Recent improvements on the wave forecasting system of Meteo-France: modeling and assimilation aspects

L. Aouf and J-M. Lefèvre

Division Marine et Océanographie, Météo-France

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OUTLINE

1- Motivation

2- upgraded MFWAM (IFS-38R2) with improved source terms

3- Results with the upgraded MFWAM

4- Assimilation of SARAL data and impact studies

5- Conclusions

Motivation

- **In the framework of MYWAVE EU project (WP1) : improve the wave breaking term , in particular under extreme conditions.**

→ Reduce the bias of SWH in the southern hemisphere and improving the dependency between Cd, U10 and the sea state

- **Only Jason-2 data are used in the MF operational wave forecasting system :**

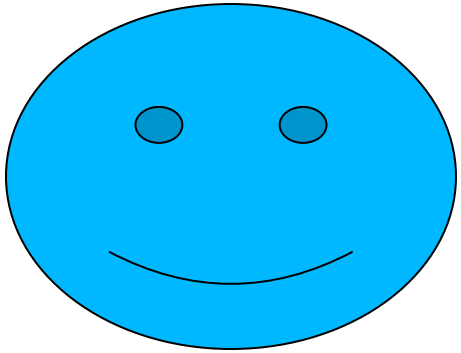
→ need to use more altimeters to improve wave model analyses and (SARAL just in time !)

- **Evaluate the impact of the assimilation of Saral/Altika wave data on the wave forecasting system (Data quality control and preparation for operational use)**

CONCLUSIONS

Key words :

Good, Successfully, Promising, Encouraging,…..!



Recent developments on modelling part

- **MFWAM is upgraded with latest ecwam code (IFS-38R2)**

- **Tail limitation drag : imposing a limitation to the high frequency part of the spectrum based on a limiting Phillips spectrum (suggested by P. Janssen). It has been tested for tropical cyclone seasons in indian ocean**

  → **3 wind forcing (ECMWF, Aladin and Blended/scaterometer) for tropical cyclone season 2011 and 2012 in indian ocean with the regional model MFWAM-Reunion**

- **New version of the wave model MFWAM has been implemented and tested globally for two fall seasons (Sep-oct-Nov 2011 and 2012).**

Wave model: MFWAM improvement and validation partly thanks to Altimetry

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:

→ avoid too strong dissipation of swell and too strong generation of wind sea for mixed wind sea-swell situations

- New term for swell damping due to air friction

- Stress reduction for MFWAM-441 to adjust with new dissipation based on saturation spectrum

$$(u'_\star)^2 = u_\star^2 (\cos\theta_u, \sin\theta_u) - |s_u| \int_0^k \int_0^{2\pi} \frac{S_{in}(f',\theta)}{C} (\cos\theta, \sin\theta)\, \mathrm{d}f' \mathrm{d}\theta,$$

Function of k or f

Su=1 for MFWAM-441

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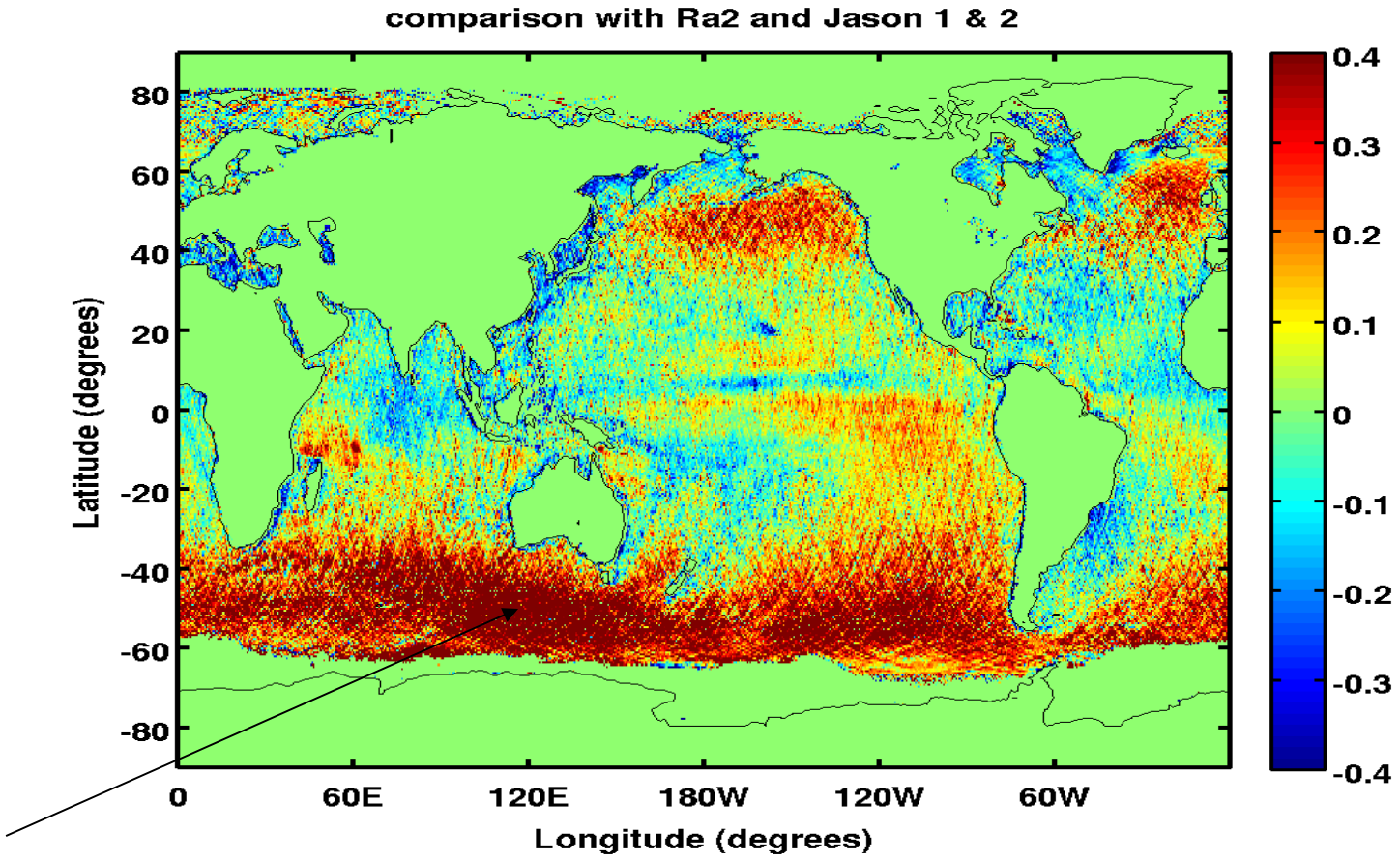
Bias map of MFWAM-OPER (comparison with altimeters)



Southern hemisphere bias

Sep-Oct-Nov 2011

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Toward a new version of MFWAM
Improvement of the dissipation and input source terms

- **Swell damping due to air friction : use of smoothing function (Rayleigh) for the transition between laminar to turbulent flows (F. Leckler)**

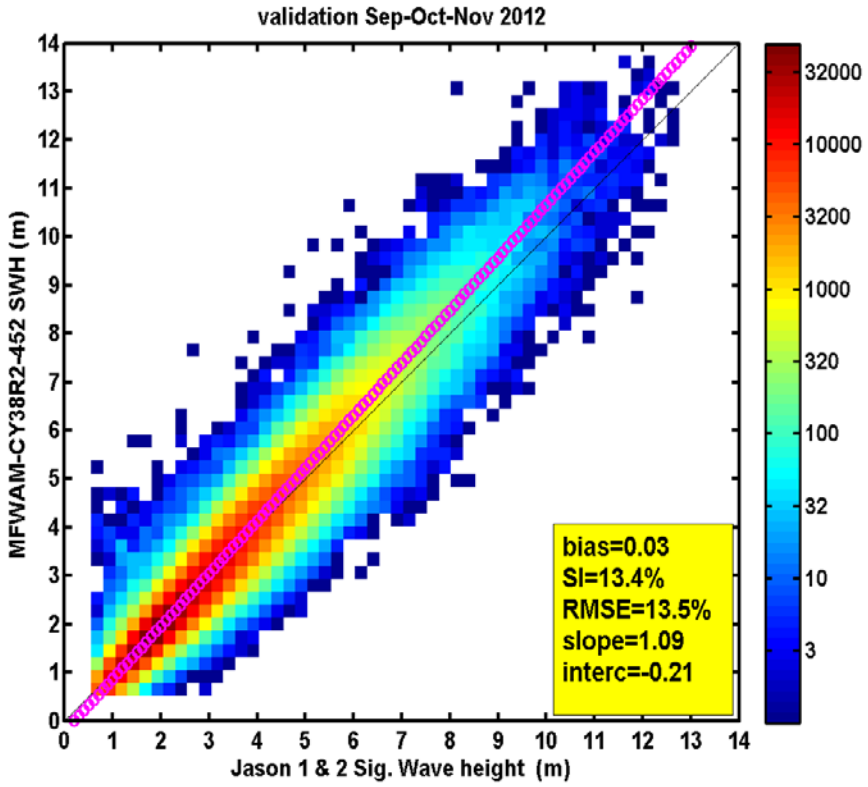
- **Adjustments of stress reduction introduced for the new dissipation based on saturation spectrum : the shelttering process is too strong for MFWAM-441**

MFWAM-upgraded-452	MFWAM-OP-441
Cds=-2.8	Cds=-2.2
Su=0.6	Su=1
C3=0.4	C3=0.4
βmax=1.52	βmax=1.52

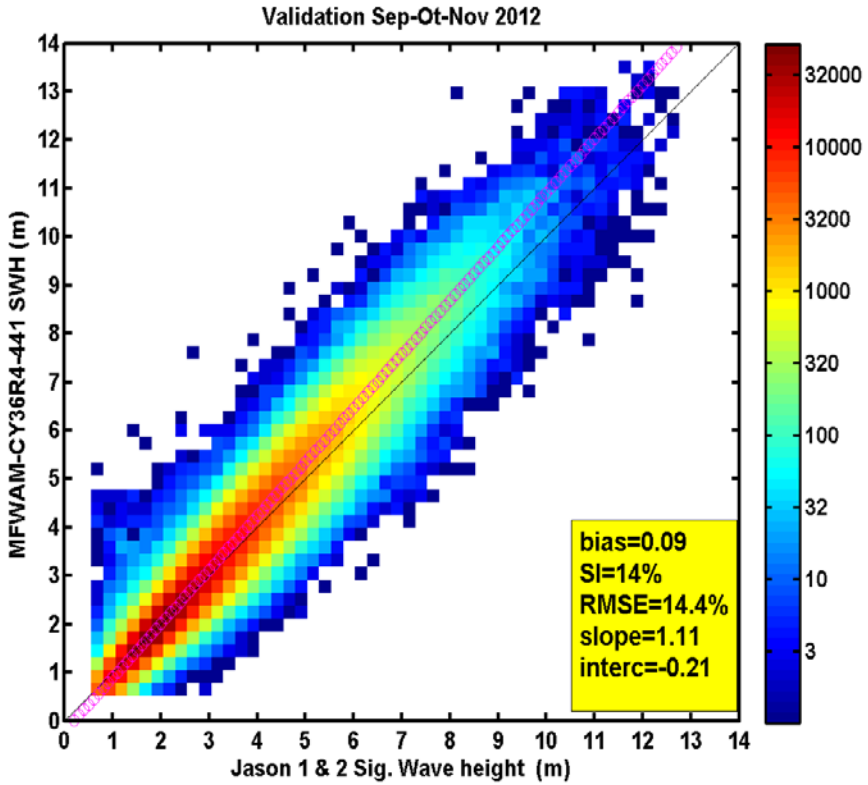
Global runs are performed for two fall seasons 2011 and 2012 with ECMWF analyzed winds. The wave spectrum is in 30 frequencies and 24 directions

Validation of MFWAM-452 sig. wave heights with altimeters data (Jason 1 & 2)

MFWAM-452



MFWAM-441



Bias = 0.03
SI = 13.4%
RMSE = 13.5%
Slope = 1 .09
Intercept = -0.21

Data collected : 1084927

Sep-Oct-Nov 2012

Bias = 0.09
SI = 14%
RMSE = 14.4%
Slope = 1 .11
Intercept = -0.21

Statistical analysis MFWAM-452 and MFWAM-441 (OP) vs altimeters (Envisat, Jason 1 & 2)

Southern hemisphere

Scatter Index (%)

Northern hemisphere

Scatter Index (%)

Comparison with SWH of altimeters (Envisat, Jason 1 & 2) fall 2011

Statistical analysis MFWAM-452 and ECWAM (CY 38r1)

Southern hemisphere

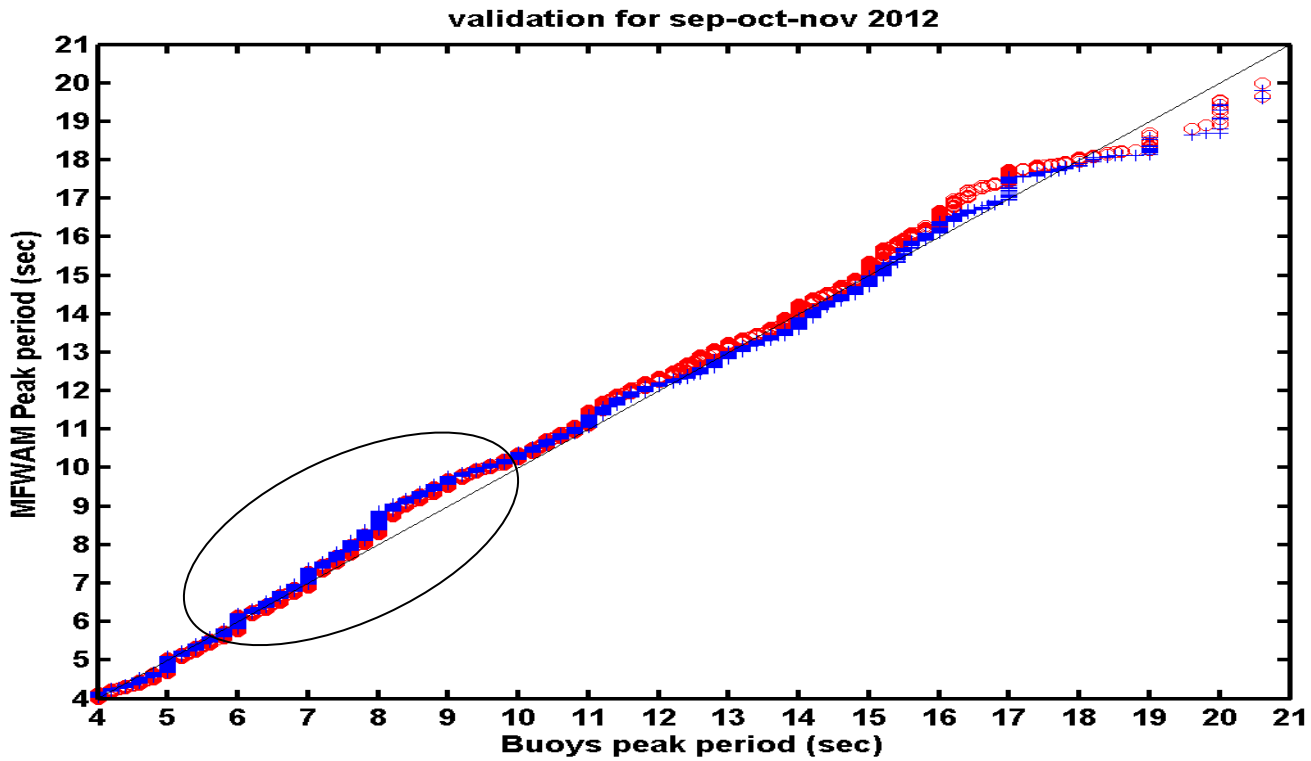
Scatter Index (%)

Northern hemisphere

Scatter Index (%)

Comparison with sig. wave heights of altimeters (Ra2, Ja 1 & 2) fall 2011

Validation at the peaks (Tp) with NDBC buoys



MFWAM-UP-452
MFWAM-OP-441

Bias = 0.18
SI = 13.8%
RMSE = 13.9%

→ **SI slightly improved by 3%**

Bias = 0.18
SI = 14.2%
RMSE = 14.3%

Comparison with NDBC buoys located in North America : Sep-Oct-Nov 2012

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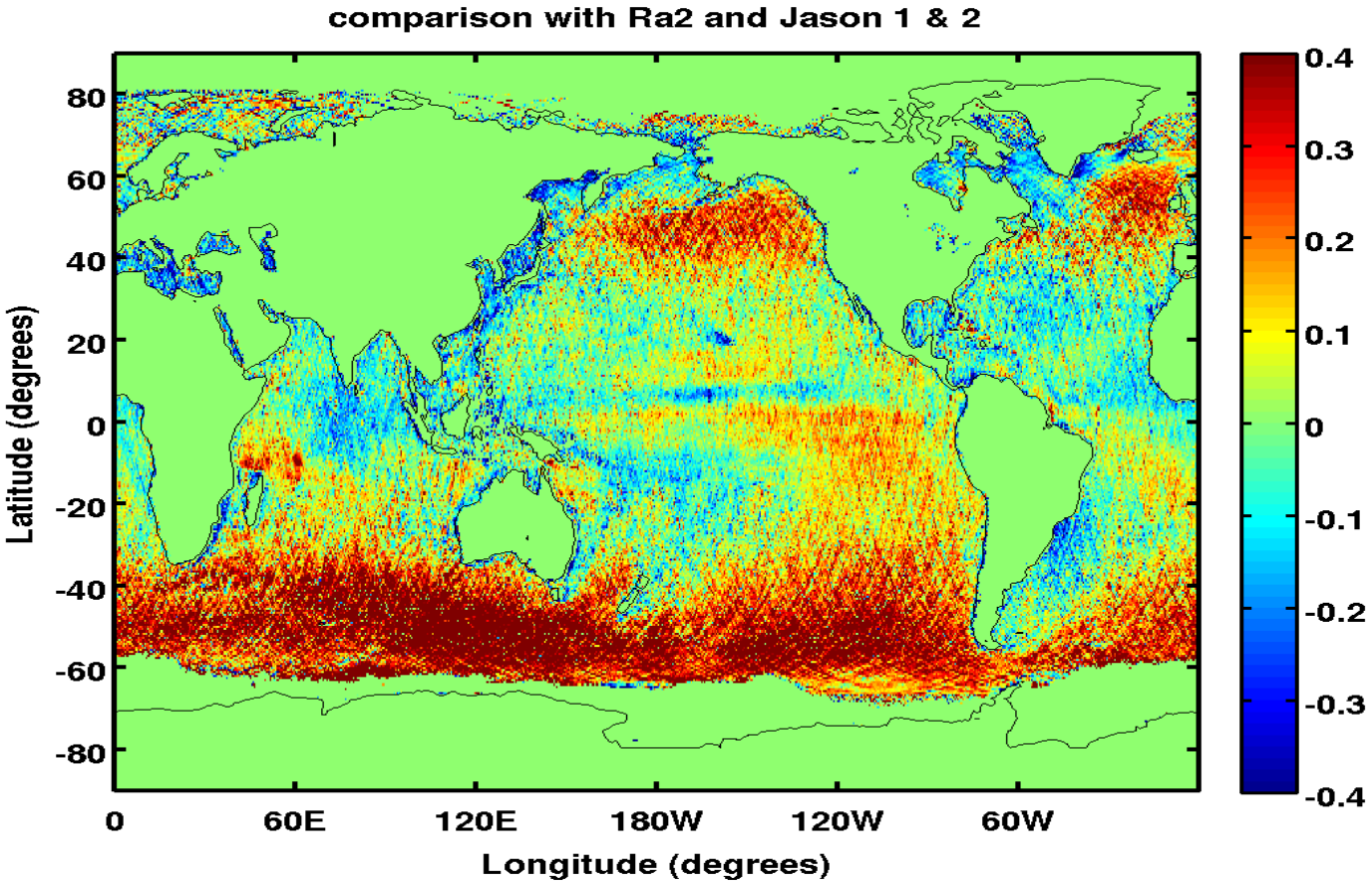
Bias map of MFWAM-OPER (comparison with altimeters)



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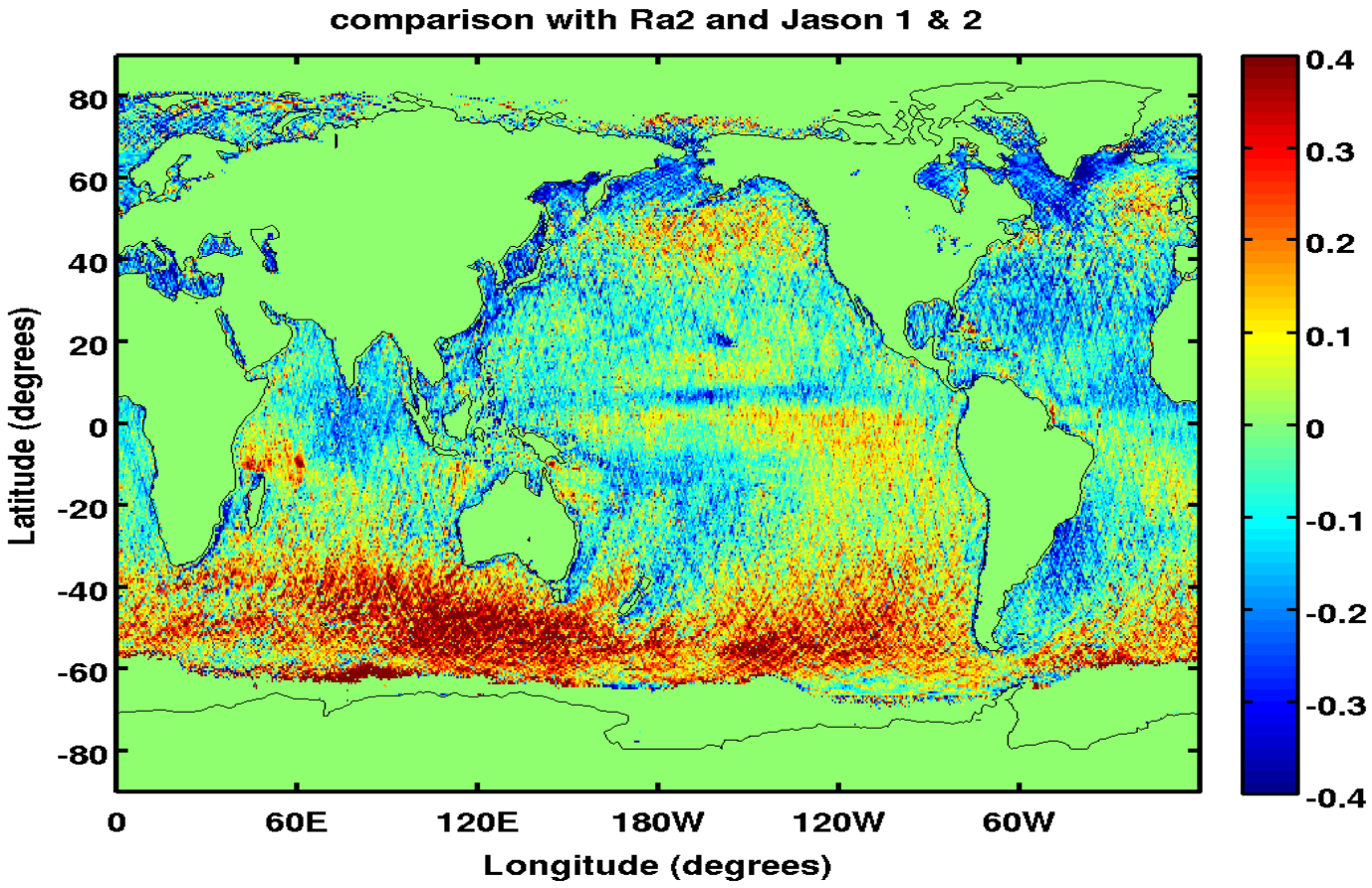
Bias map of MFWAM-452 (comparison with altimeters)



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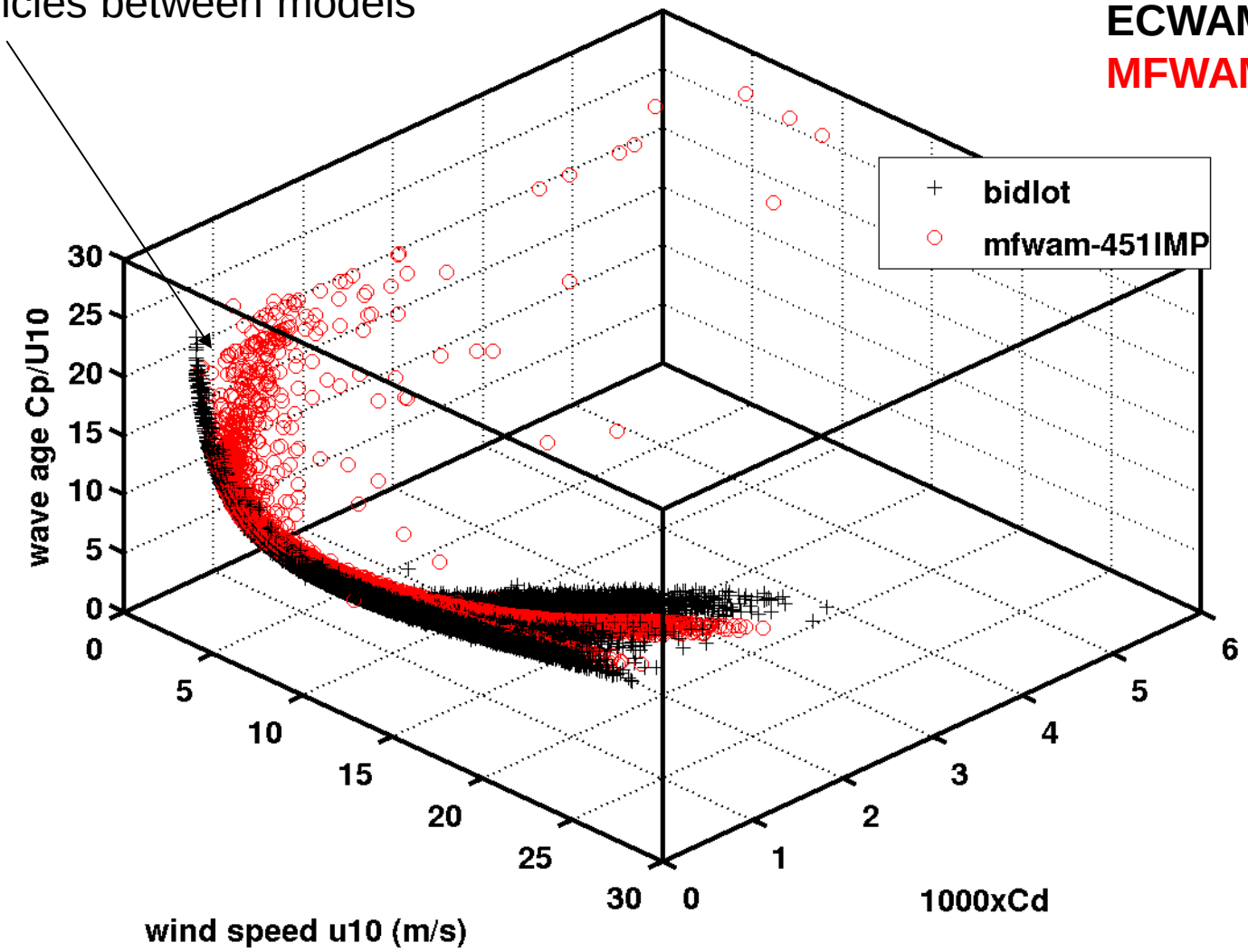
3-D variation of Cd with U10 and wave age

Discrepancies between models

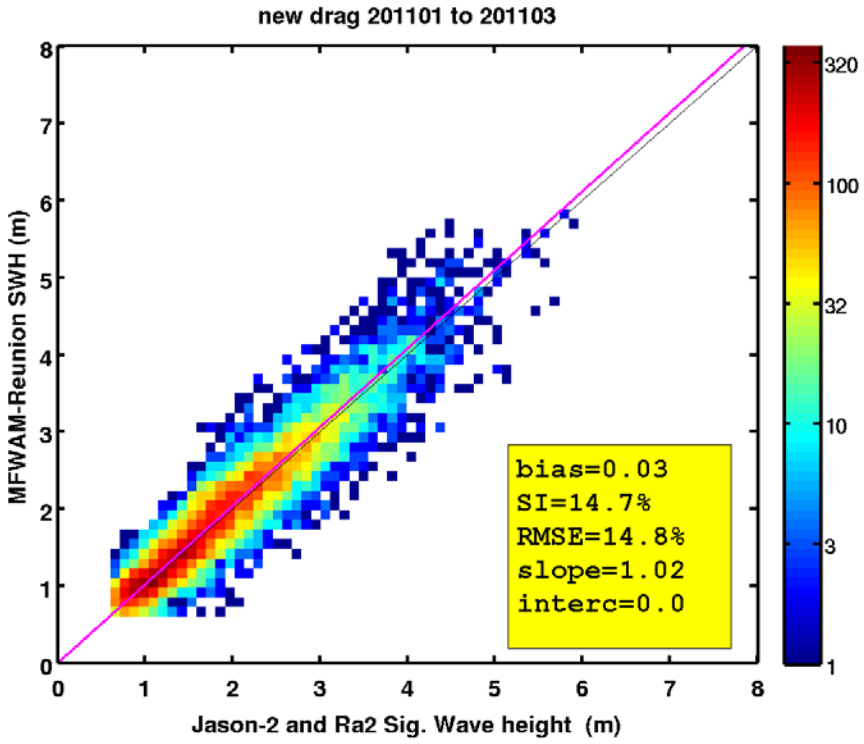
ECWAM-CY38R2

MFWAM-UP-452

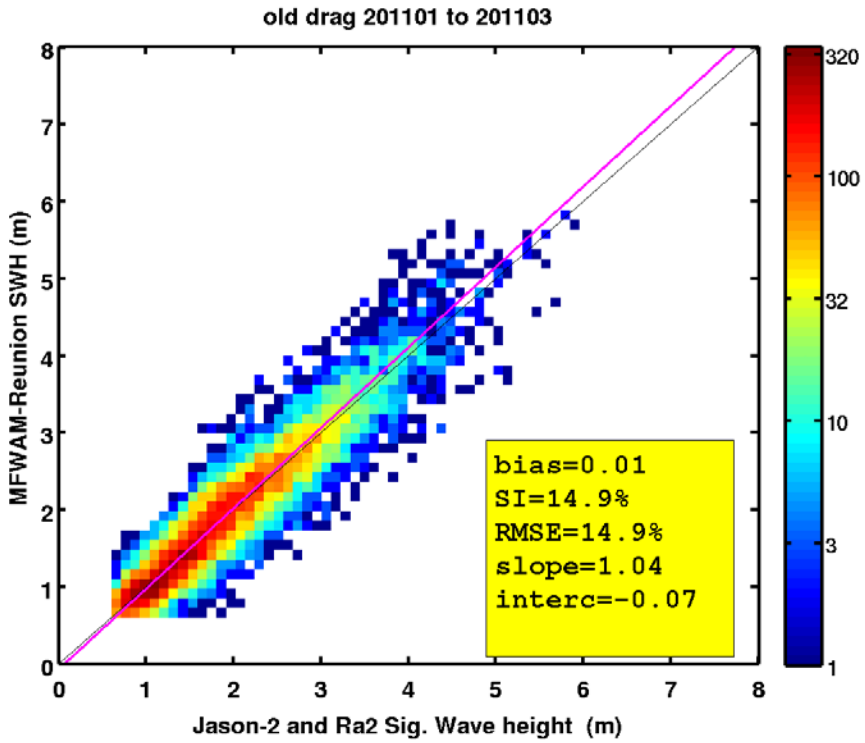


Validation of cyclone season in indian ocean with altimeters (MFWAM-Reunion 0.25°x0.25°)

with tail limitation



without tail limitation



SI=14.7%
RMSE=14.8%
Slope=1.02
Intercep=0.

Scatter index is slightly improved by ~3%

SI=14.9%
RMSE=14.9%
Slope=1.04
Intercep=-0.07

3 months (cyclone season jan-feb-mar 2011)
MFWAM run with wind fields from Aladin

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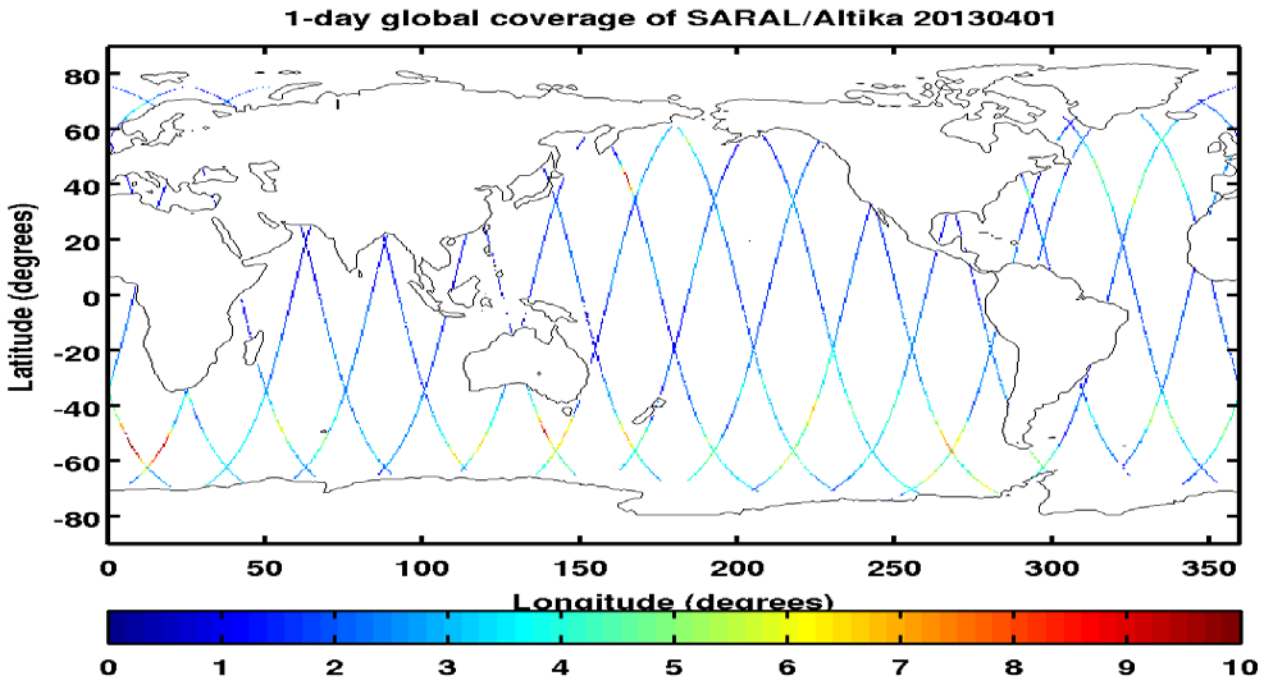
Distribution of Saral data on wave model grid

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



Example of 1-day global coverage of SARAL Sig. wave height (~5800)

Saral wave obs are collocated with model grid points : Super-observations

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Saral/Altika wave data and QC procedure

→ **Saral NRT products are downloaded in NETCDF format from period 31 March to 1 September 2013 (CALVAL activities)**

→ **Quality control procedure is implemented to prepare the data assimilation in the wave model :**

Land flag	0
RMS_SWH	<=0.3 m
SWH Min	0.5 m
SWH Max	13 m
Ice flag	0
σ0 Min	5 db
σ0 Max	30 db
Number of valid points	>=35

QC table

Threshhold values in table as for Jason-2

~22 % Saral SWH are rejected before the assimilation

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Description of runs :
from 31 March 2013 to 1 August 2013

- **Wave model set-up**
  - Wave model MFWAM (global coverage 0.5x0.5° irregular grid), wave spectrum in 30 frequencies (starting 0.035 Hz) and 24 directions
  - ECMWF analyzed winds every 6 hours
  - Assimilation time step 6 hours

→ **Assimilation** of Saral/Altika Sig. wave heights

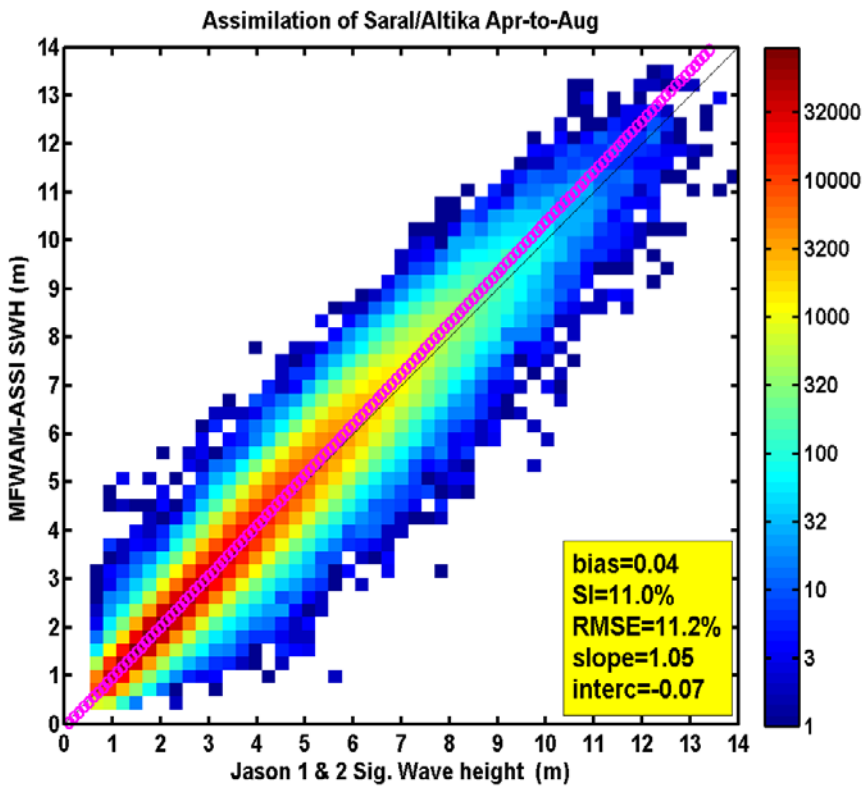
→ **Assimilation** of Saral and Jason-2 sig. wave heights

→ Outputs from the operational forecasting system (**MFWAM with assimilation of Jason 1 & 2**)

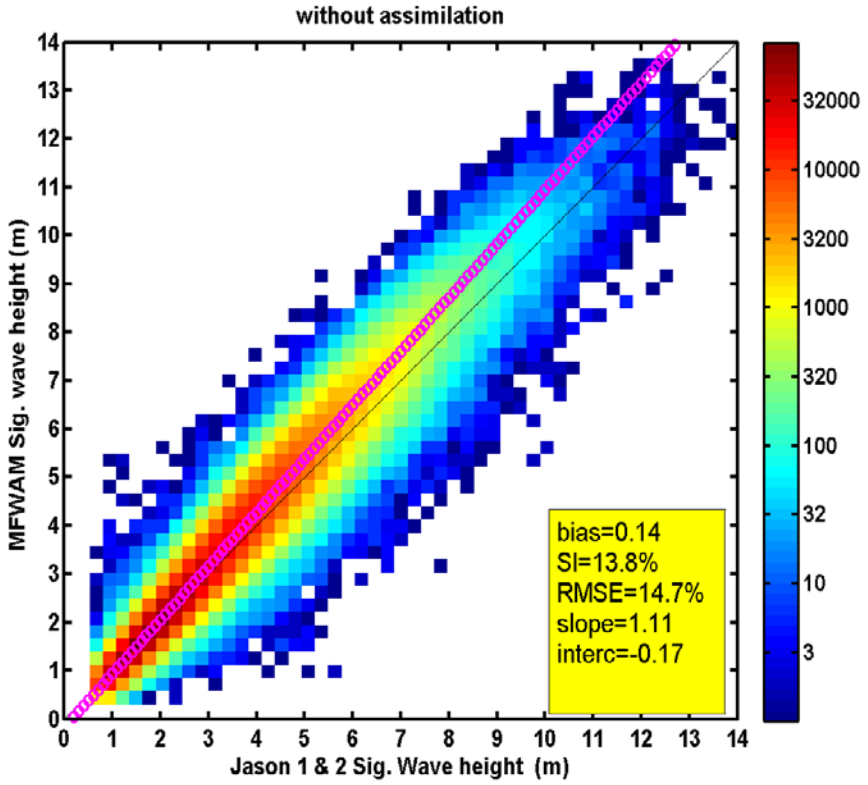
→ **Baseline** run of MFWAM without assimilation

Assimilation of Saral/Altika Sig. Wave heights Validation with Jason 1 &2

Assimilation of Saral



Without assimilation



Bias = 0.04
SI = 11%
RMSE = 11.2%
Slope = 1 .04
Intercept = -0.07

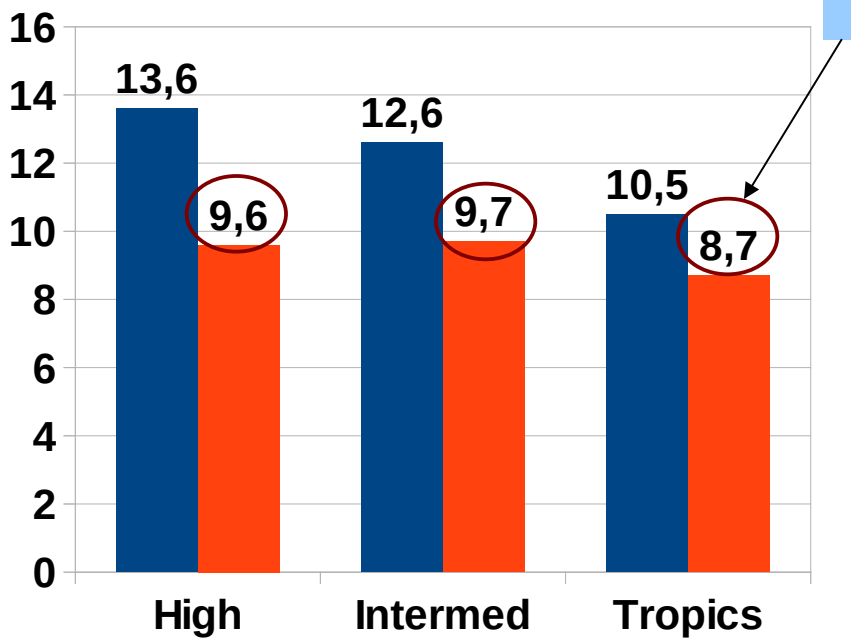
Data collected : 1661664

April to Aug 2013

Bias=0.14
SI=13.8%
RMSE=14.7%
Slope=1.11
Intercept=-0.17

Assimilation of Saral and Jason-2 in MFWAM in different ocean basins

Scatter Index of SWH (%)



great performance !

Collected data : 189097 212371 132083

Validation with Jason-1 : April, May and June (until 21)

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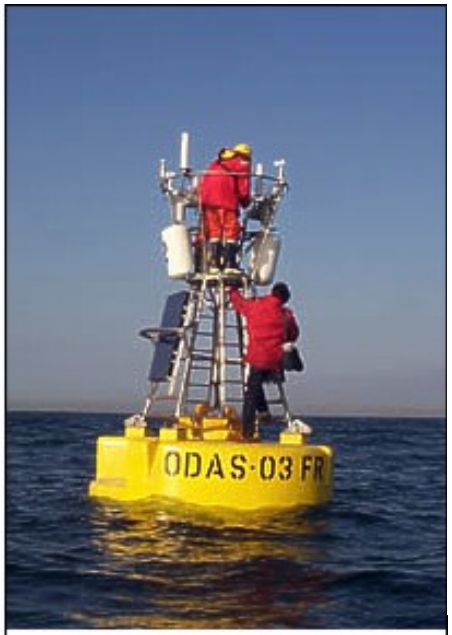
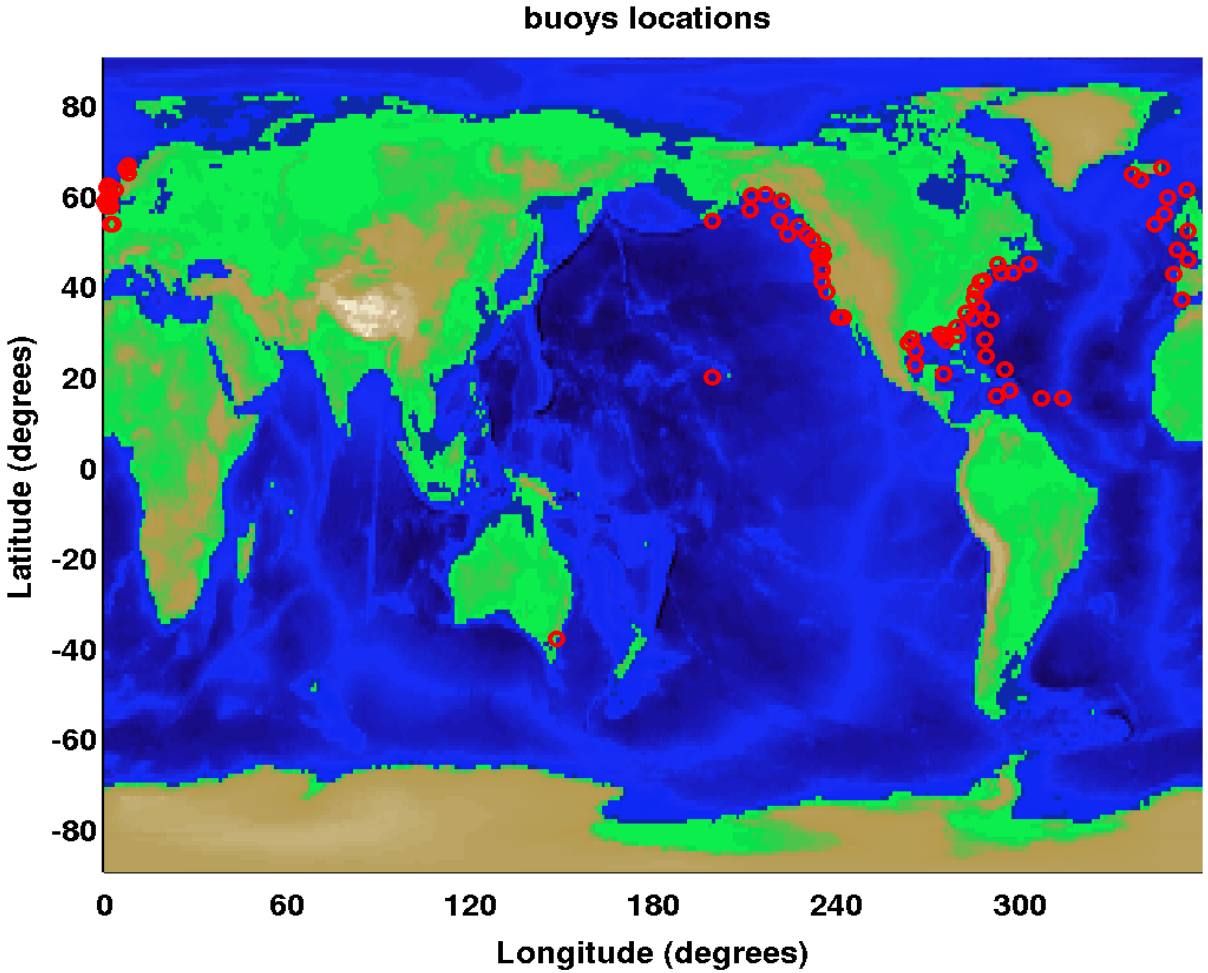
VALIDATION OF SWH WITH BUOYS DATA

Data are collected from the JCOMM model intercomparison archive produced by J. Bidlot (ECMWF))



Bouée 03FR le 16 mars 1999

Photo Météo-France



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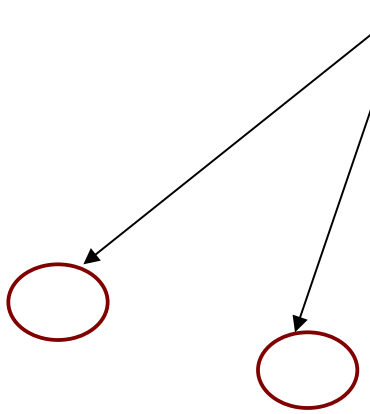
Validation with buoys Sig. Wave heights

Use of Saral is very promising !

Scatter index of SWH (%)



NOASSI : without assimilation
ASSI-SRL : assimilation of SARAL/Altika
ASSI-SRL-JA2 : assimilation of SARAL and Jason-2
OPER : Operational MFWAM with assimilation of Jason-1 & 2

April-May-June 2013 (29005 collected data)

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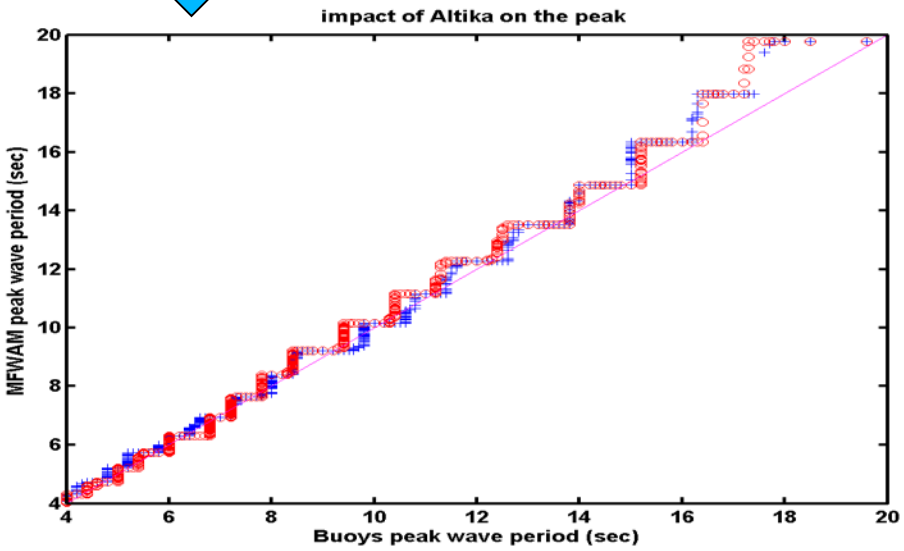
Perfomance of the assimilation of Saral/Altika at the peaks

Blue for assimilation with saral
Red is reference run

Scatter Index (%)



Scatter index is well reduced in wind sea and swell wave systems

Comparison with NDBC buoys located in North America : Jun-Jul-Aug 2013

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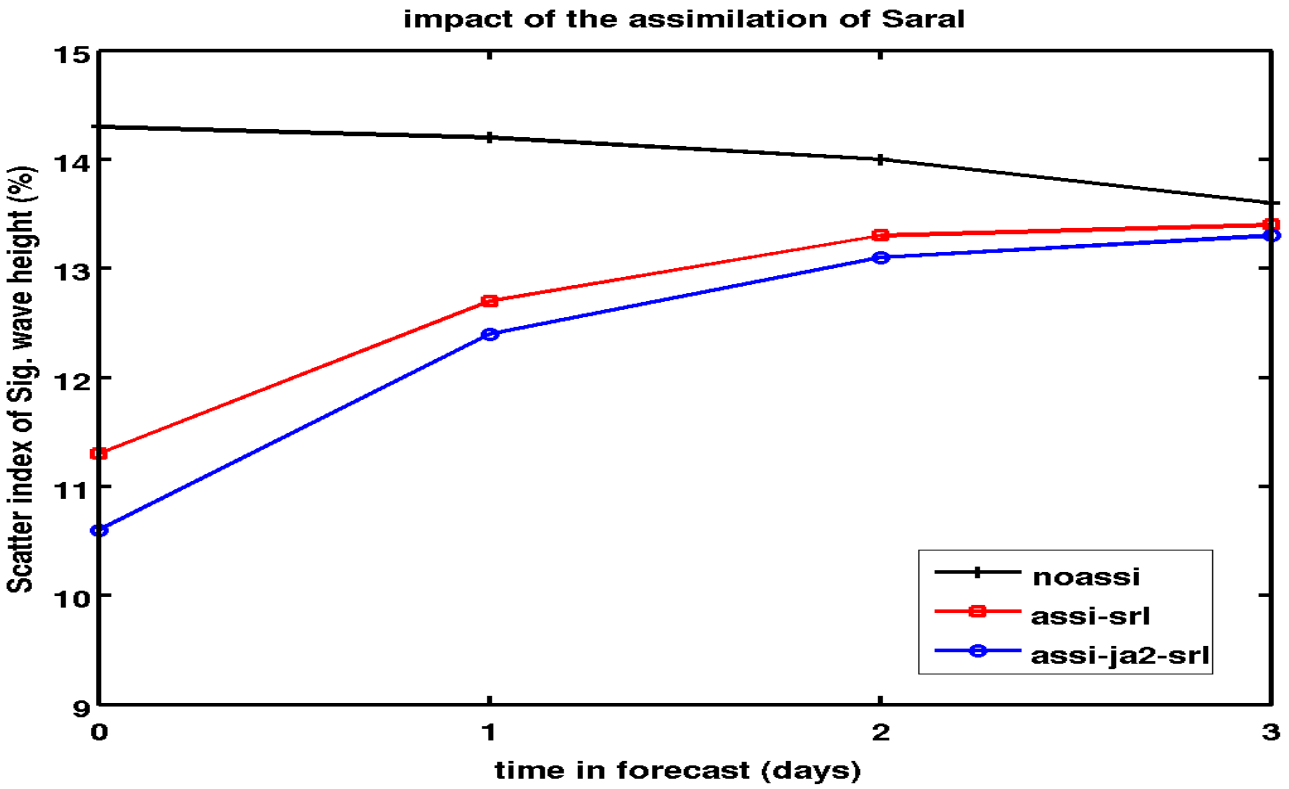
The impact of the assimilation in the period of forecast Sig. Wave heights

Scatter index of SWH (%)



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

Blue : assimilation of Saral and Jason-2
Red : assimilation of Saral only
Black : without assimilation

Comparison with Jason 1 & 2

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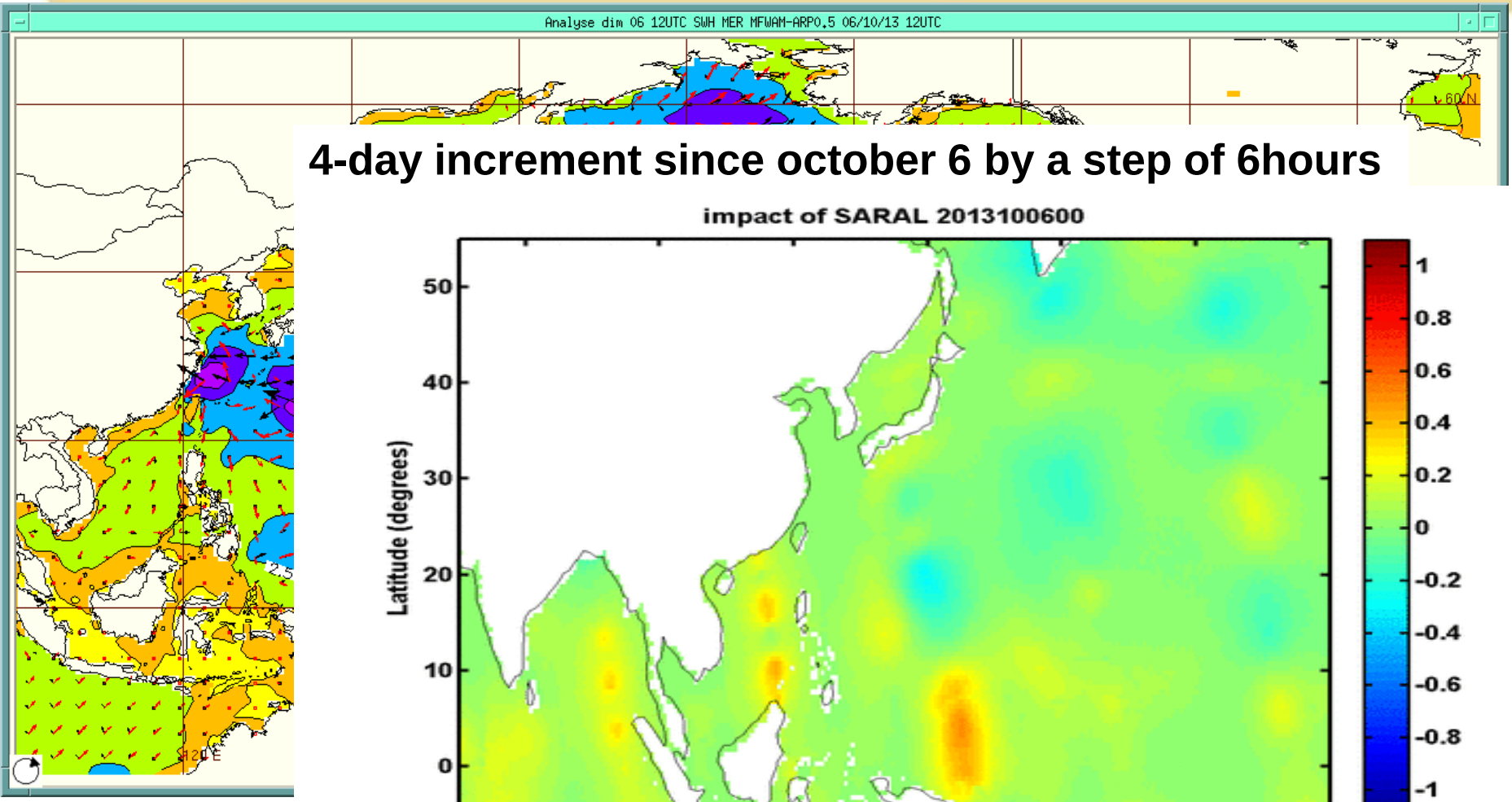
Improving the sea state forecast in high wind conditions



Snapshot o

4-day increment since october 6 by a step of 6hours

Typhoons FITOW and DANAS generating high sea state on Sunday 6 October 2013 at 12:00 (UTC)

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CONCLUSIONS

- MFWAM-452 greatly reduces the bias in SH and improves the sea state parameters.

- The dependency between Cd, U10 and the wave age is more consistent. Tests with MFWAM-452 in the ECMWF/IFS (coupling waves/atmos) are on going (Ardhuin's IFS project)

- Sea state forecasts are significantly improved when using Saral/Altika data: thanks to their good quality

- There is a positive impact of using SARAL/Altika data on wave analyses and forecast : ready to be used operationnally in MFWAM (Altika data have been distributed on the GTS since october 10th)

- The use of Saral with Jason-2 showed very promising results (the SWH errors are greatly reduced SI<9% in the tropics)

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