CFOSAT: New wind and wave observations from the nadir and near-nadir SWIM Ku-Band instrument

D. Hauser with contributions from

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OSTST Conference, Chicago 20-25 October 2019

Outline

- ❖ **Introduction**
- ❖ **CFOSAT objectives and main characteristics**
- ❖ **Wave parameters from the SWIM instrument**
- ❖ **First results**
  - ✓ Spectral parameters from off-nadir observations
  - ✓ results from nadir presented by Annabelle Ollivier (next talk)
- ❖ **Conclusion**

1- Introduction (1/2)

❖ **Continuous needs for wind and waves observations from space**

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

❖ **Needs for operational systems** : wind and wave field analysis, wave forecasting

1- Introduction (2/2)

- **Wind and waves measured by altimetry :**

  - only wind speed for wind, and only SWH for waves .

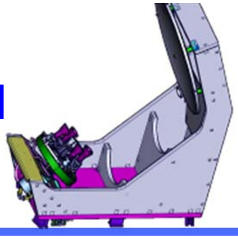
  - Useful but impact remains limited because of lack of spectral information

- **Spectral properties of ocean waves from space (directionality, wavelengths or frequency)**

  - from SAR, with some limitations (mainly long swell)

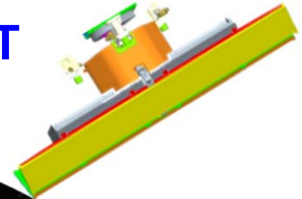
  - since end 2018: using the SWIM radar on-board CFOSAT

SWIM



2- CFOSAT

SCAT

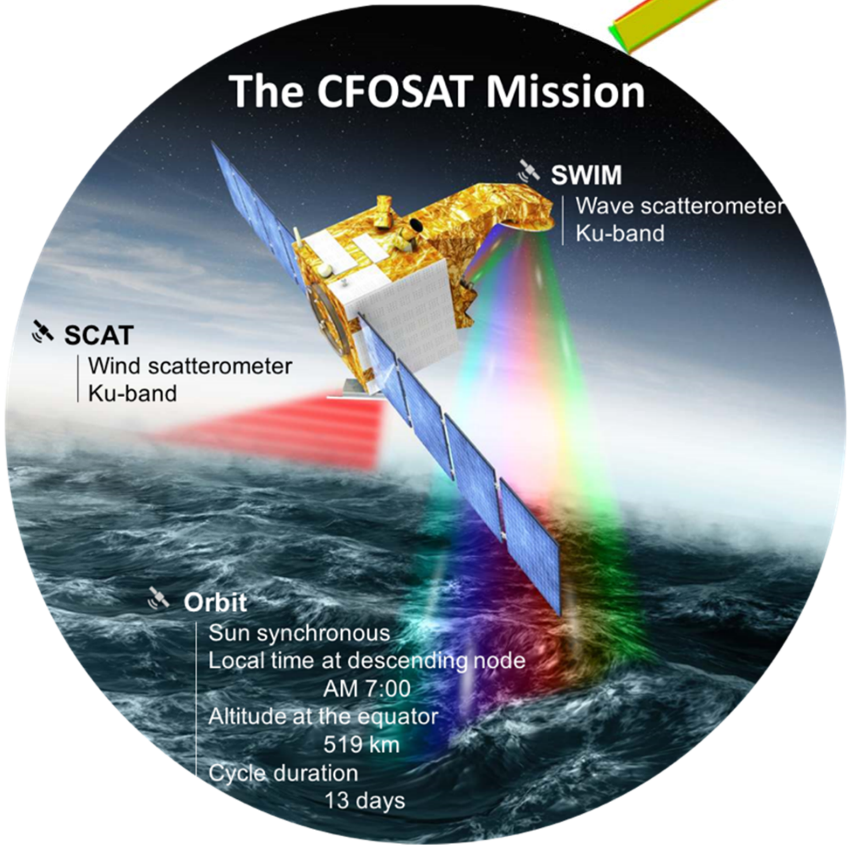


CFOSAT: A China/France joint satellite oceanographic mission.

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

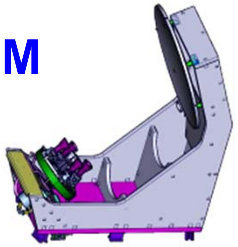
cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

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

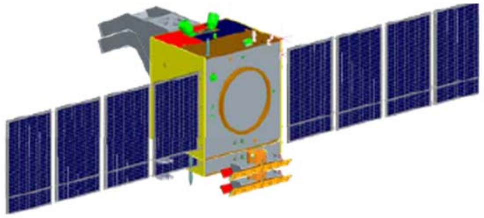
PIship : Danièle Hauser (LATMOS/CNRS), Liu Jianqiang (NSO
CoPI : Lotfi Aouf Meteo-France)

CFOSAT

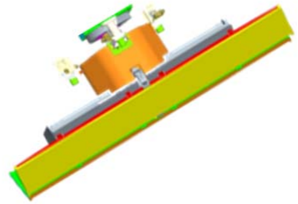
SWIM



CFOSAT



SCAT



❖ A scientific mission :

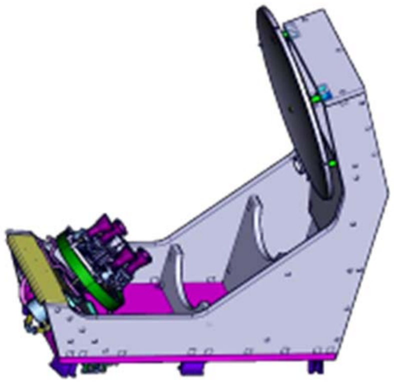
- Wave dynamics and evolution
- Wind/wave interactions,
- Impact of waves on air/sea exchanges,
- Interaction of waves with currents, sea-ice
- Contribution to wave climate study
- Boundary conditions for coastal studies

(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

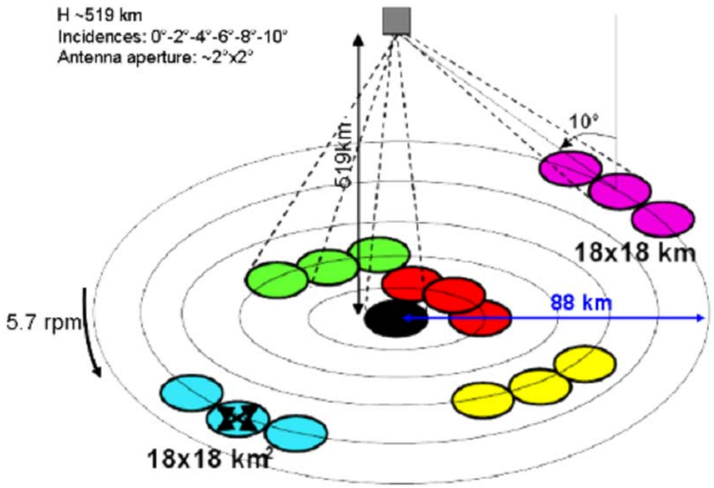


- Ku band real aperture radar

- Sequential illumination with 6 incidence angles

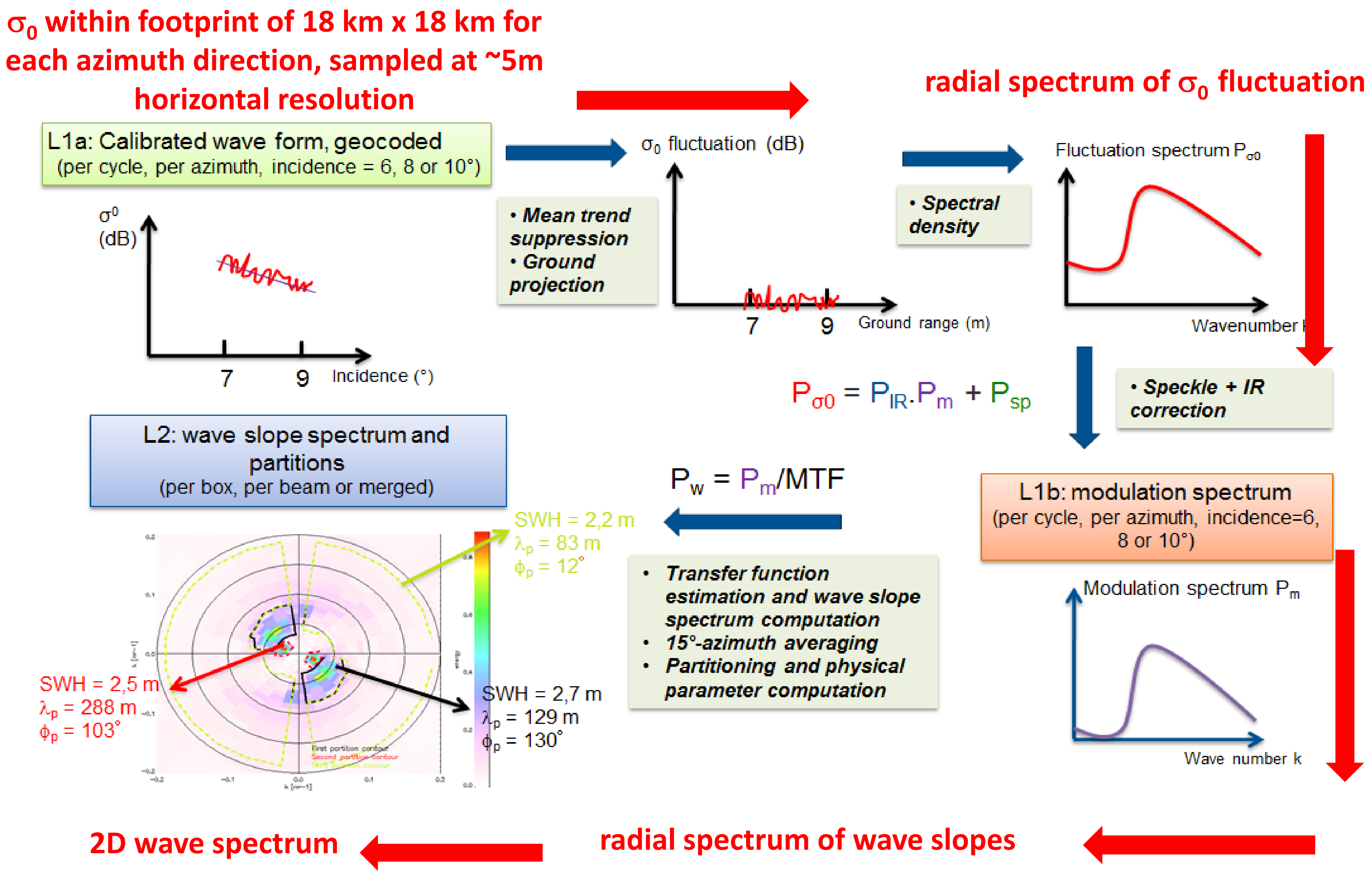
  - Beams **0°, 2°, 4°, 6°, 8°, 10°**

- Rotating antenna (all azimuth direction acquisition): 5,6 rpm



Principle and main steps of the inversion:

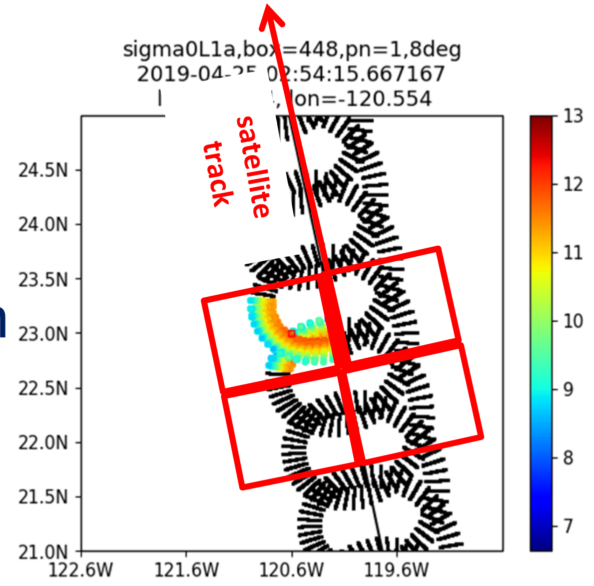
from signal to wave spectra



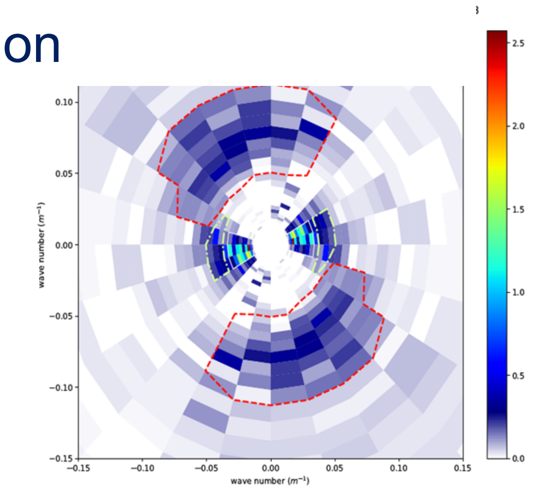
Main SWIM variables in the operational products

(CNES mission Center CWWIC)

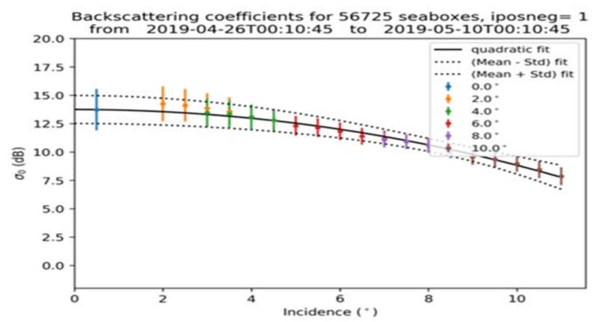
- Significant wave height and wind speed (along-track)- similar to altimeter mission



- 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

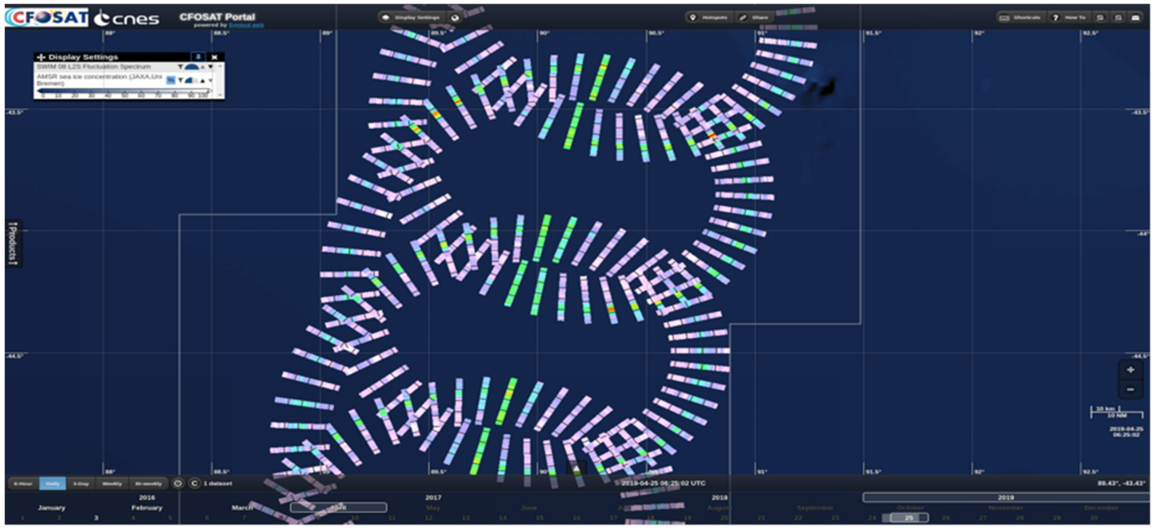


  - Backscattering coefficient (sigma0) profile



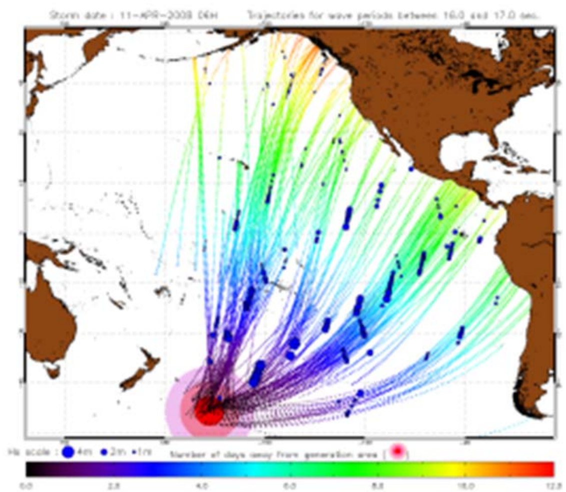
Alternative SWIM products from the Ifremer data center (IWWOC)

- **spectral energy in the original radial geometry of the instrument** (not yet converted to wave height spectra nor corrected from noise effects)



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



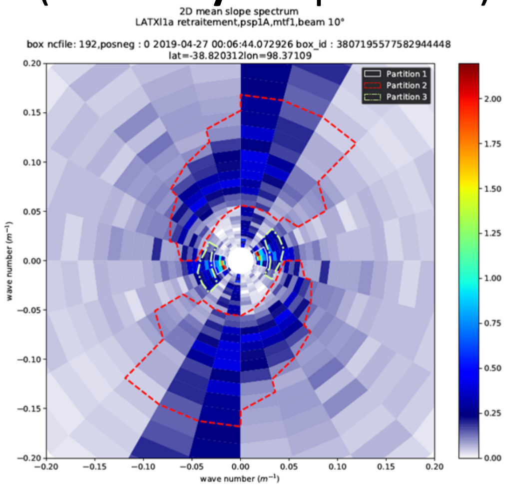
3- First results from CAL-VAL studies

Spectral data from off-nadir beams

Spectral data (from off Nadir SWIM observations)

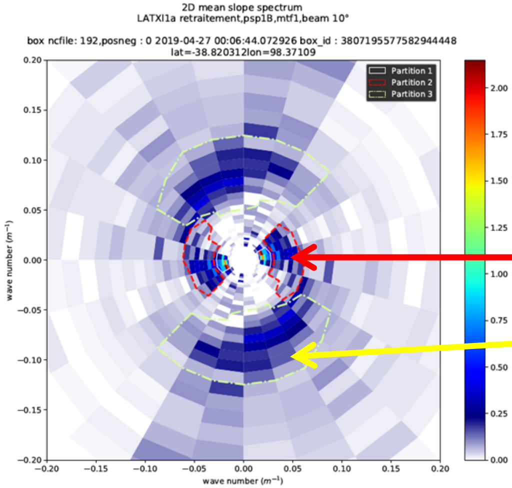
Examples of 2D wave spectra

processing defined before launch (**currently** in operation)

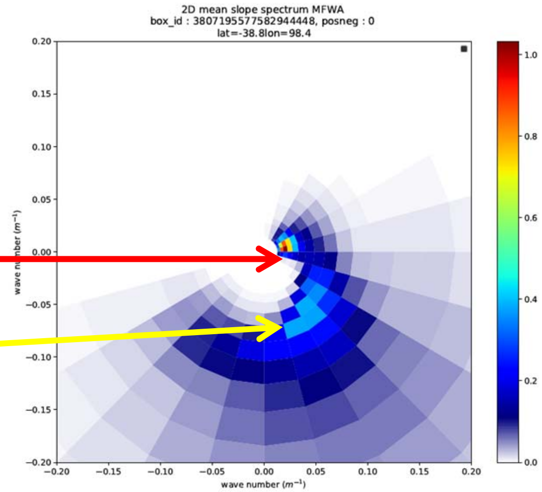


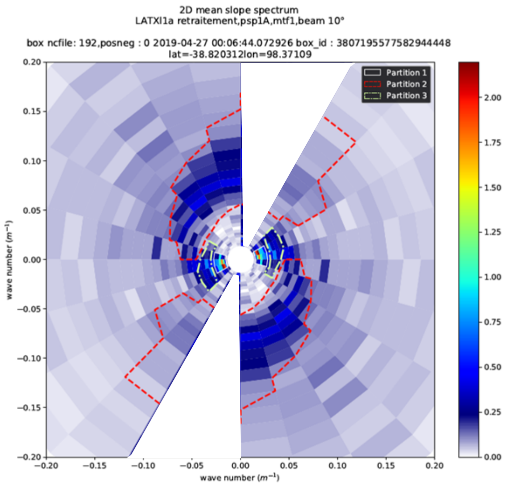
in progress

better noise elimination



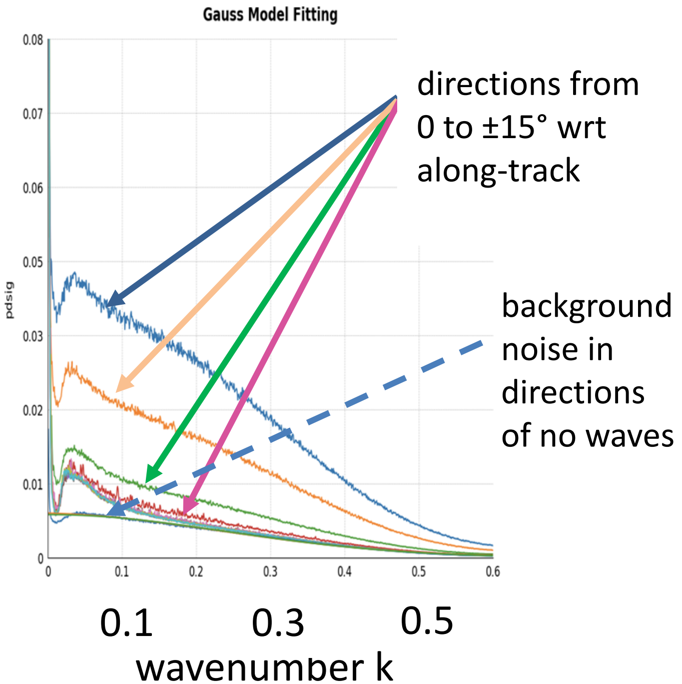
comparison to MFWAM model





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

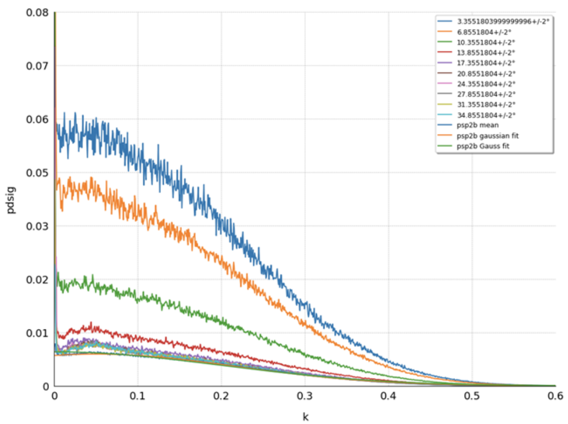
Density spectrum of speckle
Empirical analysis from fluctuation spectra of σ_0



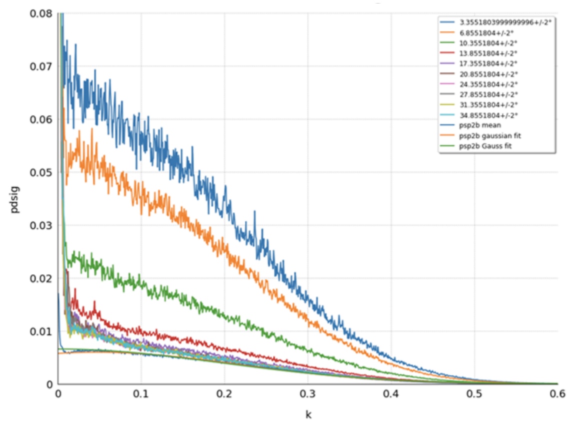
- ✓ **important increase of energy (factor 6 to 7)** in a angular sector of about ±15° with respect to satellite track
  - ✓ due to decrease of Doppler bandwidth, (correlation of echoes)
- ✓ **Far from along-track direction :**
  - o shape and level constant with azimuth , almost linear in wave number, no sea state dependence (conform to theory)
- ✓ **within the ±15° sector with respect to satellite track:**
  - ✓ depends of latitude (understood)
  - ✓ dependence with sea-state (not fully understood yet)

~ 8° incidence
inter-tropical region

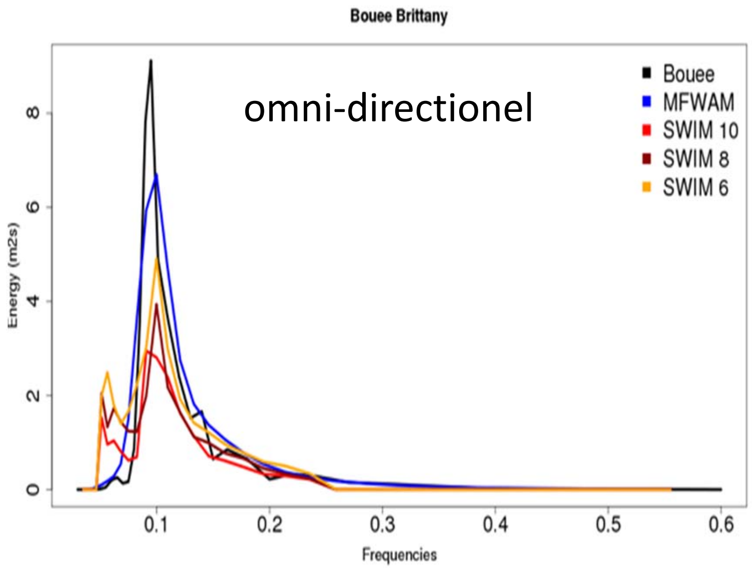
SWH < 2m and 5<WS<9 m/s



SWH < 2m and WS<5 m/s

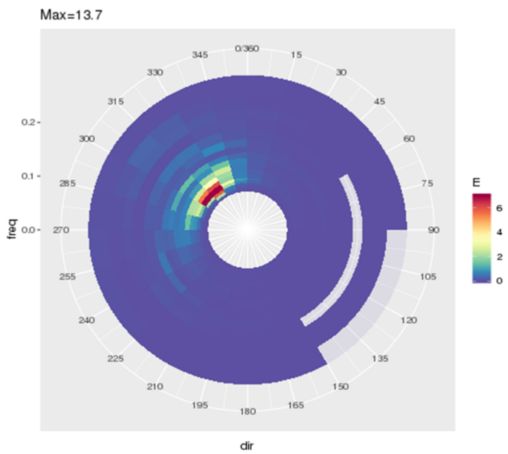


Comparison to buoy (here Brittany-Atlantic)

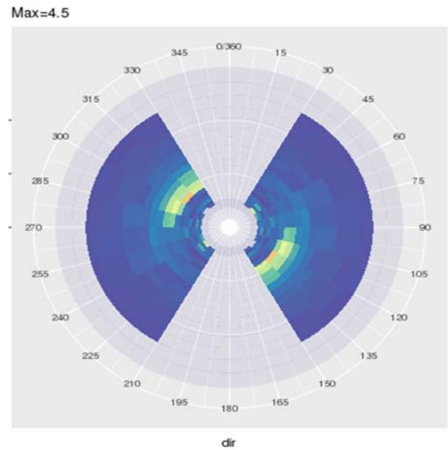


Buoy (black)
MFWAM
SWIM (10°, 8°, 6°)

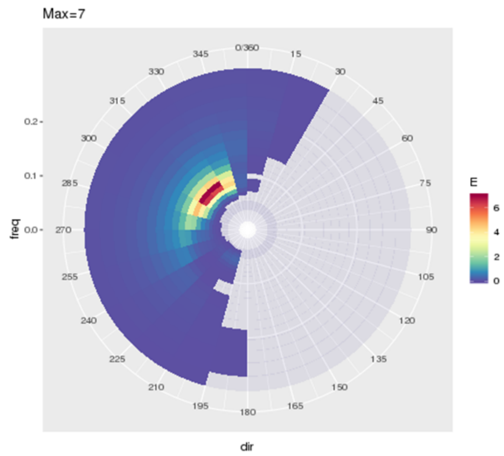
Buoy



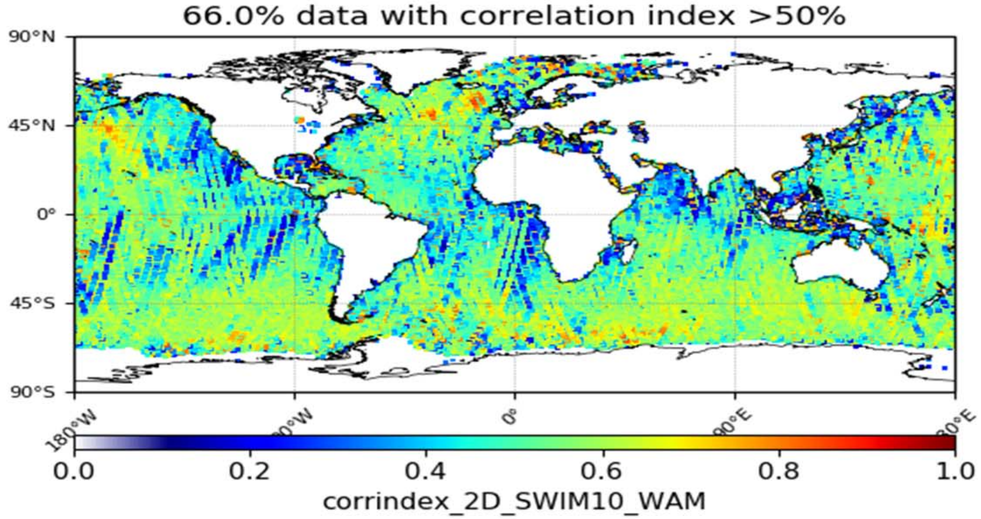
SWIM-10°



MFWAM

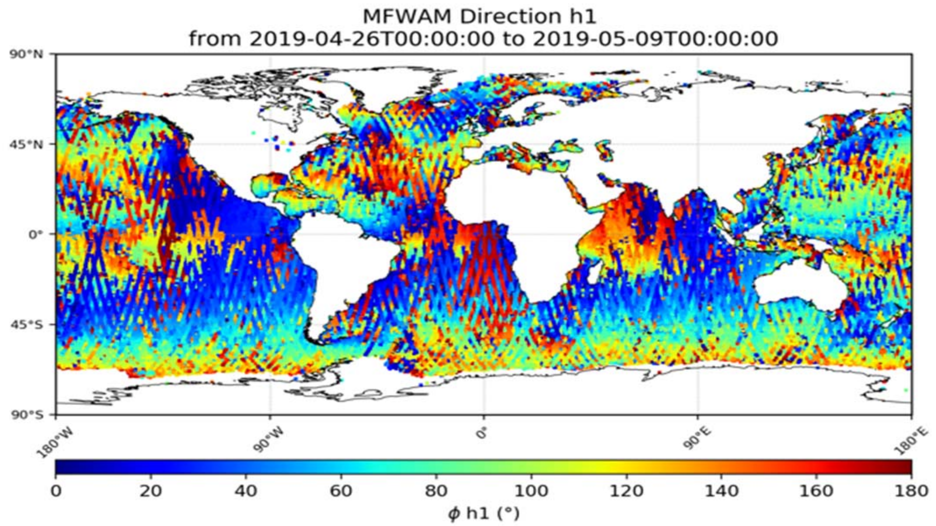


2D –spectral correlation index (Hasselmann et al, 1996) between SWIM and model (MFWAM) spectra



Correlation Index
estimated for the wavelength range 70<λ<500 m)

- ✓ 66 % of data with R > 0.5
- ✓ lowest corelation in regions of along-track propagating swells (directions of masked data) and/or low sea-state (Hs < 1m)



dominant swell direction
(from MFWAM model)

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)

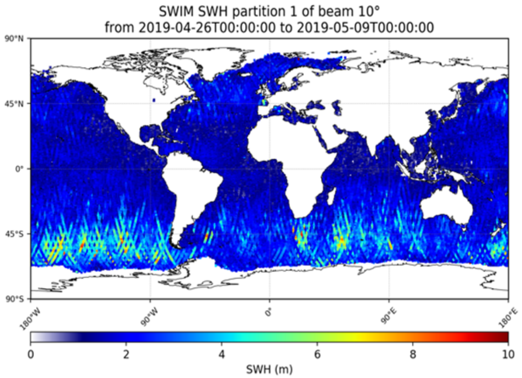
Illustrated here with SWIM beam 10° results

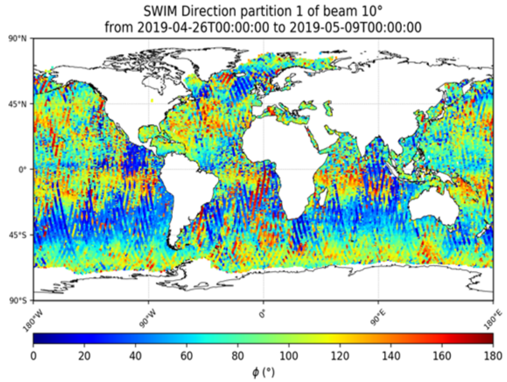
SWH

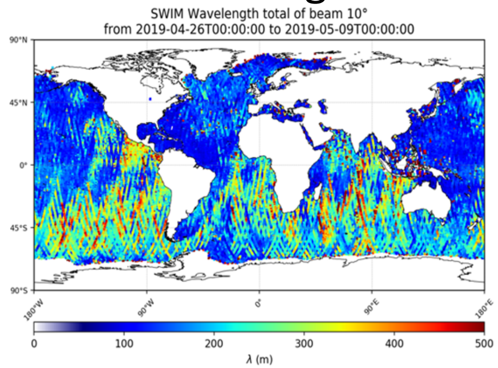
Direction

Wavelength

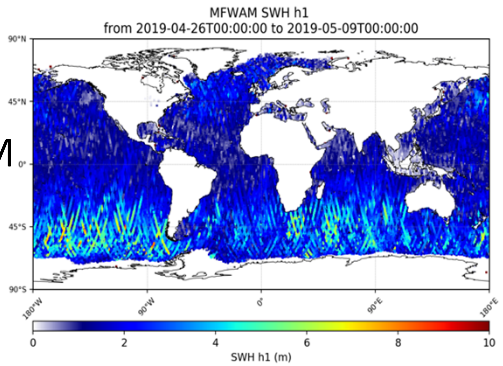
SWIM

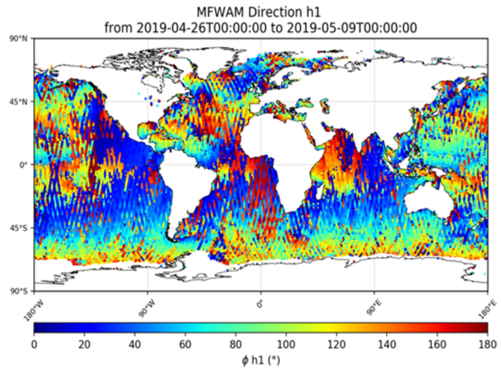


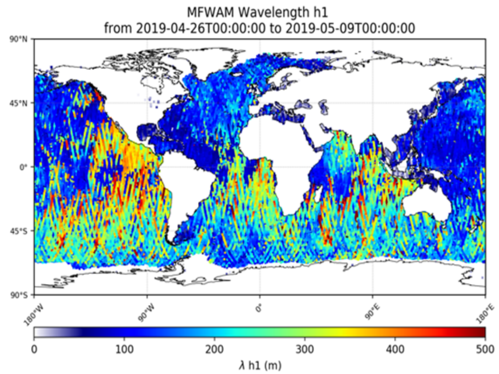




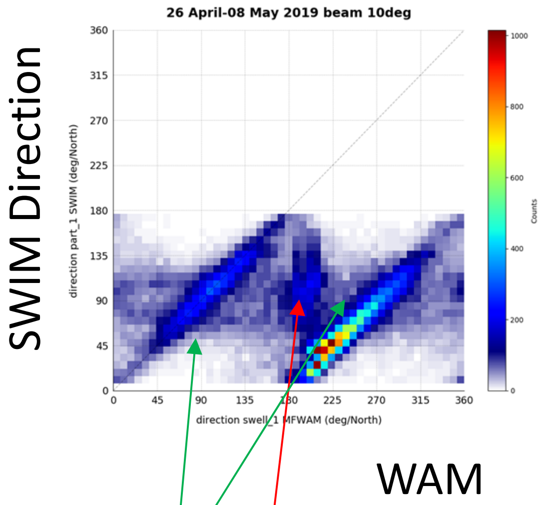
MFWAM

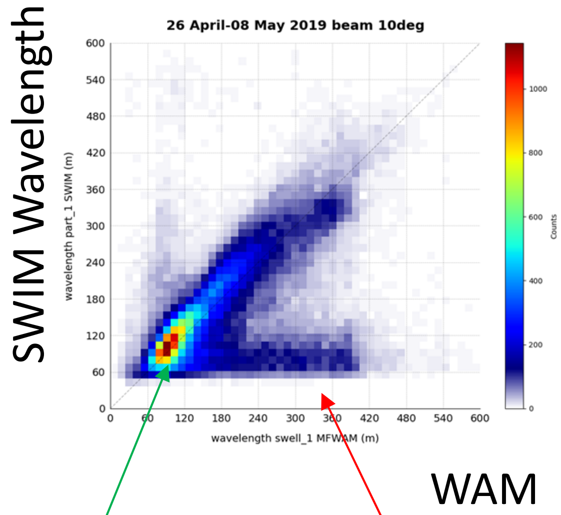


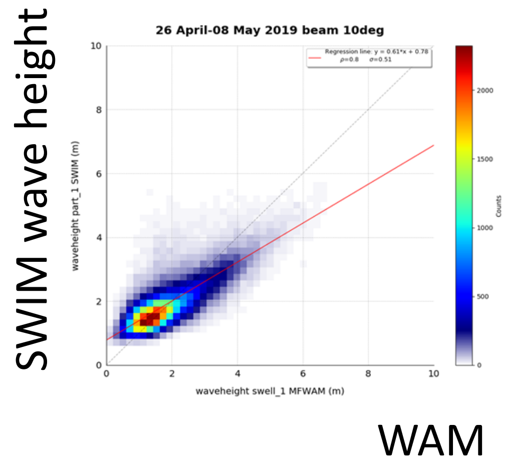




SWIM versus MFWAM parameters of partitions







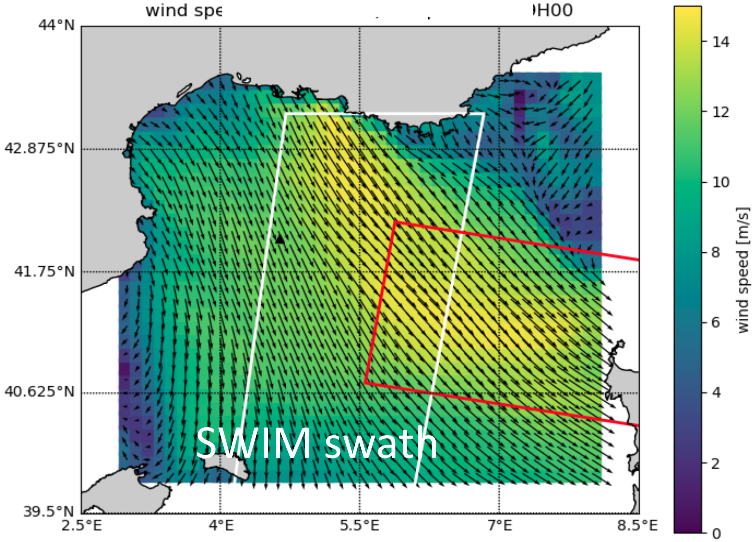
direction
=> well retrieved except for waves propagating in the along track direction (because of mask on SWIM spectra)

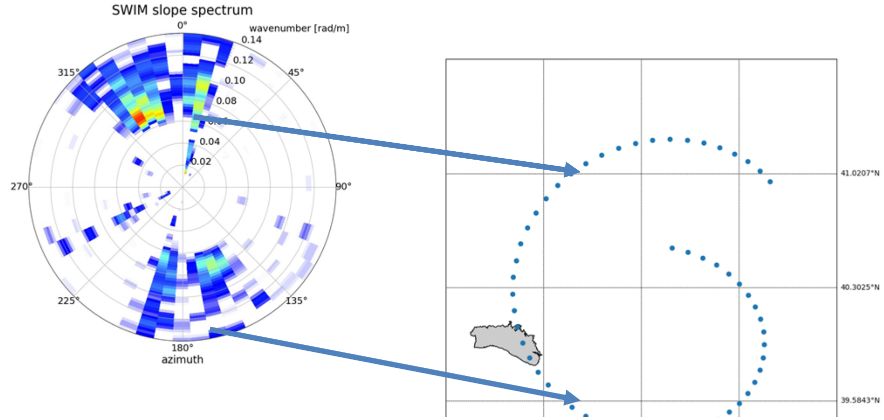
wavelength
=> well retrieved except here: partly due to to the mask?

waveheight
⇒ good correlation
BUT
overestimation at Hs < 3m ,
underestimation at Hs > 3m

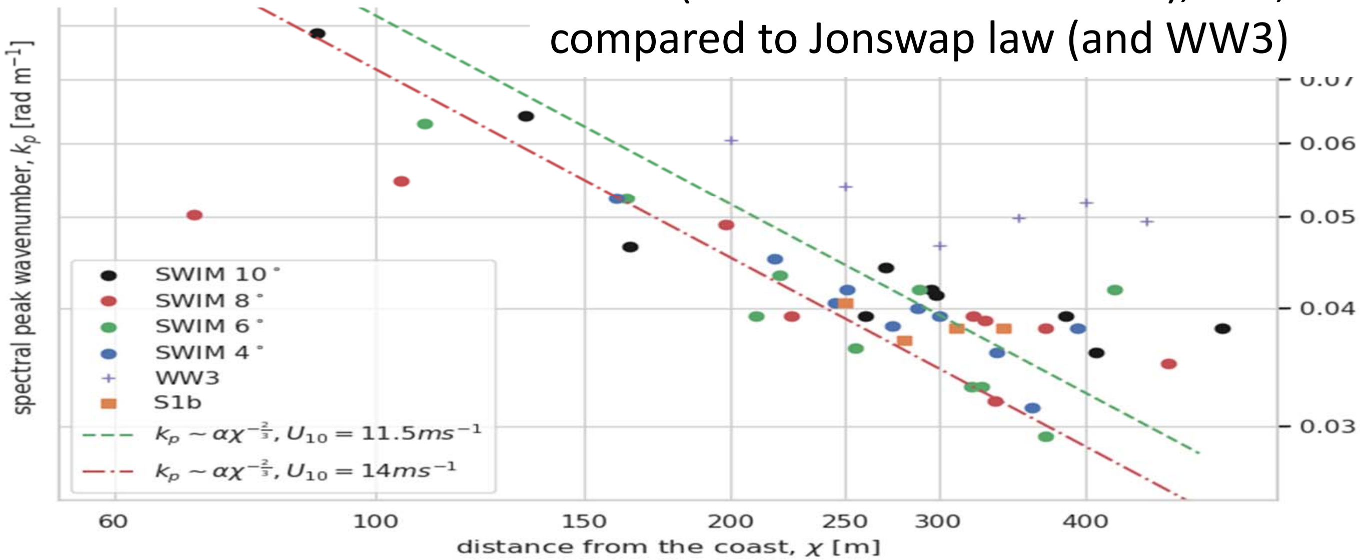
Spatial evolution of wave parameters- illustration for a fetch limited case (North Mediterranean sea)

offshore wind





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



4- Conclusion

Intense phase of the CAL/VAL completed.

- **Very innovative mission, instrument and products**
- **Wave (Hs) and wind (U) products from nadir:** excellent quality, ready to be widely disseminated and used
- **Spectral data from off-nadir:** very promising,
  - ✓ high correlation index between SWIM and model spectra
  - ✓ consistent shape of 1D height or slope spectra
  - ✓ detailed statistical performances (partition parameters) currently perturbed by the non perfect correction of speckle noise (and masking) => improvements in progress (empirical speckle model)
  - ✓ interest for global and specific wave studies (fetch limited, wave-current interaction, waves under sea ice -not shown,..)
  - **Data access:** already available for science team, access enlarged through AVISO+ starting in a few weeks - https://www.aviso.altimetry.fr/fr/missions/missions-en-cours/cfosat.html

NRT delivery to operational centers via Eumetcast (starting 2020)

Thank you !!

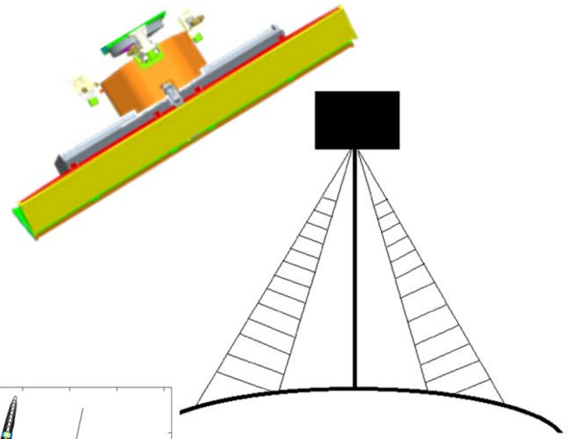
backup slides

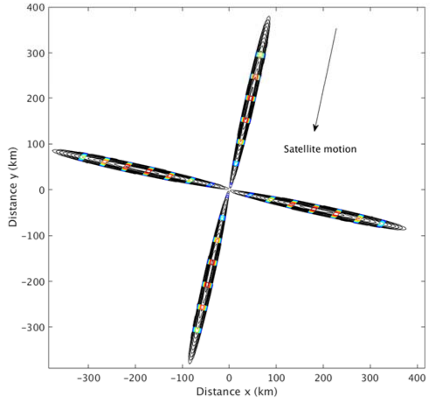
SCAT

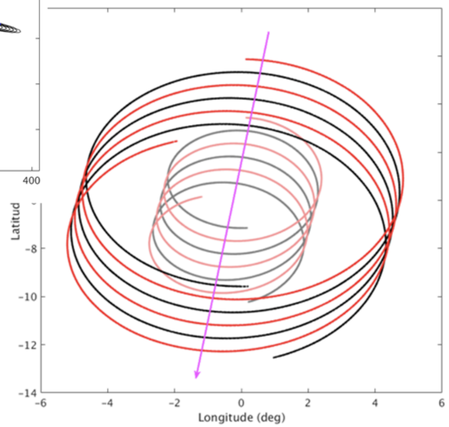
Wind scatterometer

- rotating fan beam concept with dual antenna system

⇒Combines advantages :
  - Large swath and multiple viewing geometry
  - Rotating antenna: 3 rpm
- Incidences between 26° and ~50°
- Provides
  - σ0
  - Ocean wind vector at the scale of ≈ 25 km x 25 km
  - Swath ~ 800 km

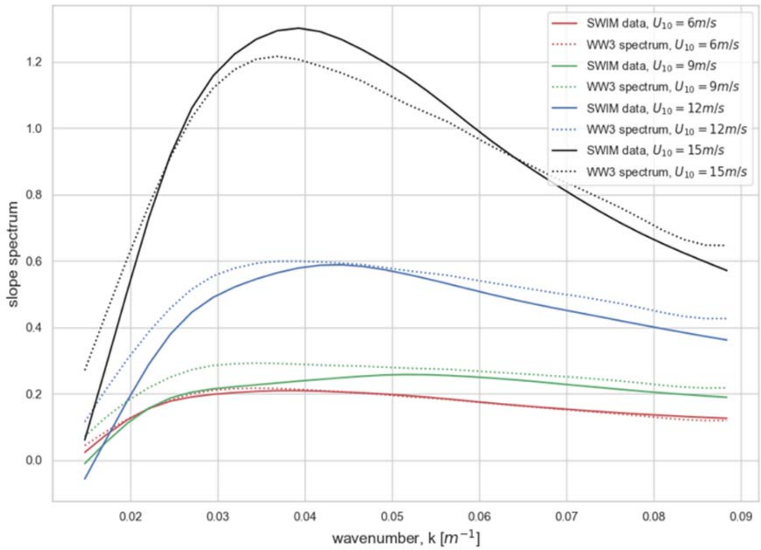






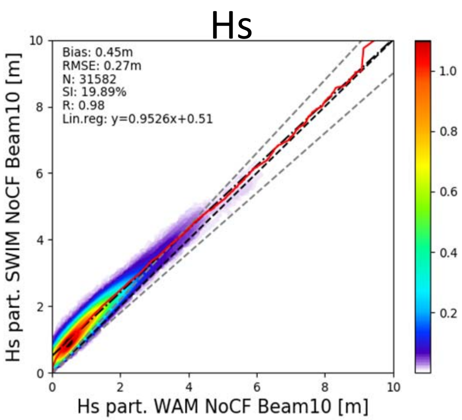
Assessment of the mean spectrum shape

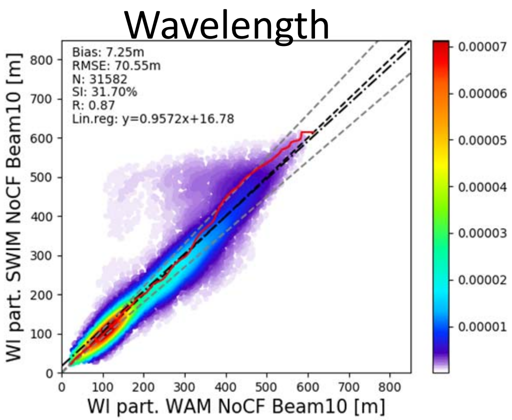
Mean 1D slope spectra : SWIM compared to WW3 for different wind speed classes

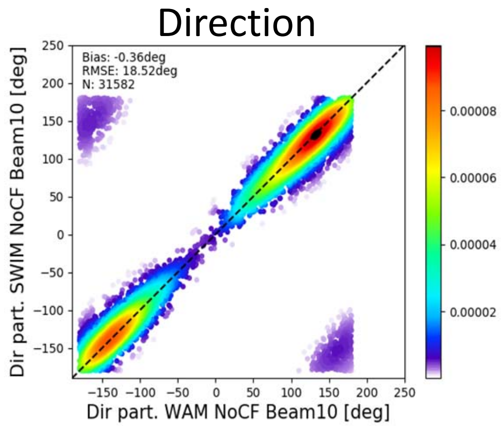


Very good agreement for waves greater than 70 m in wavelength

Further assessments: MFWAM spectra partitioned (with same mask as SWIM) and applied on the SWIM masked spectra (illustrated here with the 10° beam)







	Hs (m)	direction	Wavelength (m)
Mean bias	part1 : 0.47 m part 2 : 0.44 m	part 1 : -0.5° part 2 : -0.4°	part 1 : -1 m part 2 : 8 m
Rmse	part 1 : 0.32 m part 2 : 0.23 m	part 1 : 16.1° part 2 : 19.3°	part 1 : 62 m part 2 : 76 m
Scatter index	part 1 : 14.6% part 2 : 26.3%		part 1 : 33.3% part 2 : 33.4%

When partitions are imposed identical

- *Very good general performances*
- *Best results compared to MFWAM for the 10° beam (compared to 6 and 8 °)- not shown*
- *Wavelength : scatter due to abnormal population of long waves (probably due to non homogeneous scenes and parasitic peak at low wavenumber*
- *Overestimation of Hs of about 0.50 m , supported by the cases where Hs is less than 3m: probably due to insufficient rejection of speckle noise (see above)*