Global spectral observation of ocean waves from the CFOSAT satellite mission

D. Hauser with contributions from

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Climat change Initiative/Sea state, October 2019, Brest (France)

Outline

- **Introduction**
- **CFOSAT objectives and main characteristics**
- **Wave parameters from SWIM**
- **First results**
  - ✓Hs from nadir
  - ✓Spectral parameters from off-nadir observations
- **Conclusion**

1- Introduction

It is recognized that sea-state is an essential variable for climate survey and impact studies *(as proved by the existence this CCI sea-state program!!)*

But, question : what parameters characterize sea-state?

- Hs alone
- Hs + peak (mean) period (frequency)
- Hs + peak (mean) period (frequency) +dominant (mean)direction
- Whole directional spectrum of ocean waves
- wave “trains” (partitions) and associated parameters

All of them!! Needs, for research and/or monitoring :

- ✓ coastal processes (direction and directional spread, wavelength)
- ✓ wave/current, or wave/ice interactions (wave trains, direction, directional spread, wavelength,..)
- ✓ extreme seas (detection of mixed sea cases, shape of the directional spectrum in frequency/wavenumber)
- ✓ validation/improvement /assimilation for numerical models (evolution of frequency, directional and frequency spread from young sea to mature cases, swell attenuation, wave/current interactions,..)
- ✓ impact of climate change (change in period/wavelength and directions in relation with storm tracks evolution)

Current observations

- ✓ In situ data: mainly Hs, sometimes peak period (or frequency) , rarely 1D spectra, extremely rarely 2D information (usually not directly the spectra)

- ✓ Satellite observations
  - Altimeter (Hs and U) - 25 years of observations, global
  - SAR (2D spectrum) – good data set (20 years) but difficulties due to azimuth cutoff, and not always global

- **New** : CFOSAT (China-France Oceanographic Satellite): a new satellite launched on 29th October 2018

2- CFOSAT

CFOSAT: A China/France joint satellite oceanographic mission.

Joint measurements of surface wind and wave

- ✓ a wind scatteromerer (SCAT)
  => **ocean surface wind vector**

- ✓ a wave scatteromer (SWIM)
  => **directional spectrum of ocean waves + wind and Hs from nadir**

Funded and managed by 3 Agencies

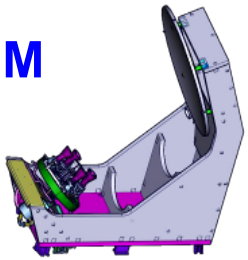
CNSA

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

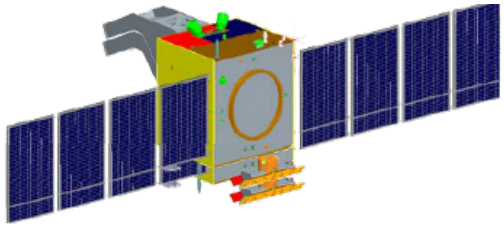
polar, sun-synchronous, global coverage, 13 day repeat cycles

PIship : D. Hauser (LATMOS/CNRS), Liu Jianqiang (NSOAS)

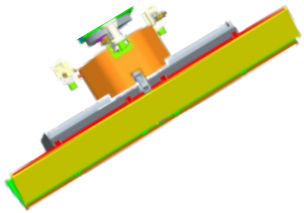
SWIM



CFOSAT



SCAT



❖ A scientific mission :

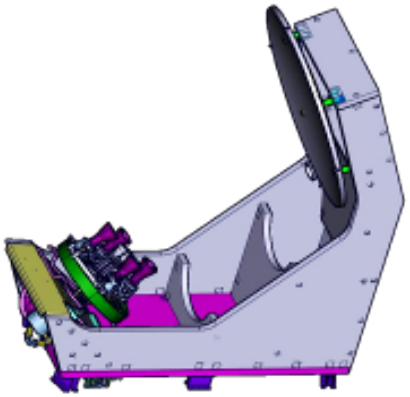
- Wave dynamics and evolution
- Wind/wave interactions,
- Impact of waves on air/sea exchanges,
- Interaction of waves with currents, sea-ice
- Contribution to wave climate study
- Boundary conditions for coastal studies

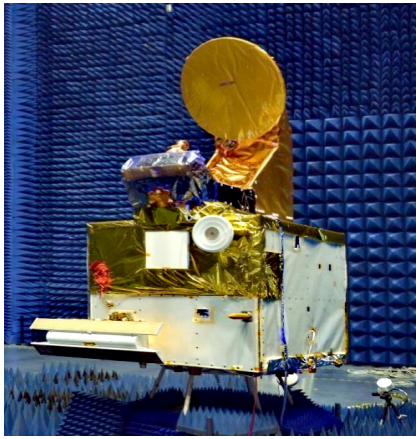
(and secondary objectives on sea-ice and continental surfaces)

❖ **A demonstration and pre-operational mission**: wind and wave field analysis, feed forecast systems (assimilation), contribution to global data bases (CMEMS,..)

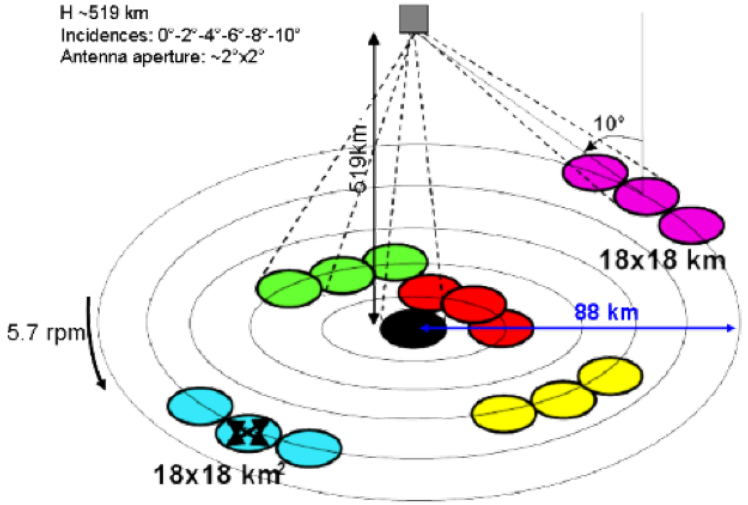
SWIM

Wave scatterometer



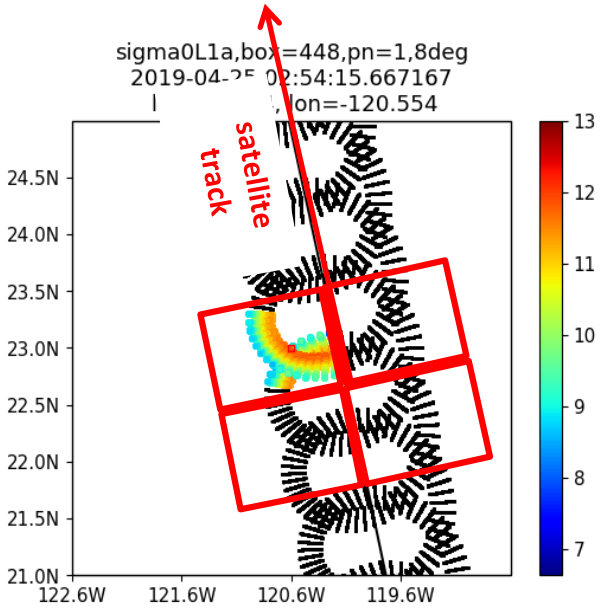


- Ku band real aperture radar
- Sequential illumination with 6 incidence angles :
  - Beams **0°, 2°, 4°, 6°, 8°, 10°**
- Rotating antenna (all azimuth direction acquisition): 5,6 rpm
- Products **:**
  - Directional wave spectra
  - Significant wave height and wind speed
  - σ_0 mean profiles, 0 to 10°

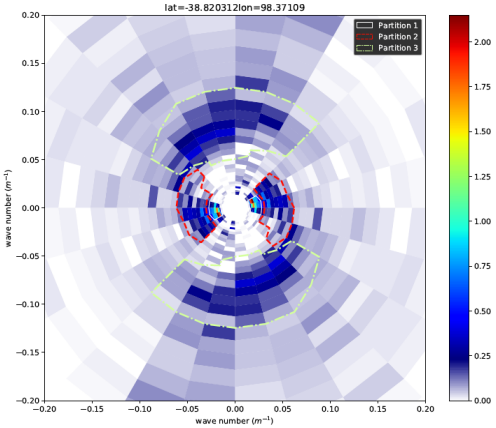


Main SWIM variables in the operational products

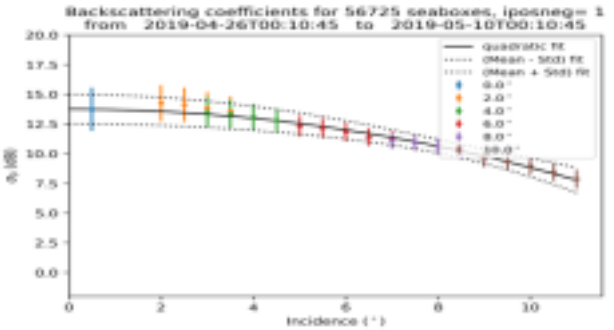
- Significant wave height and wind speed (along-track)- similar to altimeter mission



- In continuous wave cells (70 km x 90 km) on each side of the track
  - 2D wave spectra for wavelengths in the range [70-500] m- with 180° ambiguity in direction

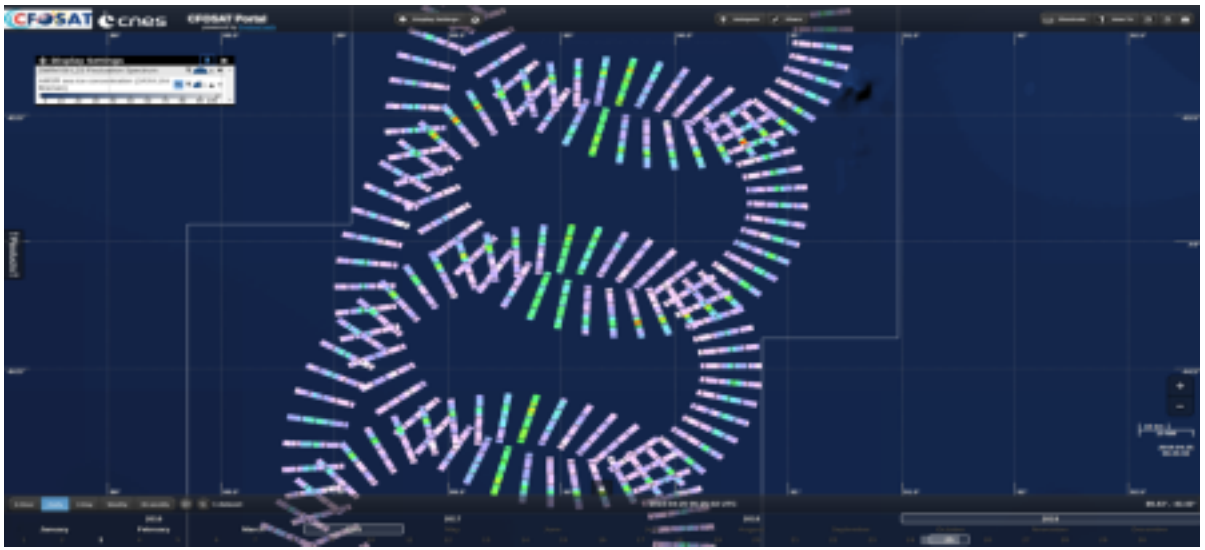


  - Backscattering coefficient (sigma0) profile



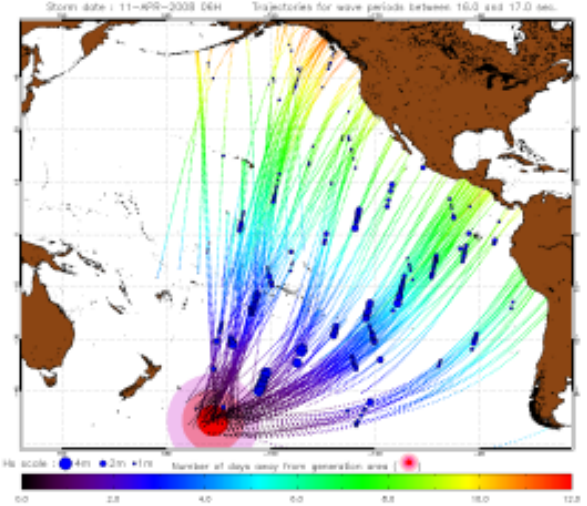
Alternative SWIM products from the Ifremer data center (IWWOC)

- **Relative wave energy in the original radial geometry of the instrument**



example of radial density spectra (color codes) along the SWIM sampling (here 8° incidence beam)

- **Space-time analysis of long swell systems** following their propagation paths after refocusing to their origin



3- First results (CAL-VAL studies)

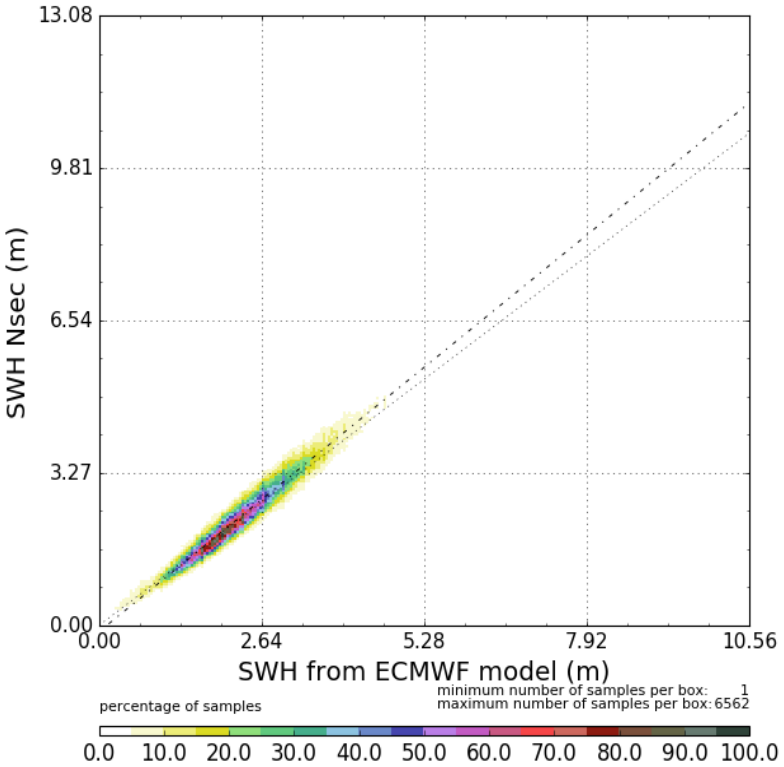
- Non spectral data (Hs) from SWIM nadir (see also talk by R. Husson)

- Spectral information from SWIM off-nadir observations

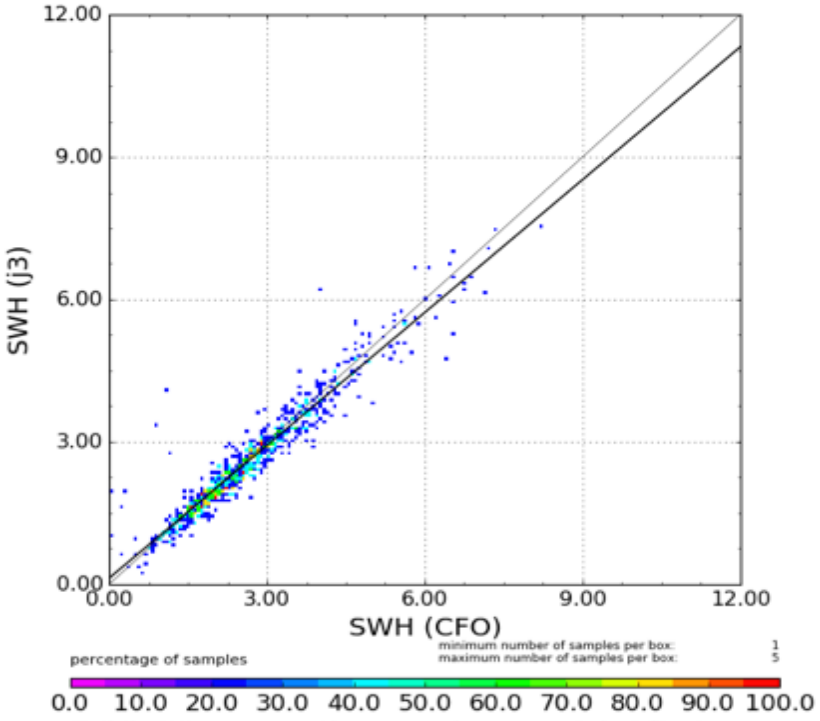
Nadir SWIM (Hs)

Excellent performances thanks to a new « retracking » altimeter algorithm (“adaptive”) which compensates the relatively low repetition rate of the nadir sequences (5Hz) due to multi-incidence geometry

Hs_nadir_SWIM vers Hs ECMWF



Hs_nadir_SWIM versus Hs Jason

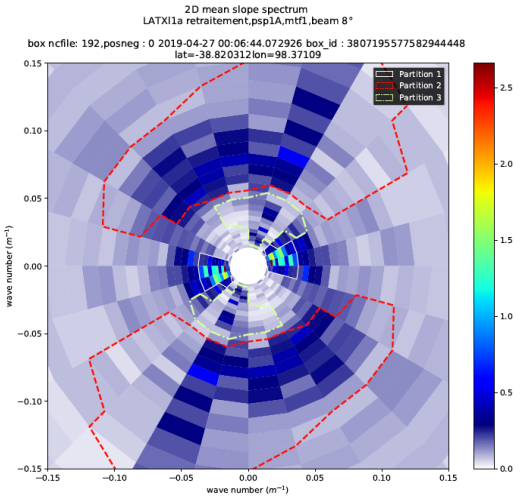


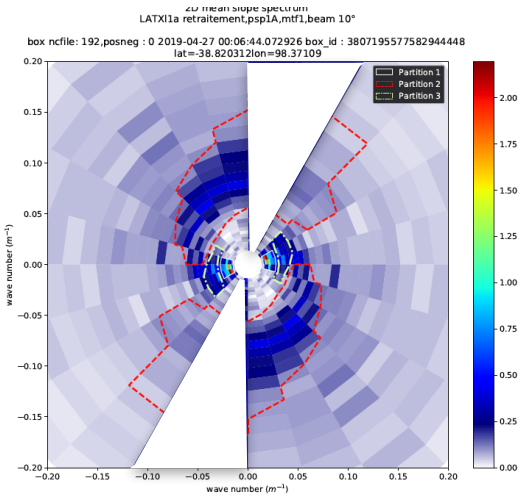
mean biais 6 cm w.r.t std 34cm

Spectral data (from off Nadir SWIM observations)

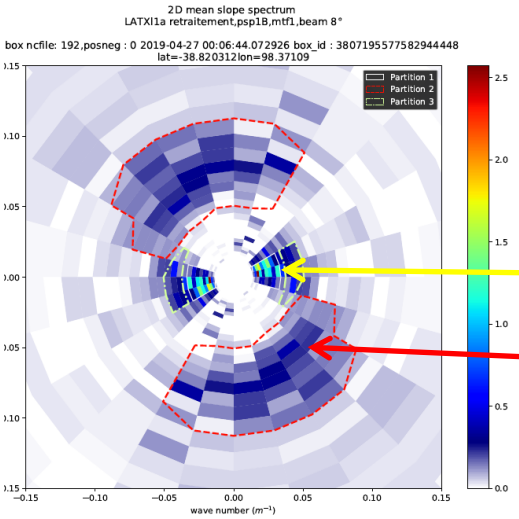
Examples of 2D wave spectra

current product

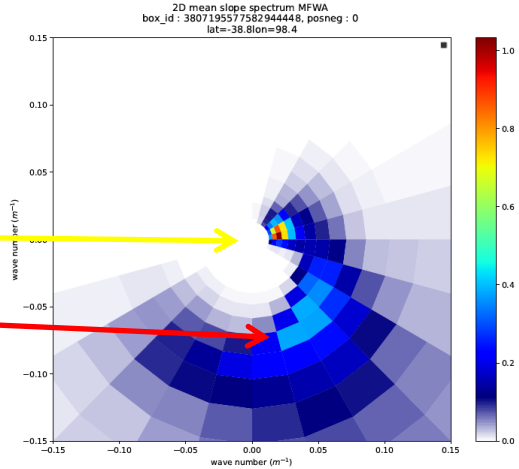




in progress
better noise elimination

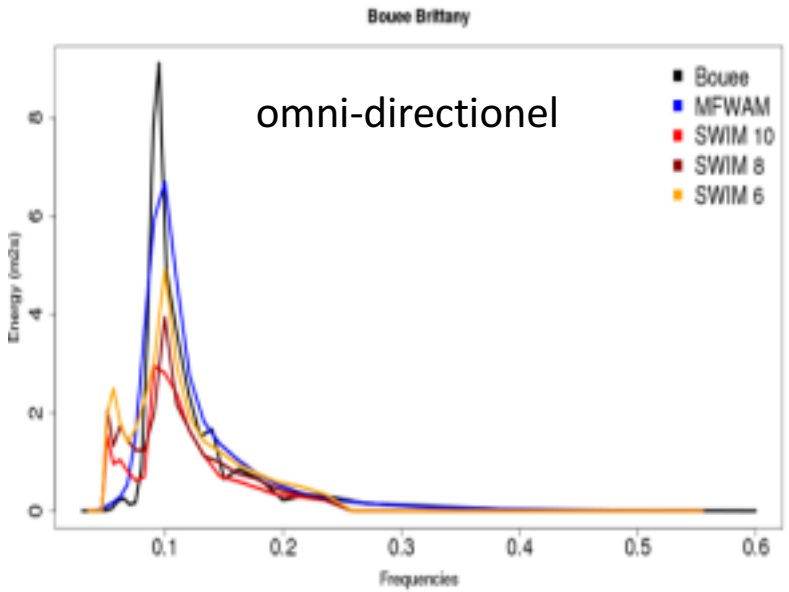


comparison to MFWAM model



2D spectra, temporary masked (±15° on each side of the satellite track) in the data products (upgrade expected in a few months)

Comparison to buoy (here Brittany-Atlantic)

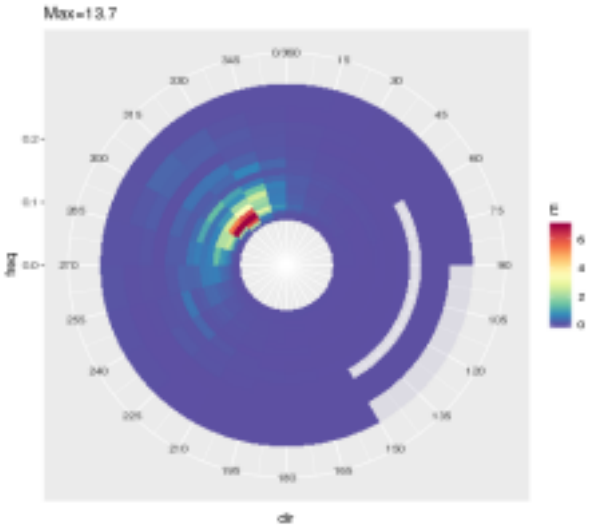


Buoy (black)

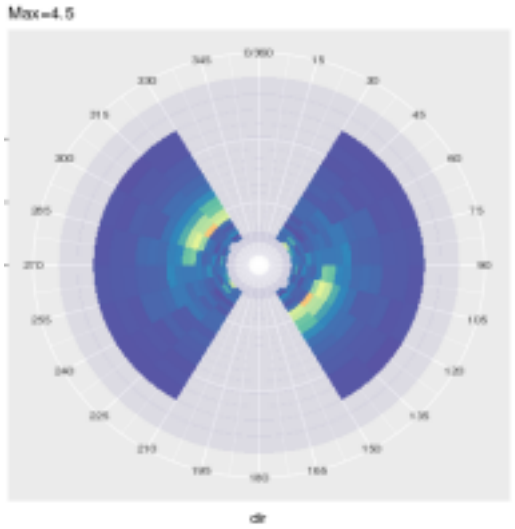
MFWAM

SWIM (**10°**, **8°**, **6°**)

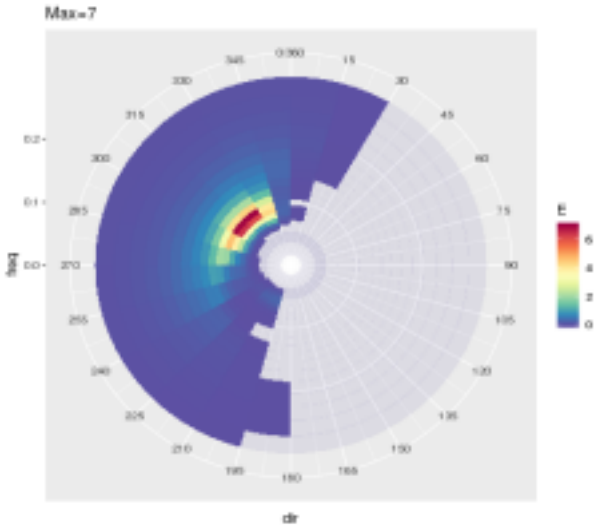
Buoy



SWIM-10°

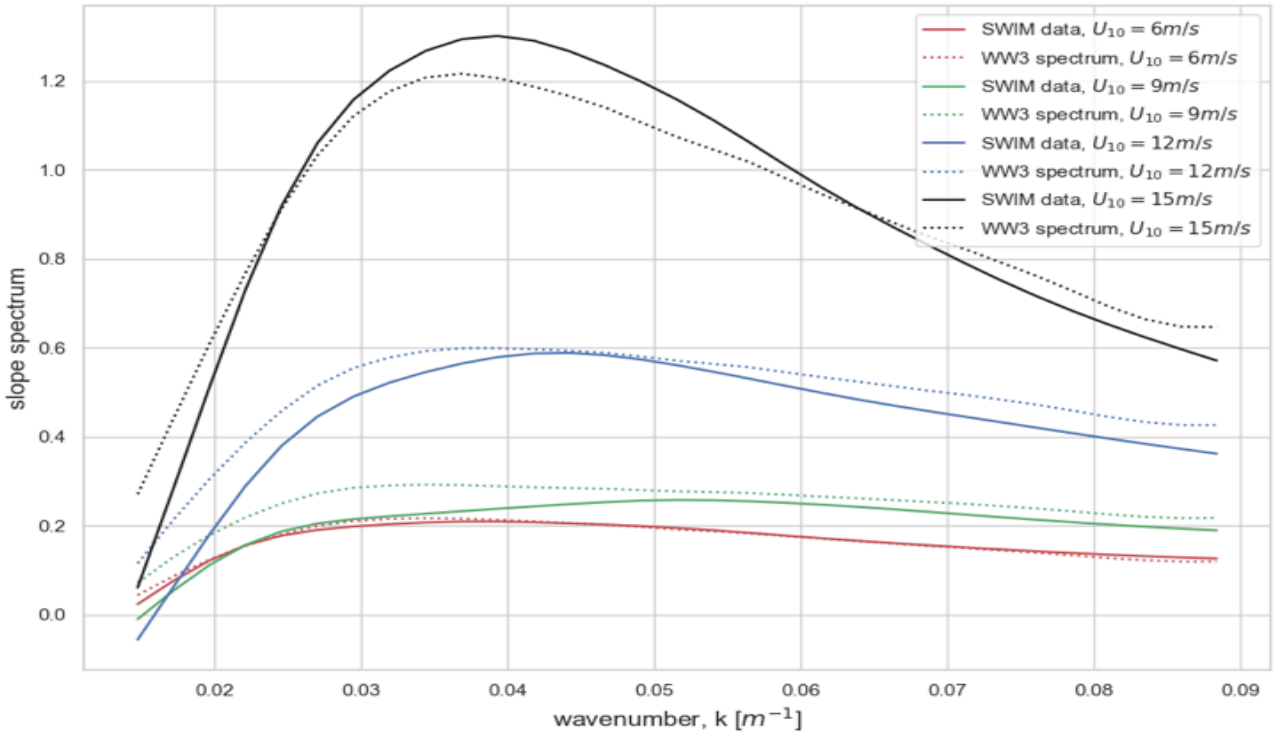


MFWAM



Assessment of the mean spectrum shape

Mean 1D slope spectra : SWIM compared to WW3 for different wind speed classes

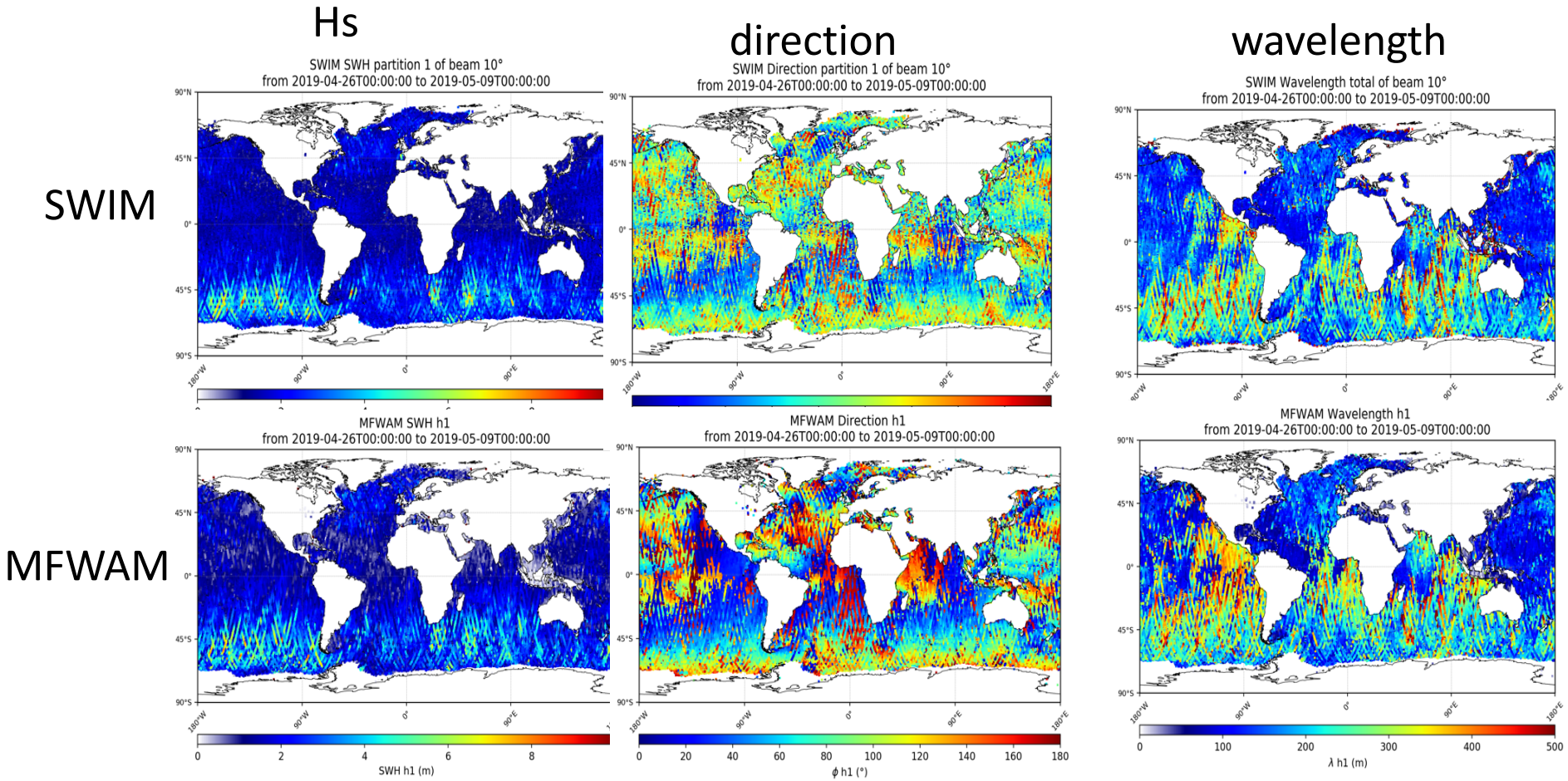


Very good agreement for waves greater than 70 m in wavelength

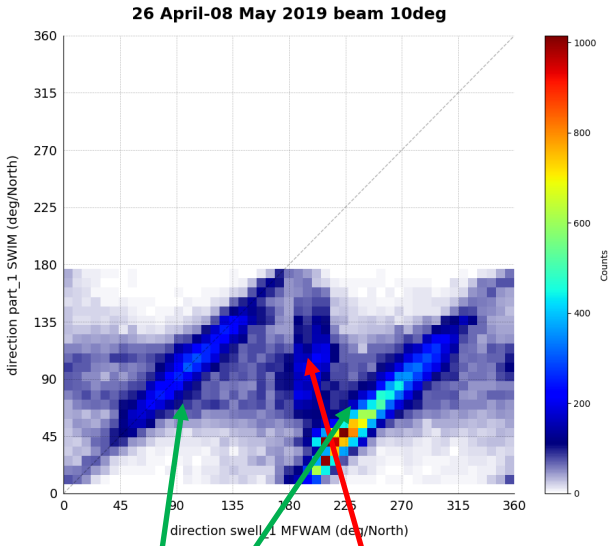
Preliminary assessments: Main parameters of the 1st partition (SWIM and MFWAM partitioned independently

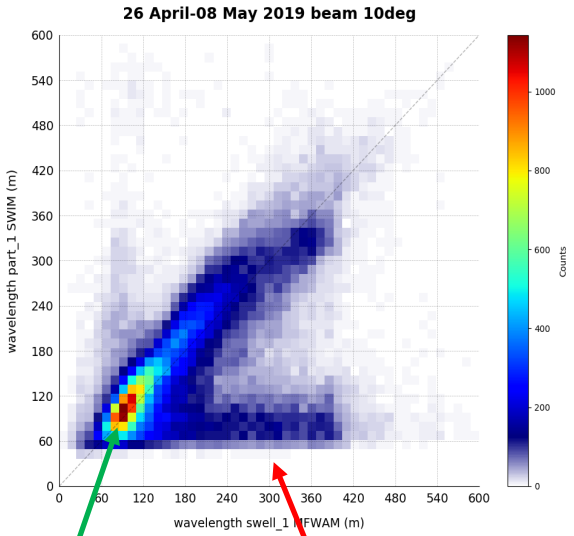
limits: no cross-assignment of partitions, ±15° azimuth sector masked on SWIM spectra)

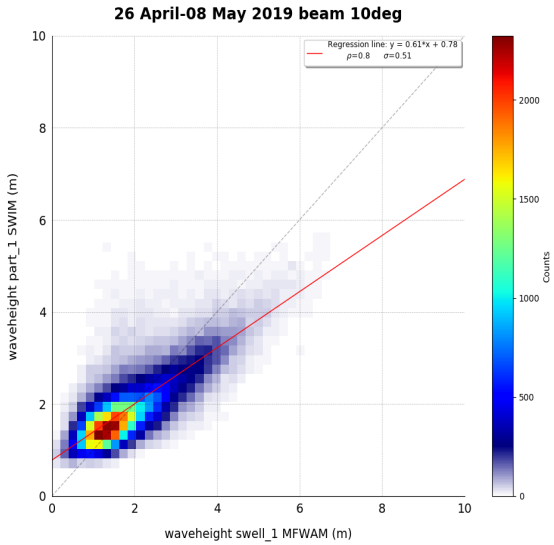
Illustrated here with SWIM beam 10° results



SWIM versus MFWAM parameters of partitions







direction

=> well retrieved except for waves propagating in the along track direction (because of mask on SWIM spectra)

wavelength

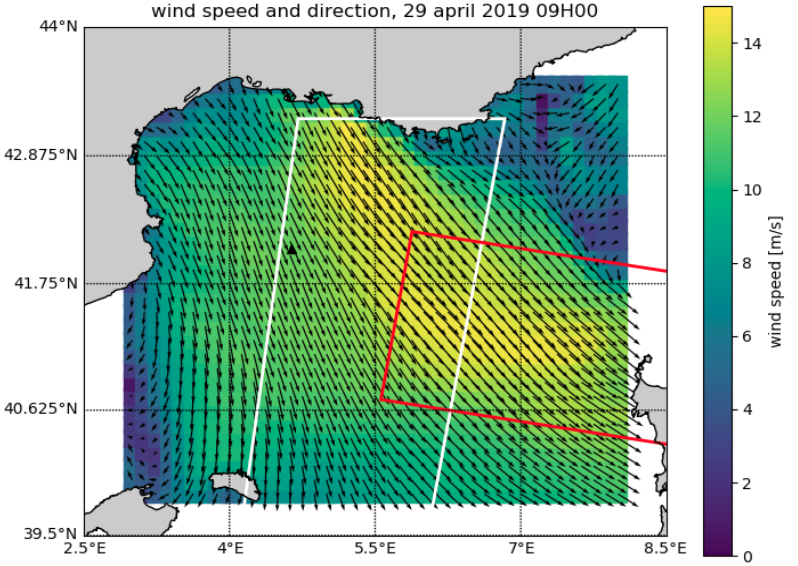
=> well retrieved except here: partly due to to the mask? parasitic peaks in SWIM spectra ?

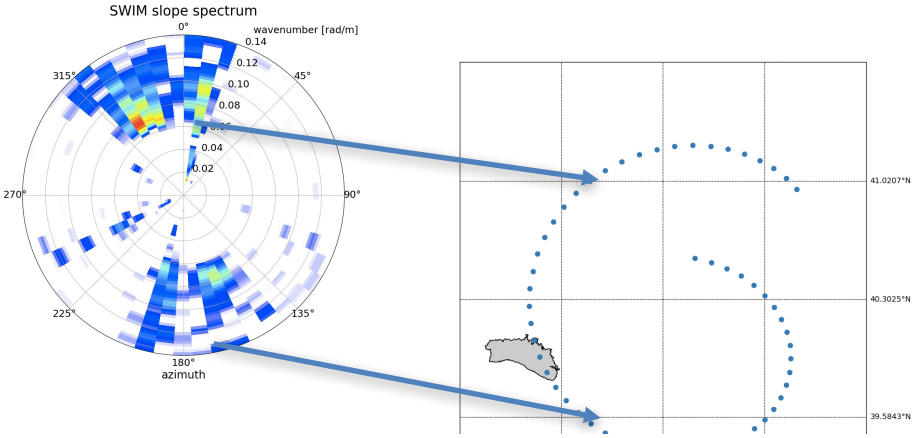
waveheight

⇒ good correlation

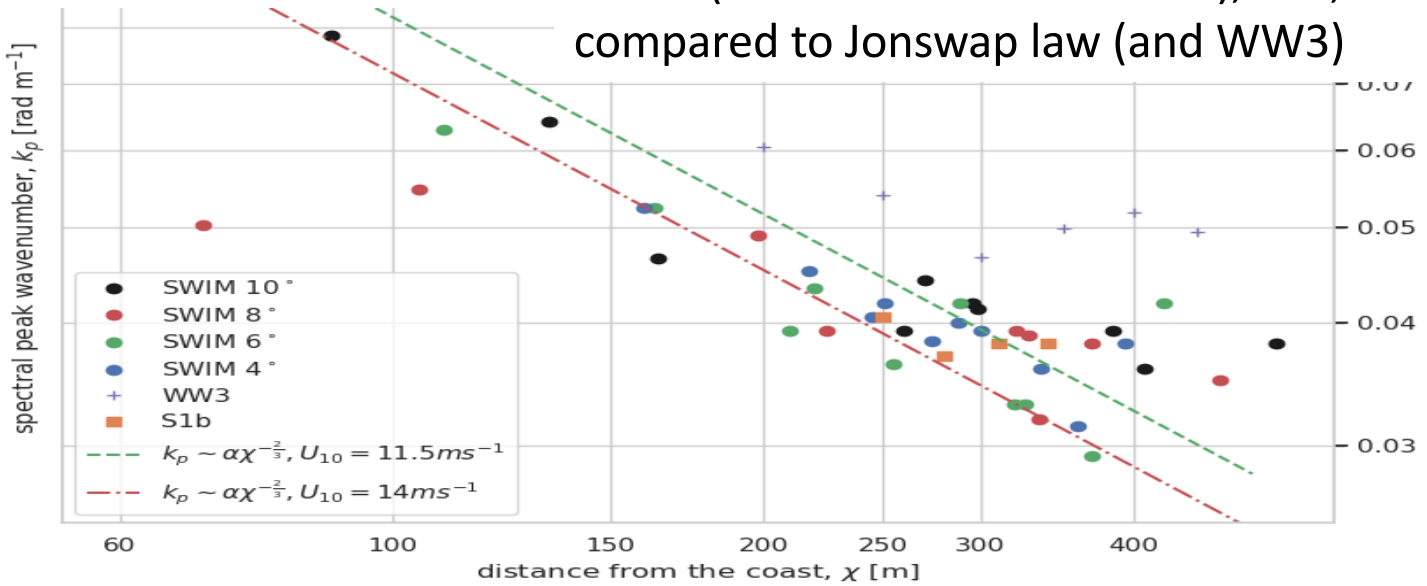
overestimation at Hs < 3m , underestimation at Hs > 3m

Wave evolution at the regional scale in a fetch limited case (North Mediterranean sea)





peak wavenumber versus fetch by combining SWIM (from 4 to 10° incidences), S1B, compared to Jonswap law (and WW3)



4- Conclusion

Already a great success for CFOSAT (launched only 1 year ago)

- **Very innovative mission, instrument and products**
- **Wave (Hs) and wind (U) products from nadir:** excellent quality,
- **Spectral data from off-nadir:** very promising (inversion method still in progress for noise mitigation)
  - ✓ consistent shape of 1D height or slope spectra, 2D spectra (in spite of temporary masking)
  - ✓ very promising for case studies at regional scale (fetch-limited, waves in current, waves under sea ice (not shown), waves generated by storms, hurricanes,..
  - ✓ work in progress to improve detailed performances (partition parameters) - currently perturbed by the non perfect correction of speckle noise (and masking)
  - ✓ => **Data access:** already available for science team, access enlarged through AVISO+ starting this fall (TBC) https://www.aviso.altimetry.fr/en/data/

NRT delivery to operational centers via Eumetcast (end 2019-beginning 2020)