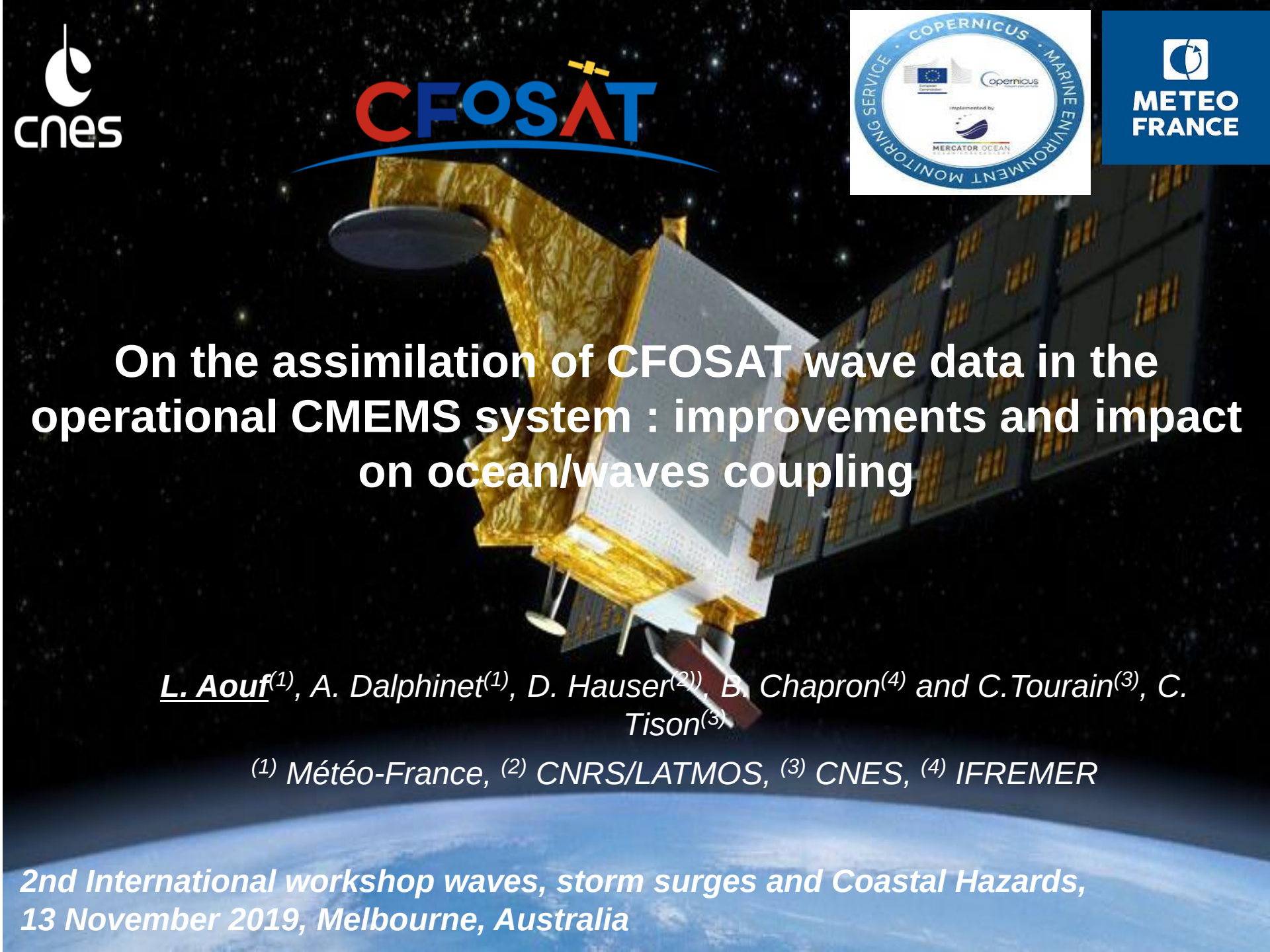


On the assimilation of CFOSAT wave data in the operational CMEMS system : improvements and impact on ocean/waves coupling

L. Aouf[(1)], *A. Dalphinet*[(1)], *D. Hauser*[(2))], *B. Chapron*[(4)] *and C.Tourain*[(3)], *C. Tison*[(3)]

[(1)] *Météo-France,* [(2)] *CNRS/LATMOS,* [(3)] *CNES,* [(4)] *IFREMER*

2nd International workshop waves, storm surges and Coastal Hazards, 13 November 2019, Melbourne, Australia

OUTLINE

1- Motivation

2- Data and Methodology

3- Results and discussions

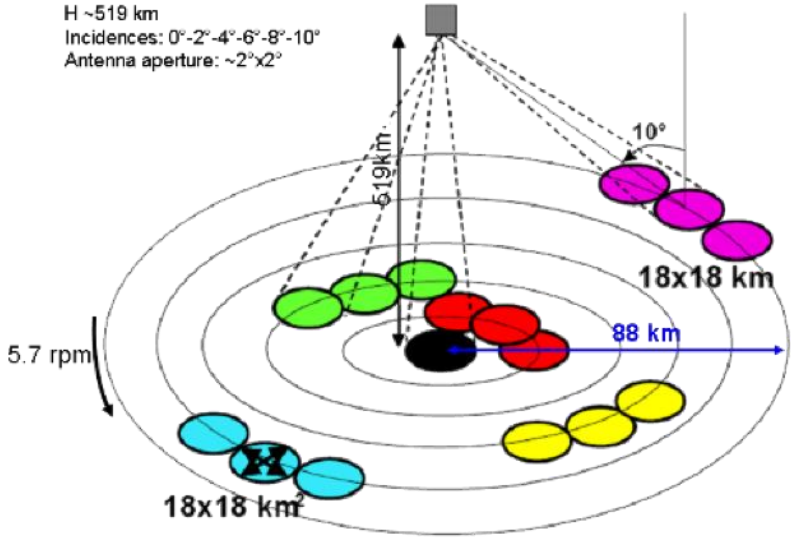
4- capability of CFOSAT data in storm events

5- conclusions

CFOSAT: A China/France joint satellite oceanographic mission

Joint measurements of ocean surface wind and wave

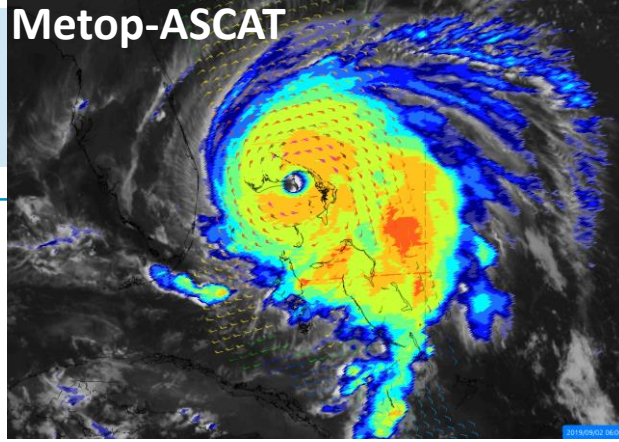
- **SCAT : wind vectors**
- **SWIM : Ku band real aperture radar**
- **Beams at 0, 6,8 and 10°**

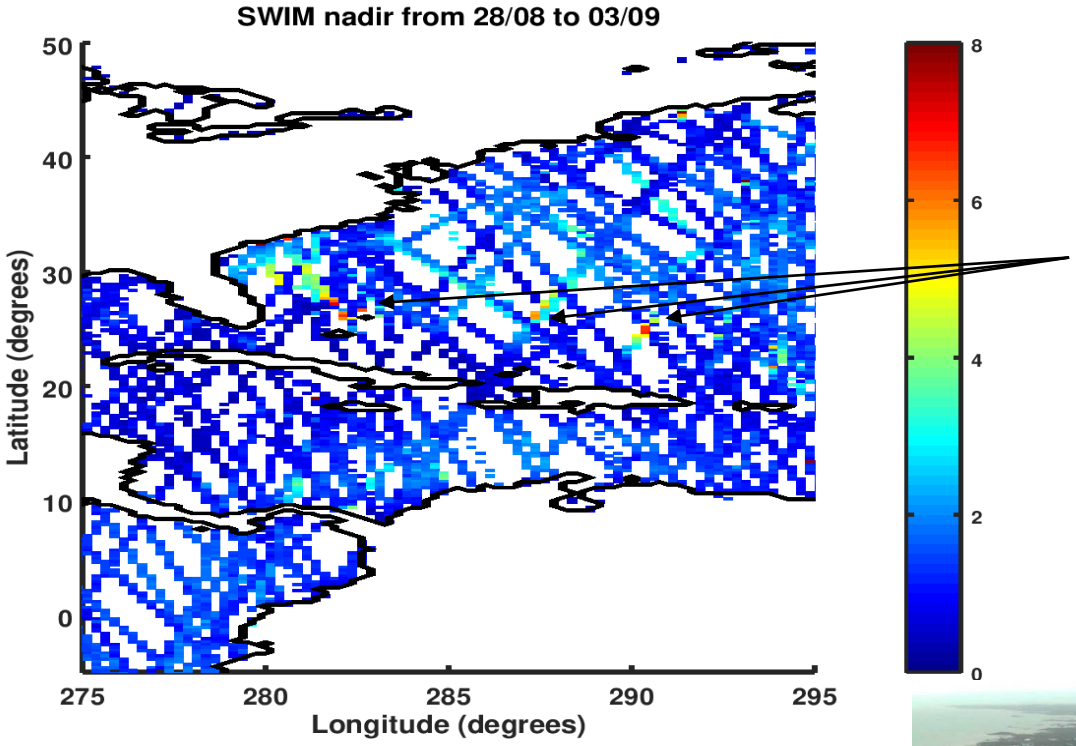


Production of level 2 wave products is nominal (~98%)

Wave data set has been provided to the science team since July 2019 after the end of verification phase

Relevance of CFOSAT wave data in extreme weather conditions : Hurricane DORIAN



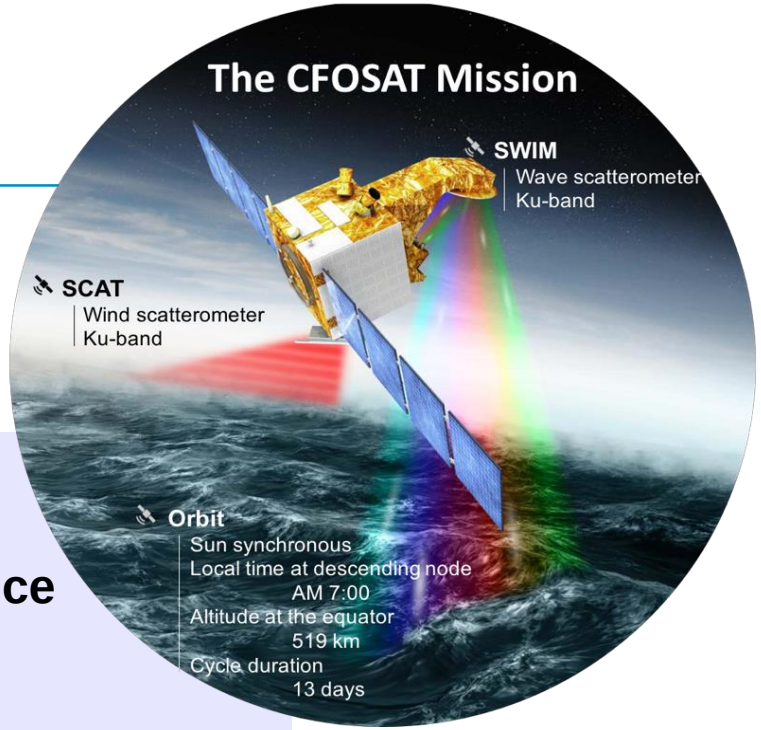


High waves captured by SWIM during Hurricane DORIAN

Damages induced by waves Flooding in Bahamas

➔ **Assimilation of CFOSAT wave data ensures the best estimate of integrated wave parameters**

Motivation



◆ **Prepare using CFOSAT wave data in operational wave systems : improvement of the wave submersion warning of Météo-France**

◆ **Evaluate the SWIM Level 2 wave data in the assimilation system of Météo-France :**

➔ **Contribution of Nadir SWH and SWIM wave spectra at different beams (6, 8 and 10°)**

◆ **Wind and waves observations in the same ocean area :**

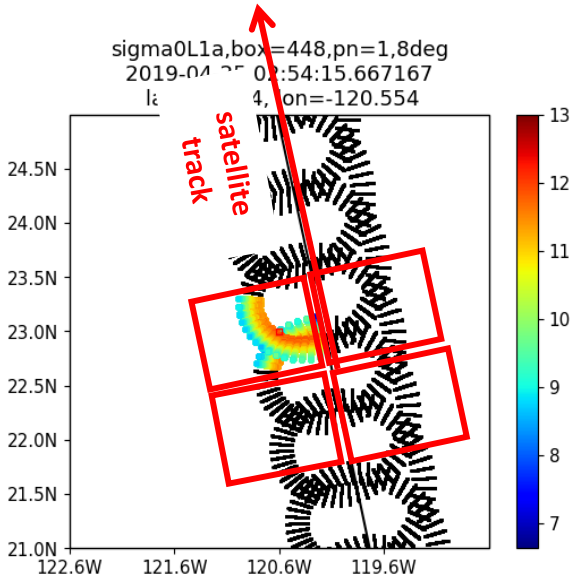
➔ **a challenge to better understanding the wave physics and consequences to Ocean/Atmosphere coupling.**

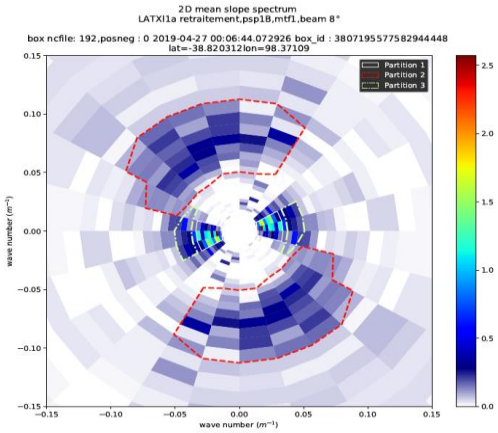
METEO FRANCE

Main level 2 variables from CFOSAT operational products

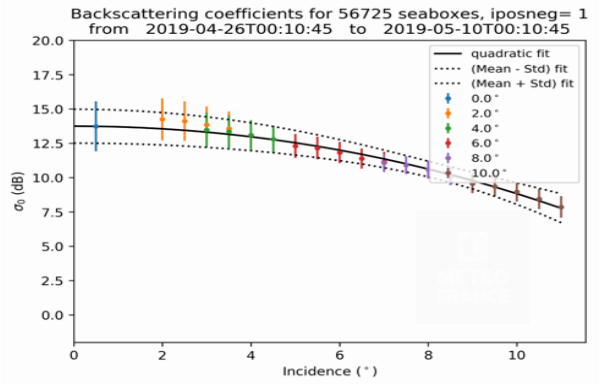
■ **Significant wave height and wind speed from nadir look (along-track)- similar to altimeter mission (new algorithms adaptive retracking)**

■ **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- from beams 6, 8 and 10°



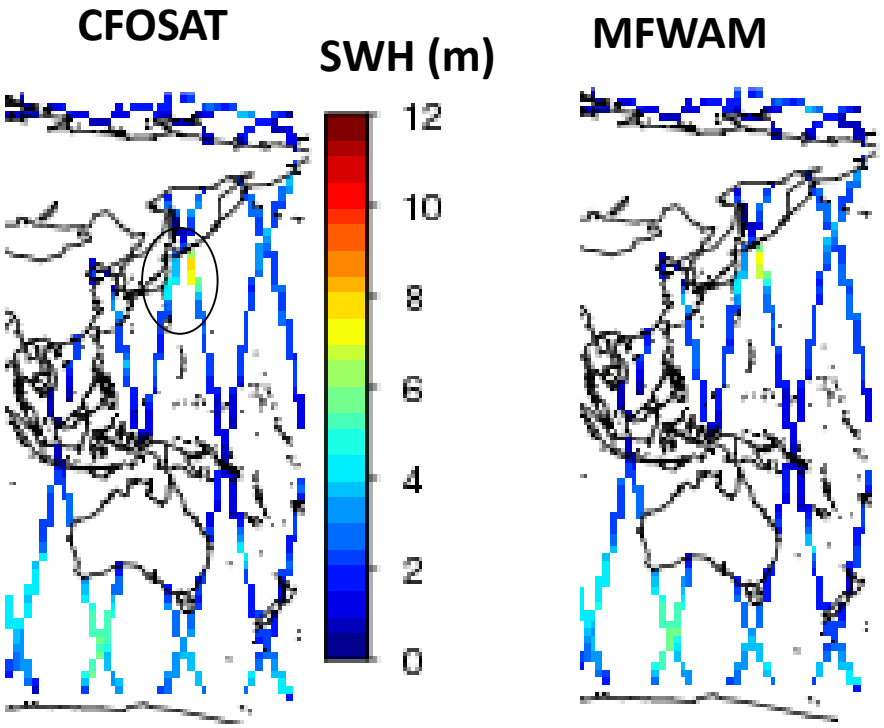


■ **Backscattering coefficient (sigma0) profile**



Monitoring the quality of SWIM 1Hz nadir SWH

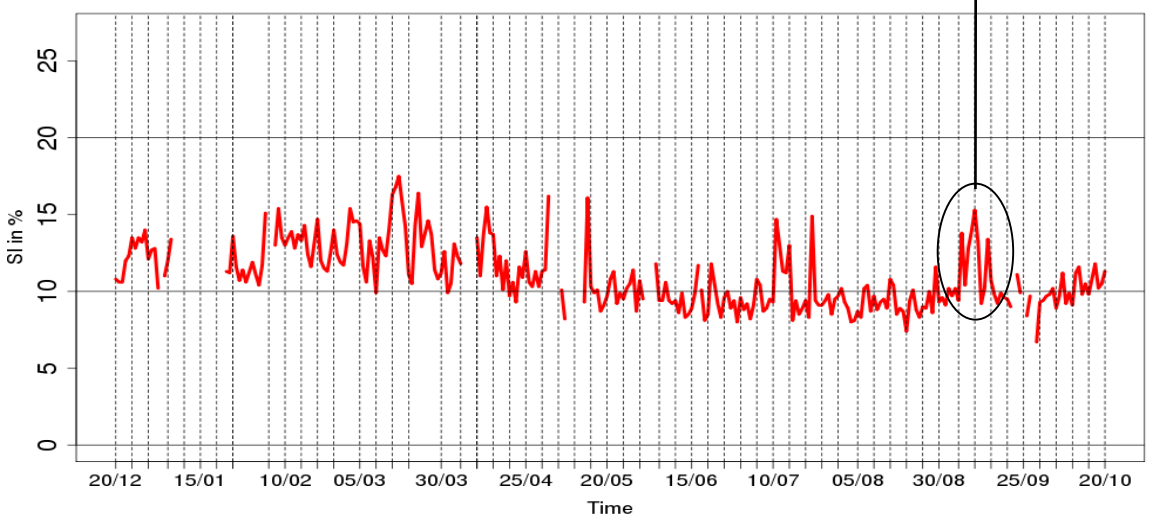
SWH captured during typhoon Hagibis (12 Oct. 2019)



➔ **Routinely comparison with operational MFWAM which is assimilating altimeters and SAR spectra from S1**

Cyclonic events Inducing high SWH

Scatter index (%) time series



Good scatter index of SWH roughly ~10 %
From December 2018-20 October 2019

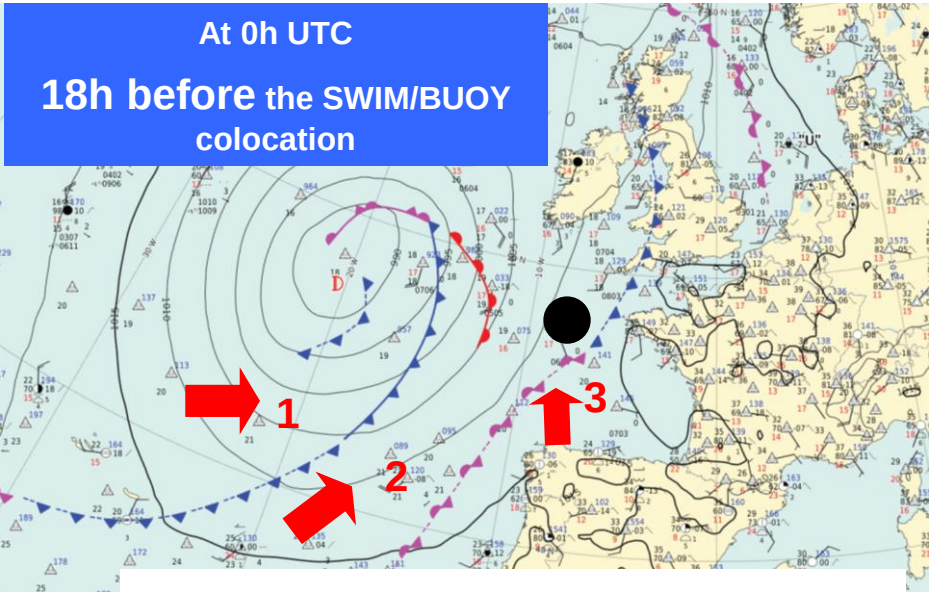
SWIM spectra compared to MFWAM and buoy brittany

Good description of mixed sea By SWIM

24th of July a storm in north-east Atlantic

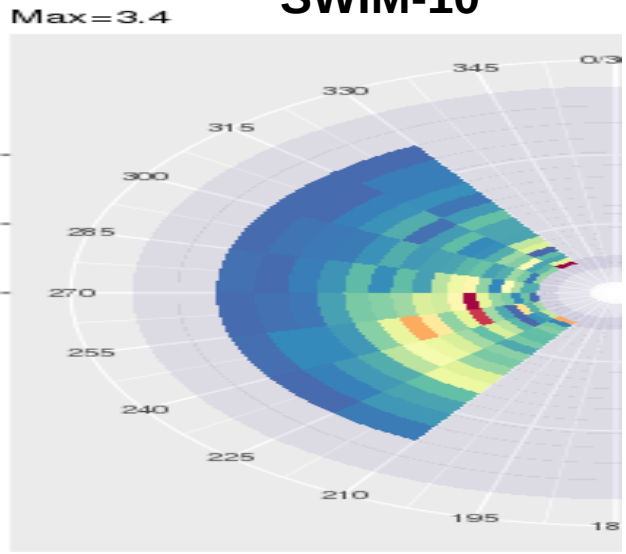
At 0h UTC

18h before the SWIM/BUOY colocation

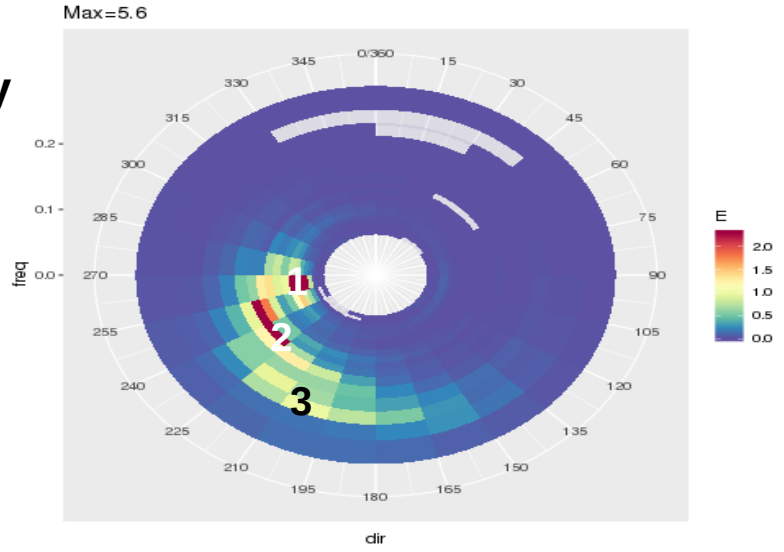


Two swell Systems (1 &2) And one Wind-sea (3)

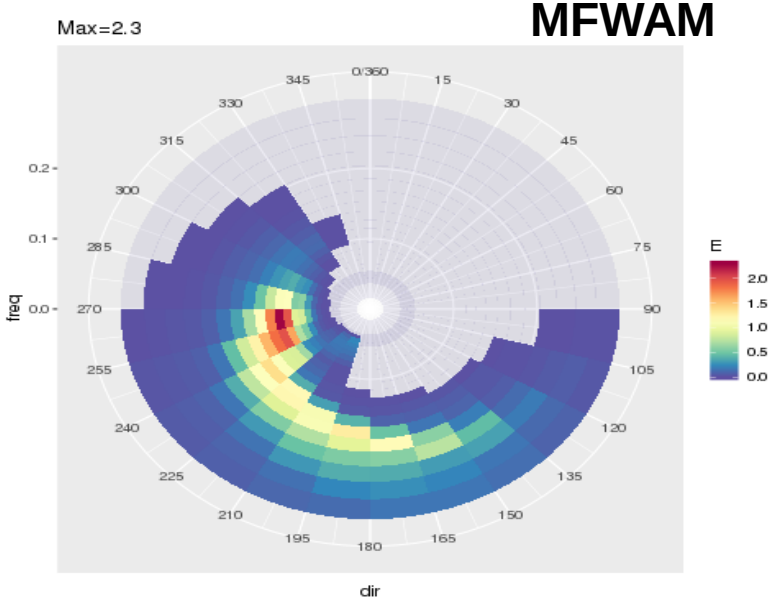
SWIM-10°



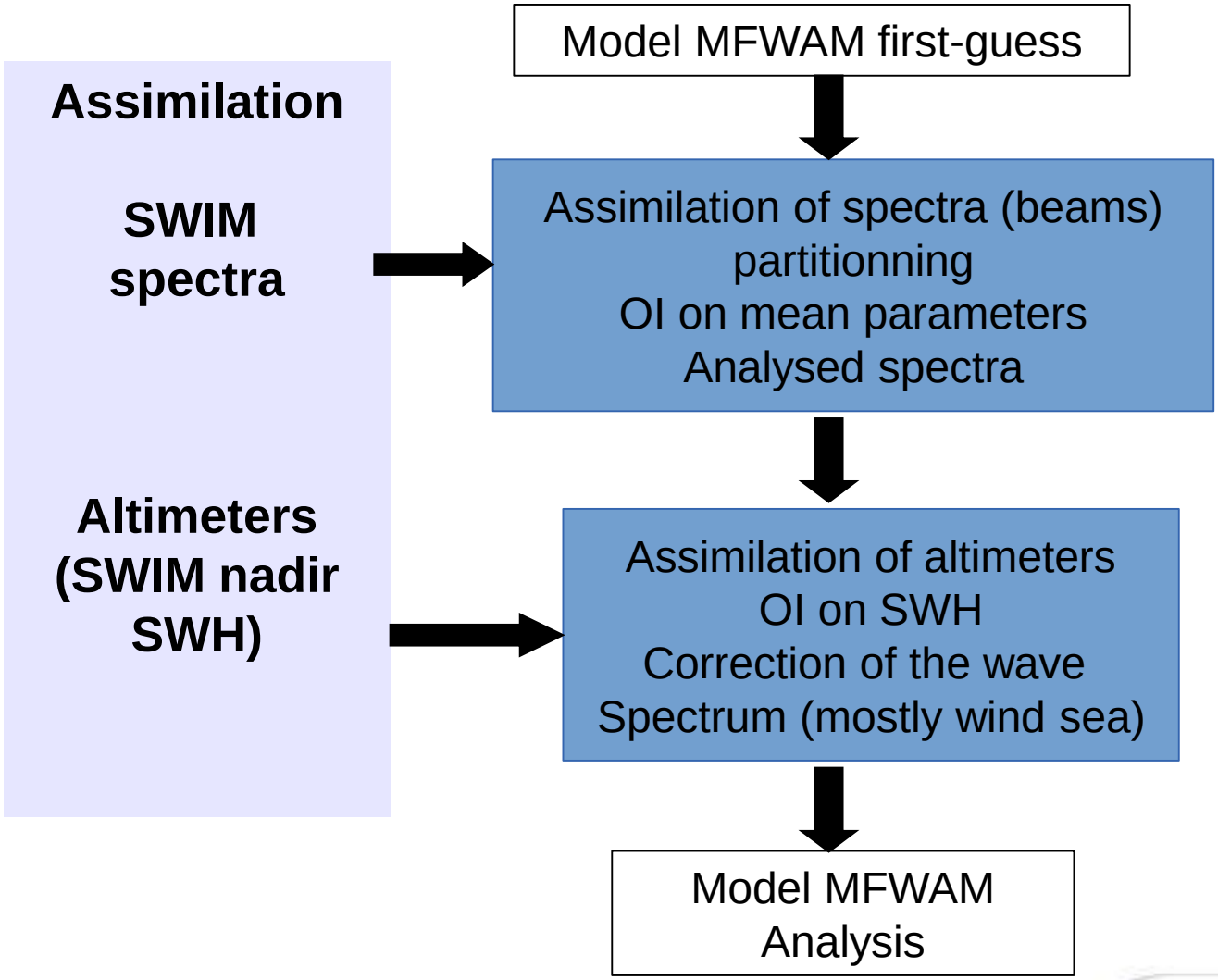
Buoy



MFWAM



Description of combined assimilation system



Data set for CFOSAT science team (26 April to 21 May 2019)

◆ Quality control procedure implemented to qualify SWIM wave data in the assimilation in the model MFWAM. Use of along track mask because of speckle noise.

◆ MFWAM model set up : forcing from IFS-ECMWF winds

◆Several assimilation runs have been performed :

- SWIM nadir SWH 1 Hz
- SWIM nadir 1Hz and combined spectra
- SWIM combined wave spectra
- SWIM several beams (6, 8 and 10°)

◆Optimization of assimilation parameters : cross-assignment threshold

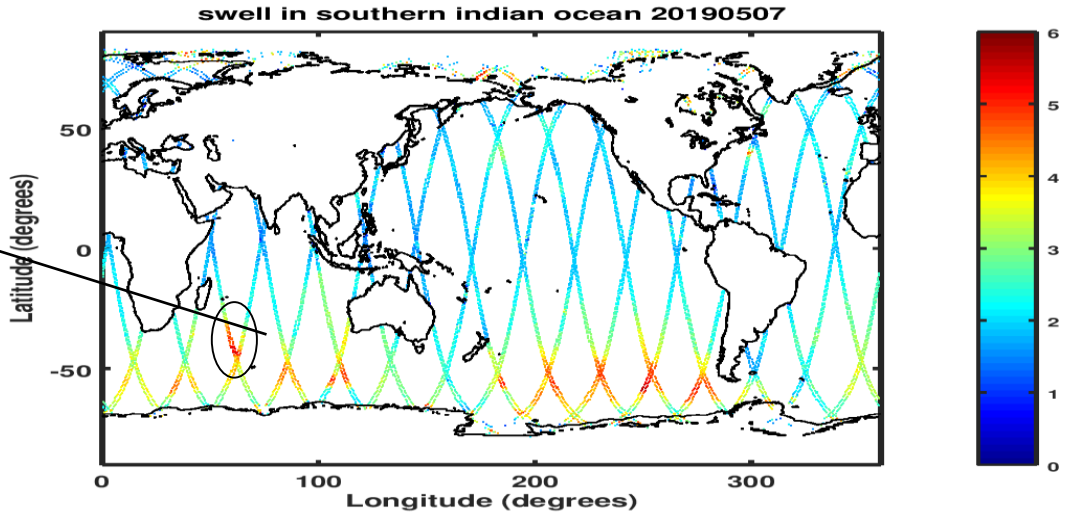
◆Azimuthal cut-off roughly 0.121 Hz on SWIM spectra (sensitivity tests)

◆Validation with independent altimeters and buoys data

METEO FRANCE

Example of swell in the indian ocean 7 may 2019
early start of southern winter storms

Location 64.2° E
40° .5° S

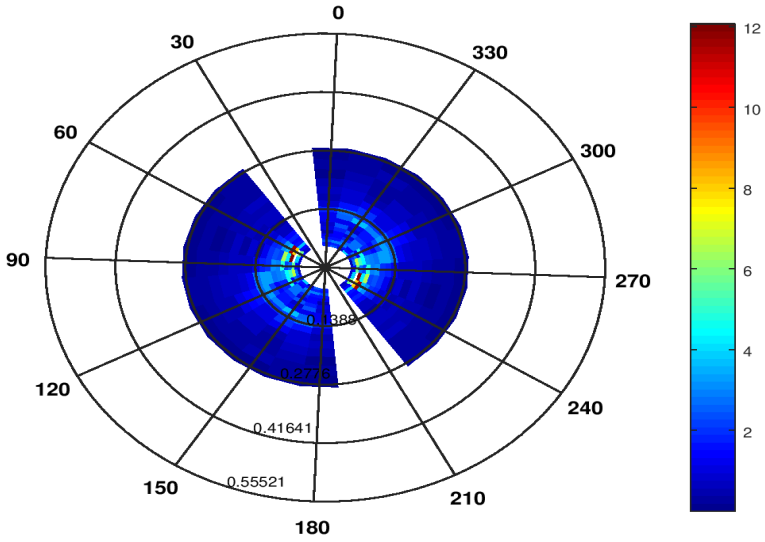


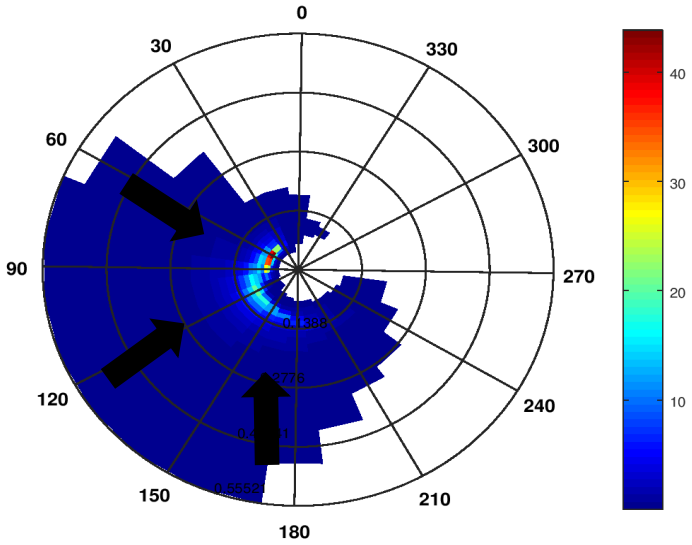
SWH from nadir (along-track)

SWIM beam 6°

Good description of directional properties by SWIM

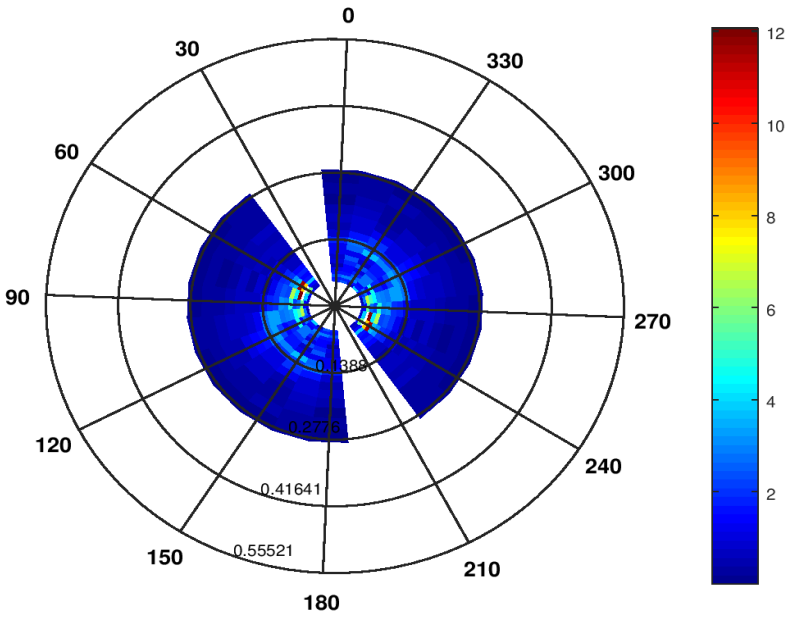
MFWAM-first guess



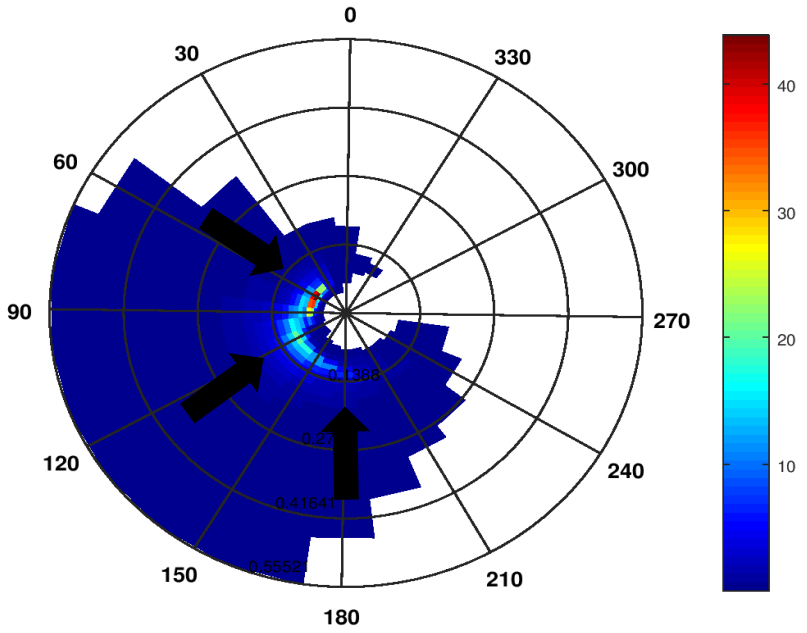


Swell in the indian ocean

SWIM beam 6°

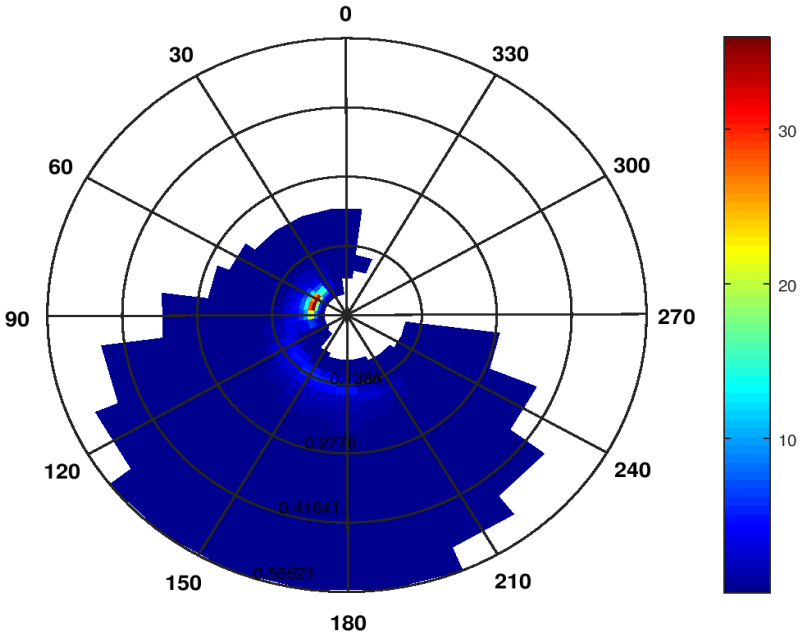


MFWAM-first guess



Correction of the energy partition overestimated by the model

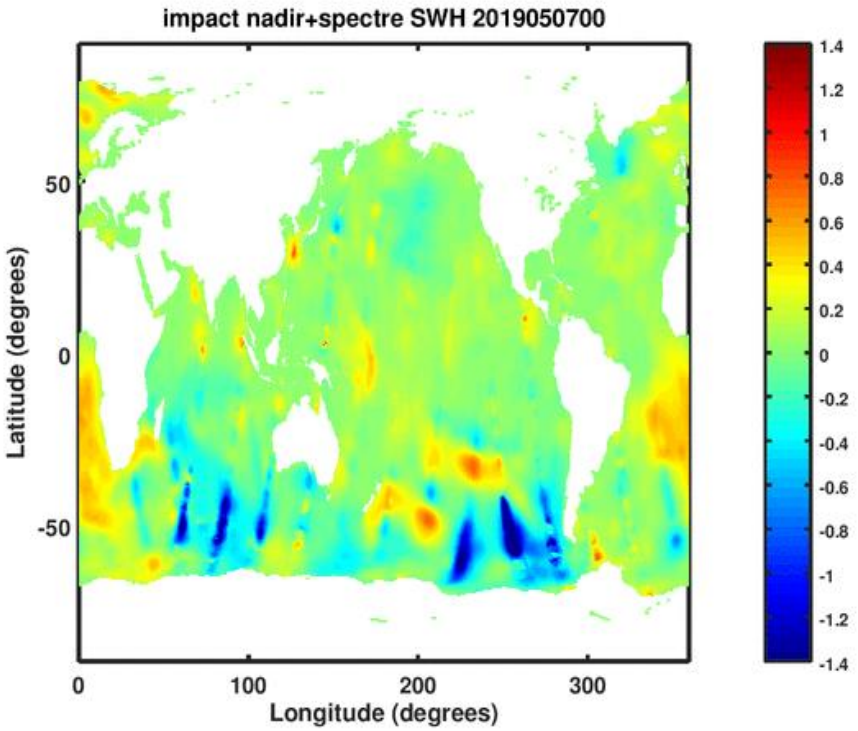
MFWAM-analysis



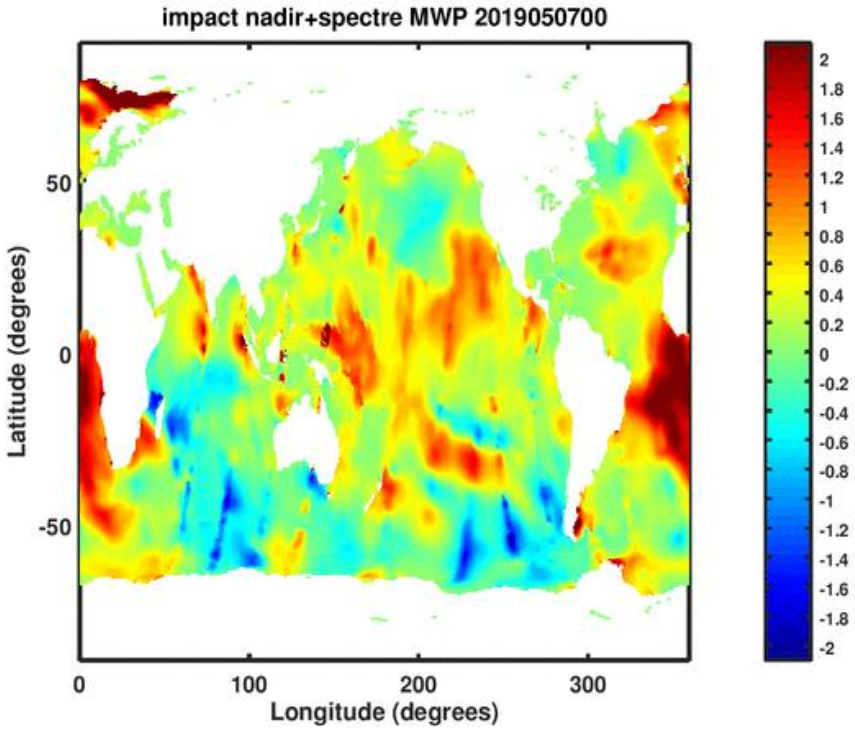
METEO FRANCE

Impact of the assimilation of nadir SWH and spectra beam 6° provided by SWIM

Sig. Wave Height



Mean wave period



6-hourly difference of wave parameters from runs with and without assimilation of SWIM wave data, starting On 7 May at 0:00 until 8 May 2019 at 18:00

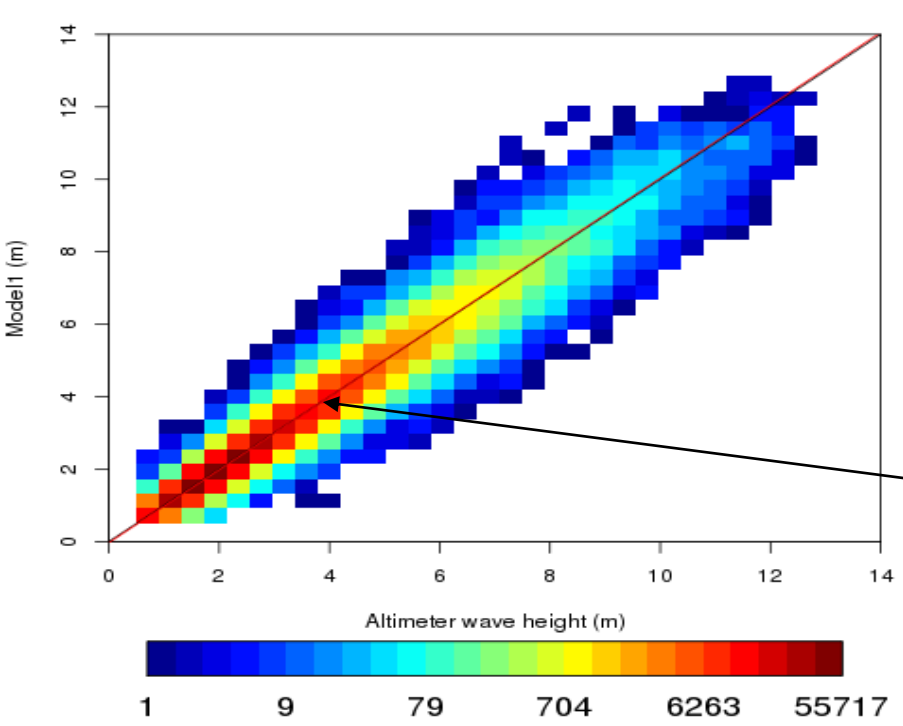
significant impact on mean period roughly 2 seconds on the propagation tracks of swells

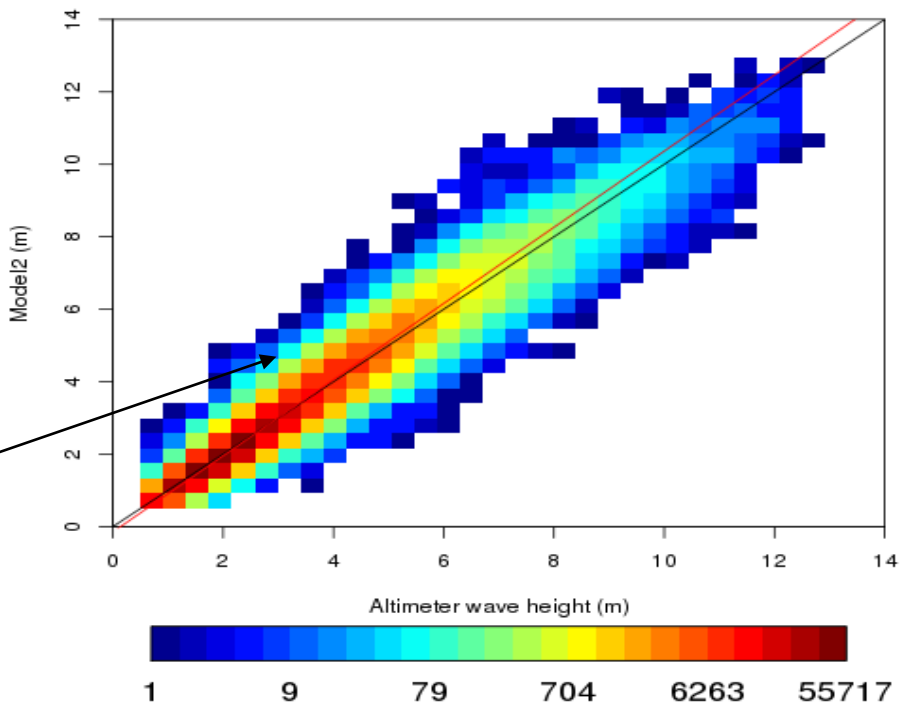
Period of run from 25 April to 20 May 2019

Impact of the combined assimilation
Scatter plots of SWH

Assimilation of SWIM-L2 (Nadir+ spectra beam)

Without assimilation





Bias=-0.01
SI=10.6 %
RMSE=10.6%
Slope=1.01
Intercep=-0.04

Better slope and significant improvement of Scatter index after the assimilation of SWIM L2 (Nadir+ spectra 6°) by ~17%

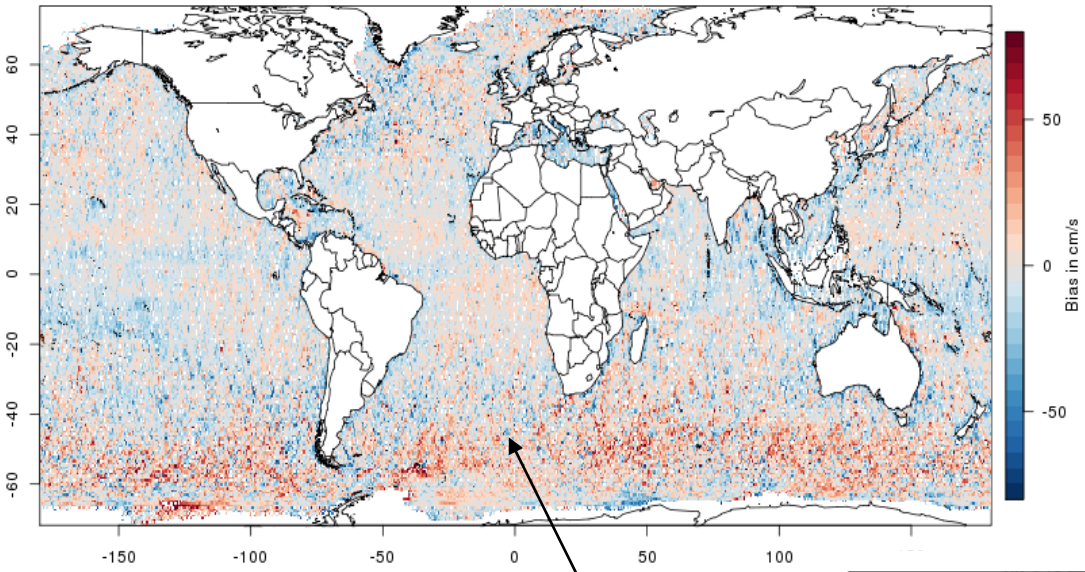
Bias=-0.01
SI=12.6 %
RMSE=12.6%
Slope=1.05
Intercep=-0.14

METEO FRANCE

Validation with Jason-3, Saral and S3

Bias maps of SWH : 26 April – 20 May 2019
Impact of the assimilation of SWIM L2 (nadir+beam spectra 6°)

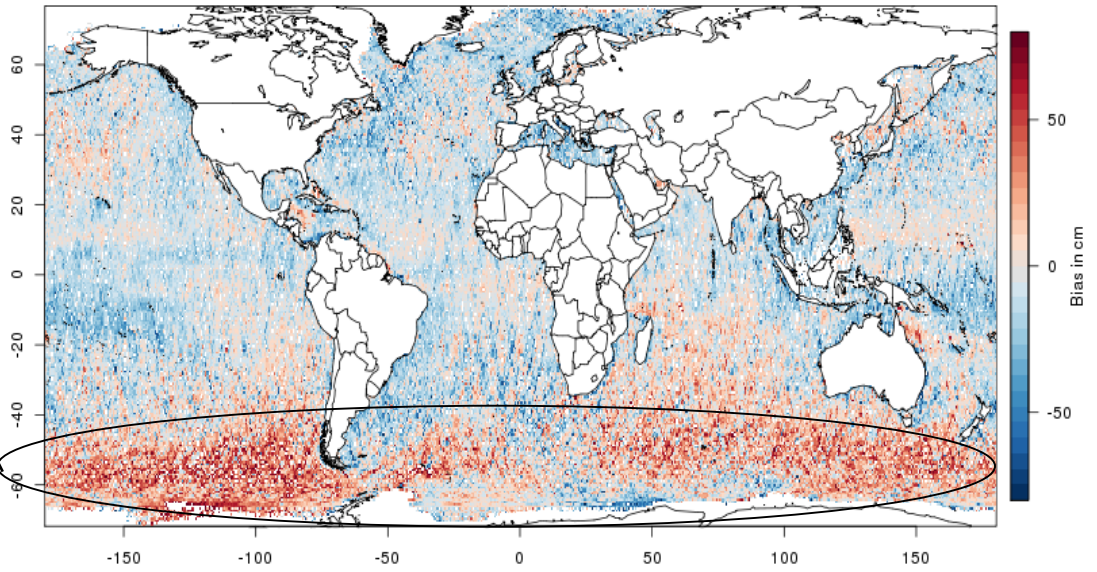
Assimilation of SWIM L2 (nadir+spectra)



Bias significantly reduced in high latitudes of Southern ocean, North-Atlantic and mid-latitudes

Maximum range 60 cm

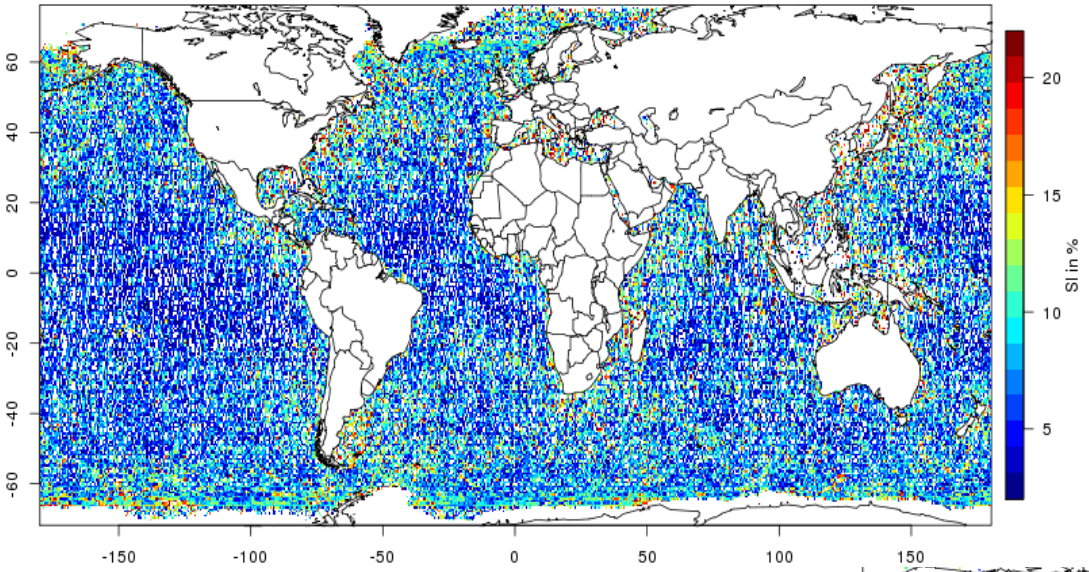
Without assimilation



Comparison with SWH from Jason-3, Saral and S3A

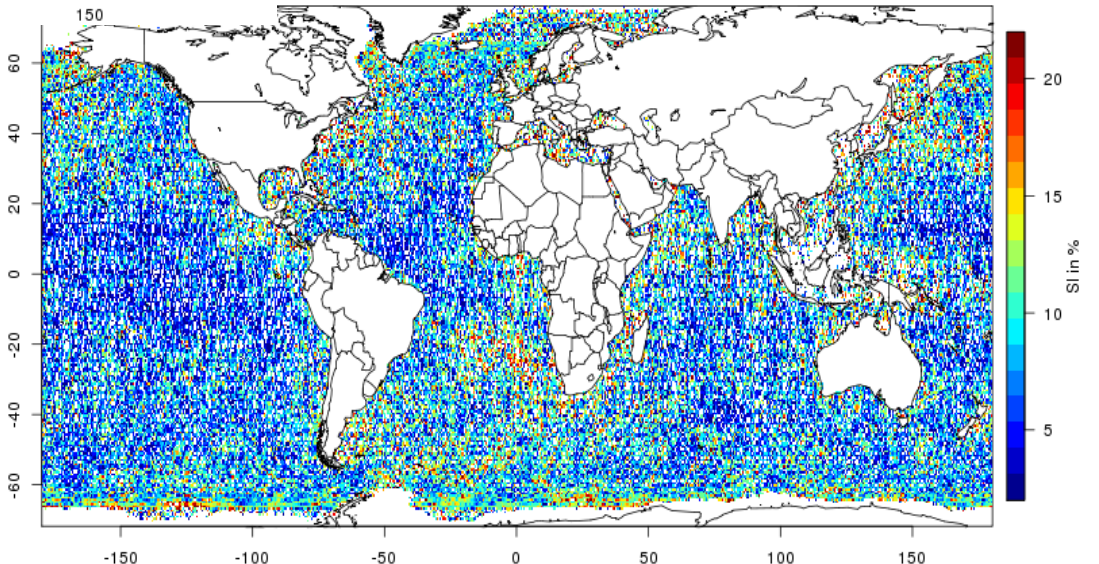
Scatter index maps (in %) of SWH
26 April to 20 May 2019

Assimilation of Nadir+spectra (beam 6°)



Clearly better SI globally when Using Nadir and wave spectra From SWIM L2

Without assimilation

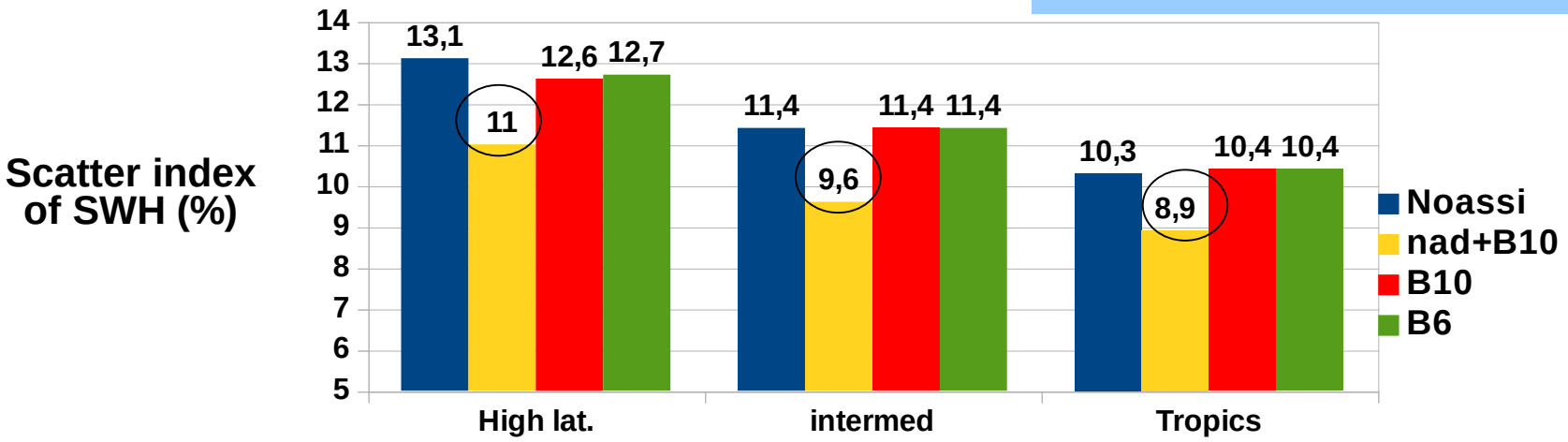


Blue is good
Red is bad

Comparison with SWH from Jason-3, Saral and S3A

Performance of the assimilation in different ocean basins

High Lat |□|> 50°
Intermediate lat 20° <|□|<50°
Tropics |□|<20°



Good performance of the combined assimilation of Nadir SWH and beam 10 spectra from SWIM : SI significantly improved In high and intermediate latitudes and the tropics (in circles).

Same performance between beam 10° and 6°, improvement in high Latitudes only (slightly better for beam 10).

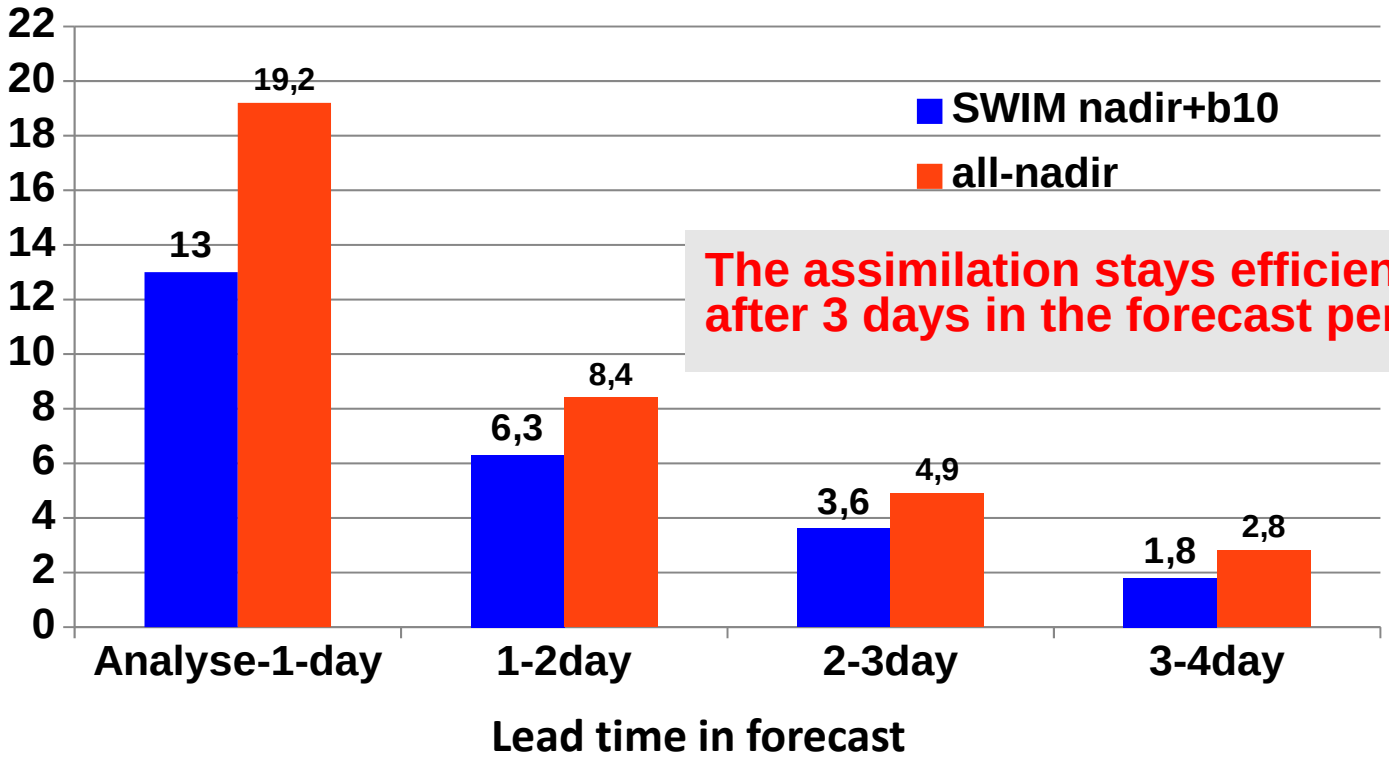
Validation with SWH from Jason-3 Saral and S3

METEO FRANCE

Impact in the context of operational configuration during the forecast period

All nadir : Ja3+S3+CR2+SARAL+CFOSAT

Significant improvement in the forecast



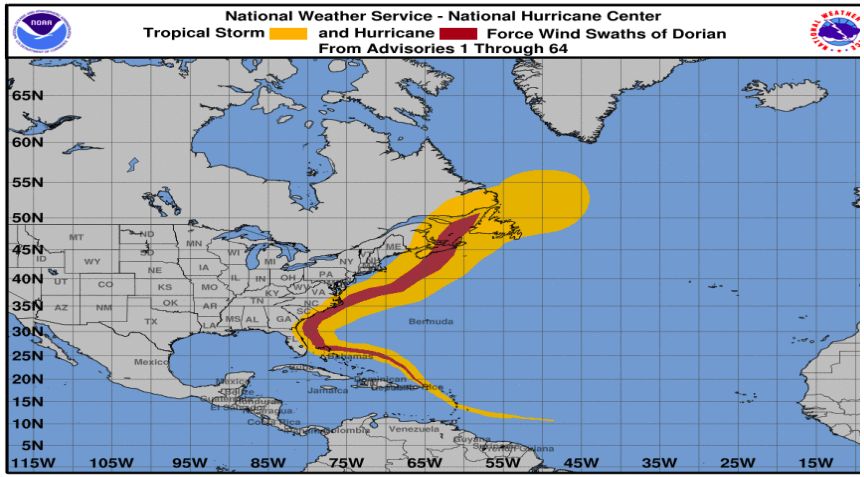
The assimilation stays efficient after 3 days in the forecast period

Analysis with DA | **forecast No DA**

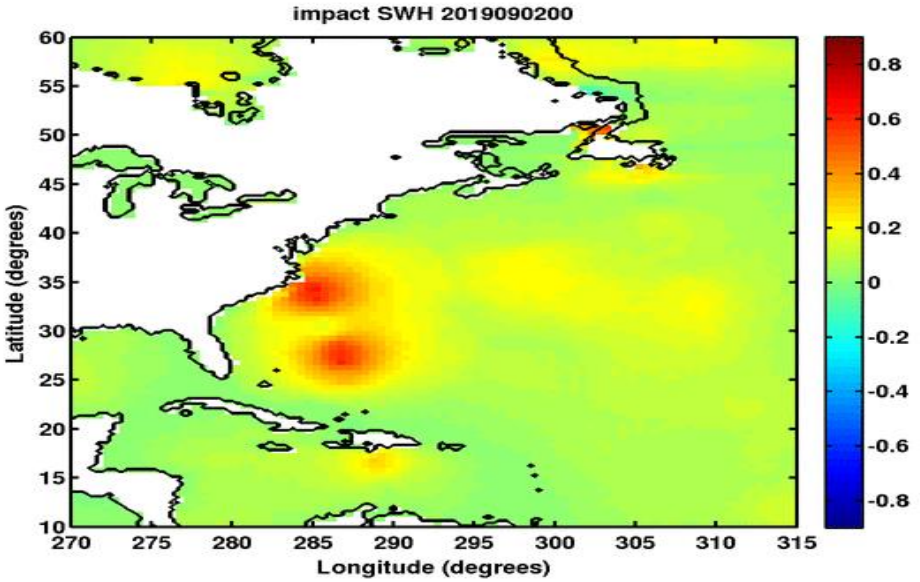
Validation with altimeters (Jason-3 and Saral)

METEO FRANCE

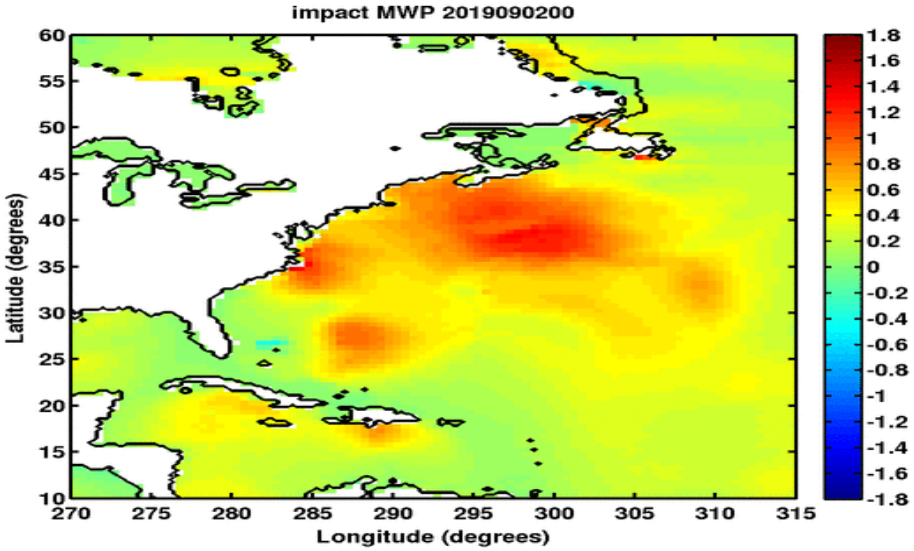
Impact of the assimilation of SWIM data during hurricane DORIAN (Sep. 2019)



SWH



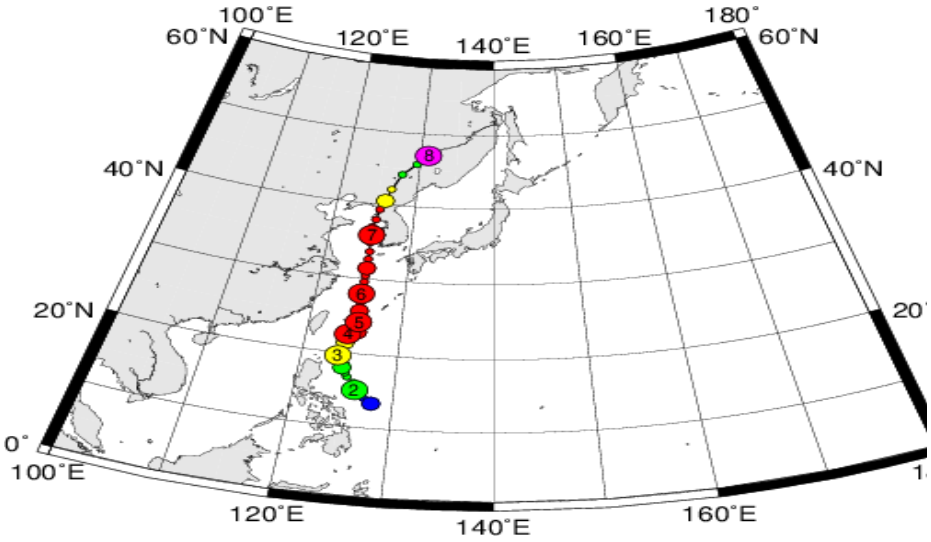
Mean period



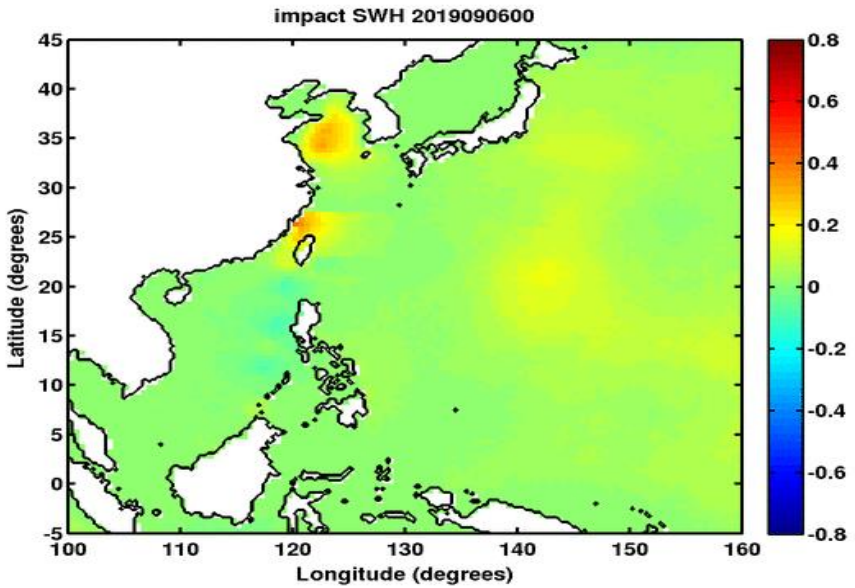
During this event the assimilation of SWIM induces an improved SI of SWH by roughly 16 % in comparison with altemeters

6-hourly difference of wave parameters From 02/09 until 04/09

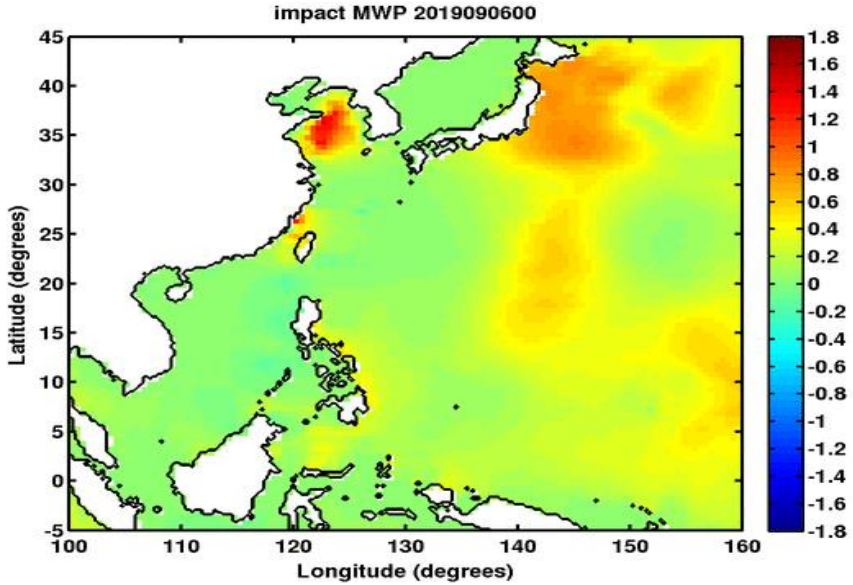
Impact of the assimilation of SWIM in west Pacific Typhoon LingLing (Sep. 2019)



SWH



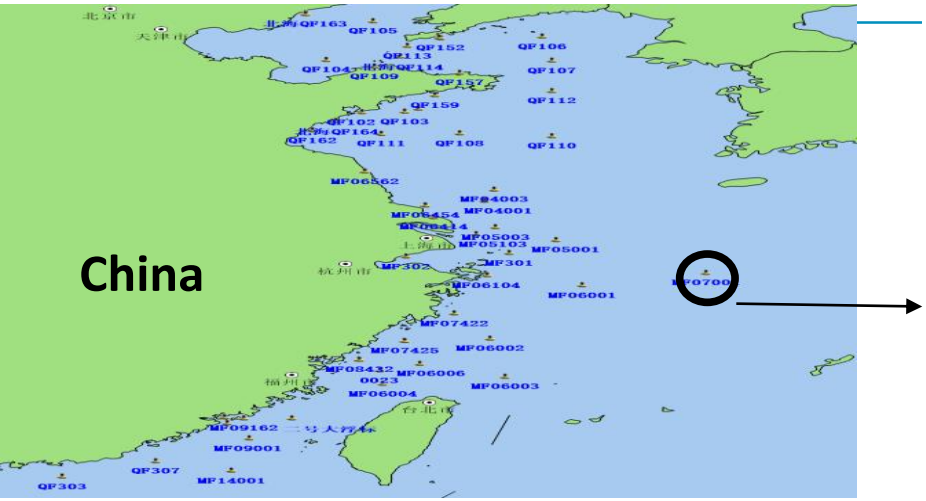
Mean period



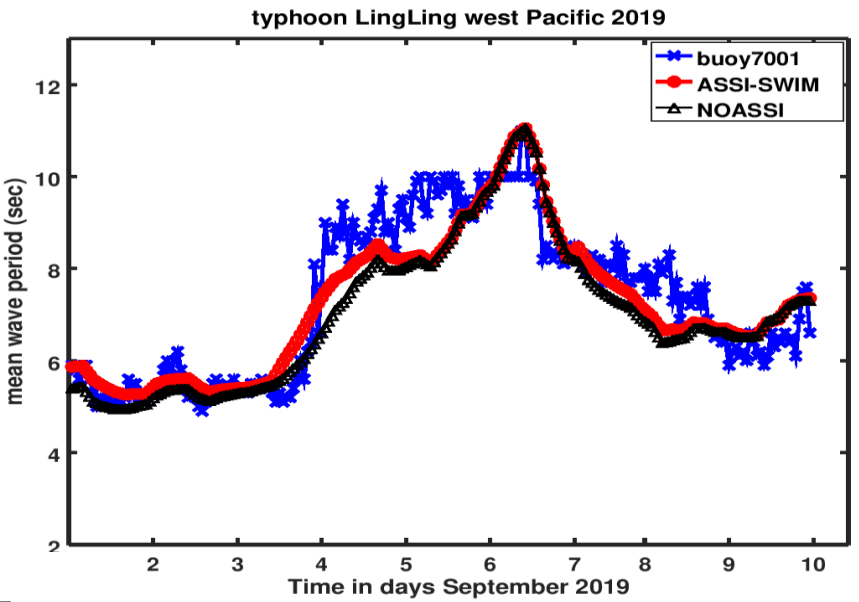
During this event the assimilation of SWIM induces an improved SI of SWH by roughly 16 % in comparison with altemeters

6-hourly difference of wave parameters From 06/09 until 08/09

Typhoon LingLing September 2019 Performance at NMEFC buoy 07001

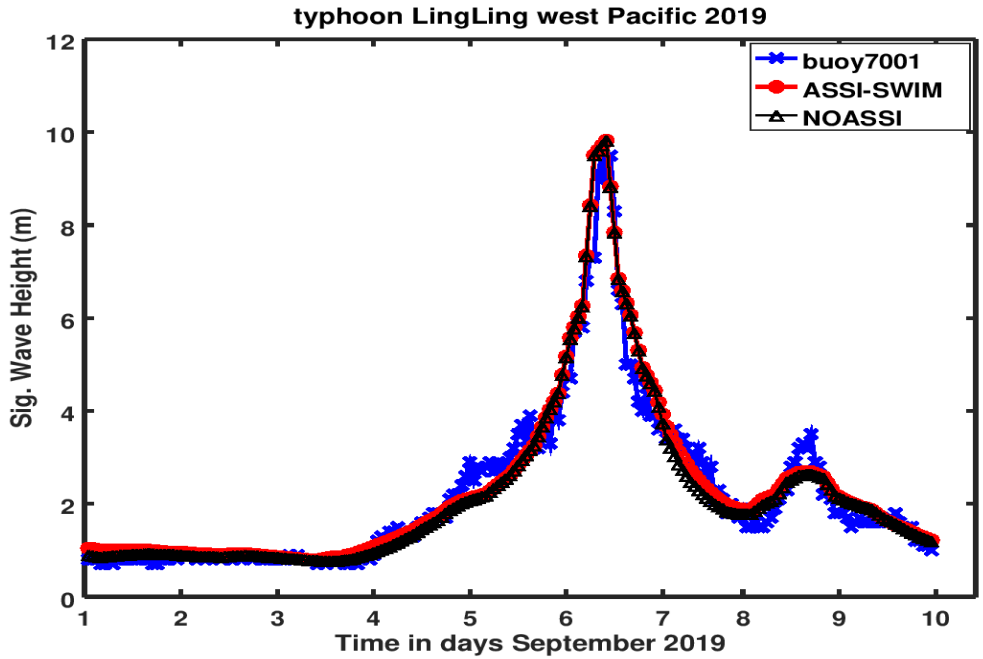


Time series of Mean wave period



Bias and scatter index for MWP are well improved from -0.32 to -0.11 Sec and from 9.7 to 8.9 %, respectively

Time series of SWH (model was good)

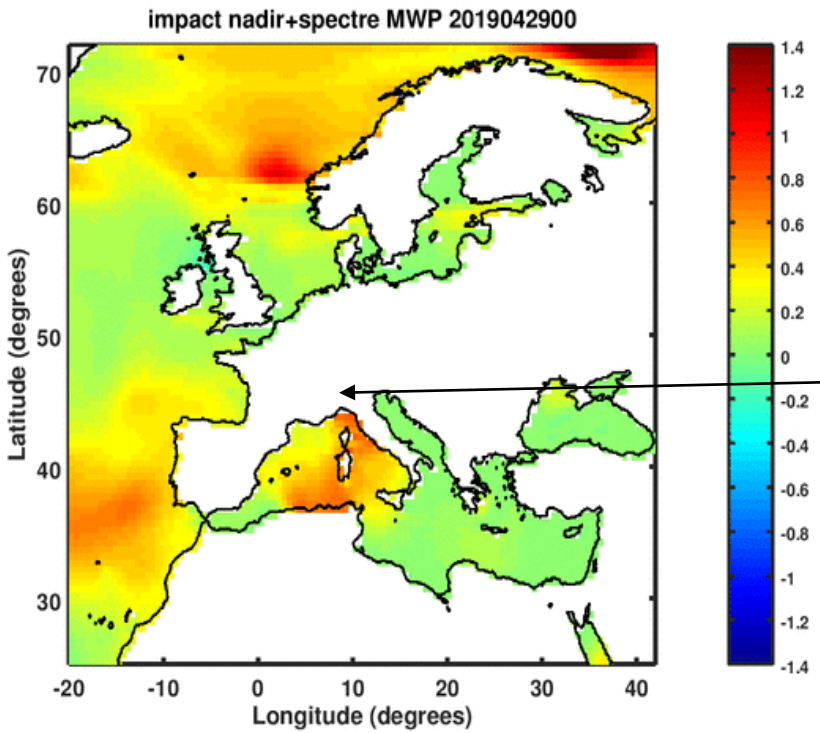


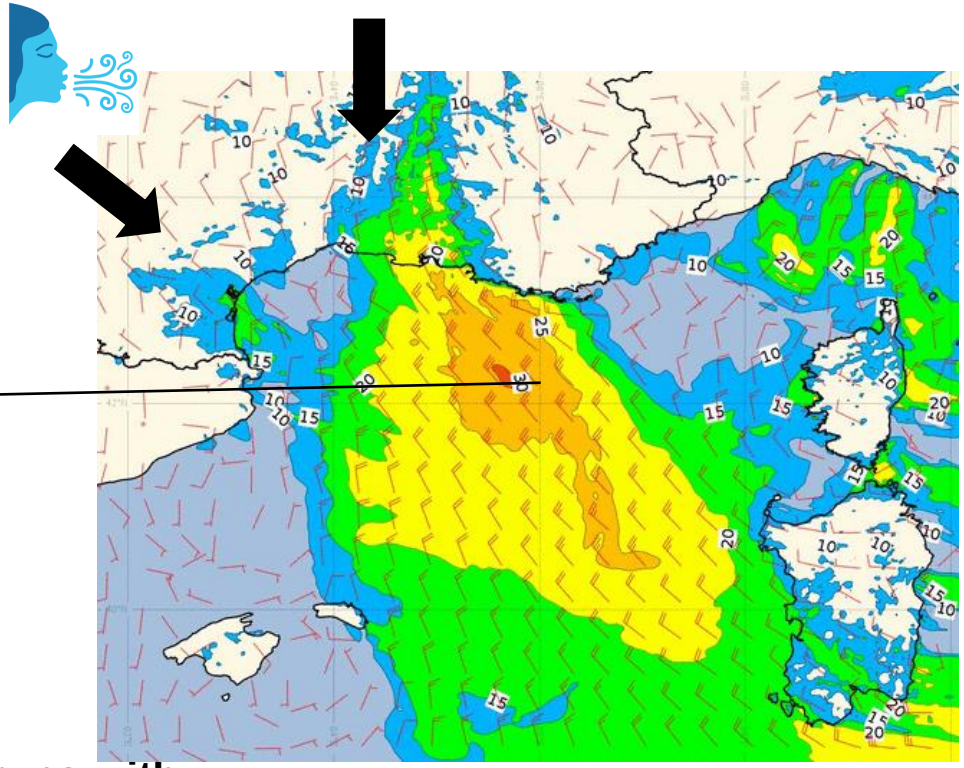
For SWH the scatter index is Slightly improved from 17.9 to 17.2 %

Impact of the assimilation of nadir SWH and spectra beam 6°

Mean wave period

Winds from AROME-1km : Mistral/tramontane wind regime : rapid wave growth in short limited fetch (weakness of wave models)





6-hourly difference of wave parameters from runs with and without assimilation of SWIM wave data, starting On 29 April at 0:00 until 30 April 2019 at 06:00

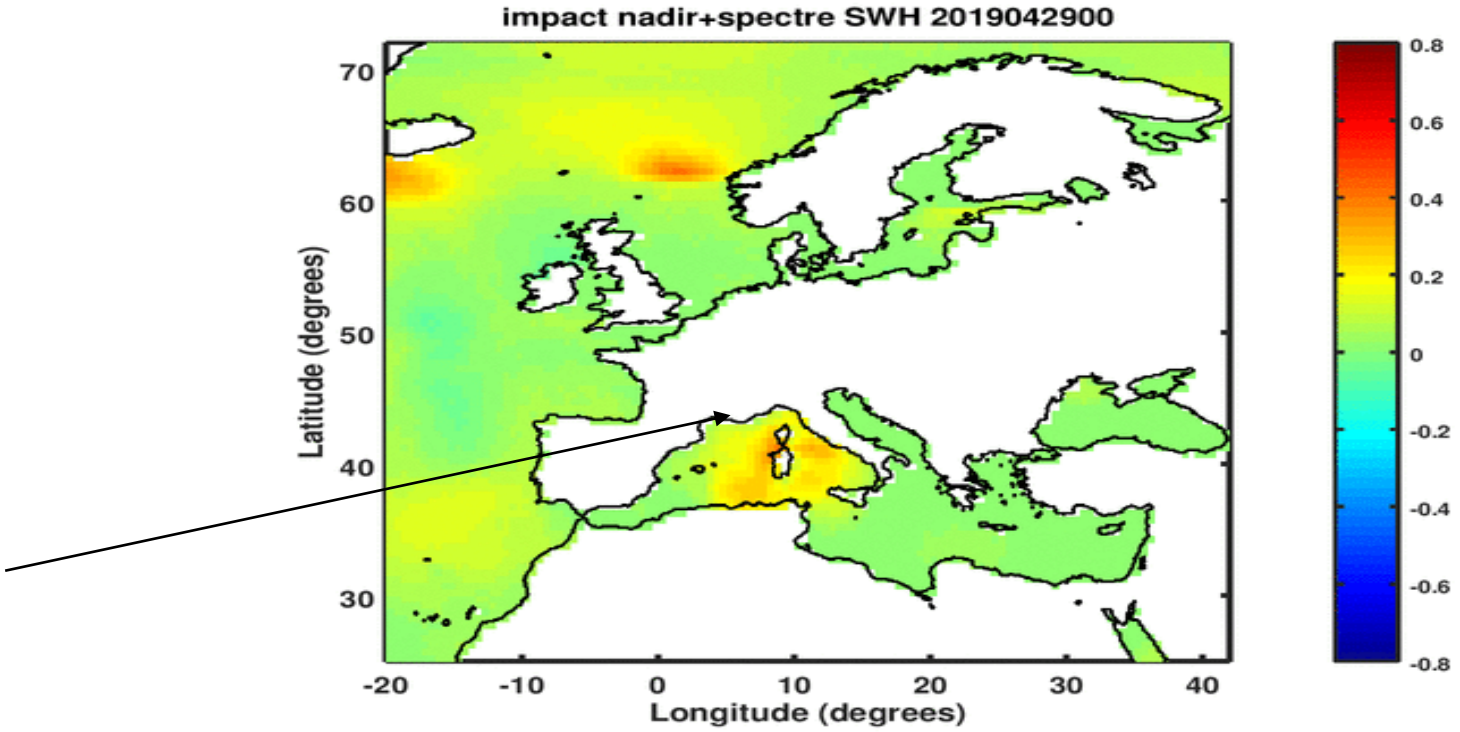
significant impact on mean period roghly 2 seconds after the passage of CFOSAT

METEO FRANCE

Mediterranean case 29 April 2019

Impact of the assimilation of nadir SWH and spectra beam 6° Mediterranean case 29 April 2019

Sig. Wave Height

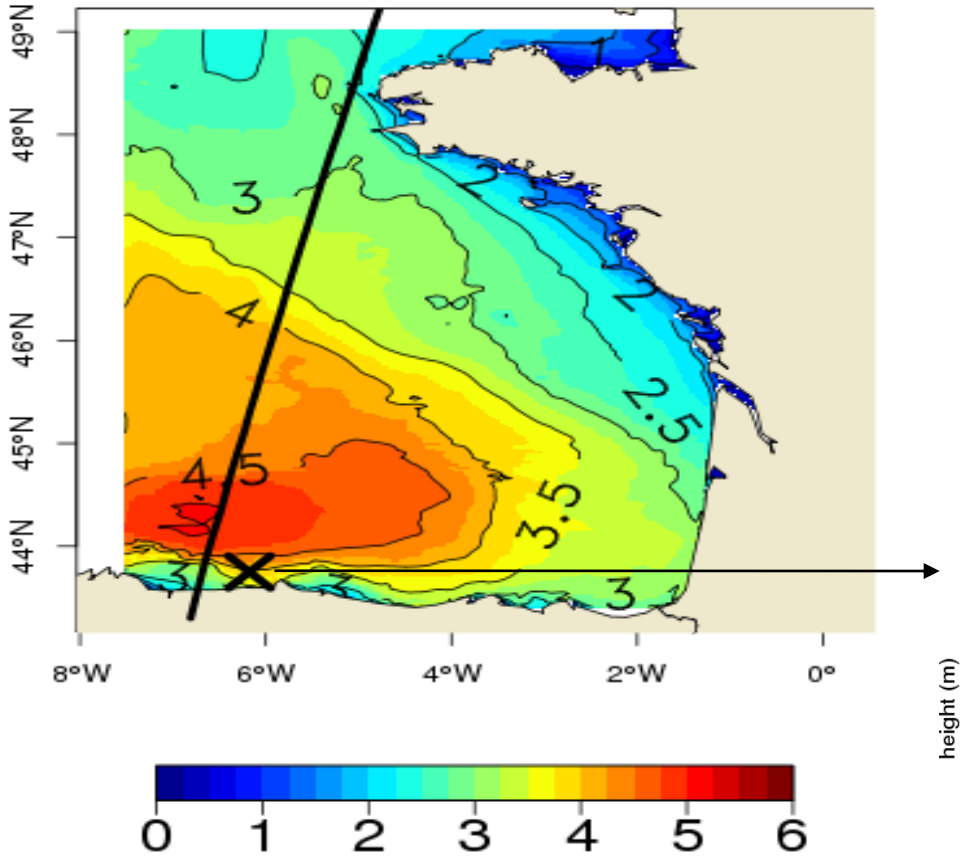


6-hourly difference of wave parameters from runs with and without assimilation of SWIM wave data, starting On 29 April at 0:00 until 30 April 2019 at 06:00

significant impact on SWH roughly 1 m after the passage of CFOSAT

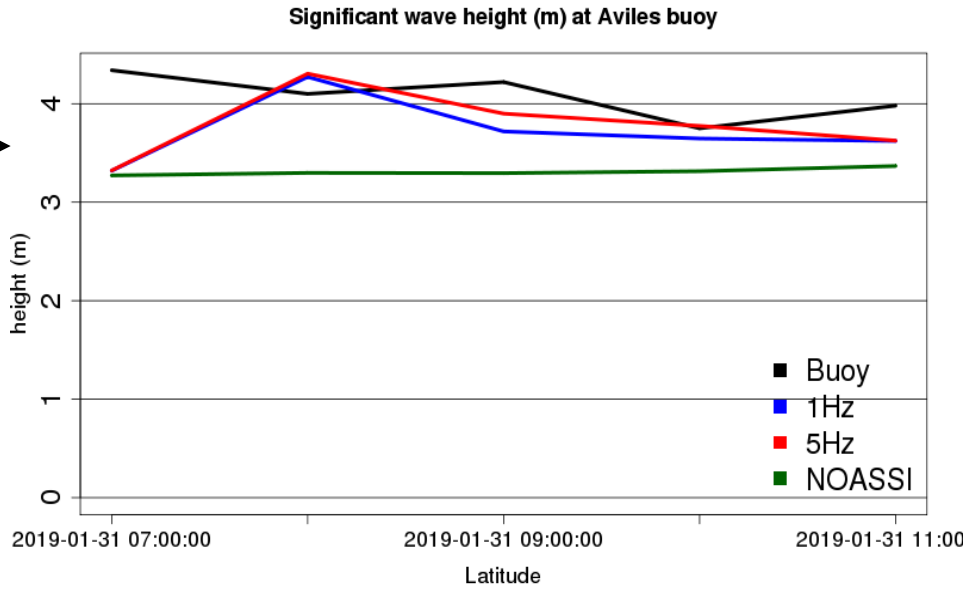
Impact of 5Hz SWH for coastal MFWAM model (along-track ~1.5km)

31 january 2019 at 08:00 (along-track)



The assimilation of 5-Hz induces a SWH closer to the buoys : promising for coastal applications

SWH time series in coastal buoy

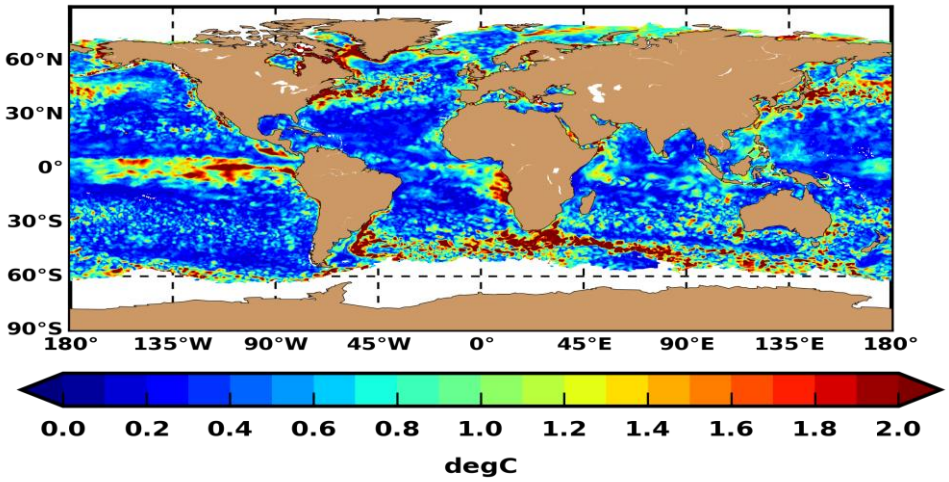


Comparison with Aviles spanish Coastal buoy

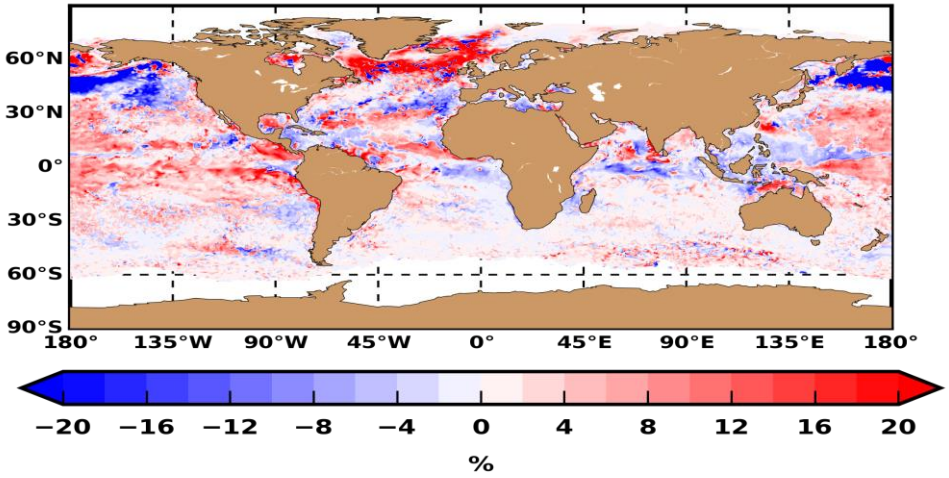
METEO FRANCE

Relevance of combined assimilation (Altimeters+SAR) on waves/ocean coupling (MFWAM/NEMO)

SST RMSE

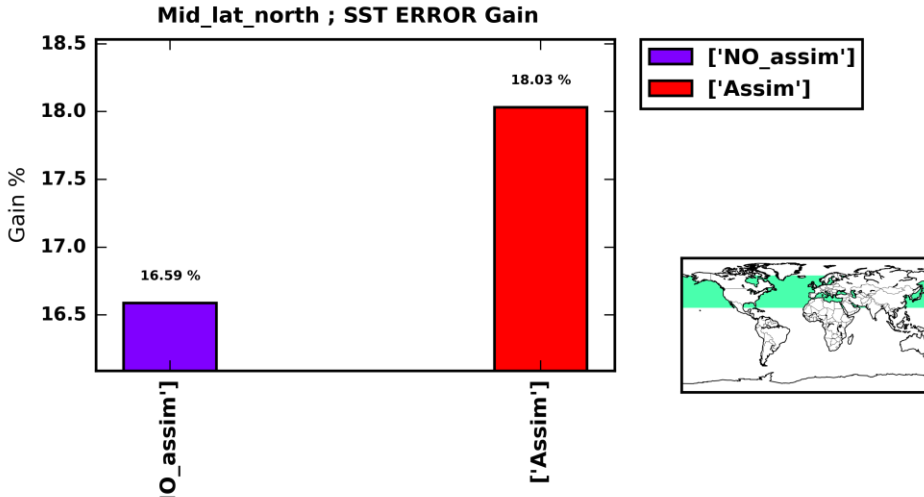


Improvement (%) of SST RMSE thanks to assimilation



Validation with OSTIA L4 SST for September 2016

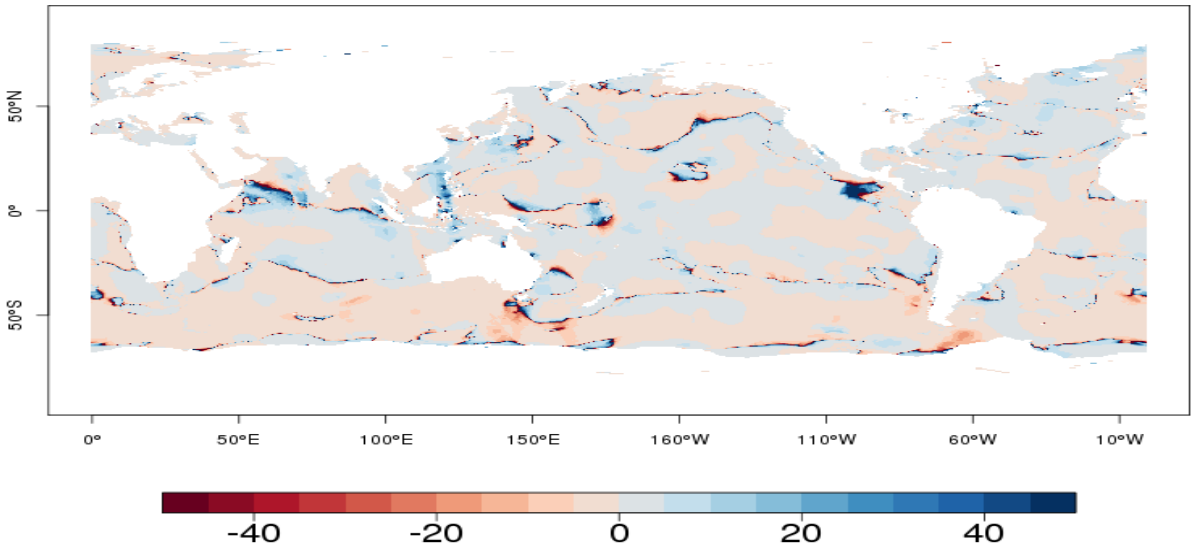
Northern mid-latitude gain index



Wave forcing with assimilation reduces SST bias in northern mid-latitude (hurricane and typhoon seasons)
The gain index is increased from 16.6 to 18 % when using the assimilation

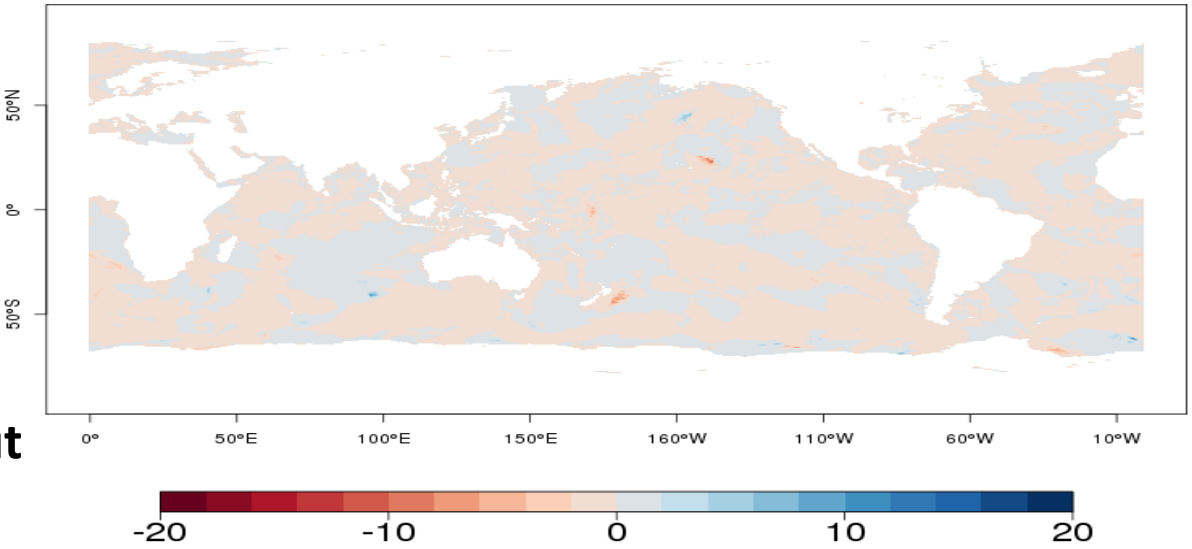
Impact of the assimilation of CFOSAT on waves forcing for NEMO : Stokes drift and TAUOC

Stokes U-component



Significant increment induced by the assimilation. It can Exceed 30 % for U-stokes. Very promising for coupling MFWAM/NEMO

Stress Mom. flux to Ocean Increment in average 5 to 10 %



Difference (%) with and without Assimilation on 7 May 2019 at 12:00UTC

Conclusions

■ **The assimilation of SWIM L2 Nadir and beam 6° or 10° spectra show significant improvement of SWH in the analysis and forecast period :**
➔This opens the use of SWIM-nadir SWH operationnaly (november 2019).

■ **The CFOSAT data are well skilled to correct efficiently models misfits in storms events (cyclones, typical mediterranean cases).**
➔ Look Forward to investigate the synergy between SWIM and SCAT data

■ **Wave spectra from SWIM shows good ability to capture partitions in mixed sea conditions. However work in progress to reduce speckle noise (upgrade processing expected in early 2020).**

■ **5-Hz SWH from CFOSAT shows a promising impact for coastal wave froecasting : good for coastal applications**

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Data release for users (Join the CFOSAT users !)

CFOSAT data access :
open very soon november 2019 for world wide operational and science users :

➔ On AVISO/CNES web portal :
Vist the link below for update and Cal/Val report

https://aviso.altimetry.fr/fr/missions/missions-en-cours/cfosat.htm

➔ On GTS (EUMETSAT) : (early 2020)

Welcome any feedback from users :
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lotfi.aouf@meteo.fr

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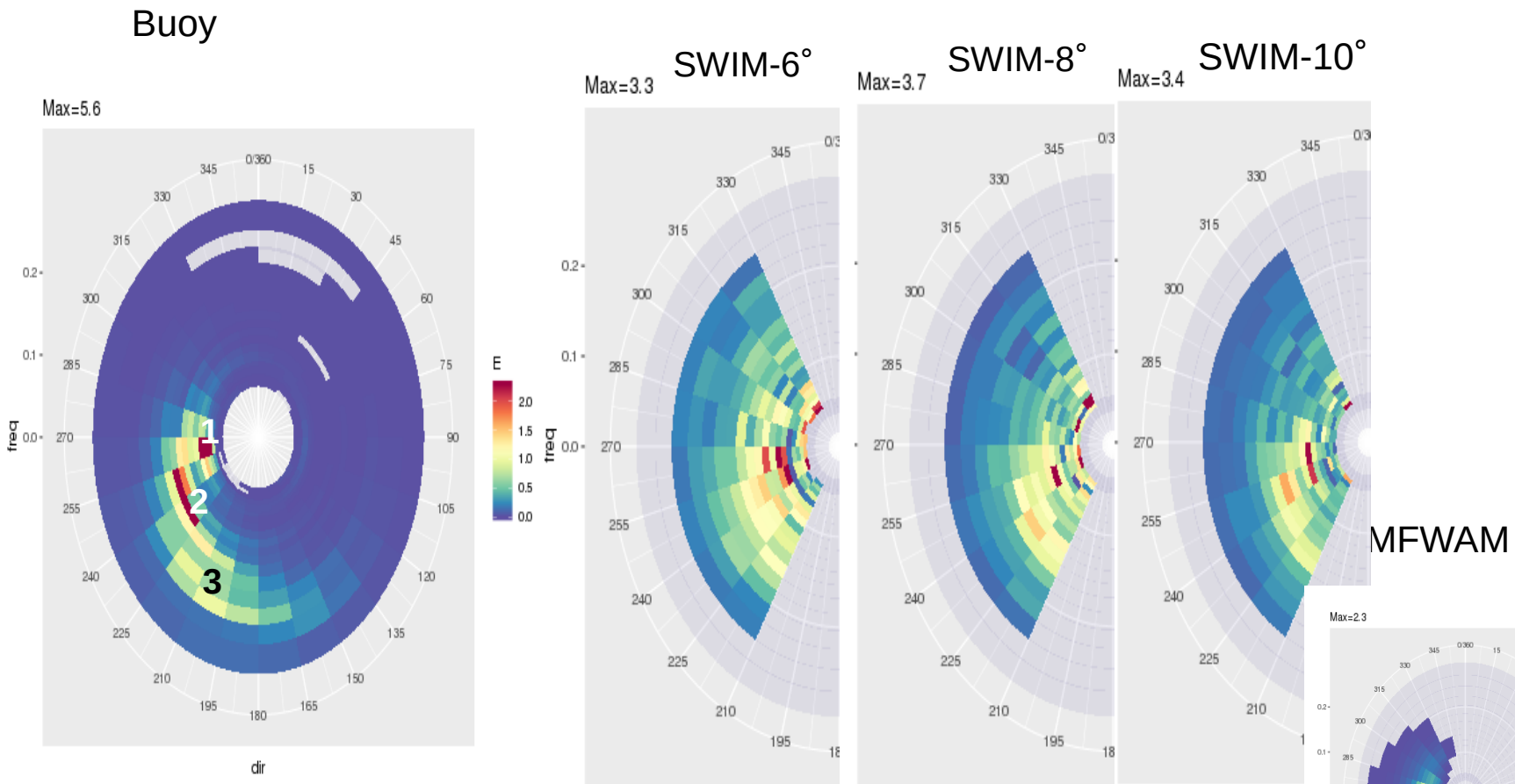
SWIM spectra compared to MFWAM and buoy data

example in a case of mixed sea in the Atlantic (brittany buoy)



Part 1 : westerly swell around 11s
Good represented by SWIM
Best direction with beam 10°
Best energy with beam 8° and 10°

Part 2 (swell of 6 s) and part 3 (wind wave) not well captured by SWIM