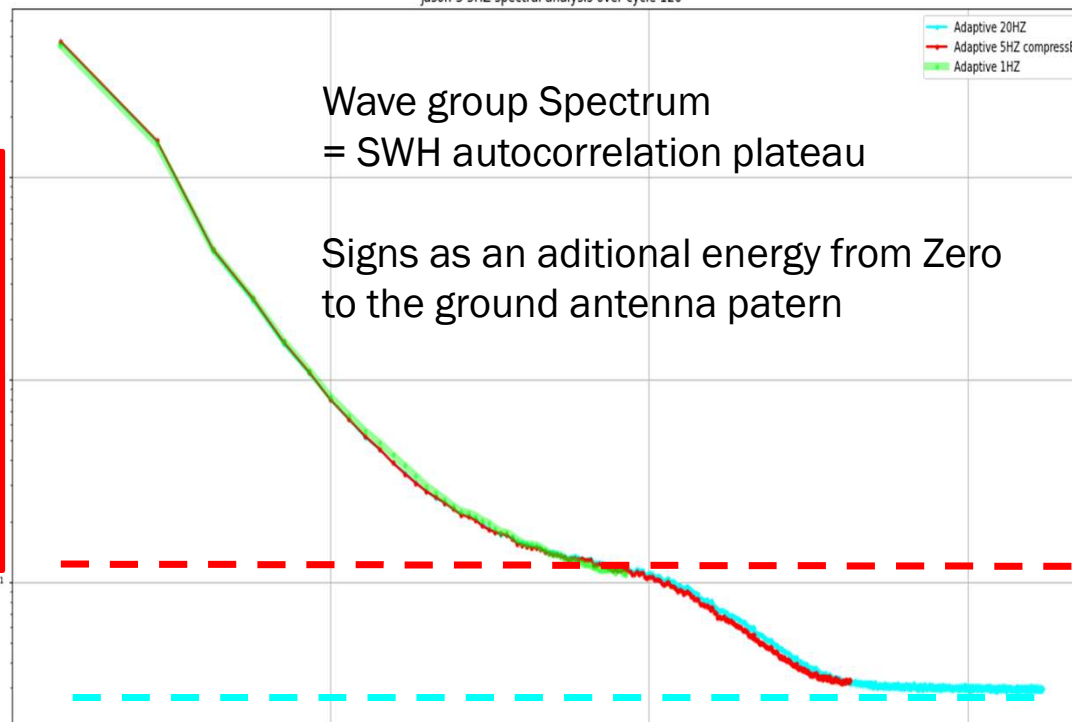
→ « Wave groups » pattern correlated by the ground track
= envelope/ autocorrelation of waves (Rice et al. 1944)

→ See Marine De Carlo et al. (Ifremer) dedicated presentation CFOSAT Session

Wave groups and spectral plateau signature

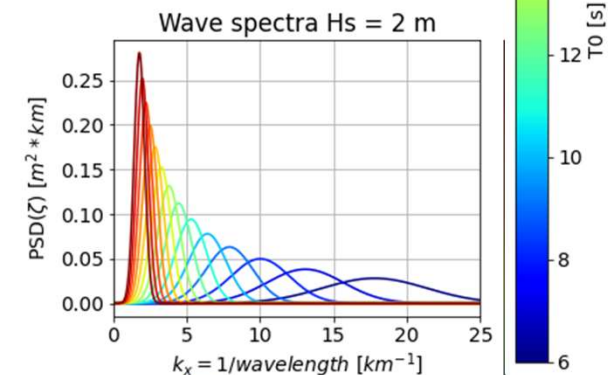


Jason-3 5HZ spectral analysis over cycle 120



SWH direct spectrum

Invisible for nadir >1km



...km

1000km

100km

10km

1km

100m

10m

→ See Marine De Carlo et al. (Ifremer) dedicated presentation CFOSAT Session

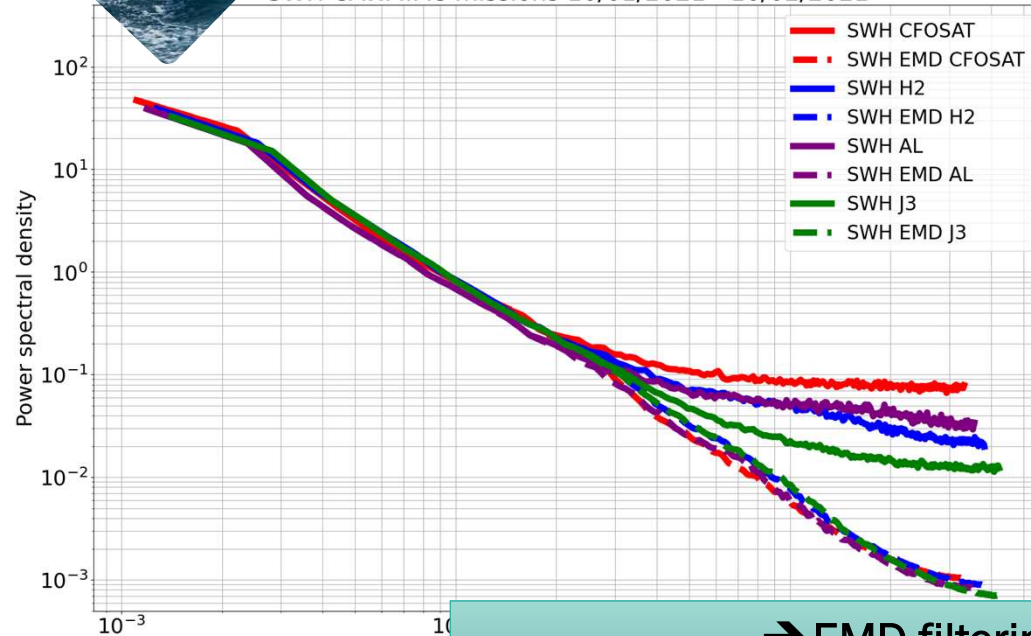
5Hz products filtered/ non filtered : per class of Period/Wavelength



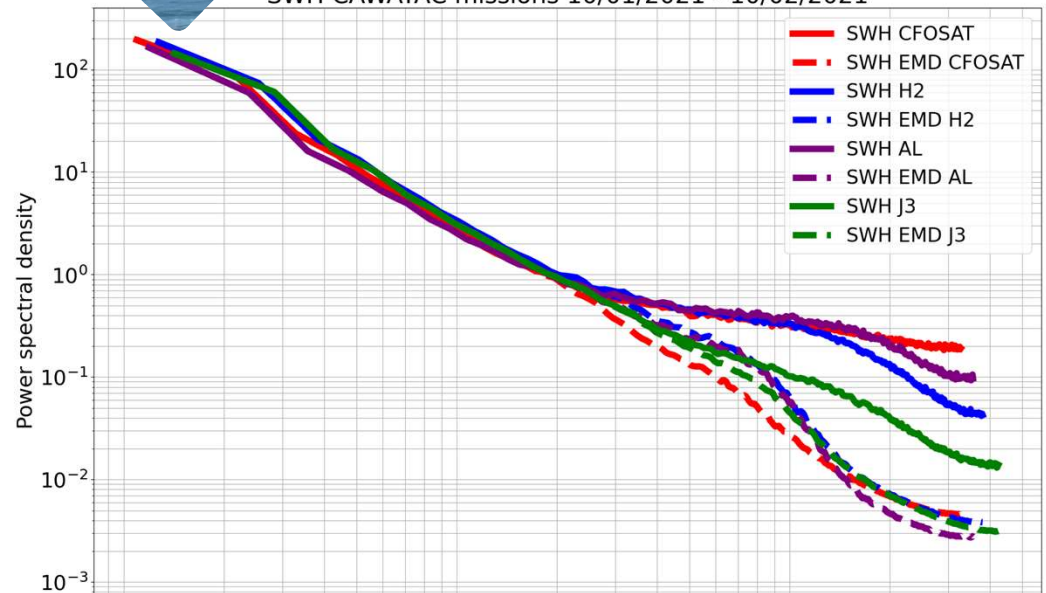
- Wind wave:
wavelength < 90 m

- Long swell:
Wavelength > 200 m

SWH CAWATAC missions 10/01/2021 - 10/02/2021



SWH CAWATAC missions 10/01/2021 - 10/02/2021



→ EMD filtering adapted to wave ondulatory structures

EMD std(Residual) proposed as an Uncertainty field



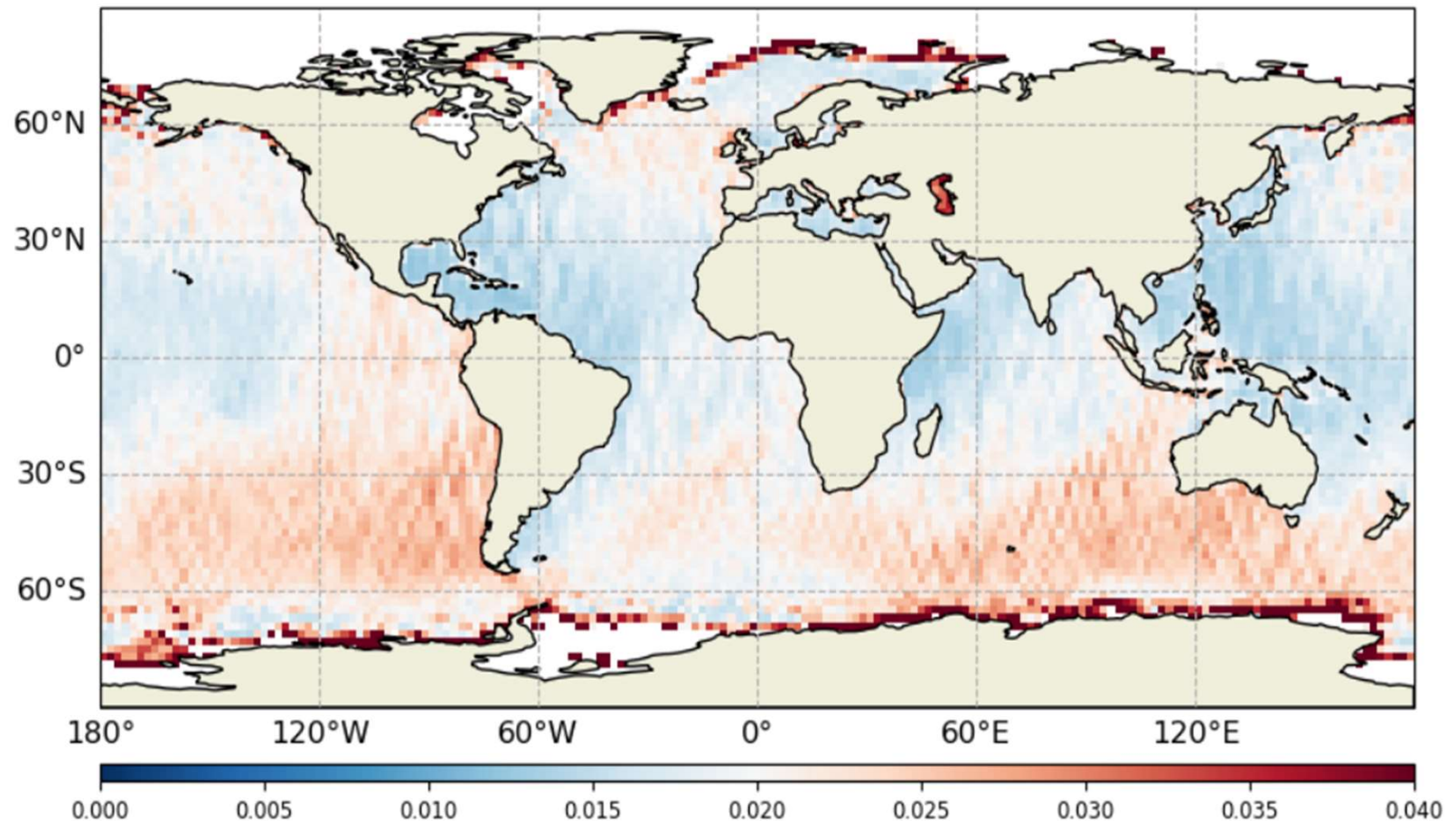
Demo product 5Hz along track SWH

Residual =
 $\text{std}(\text{SWH} - \text{SWH}_{\text{filtered}})$

Per box over 3 months

→ Wave group effect removed.

No signature of currents in the residual! 😊



Conclusions/Perspectives



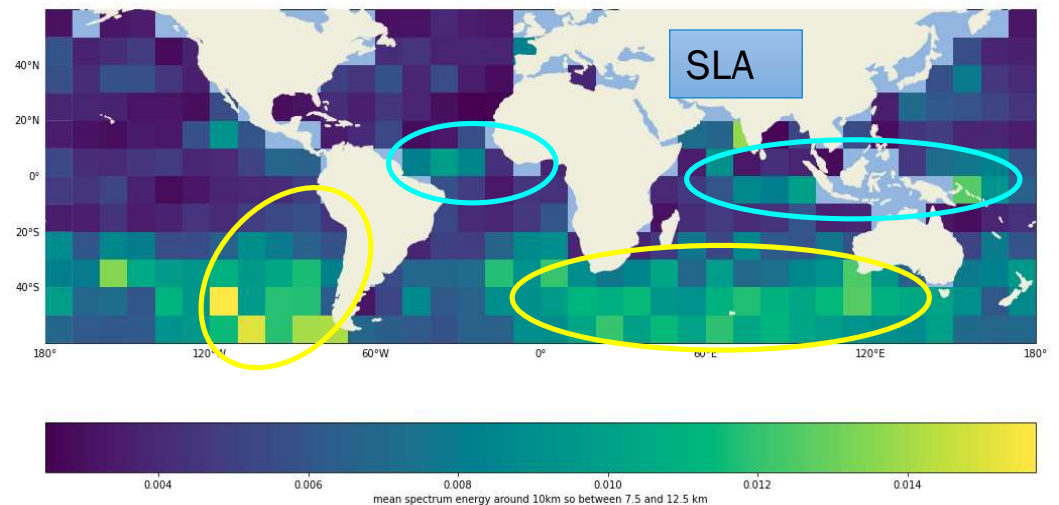
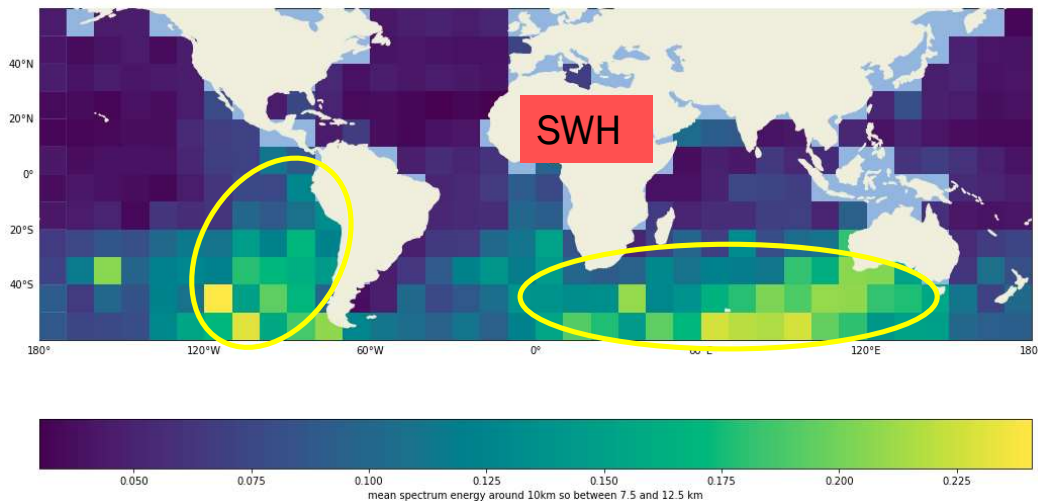
5Hz Demo products will be optimized products:

- 1 - They promote toward users the latest/best processings
 - ➔ SAR doppler products also planned for 2023
 - ➔ Planned future versions depending on users feedbacks (additionnal variables...)
- 2- Near Coasts and elsewhere...
 - ➔ Some feed backs already received from MeteoFrance/ Ifremer... (CFOSAT Science Team)
- 3 -They highlight the bump which is a correlated signal, related to waves groups :
 - ➔ signature explained theoretically on the altimetric spectrum (see *M. DeCarlo CFOSAT session*)
 - ➔ Also visible on Sentinel-1 imageries, IceSAT-2 profiles and SAR Doppler (red noise rather than bump that disappears for wind sea conditions)
- 4- They provide an uncertainty field
 - ➔ thanks to EMD to remove the bump if users prefer

SLA spectral bump dominated by waves effects

For SLA, demonstrated by (Dibarboure et al. 2014) to be a correlation effect (bloom, rain...)

Mean spectrum energy between 7.5km and 12.5km for each regional box :
Over 20 days, Jason3



- Rain, blooms (<10% occurrence)
+ Large period swell (30-65% occurrences)

→ « Sea State Effect » correction to be developed...



Thank you for your attention!

Contact: aollivier@groupcls.com

•Methodology:

- Cedric Tourain, Fanny Piras, Annabelle Ollivier, Danièle Hauser, Jean-Christophe Poisson, et al.. Benefits of the Adaptive algorithm for retracking altimeter nadir echoes: results from simulations and CFOSAT/SWIM observations. IEEE Transactions on Geoscience and Remote Sensing, Institute of Electrical and Electronics Engineers, 2021, 59 (12), pp.9927-9940. <https://doi.org/10.1109/TGRS.2021.3064236>
- Tran et al. Assessing the effects of sea-state related errors on the precision of high-rate Jason-3 altimeter sea level data, Advances in Space Research 68 (2021) 963-977 . <https://doi.org/10.1016/j.asr.2019.11.034>
- Dodet et al, The Sea State CCI dataset v1: towards a Sea State Climate Data Record based on satellite observations, Earth System Science Data, 2020. <https://doi.org/10.5194/essd-12-1929-2020>
- Quilfen, Y., & Chapron, B. (2019). Ocean surface wave-current signatures from satellite altimeter measurements. *Geophysical Research Letters*, 46, 253-261. <https://doi.org/10.1029/2018GL081029>

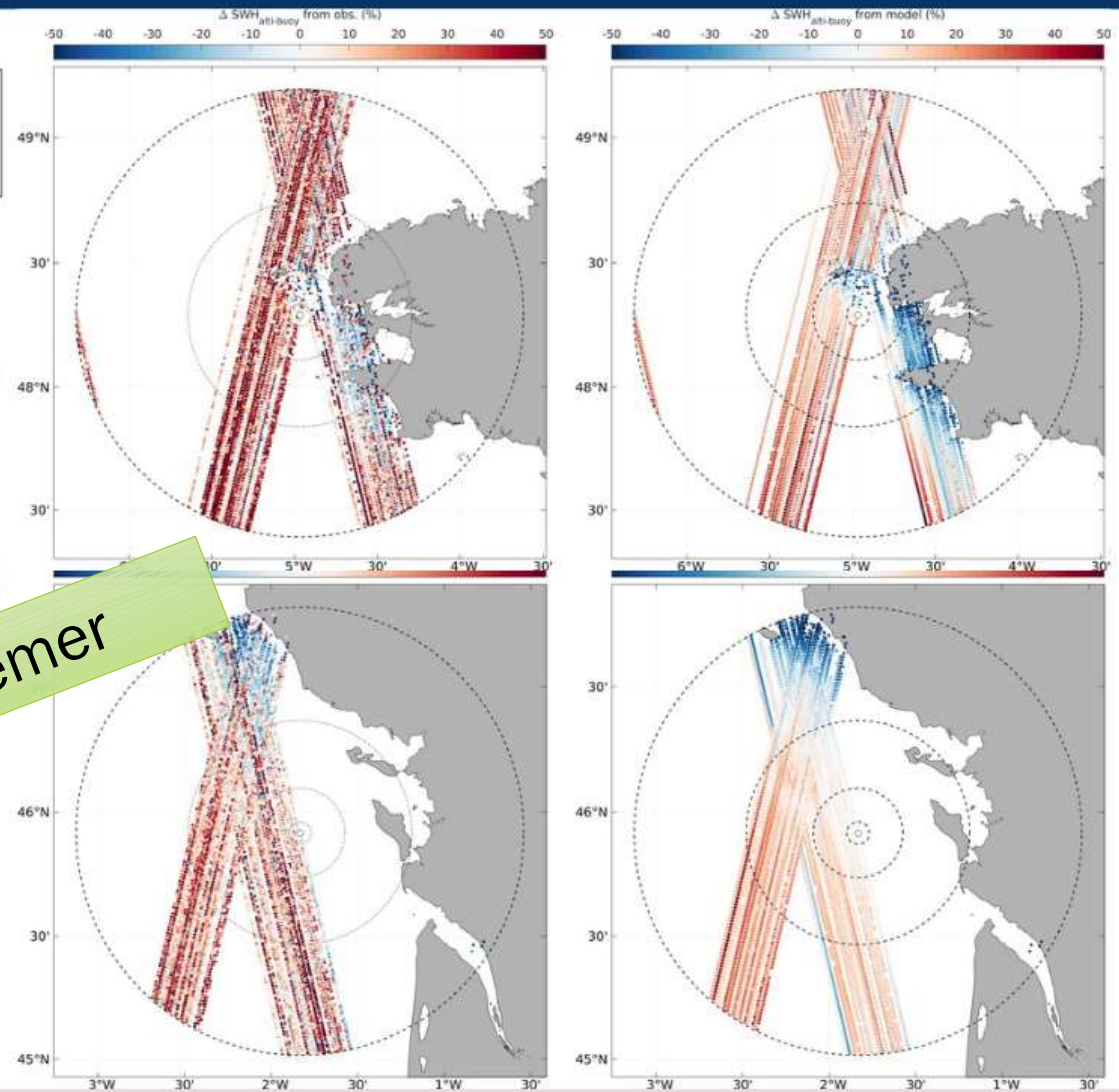
Results : SWH variability around coastal buoys

Is SWIM nadir altimeter able to capture SWH variability in the coastal zone ?

Here we compare the normalized difference between SWH at the buoy location and along SWIM ground track (left panels)

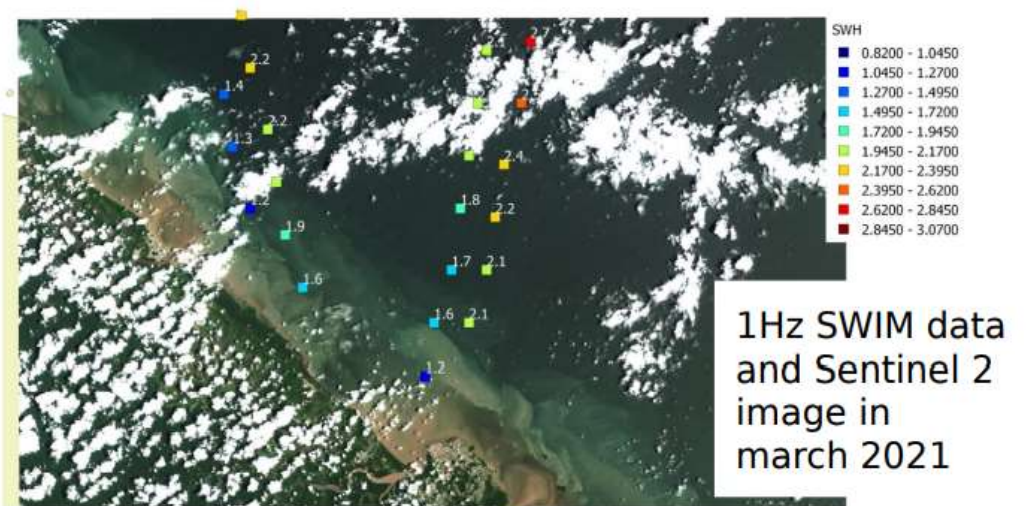
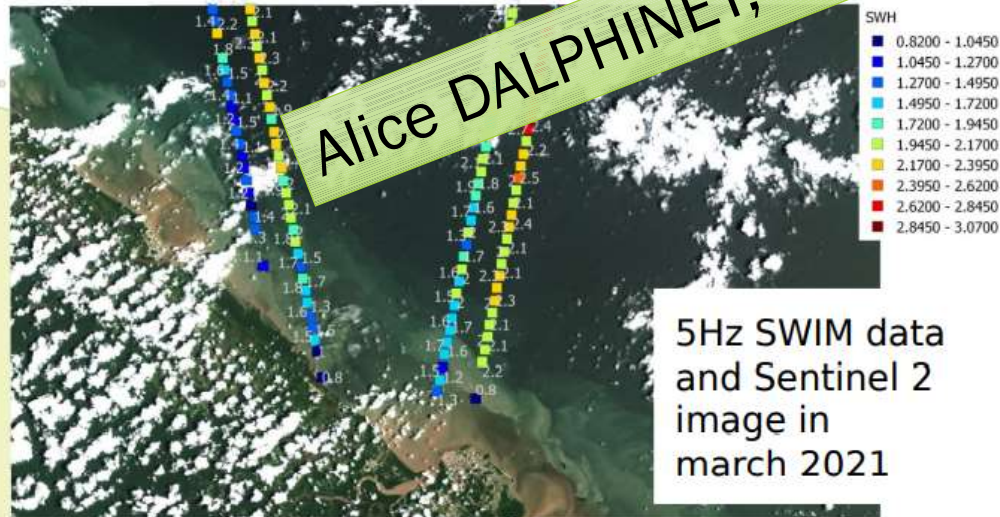
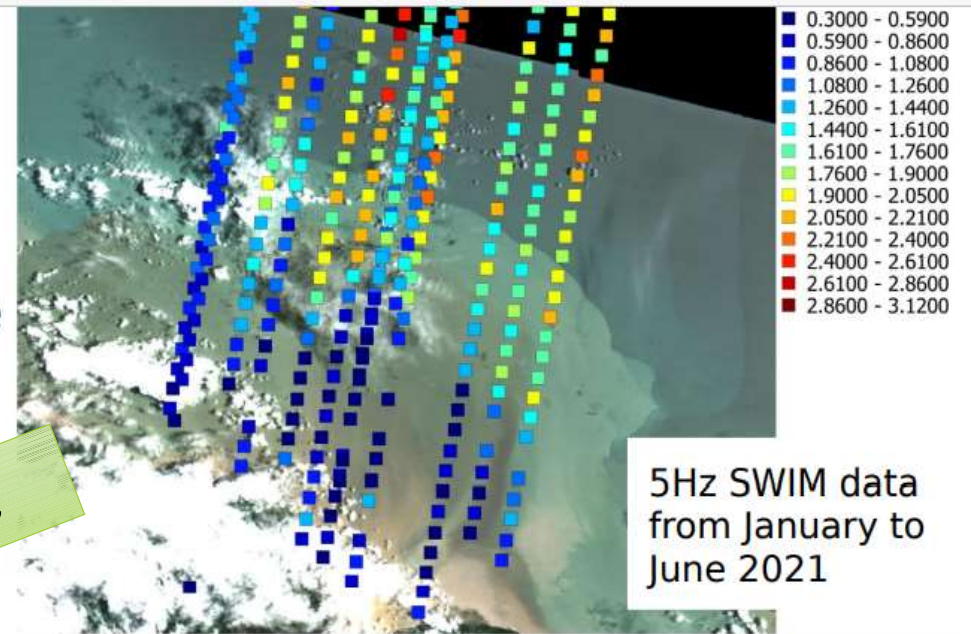
Coherent structures of over / under estimation are observed, comparable to WW3 simulations (right panels) but much more noisy.

Guillaume DODET, Ifremer



Perspective

- Amélioration de la prise en compte de la vase en Guyane, grâce aux bathy mis à jour par Sentinel 2
- Collaboration avec le Shom (envoi de données CFOSAT, vent et conditions aux limites de 2020 à juin 2021)



Alice DALPHINET, MétéoFrance

Summary

- Even though SWIM resolution is quite coarse and spatial coverage is fairly limited, SWIM Hs spatial distribution around TC center compares well with IFREMER model
- This is important especially knowing that certain 'wave sensitive' missions depend on modeled Hs for their retrieval (e.g. CyGNSS, SMAP).
- confirmed Hs asymmetry around TC where strongest Hs is found on the right hand side of TC within Northern Hemisphere and left hand side within Southern Hemisphere
- 7m+ **mean** HS extends to 150-200 km from right of TC center (AL basin)
- presence of small positive bias between SWIM and ECMWF Hs given either ECMWF or HWRF winds between 0 and 20 m/s
- Quite large discrepancies between IFREMER and SWIM HS from first and second partitions (especially the latter)

Possible future work

- compare SWIM data with Kaia measurements including MFWAM, NOAA WW3, Hs from Altimeter data
- Include in future analysis SWIM data produced by OceanDataLab/IFREMER



NOAA National Environmental Satellite, Data, and Information Service

Ka/Ku-band Interferometric Altimeter (KaIA) :

- KaIA is a nadir-looking Ka/Ku-band interferometric radar altimeter installed on the NOAA WP-3D aircraft since the 2020 hurricane season
- Capable of synthetic aperture altimetry (500 MHz band-width)
- Can retrieve significant wave height (SWH), mean-squared slope (MSS), relative ocean height, low-to-moderate wind speeds
- Implements a real-time tracker and co-tracker to provide altimetry products
- Records the raw complex return from the surface
- Ku-band channel added in winter 2021 (far right):
 - Adds rain retrieval, rain correction, and ice freeboard measurement capability



Source: AMS 38th conf 2022, Joe Sapp et al.

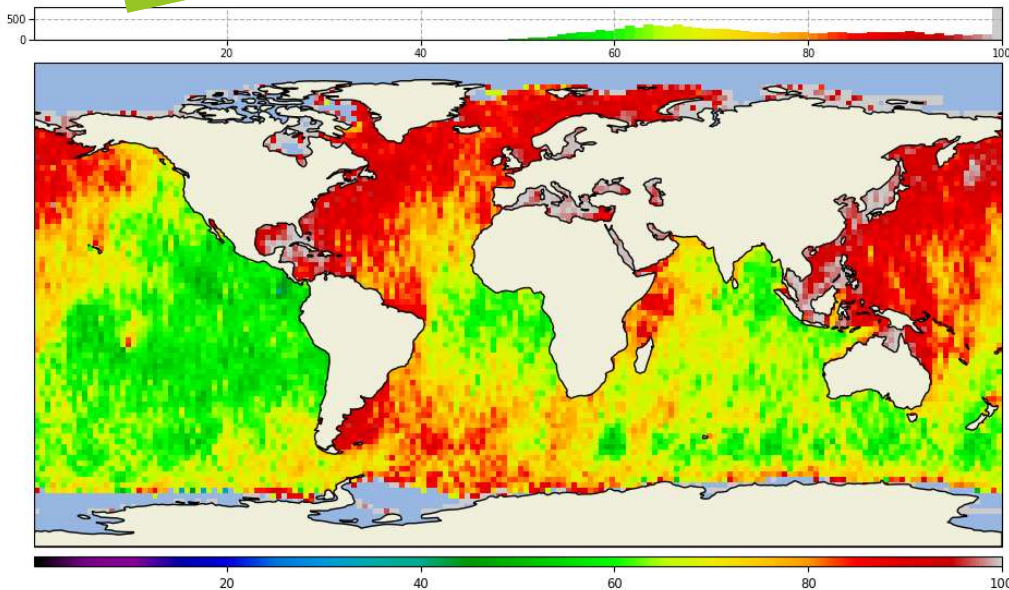


Occurrences of inhomogeneity sources

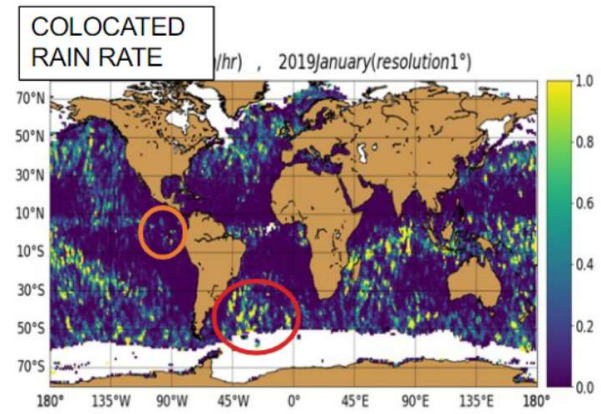
Contributions of inhomogeneity for SLA (Dibarboure et al. 2014):

- Rain, blooms (<10% occurrence)
- Large period swell (30-65% occurrences)

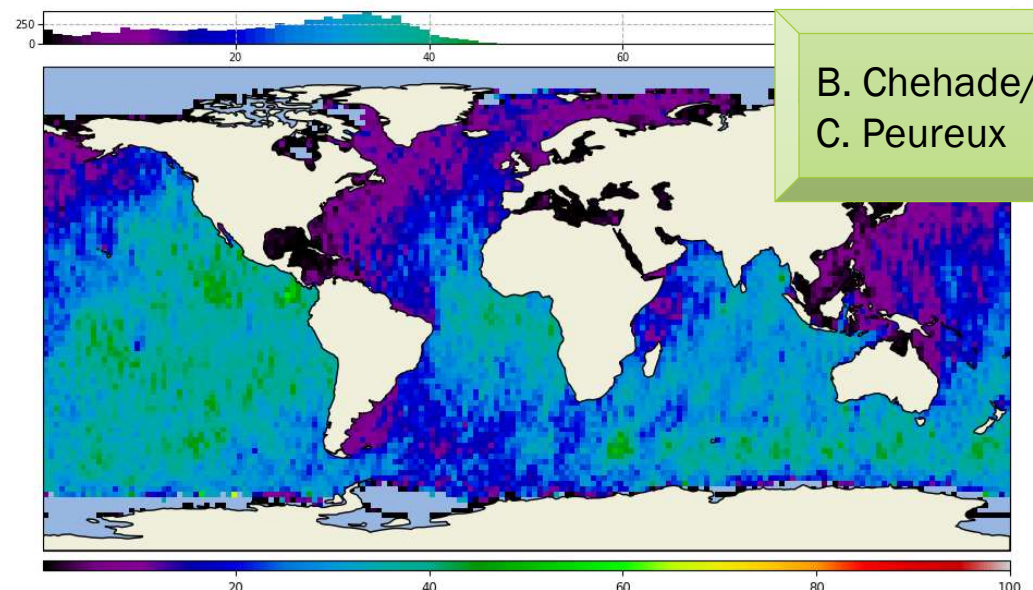
Percentage of points number for: $0 < wl < 200$



Comparison between the classes of WAM wavelength (% of points computed over 3 months April-May-June 2021) See CFOSAT session



Percentage of points number for: $200 < wl < 500$



B. Chehade/
C. Peureux

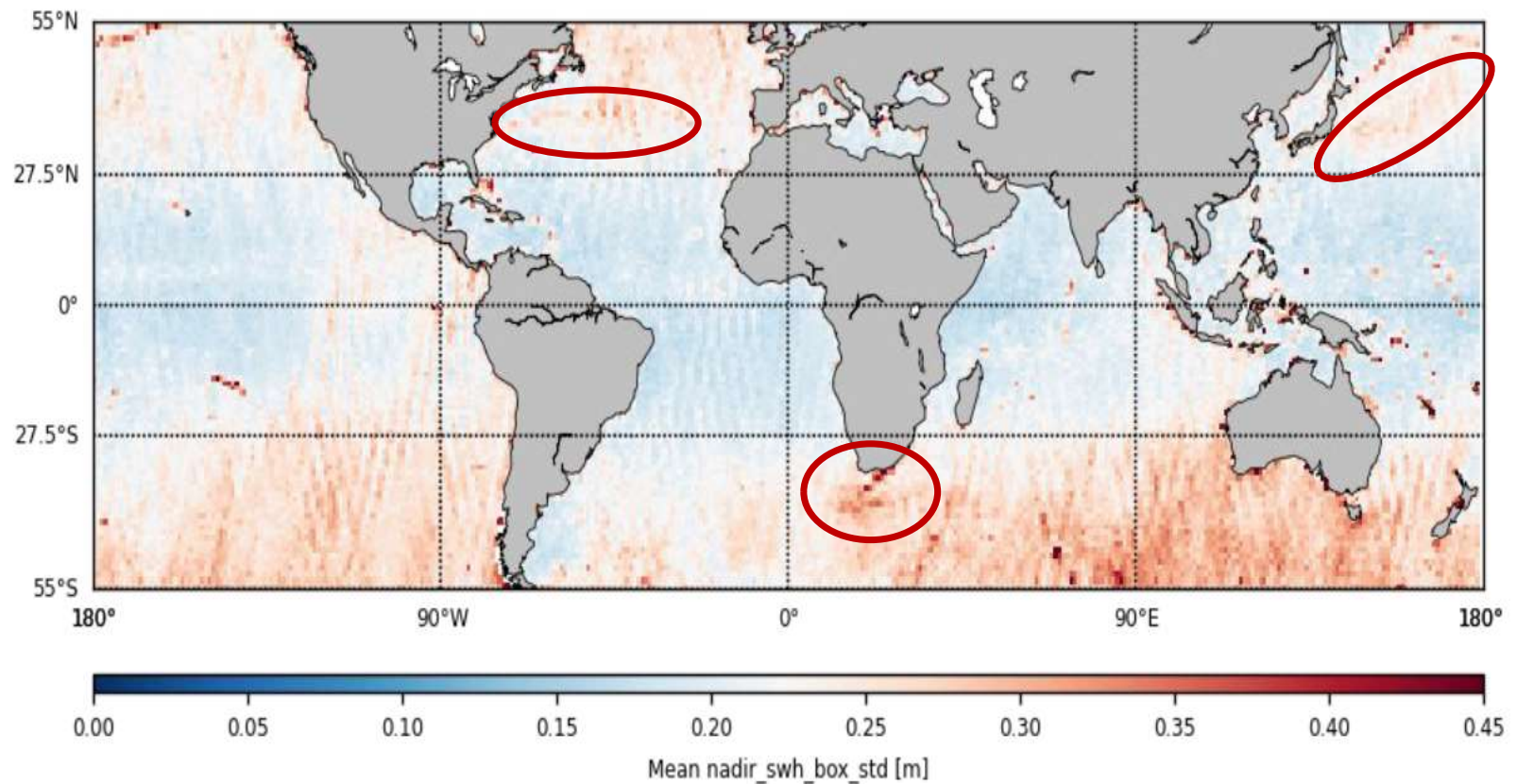
Very promising results for Wave- Currents interactions



Demo product 5Hz along track SWH

Unfiltered

Standard Deviation
below 70km along track



Different resolution waves content

