On the impact of the assimilation of ASAR wave spectra in the wave model MFWAM

Lotfi Aouf , Jean-Michel Lefèvre

Météo-France, Toulouse

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Outline

1- Motivation

2- Description of the new operational forecasting system
- New model MFWAM
- Assimilation suite

3- Validation of the operational wave parameters

4- Results on the optimization of the assimilation scheme

5- case of high sea conditions (hurricane KATIA Aug-Sep 2011)

6- Conclusions and future works

Motivation

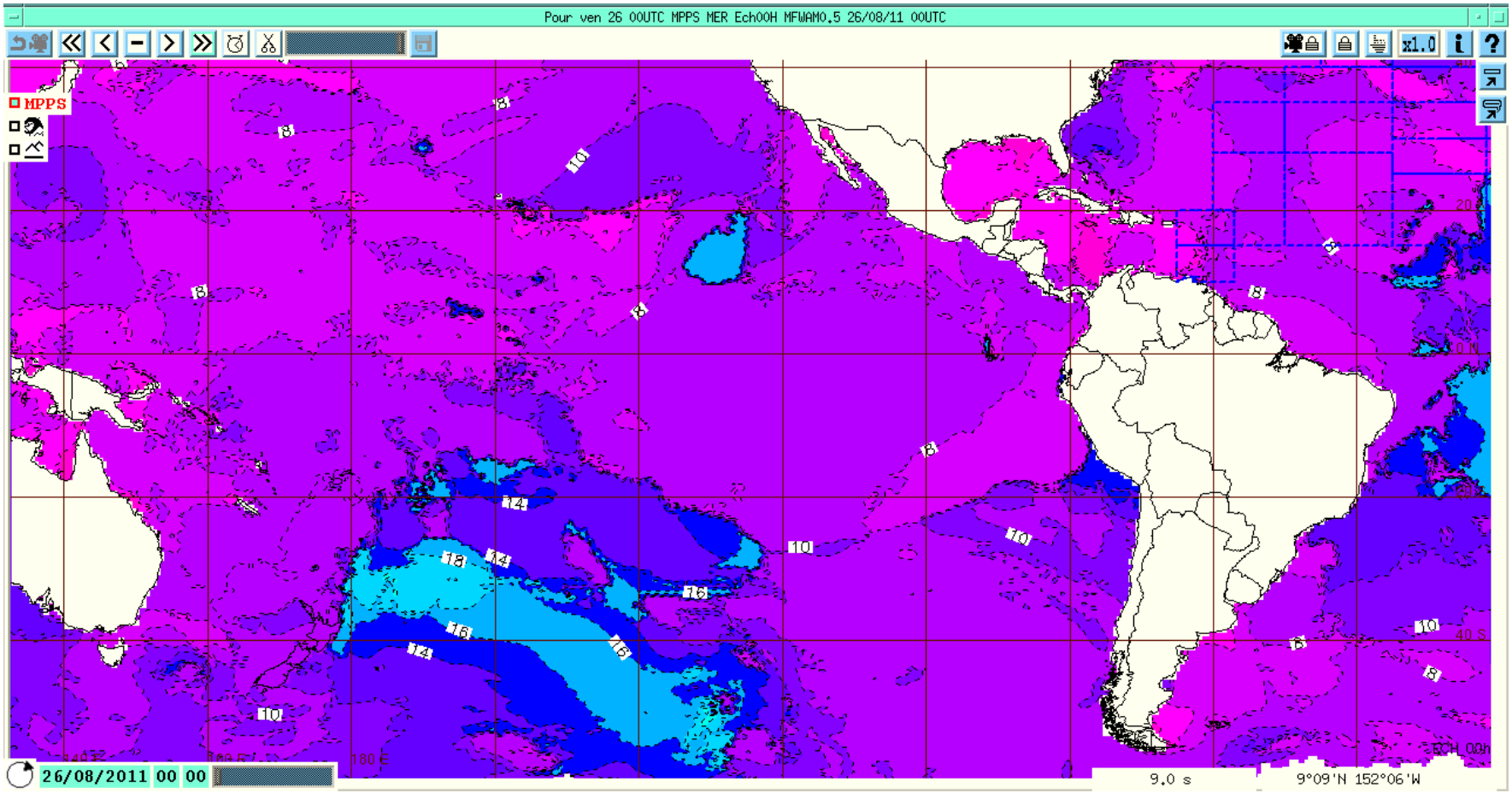
→ Assessement of the assimilation system in the new wave model MFWAM (improving the wave forecast)

→ improve high seas forecast (case of hurricanes) : better boundary conditions for regional models

→ Evaluate the contribution of each instrument of satellite wave observations (SAR, altimeters,)

→Preparation to future satellite missions CFOSAT (low cut-off ~70 m) complementary use of different instruments (ASAR, SWIM,Jason-3..)

Relevance of using good swell conditions in the generation zone



Meteo-France is responsible for issuing marine forecasts (wind and sea-state) at national level (Safety of people and goods, Navy, …) and international level (GMDSS: Global Maritime

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The new wave model MFWAM

-Based on ECWAM code with new physics for dissipation: (Ardhuin et al. 2010, JPO)

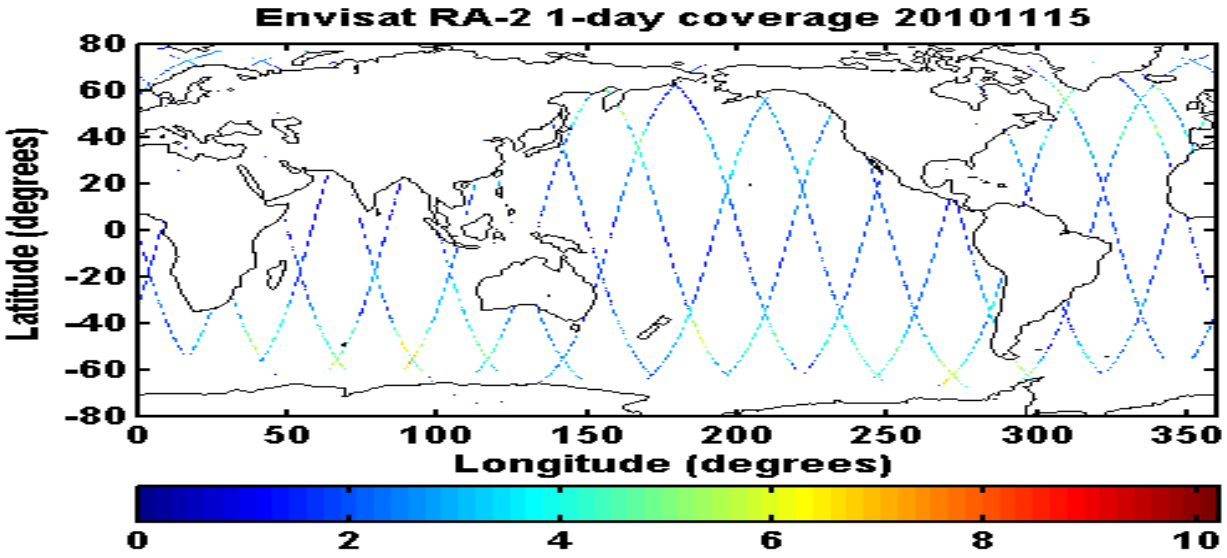
- Non isotropic dissipation:
-> Better adjustment of the mean direction and angular spreading

- Threshold mechanism from the saturation spectrum , instead of mean wave steepness dependency
Breaking term:

- New term for swell damping due to air friction

The assimilation system

- Assimilation of altimeters RA2 and Jason-2
  - → Optimal interpolation on SWH (Significant wave height)
  - → Correction of wave spectra using empirical laws and assumptions



ENVISAT RA-2

Example of 1 day global coverage
of total wave height

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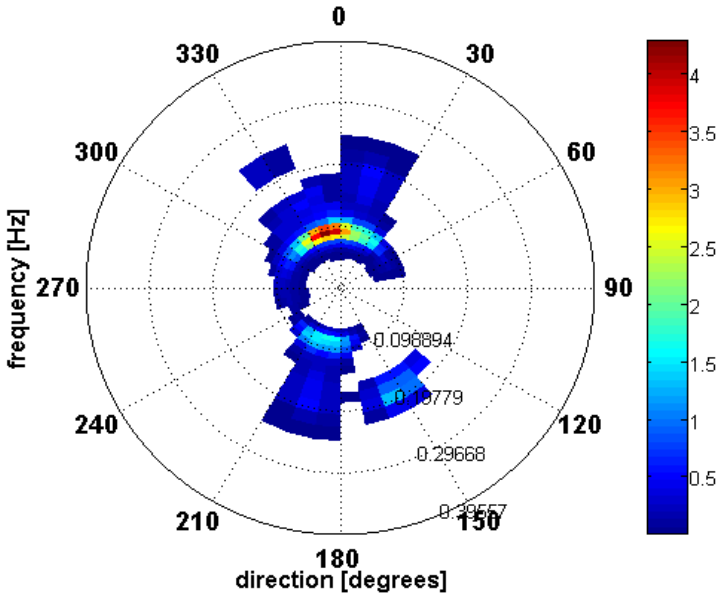
The assimilation of ASAR L2 wave spectra

- Available on the GTS of meteorological services since August 2010
- Robust Quality control procedure for ASAR wave spectra (Aouf et al. 2008)

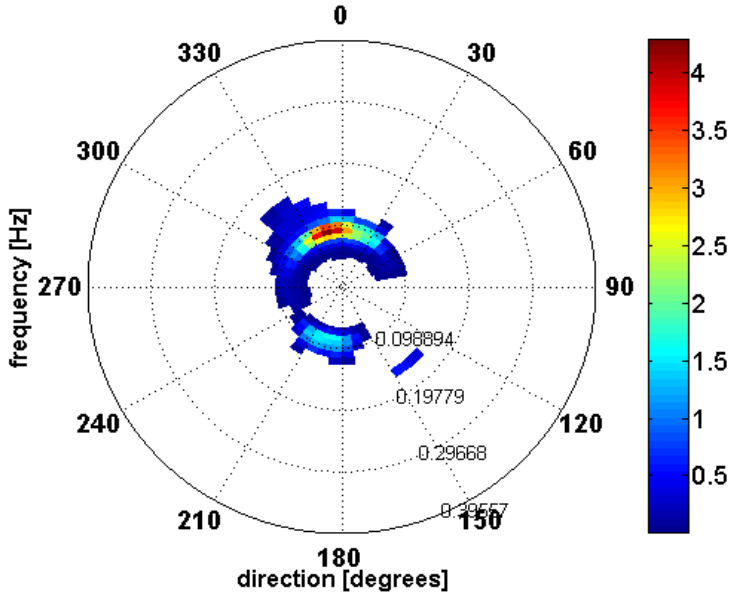
Threshold intervals for signal parameters (3<snr <30, NVI ASAR imagettes 1-1.6 and wind speed)

- Use of a variable cut-off for SAR wave spectra depending on the azimuthal cut-off, the orbit track angle and the wave direction from the model

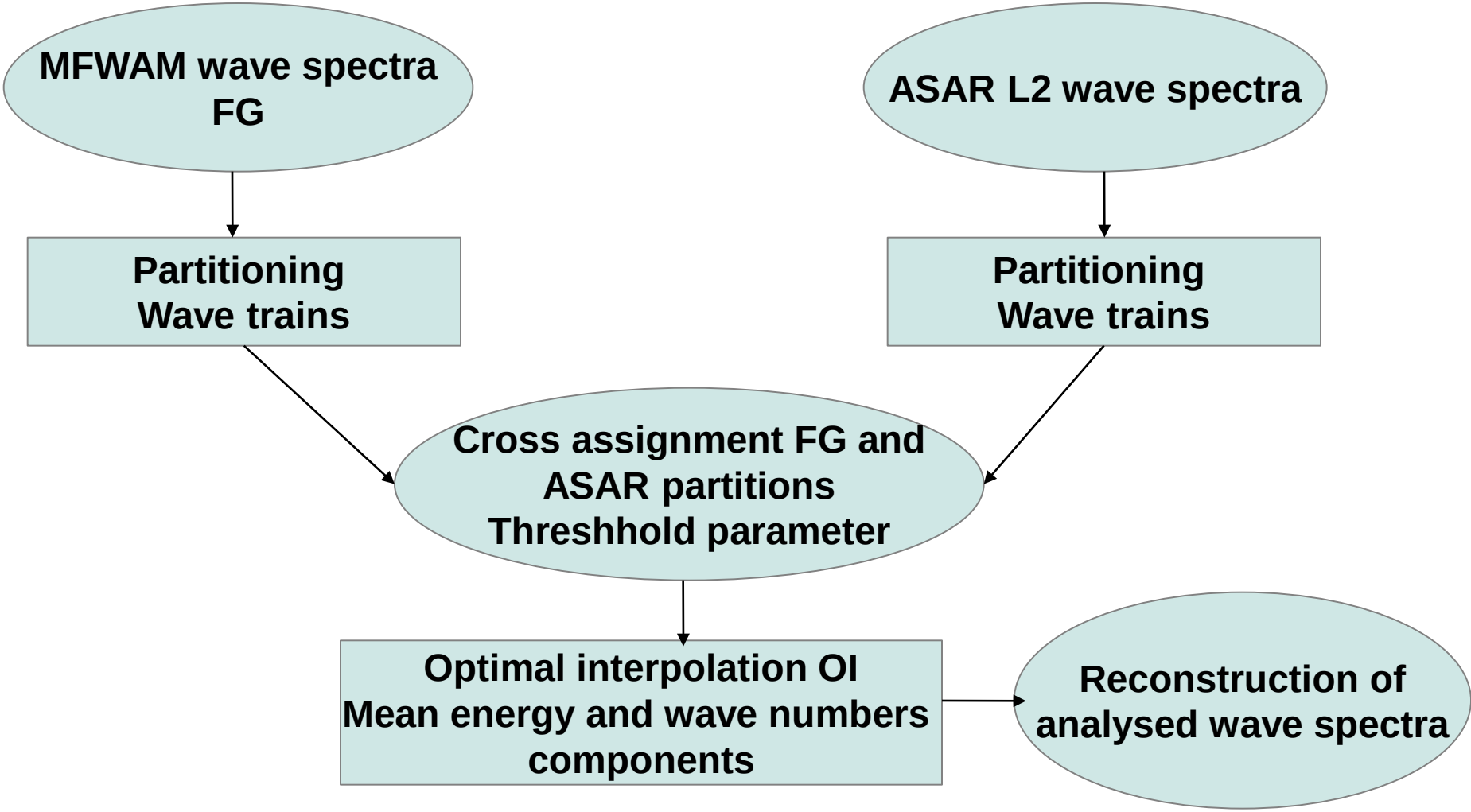
ASAR wave spectrum (before cut-off)



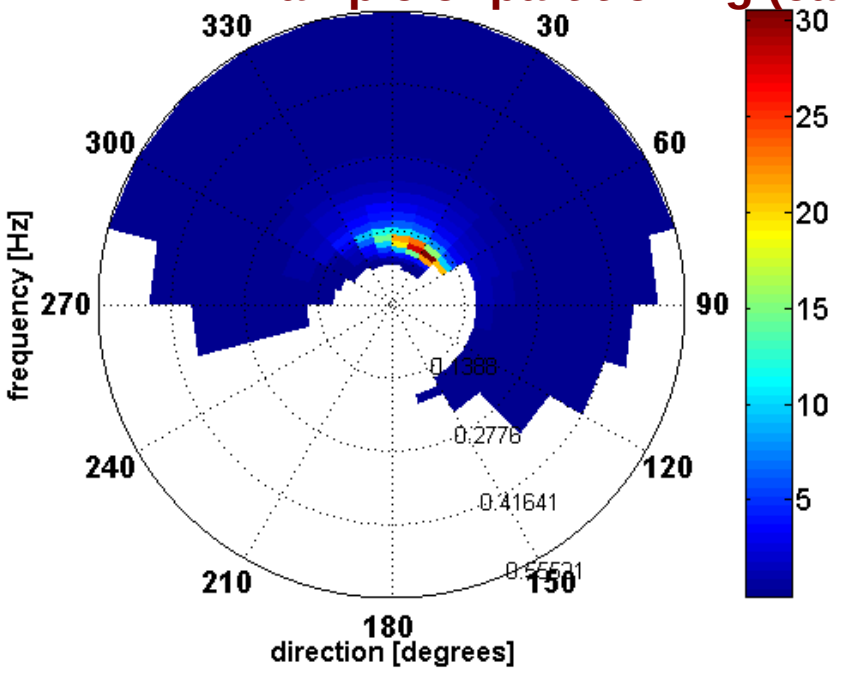
After using variable cut-off

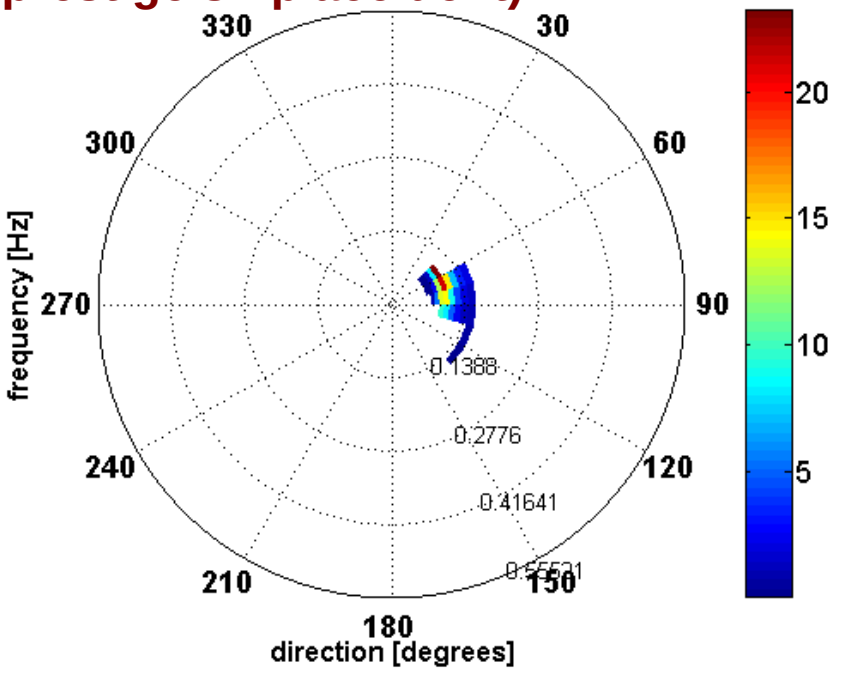


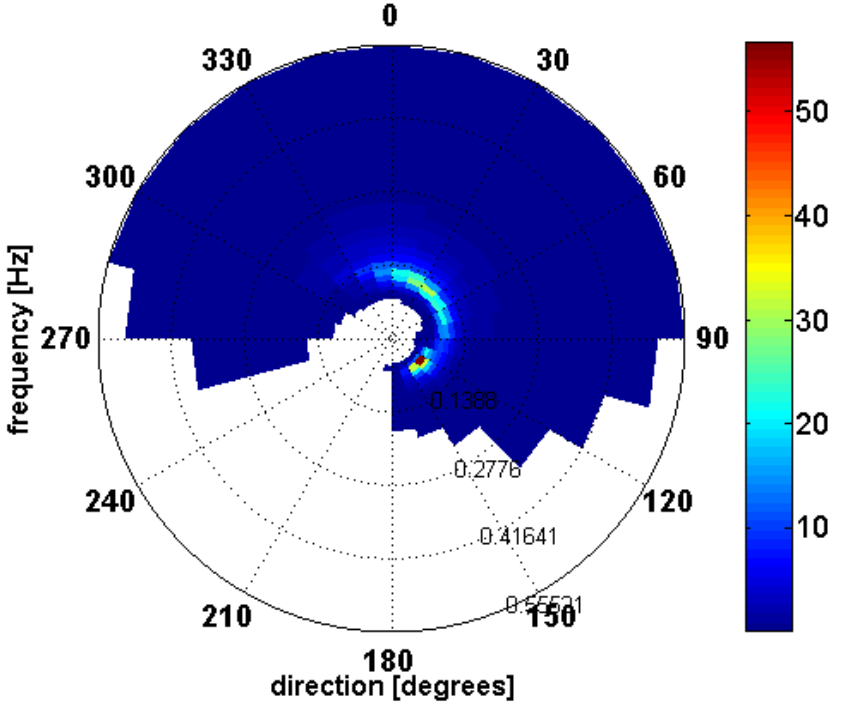
Description of the assimilation of ASAR L2 wave spectra

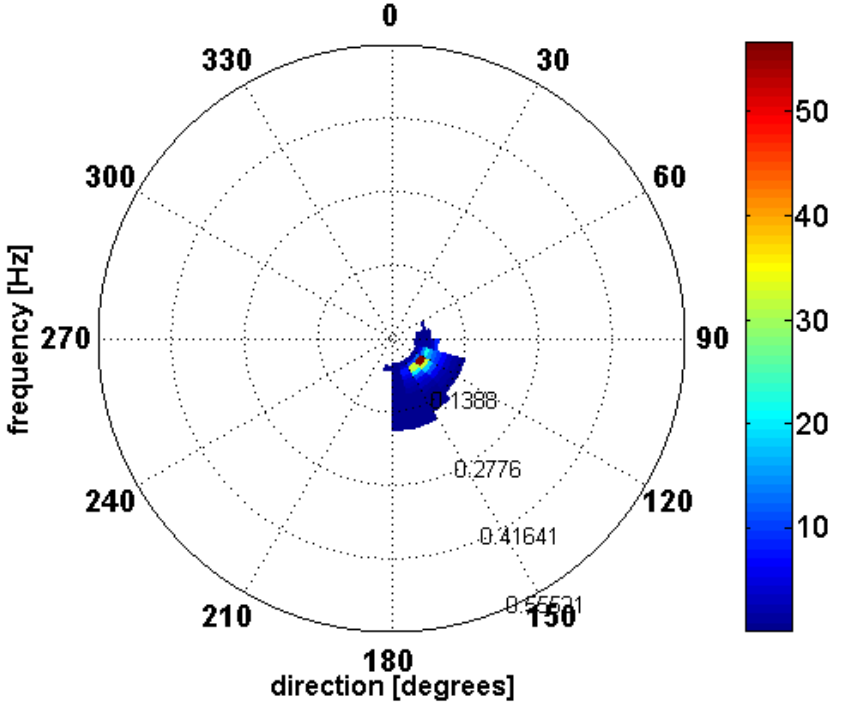


Example of partitioning (case of prestige ship accident)









Optimal interpolation

$$X^a = X^f + \sum_i^N W_i (X_{i^o} - HX_{i^f})$$

Where Xa and Xf stand for the analysed and first-guess wave parameters (energy, wave umber)

The corrected weights depend on the covariance error matrix :

$$W = PH^T \left[HPH^T + R \right]$$

P and R are respectively the background and observations covariance errors. While H is location operator

$$P = \sigma_i^f \sigma_j^f \exp\left(- \left(\frac{d_{ij}}{\lambda_c} \right) \right) \quad \text{and} \quad R = \sigma_o^2$$

σ indicates the standard deviation and d is the distance between the observations and affected grid points. While l stands for the λ correlation length.

New wave forecasting system of Meteo-France:

- Global version of the model MFWAM is running at 55 km resolution driven by wind forcing of ECMWF, the grid is irregular in longitude
- The wave spectrum resolution is 24 directions and 30 frequencies
- The assimilation uses altimeters and ASAR L2 wave spectra available on the GTS since August 2010. the time step is 6 hours and the analyses are produced 2 times a day (R0 and R12)
- The output of 32 mean wave parameters is produced every 3 hours and archived in the MF data base (BDAP)
- Boundary conditions are produced for two regional models :

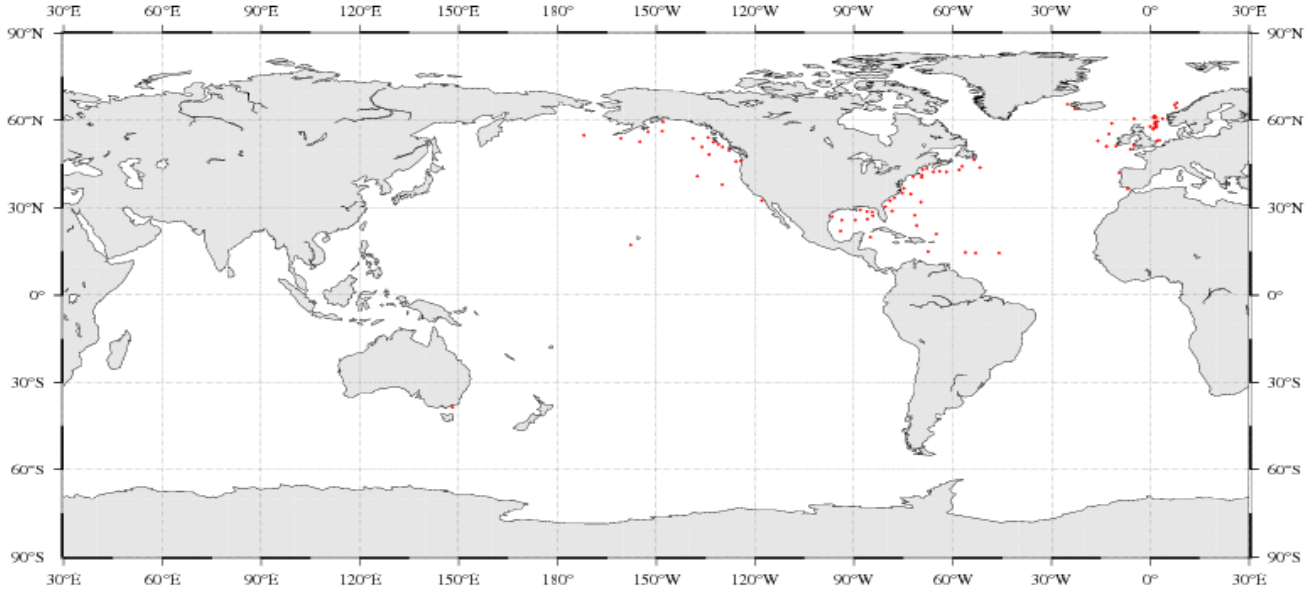
Regional version at 0.25 ° resolution running over South Indian Ocean

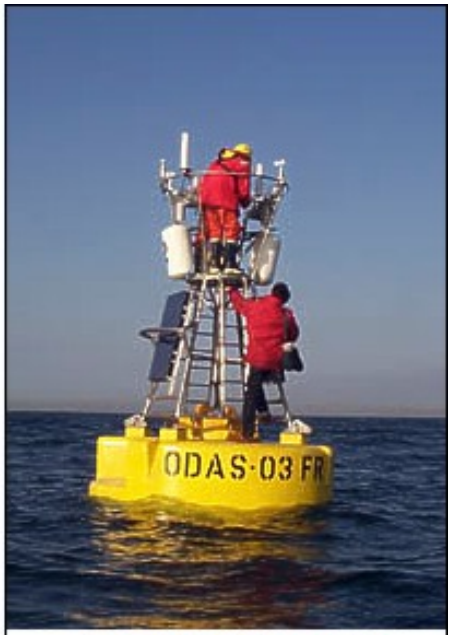
Regional versions for European Aera at 10 km resolution

VALIDATION OF SWH WITH BUOYS DATA

Data are collected from April to December 2011 (JCOMM model intercomparison archive produced by J. Bidlot (ECMWF))

Location of common Automatic Weather Stations AWS (wind + waves), all real time and on GTS





Bouée 03FR le 16 mars 1999

Photo Météo-France

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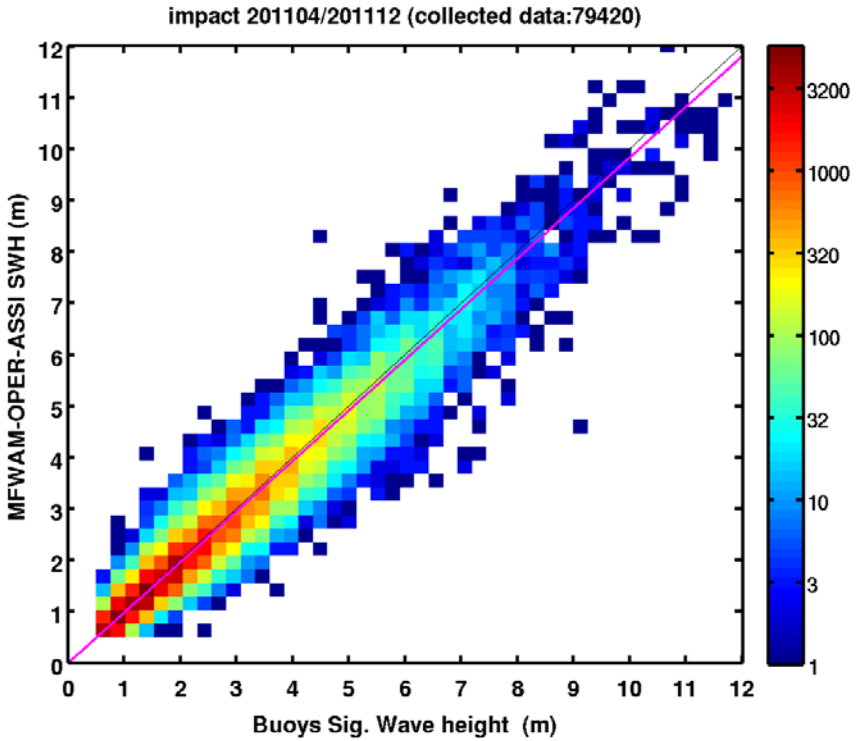
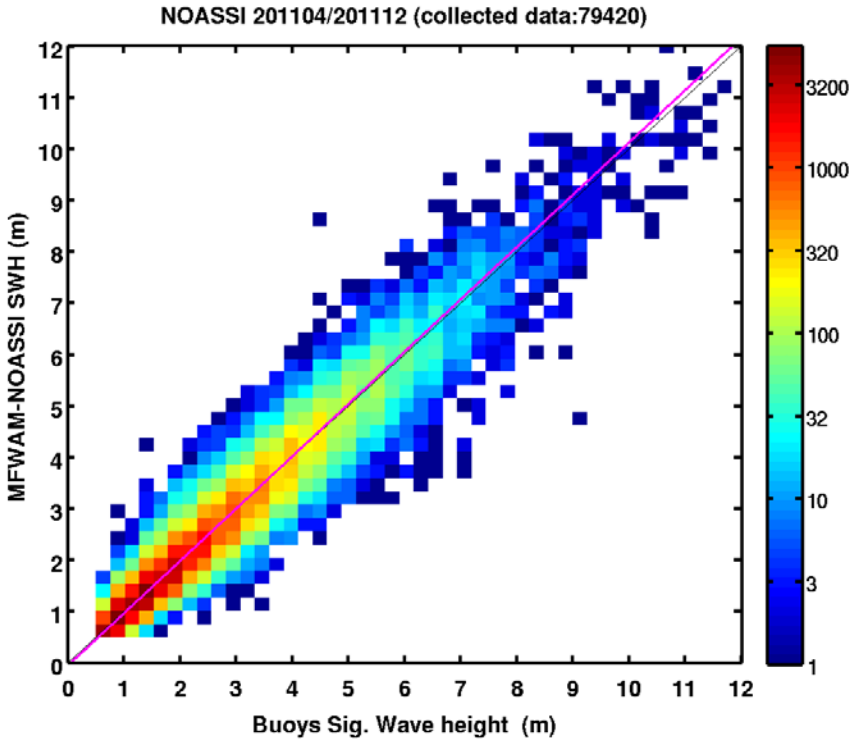
Scatter plots of Sig. Wave Heights from MFWAM operational system and Buoys

Operational with assimilation of SAR Jason-2 and Envisat Ra2



Bias = -0.04
SI = 15.1%
NRMS = 15.3%
Slope = 0.98
Intercept = -0.01

Run without assimilation



Bias=-0.01
SI=16.1%
NRMS=16.4%
Slope=1.02
Intercept=-0.05

Data collected : 79420

April to December 2011

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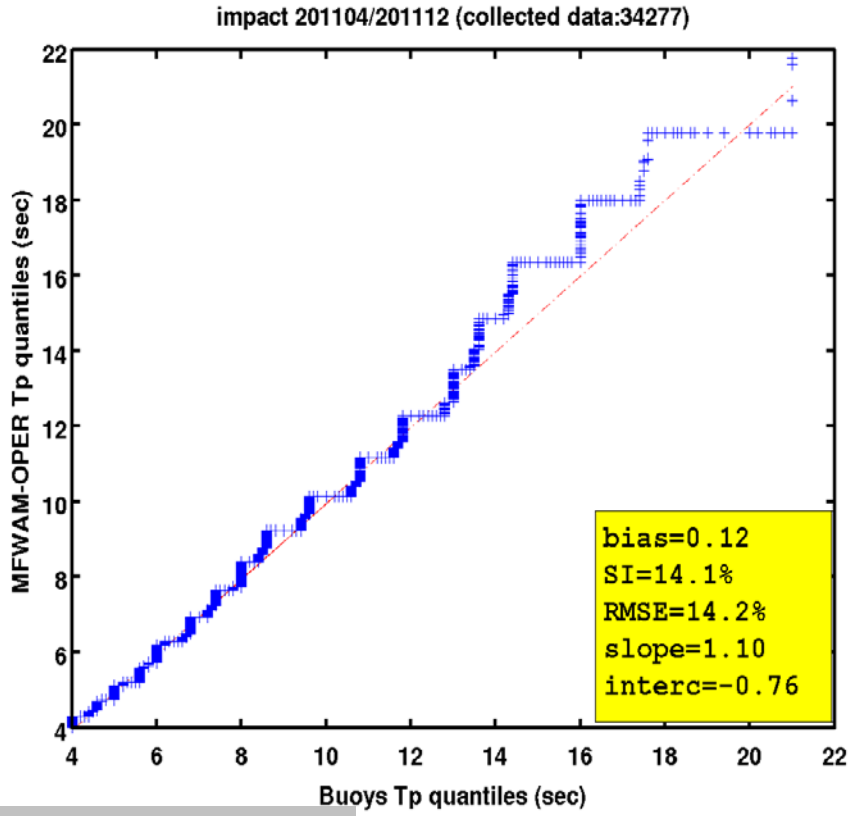
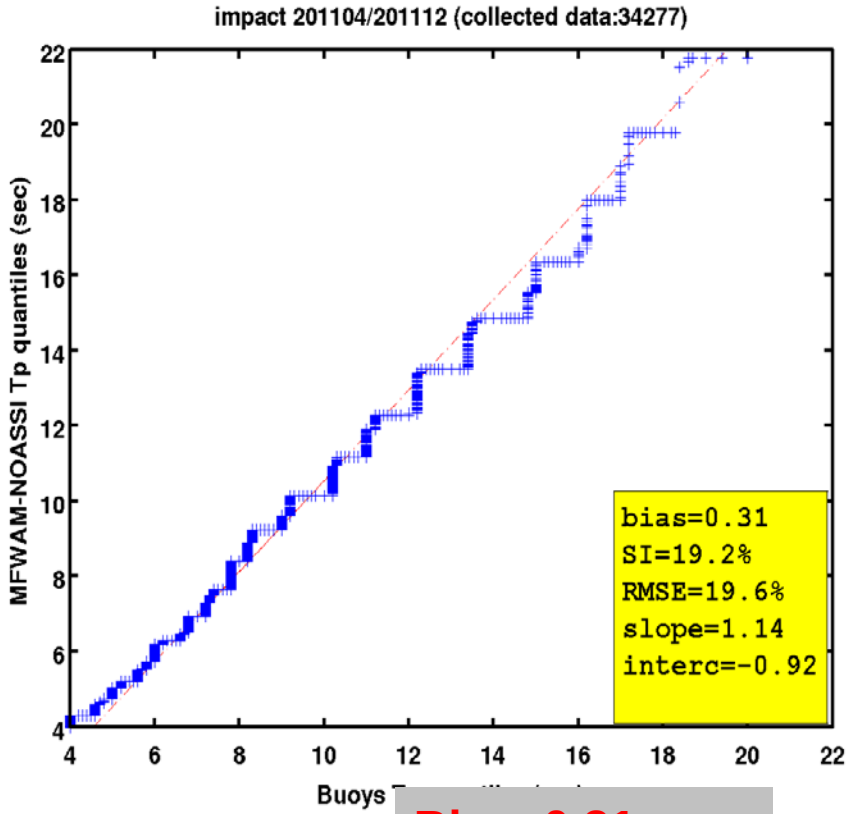
Output from MFWAM operational forecasting system
Q-Q plot of Peak period Tp from MFWAM andBuoys (North America)

Operational with assimilation of SAR Jason-2 and Envisat Ra2



Run without assimilation



Bias = 0.12
SI = 14.1%
NRMS = 14.2%
Slope = 1.10
Intercept = -0.76

Data collected : 34277

Bias=0.31
SI=19.2%
NRMS=19.6%
Slope=1.14
Intercept=-0.92

April to December 2011

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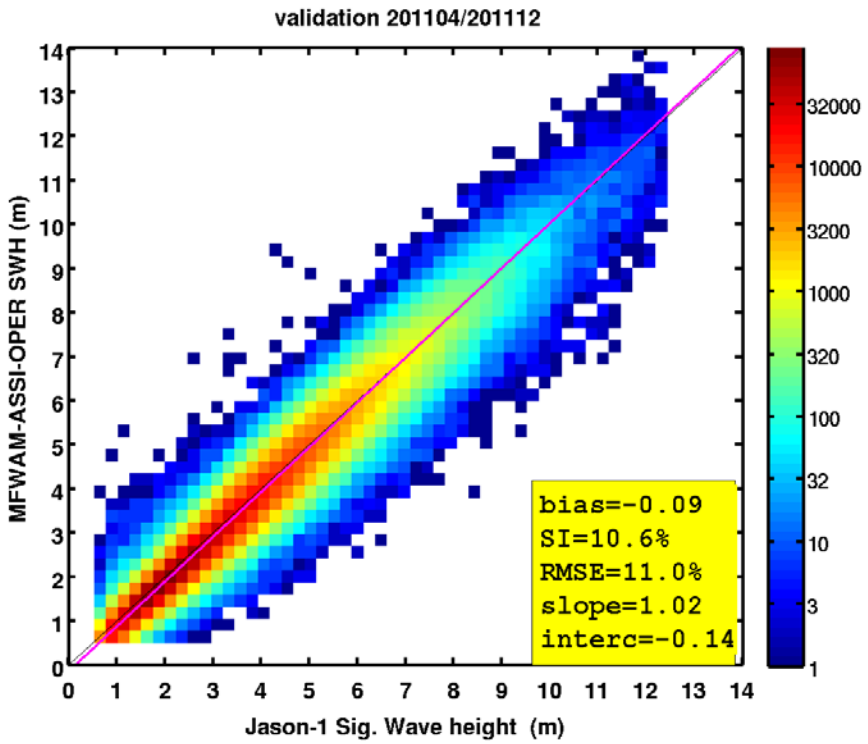
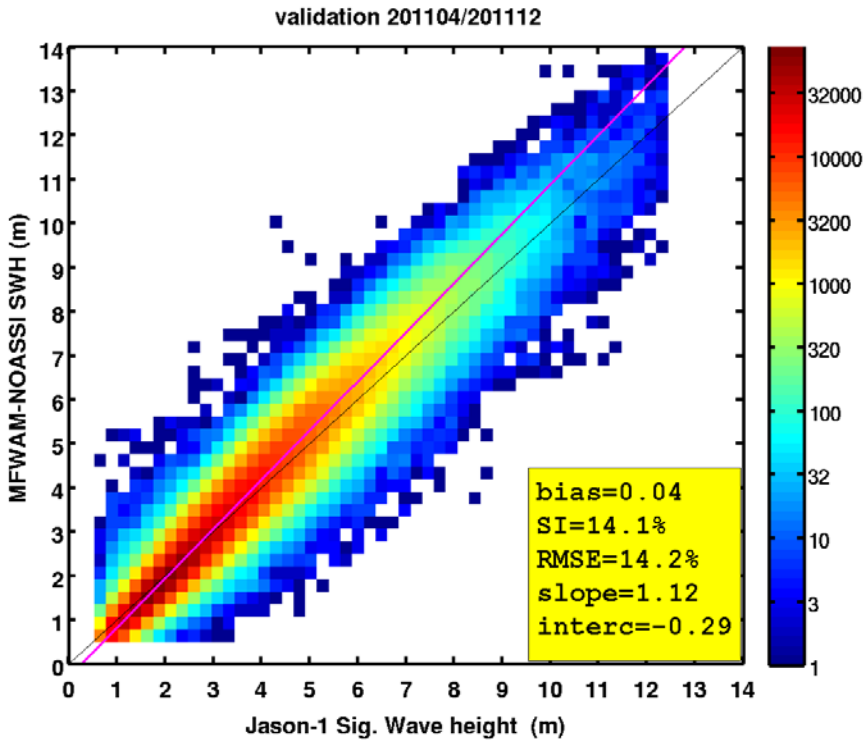
VALIDATION WITH JASON-1 Sig. Wave Height (Jason-1 data not assimilated in 2011)

Output from MFWAM operational forecasting system
Validation with Jason-1 Sig. wave heights

Operational with assimilation of SAR Jason-2 and Envisat Ra2



Run without assimilation



Bias = -0.09
SI = 10.6%
NRMS = 11.0%
Slope = 1.02
Intercept = -0.14

Data collected : 170942

Bias=0.04
SI=14.1%
NRMS=14.2%
Slope=1.12
Intercept=-0.29

April to December 2011

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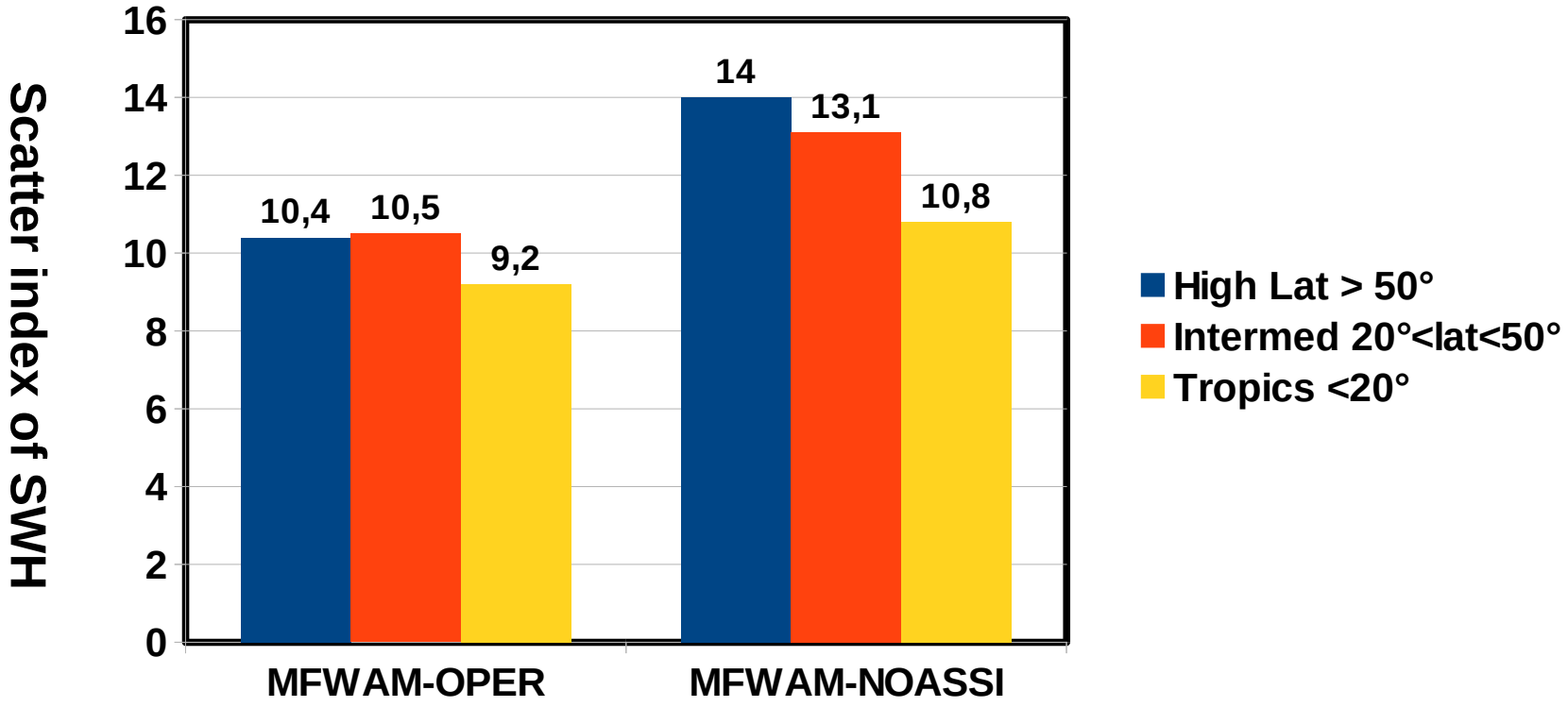
Output from MFWAM operational forecasting system
Validation of with Jason-1 Sig. Wave height (off assimilation)

Since starting the assimilation of ASAR directional wave spectra and both Jason-2 and Ra2 atlimeters wave heights

Statistics for different ocean basins



Collected Jason-1 data: 1701942

April to December 2011

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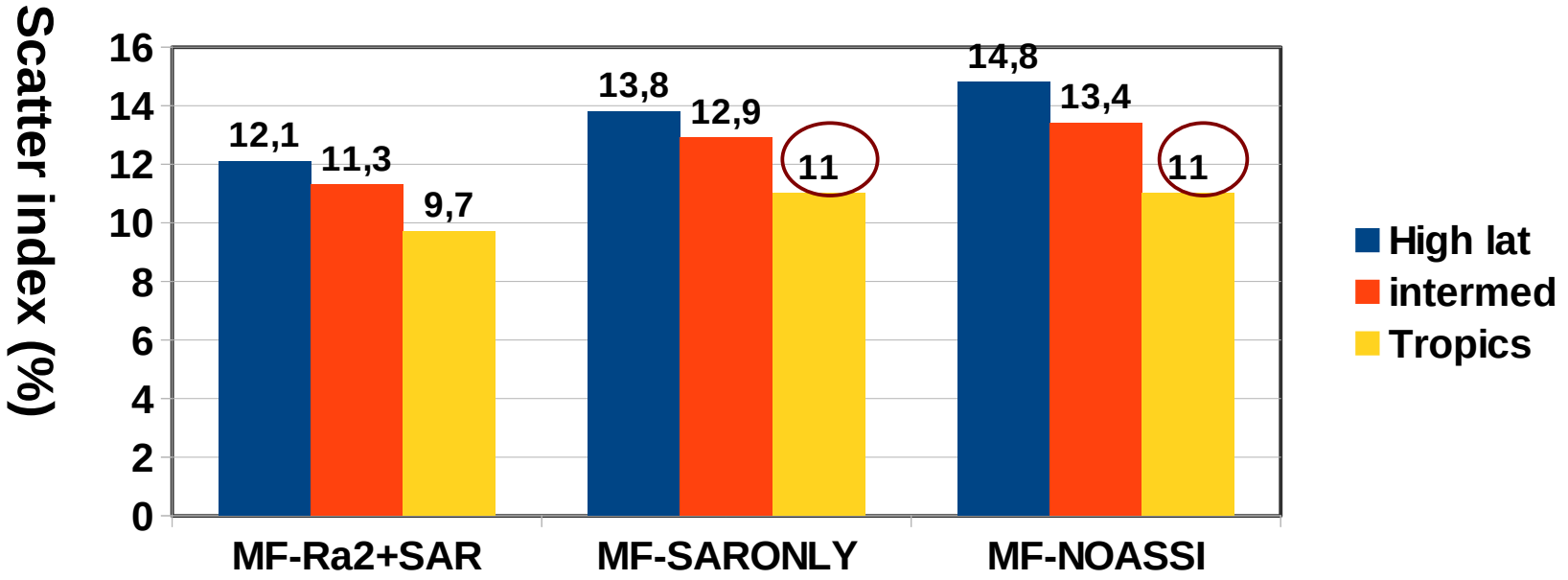
Results on the assimilation of ASAR L2 only
Comparison with jason 1 & 2 wave height

MF-Ra2+SAR : MFWAM with the assimilation of Envisat Ra2+SAR
MF-NOASSI : MFWAM without assimilation
MF-SARONLY : MFWAM with assimilation of SAR only

Statistics for different ocean basins



Because of the new Dissipation in the MFWAM, there is no impact in the tropics

Sep. 2010 to March 2011

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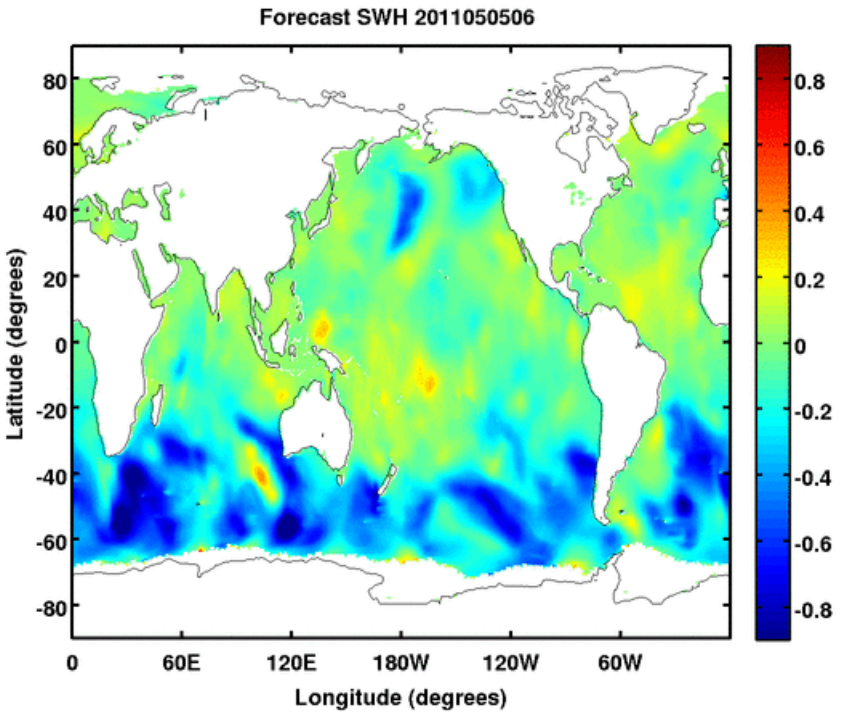
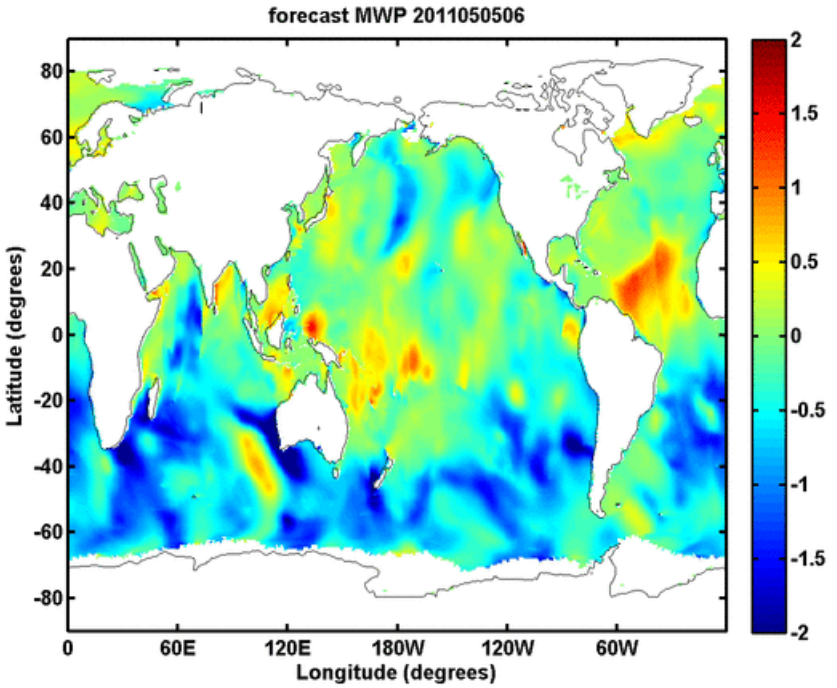
Impact of the assimilation in the forecast period

SWH



Mean Wave Period



Difference between runs of MFWAM with and without assimilation

3-day forecast starting from 5 May 2011, by step of 6 hours

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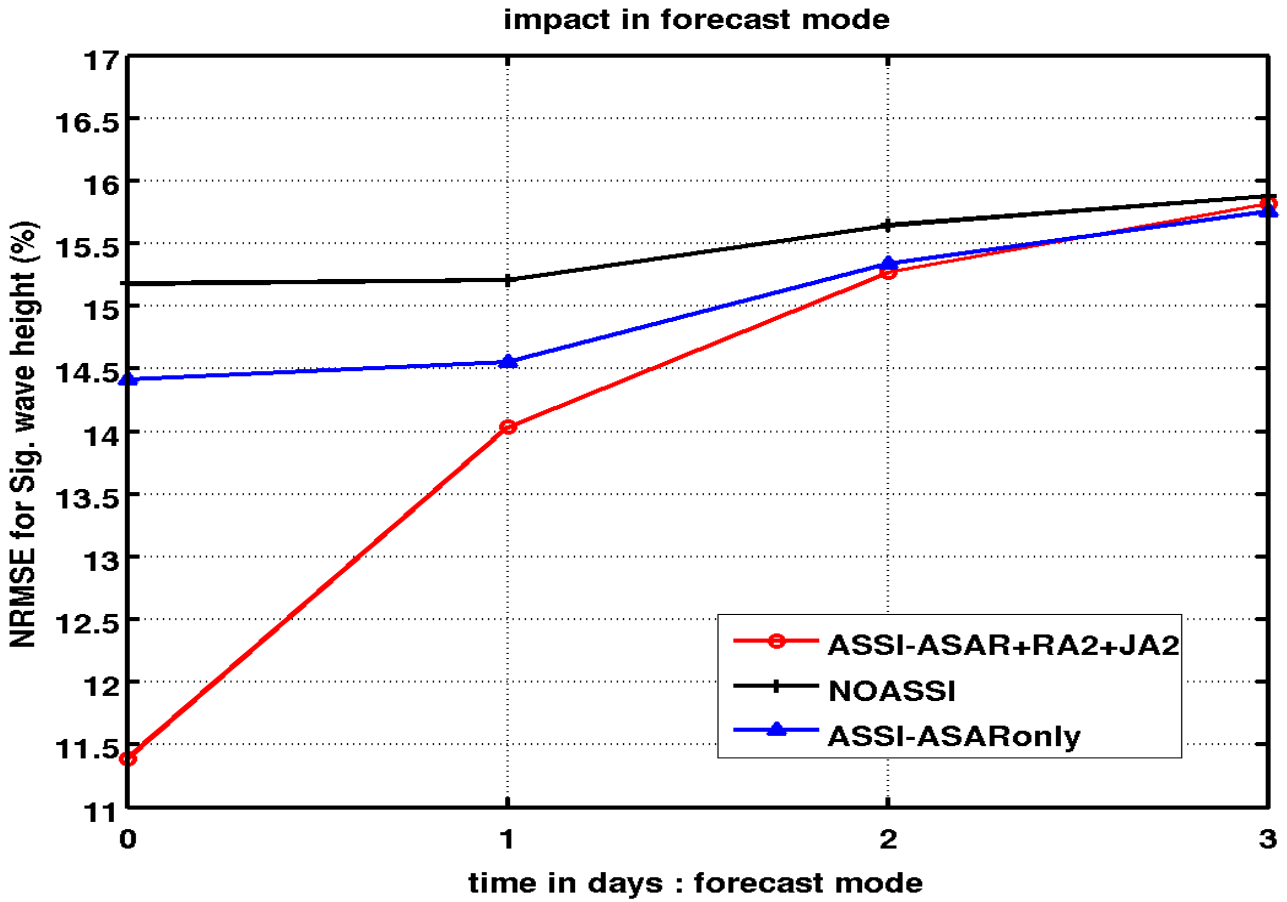
Impact of the assimilation of Altimeters and ASAR wave data
Period of forecast

→ Positive impact for the significant wave height

4-day forecast



1 is 0-24h average period, 2 is 24-48h,….

Comparison with Jason-2 and Envisat Ra-2 in the period of forecast

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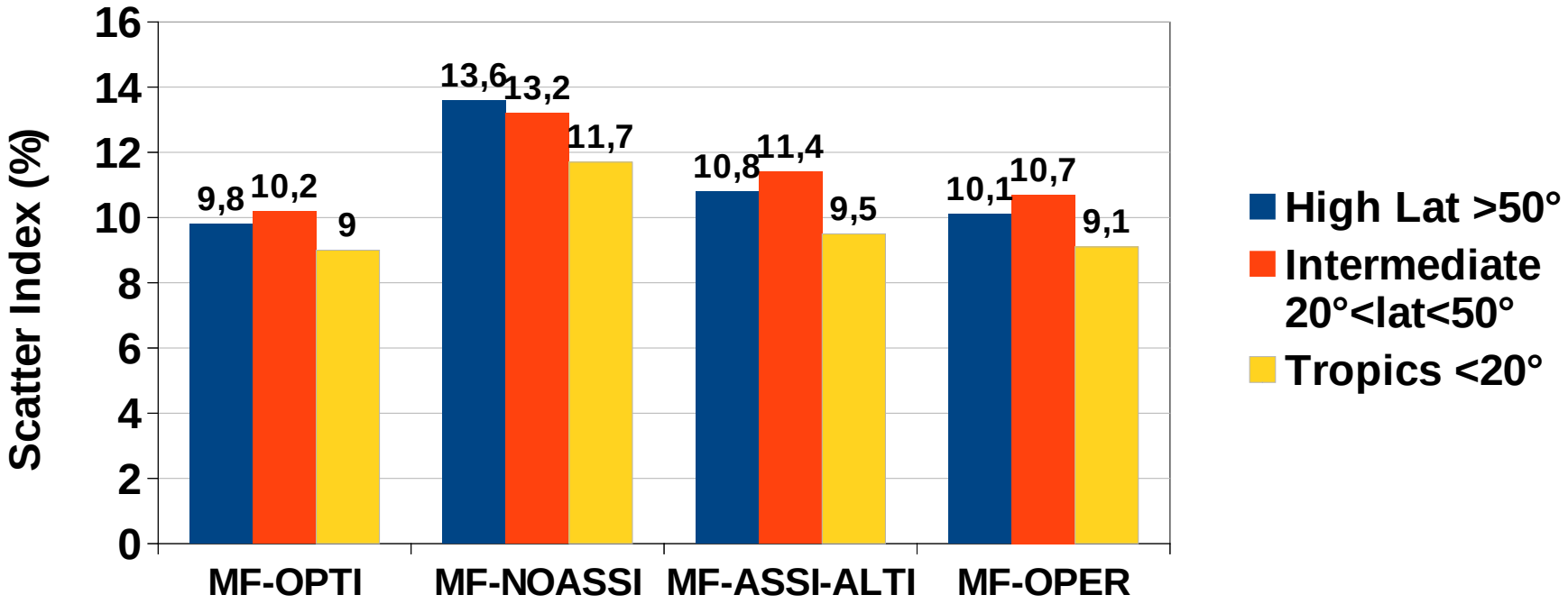
Optimization of the assimilation scheme

- Adjustment of the correlation legnth and the distance of influence of the ASAR wave spectra
- Adjustment of threshhold level for combining two peaks of partitions when they are close to each other
- Smoothing of the filling gaps between the analysed partitions in order to reconstruct the analysed wave spectrum
- Reject the partition when the wave height of the partition exceeds 30 cm in order to avoid noisy spectrum
- Run test of 3 months (April to June 2011)

Optimization of the assimilation scheme
Validation with Jason-1 Sig. Wave height (off assimilation)



MF-OPTI : MFWAM with the optimized assimilation scheme
MF-NOASSI : MFWAM without assimilation
MF-ASSI-ALTI : MFWAM with assimilation of altimeters only
MF-OPER : MFWAM operational (with assimilation of SAR and Ja2 and Envisat)

3 month test : April to June 2011

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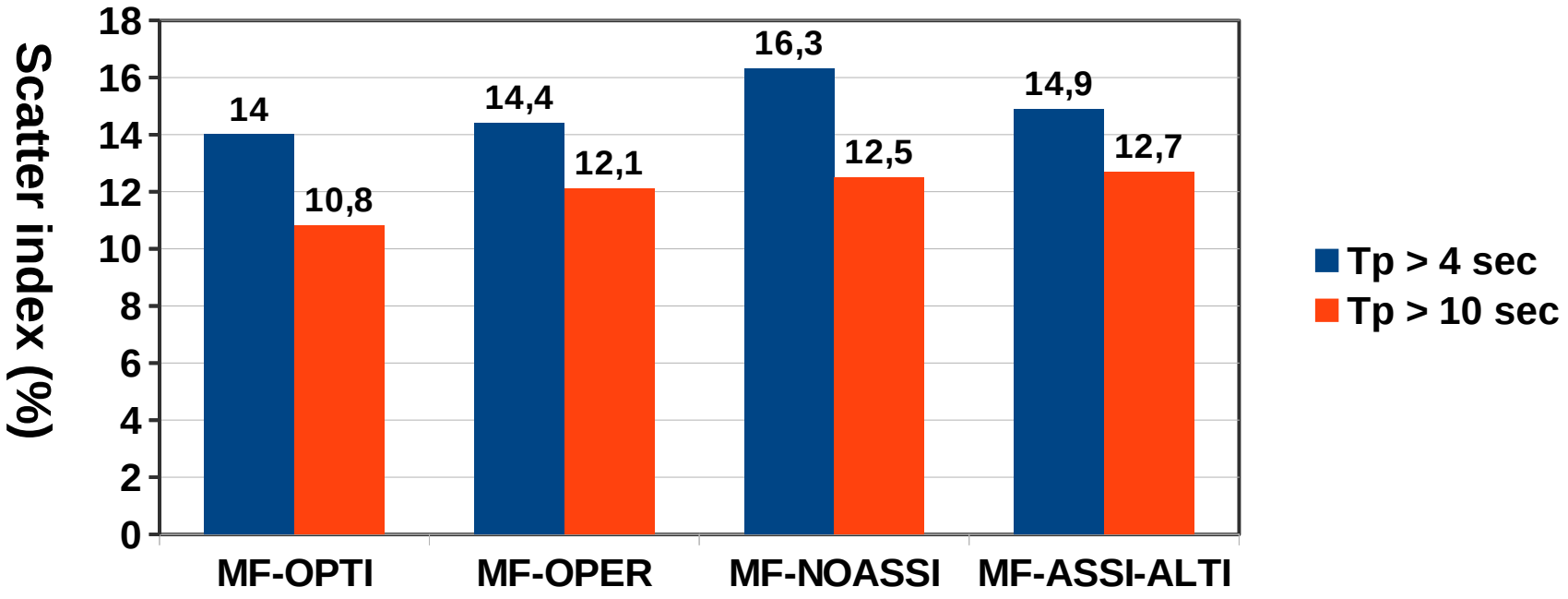
Optimization of the assimilation scheme
Validation with buoy peak period Tp (NA)



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MF-ASSI-ALTI : MFWAM with assimilation of altimeters only
MF-OPER : MFWAM operational (with assimilation of SAR and Ja2 and Envisat)

3 month test : April to June 2011

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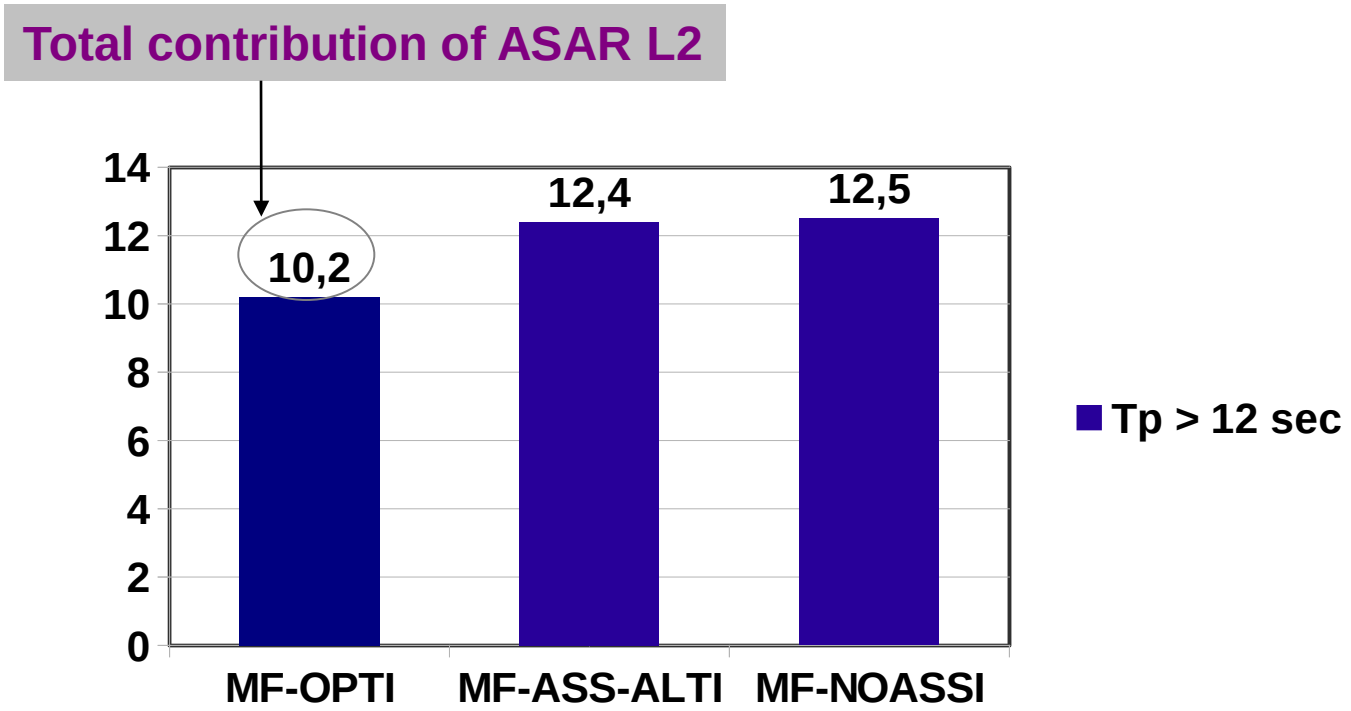
impact of the ASAR on peak wave period (Tp>12 sec)



MF-OPTI : MFWAM with the optimized assimilation scheme
MF-NOASSI : MFWAM without assimilation
MF-ASSI-ALTI : MFWAM with assimilation of altimeters only

3 month test : April to June 2011

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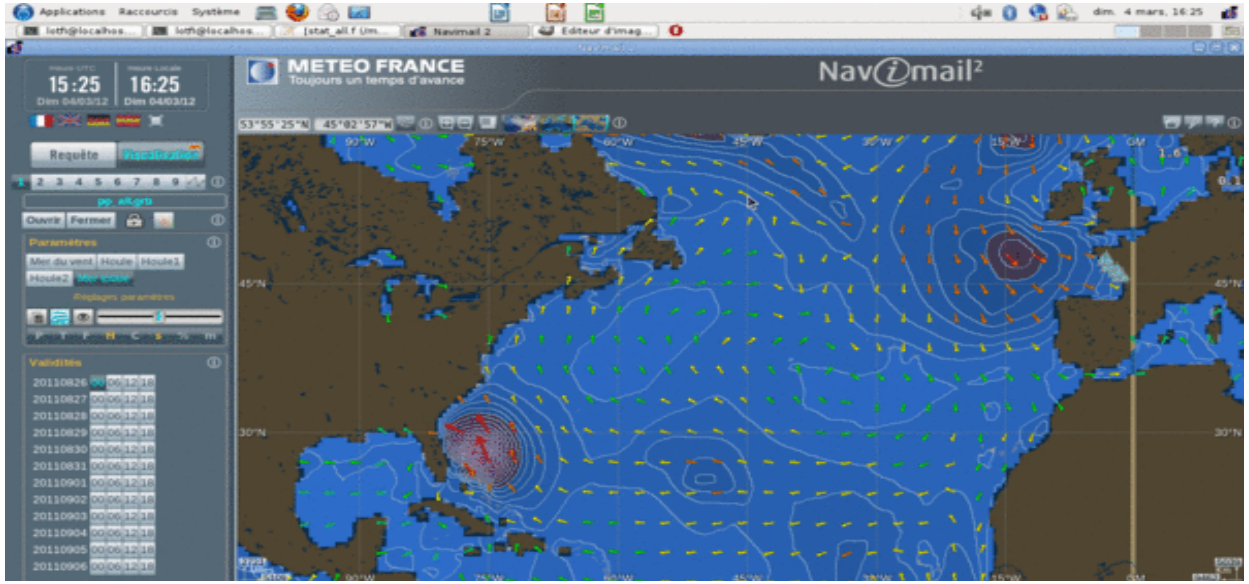
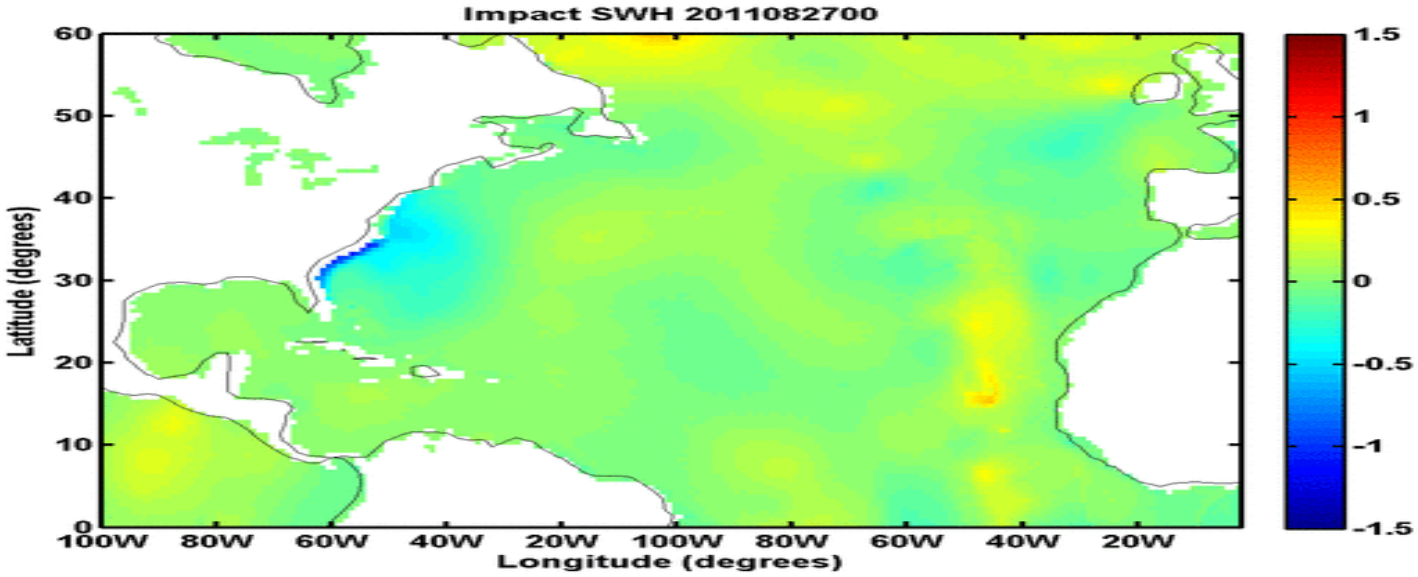
Impact of the assimilation in hurricane season 2011 (Hurricane Katia)

Snapshot of SWH from operational MFWAM



From August 26 to Sep 6, 2011

Increment induced by the assimilation (Analyses-without assimilation) with a step of 6 h



Impact of the assimilation in case of hurricanes validation of Sig. Wave height with Jason-2

Statistics of Sig. Wave height (NA domain)

	A	B
BIAS	-0.02	0.11
Scatter index	13.3	14.6
Slope	1.06	1.12
Intercept	-0.19	-0.23

A : 1-day forecast of the operational MFWAM with assimilation
B : Analyses of MFWAM without assimilation

--> The 1-day forecast improves the wave heights by ~9%

Aug. 26 to Sep. 6, 2011

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Conclusions

→ The impact of the assimilation is significant on the wave analyses performed by the new MF wave forecasting system with different values depending on reference data

- 10% and 25% when estimated with swh and Tp from buoys
- 25% when estimated with altimeter swh

→MF is the first Met Service assimilating operationally ESA/ASAR L2 products as defined by IFREMER and NORUT

→ The contribution of ASAR in the assimilation is clearly showed for the peak period Tp>12 sec : only the use of ASAR improves the analyses by more than 20%

→ The assimilation of ASAR L2 only improves the estimate of Sig. Wave height by roughly 10% in comparison with altimeters (mainly in high and intermediate latitudes)

Conclusions and future works

→ Positive impact of the optimization of the scheme in particular for Tp > 10 sec (improvement by ~12%)

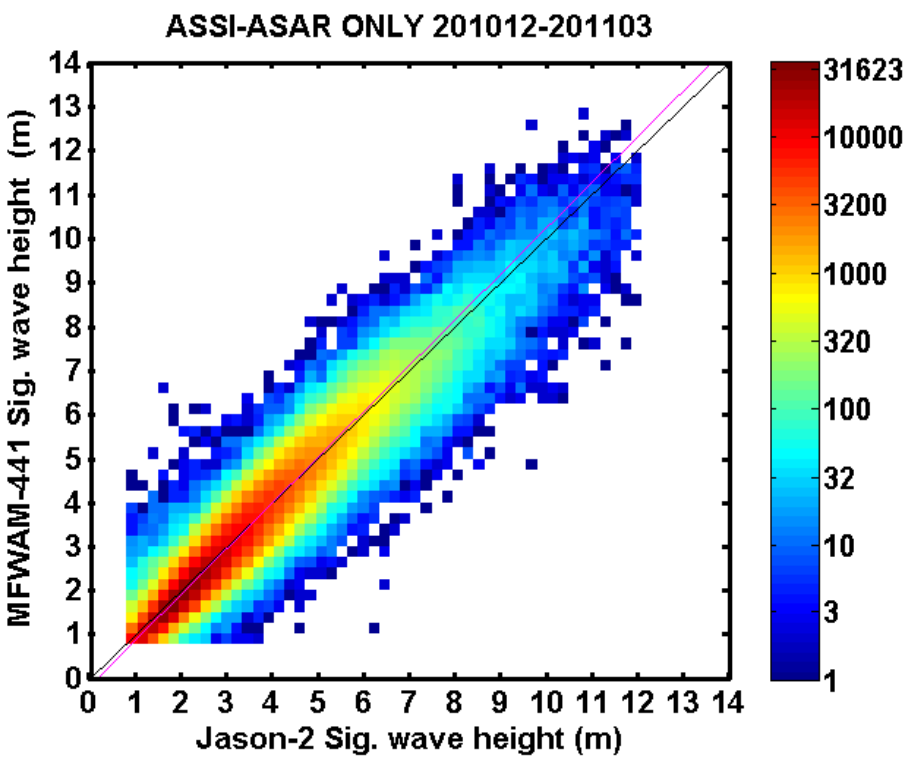
→ The assimilation reveals efficient for high sea conditions as shown in the case of hurricane Katia

→ Impact studies based on synthetic wave spectra from SWIM instrument on CFOSAT satellite (Chineese-French program, launch 2015) and performances combining several instruments (new ASAR and altimeters)

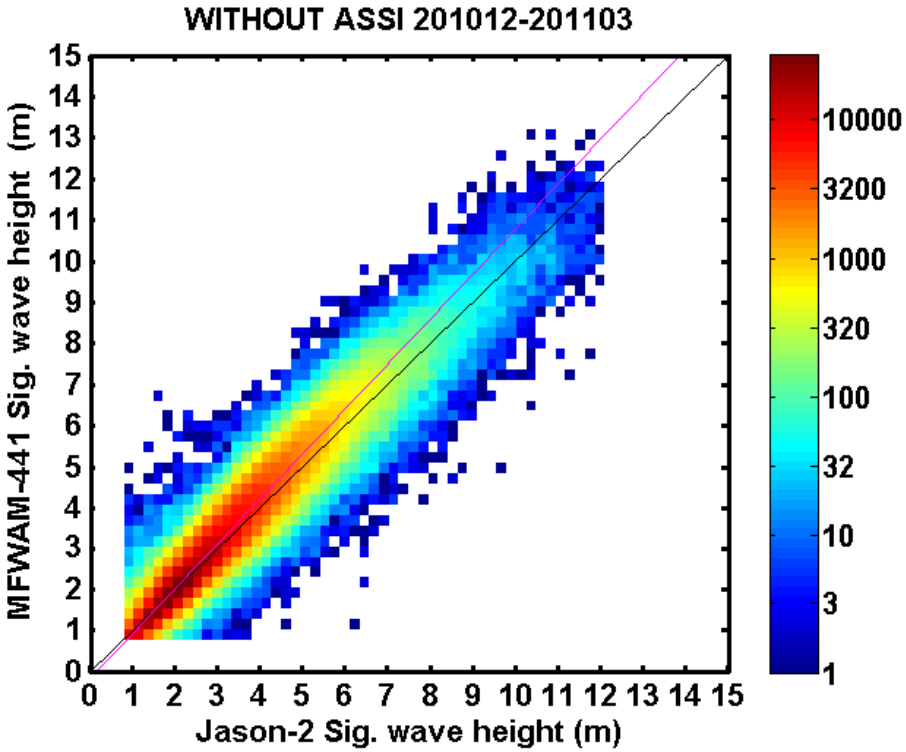
→ Improvement of the assimilation scheme (modify error covariance functions- use of wave partitions to adapt correlation lengths)

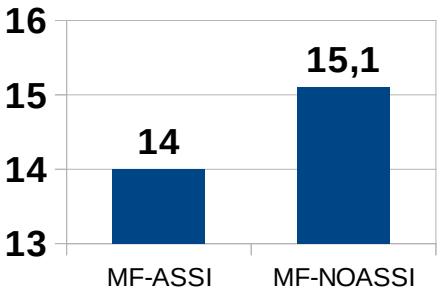
Impact of the assimilation of ASAR wave spectra only comparison with Jason 1&2 wave heigths

Assimilation of ASAR only



Run without assimilation





Data collected : 170942

Sep. 2010 to March 2011

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