On the assimilation of SAR wave spectra of S-1A in the wave model MFWAM

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14th wave forecasting and hindcasting, Key West
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OUTLINE

1- Motivation

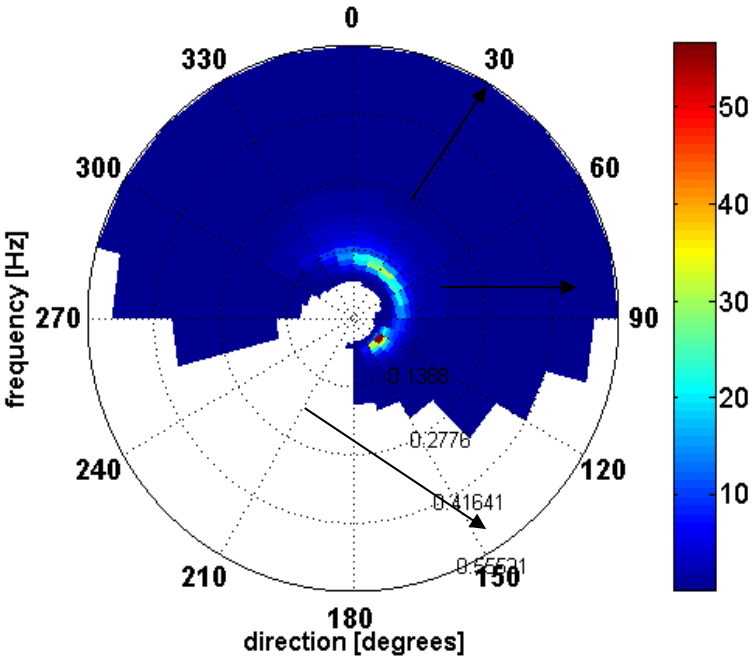
2- Sentinel-1 SAR Level 2

3- Assimilation of SAR (results and validation)

4- Mercator currents in MFWAM

5- Conclusions

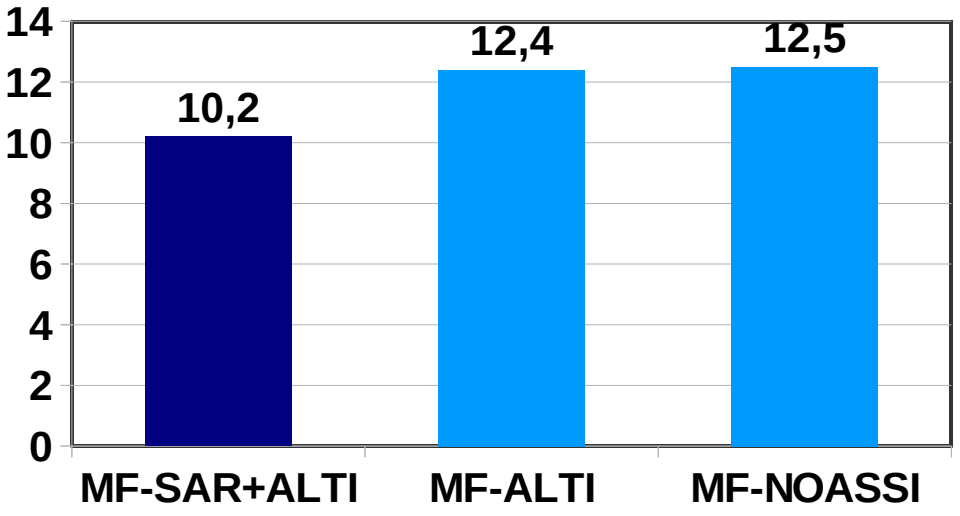
Lessons from ENVISAT : the contribution of SAR spectra



Exemple 3 wave systems seen by SAR

The use of SAR wave spectra improved the peak period by ~20 % for swell over 12 seconds (~225 m).

Scatter index of Tp



Comparison with buoys

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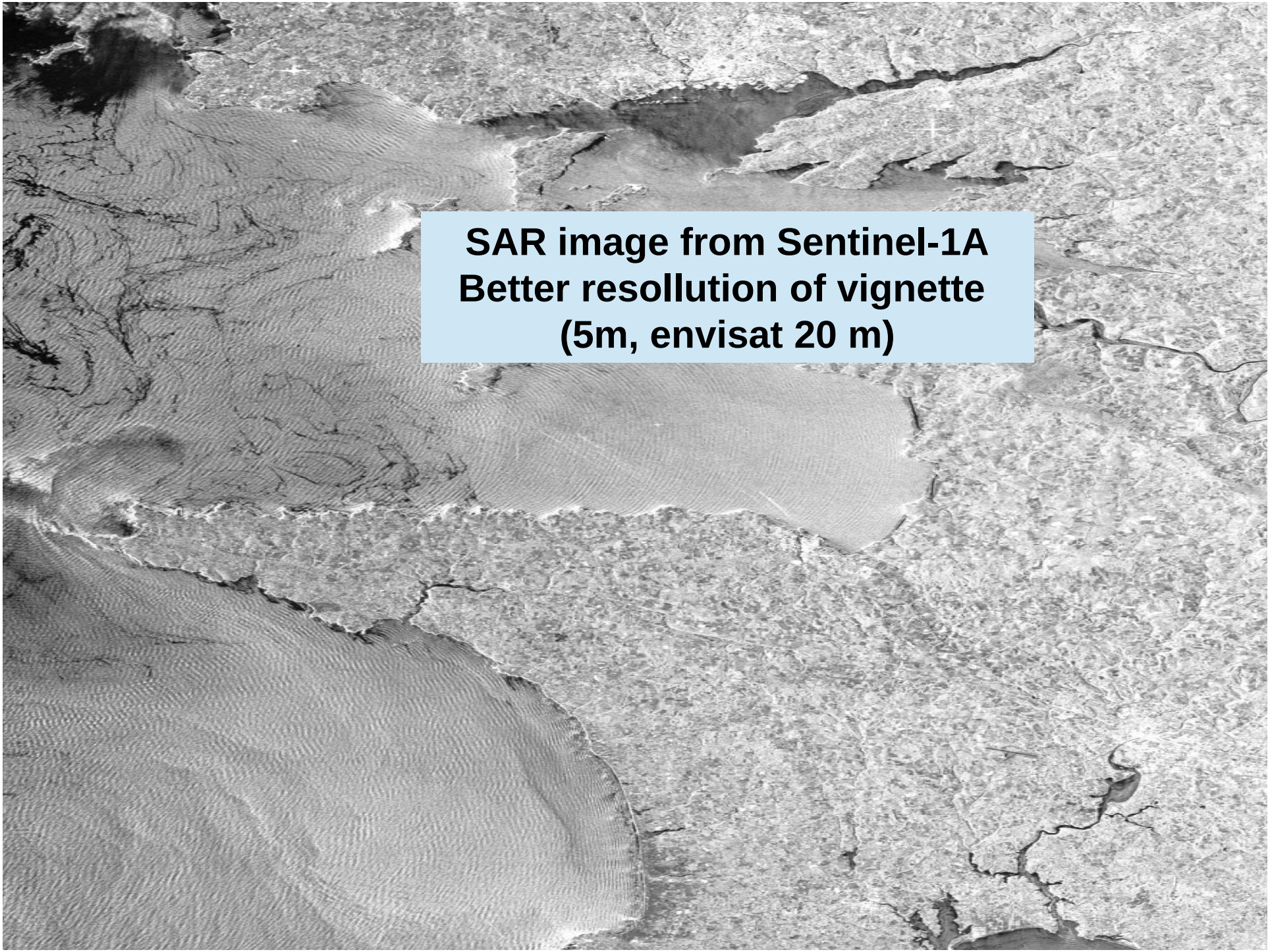
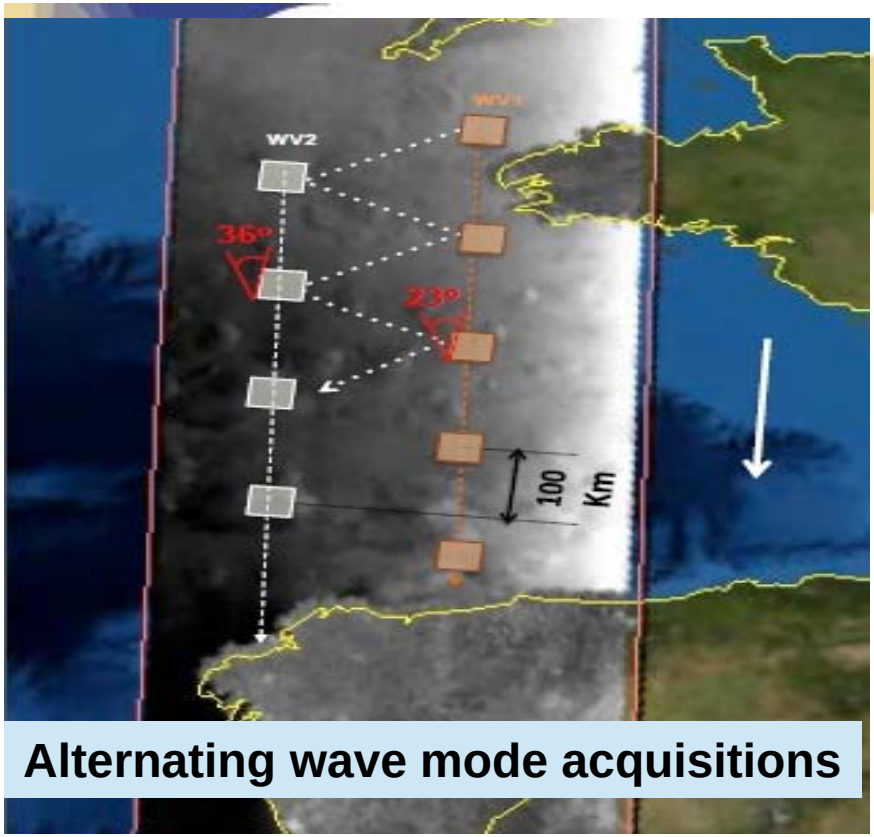
MOTIVATION

- **Improving the swell forecast and in particular directional properties in the wave model MFWAM**

- **Implementing a quality control procedure for the L2 SAR wave spectra of Sentinel-1A : Thresholds for signal and wave parameters**

- **Evaluating the impact of the assimilation of SAR-L2 of S-1A (both WV-1 &2 in MFWAM. Performing also combined assimilation with altimeters.**

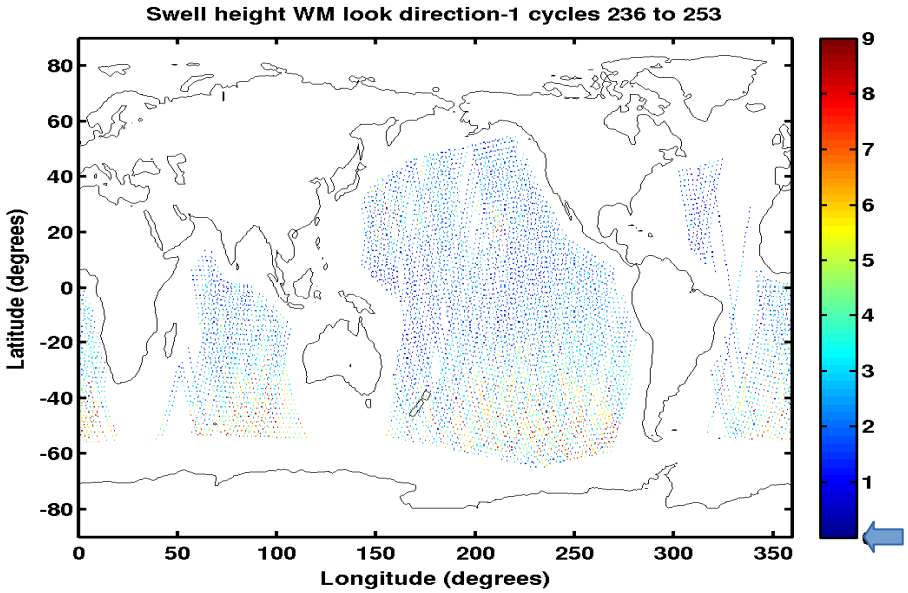

SAR image from Sentinel-1A
Better resollution of vignette
(5m, envisat 20 m)



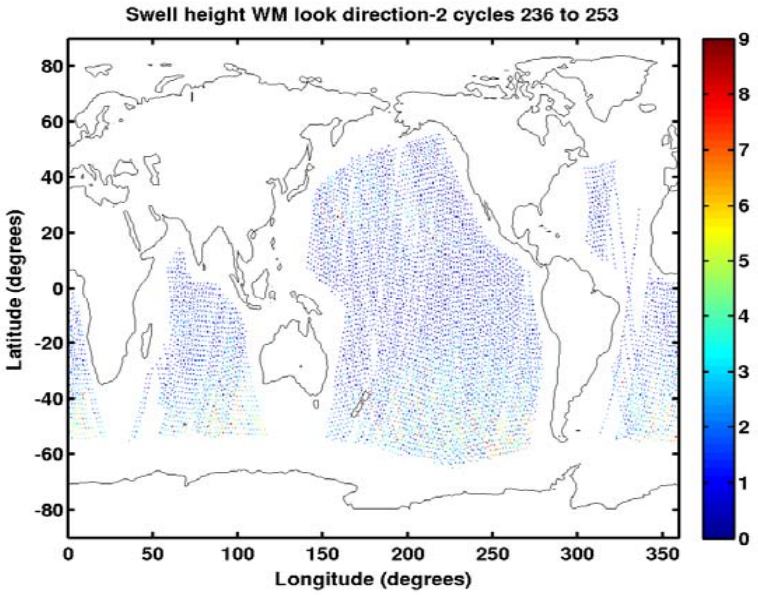
Alternating wave mode acquisitions

In WV, a single stripmap image is acquired with an alternating elevation beam at a fixed on/off duty cycle, resulting in the generation of vignettes 20 by 20 km in size at regular intervals of 100 km.

Vignettes on the same incidence angle are separated by 200 km. Swaths alternate incidence angles between near range and far range (23° and 36.5° respectively).



WV-1



WV-2

Swell wave height retrieved from the L2

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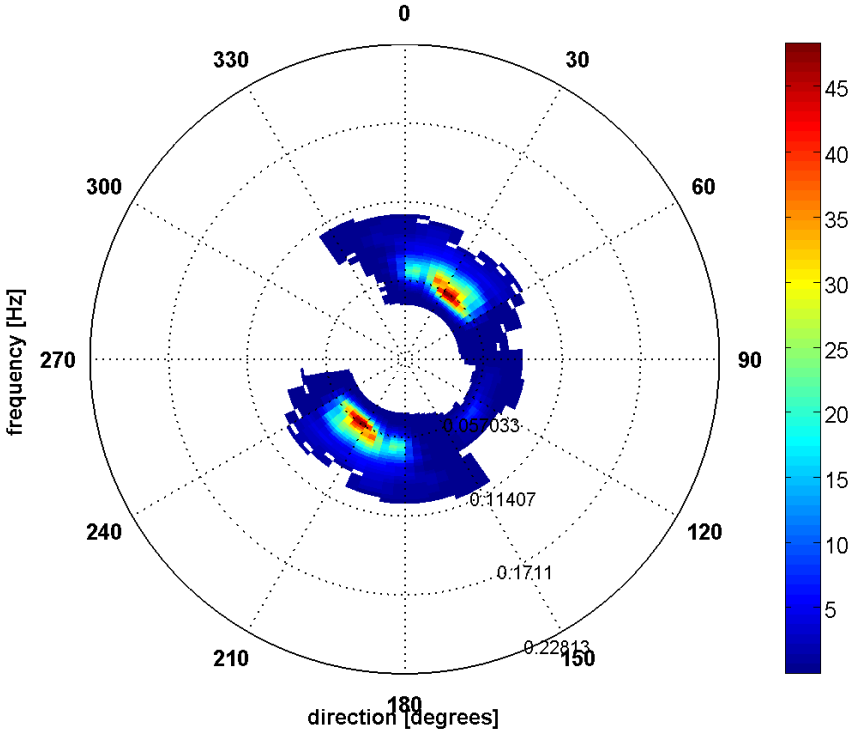
The SAR (L2) wave spectra of Sentinel-1A
Cycles 236-253

 Since 30 June 2015 the level 2 wave products are provided globally at ifremer (produced by ESA-MPC of S-1A). In this study the data cycles from 236 to 253 have been carried out. The resolution of SAR wave spectrum is 60 frequencies from 0.04 to 0,23 Hz and 72 directions (by step of 5°)
The L2 wave products cover the period from 24 August to 11 September 2015.



Exemple of wave spectrum from S-1A WM-1

Sample of Sentinel-1 Level 2 wave products provided by ESA/IFREMER :
- goo resolution of the wave spectrum (30 fréquence-Max-0.22hz et 72 directions)

Swell wave height retrieved from the level 2
Maximum swell heights of 9 meters

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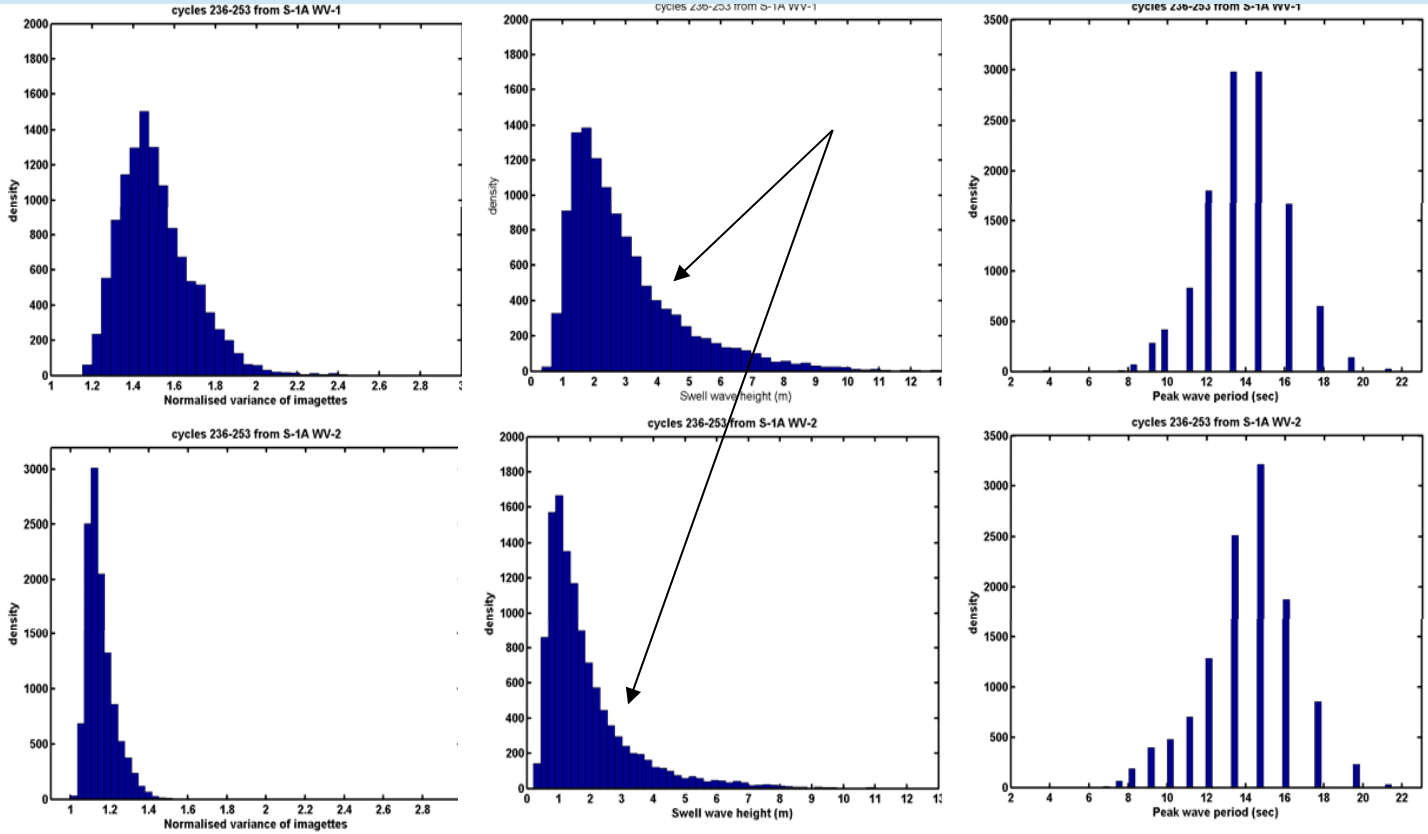
Quality control on signal and wave parameters

NV of imagette **Swell height** **Peak period** **.....SNR**



Wave Mode 1

Wave Mode 2

Only normalized variance of imagette between 0.9 and 1.8 are left : WV-2 (<1%), WV-1 (~9%)

Threshhold on NVI for WV-1 must be adapted

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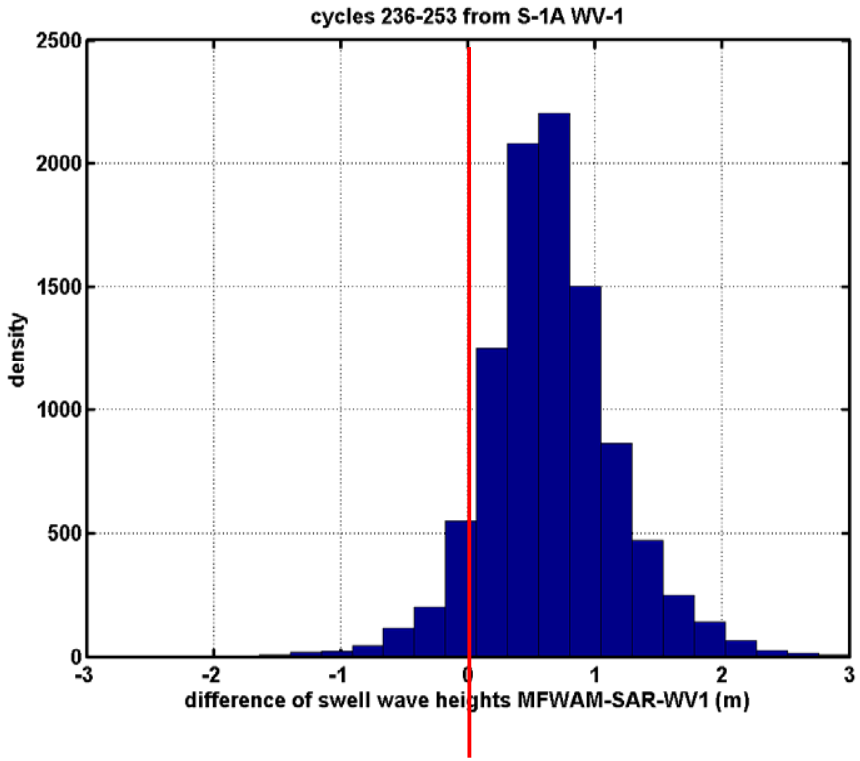
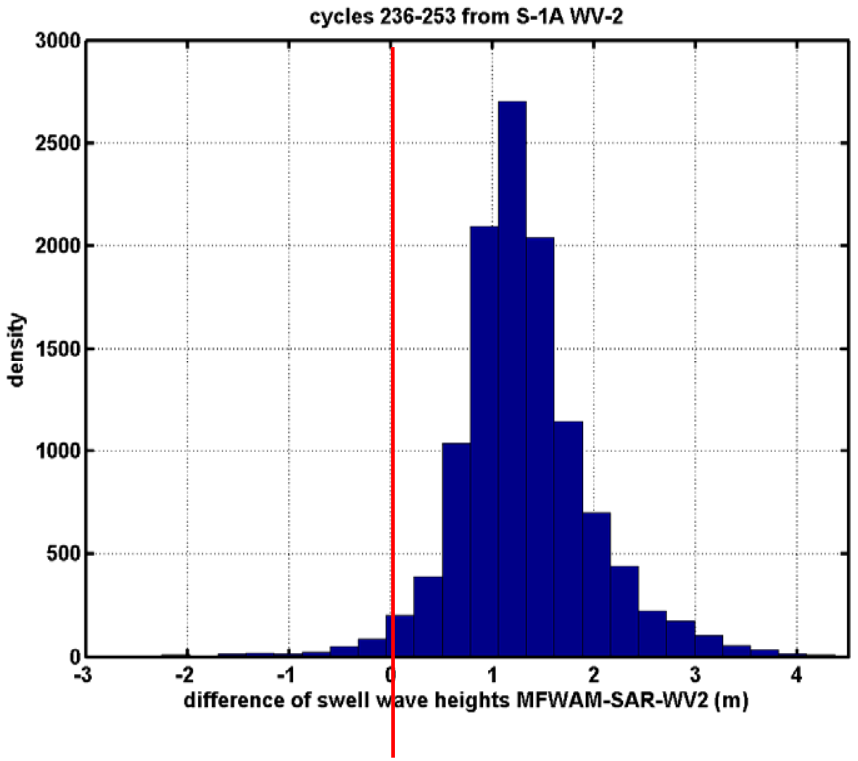
Difference of swell wave height S-1A and MFWAM

MFWAM-WV1



MFWAM-WV2



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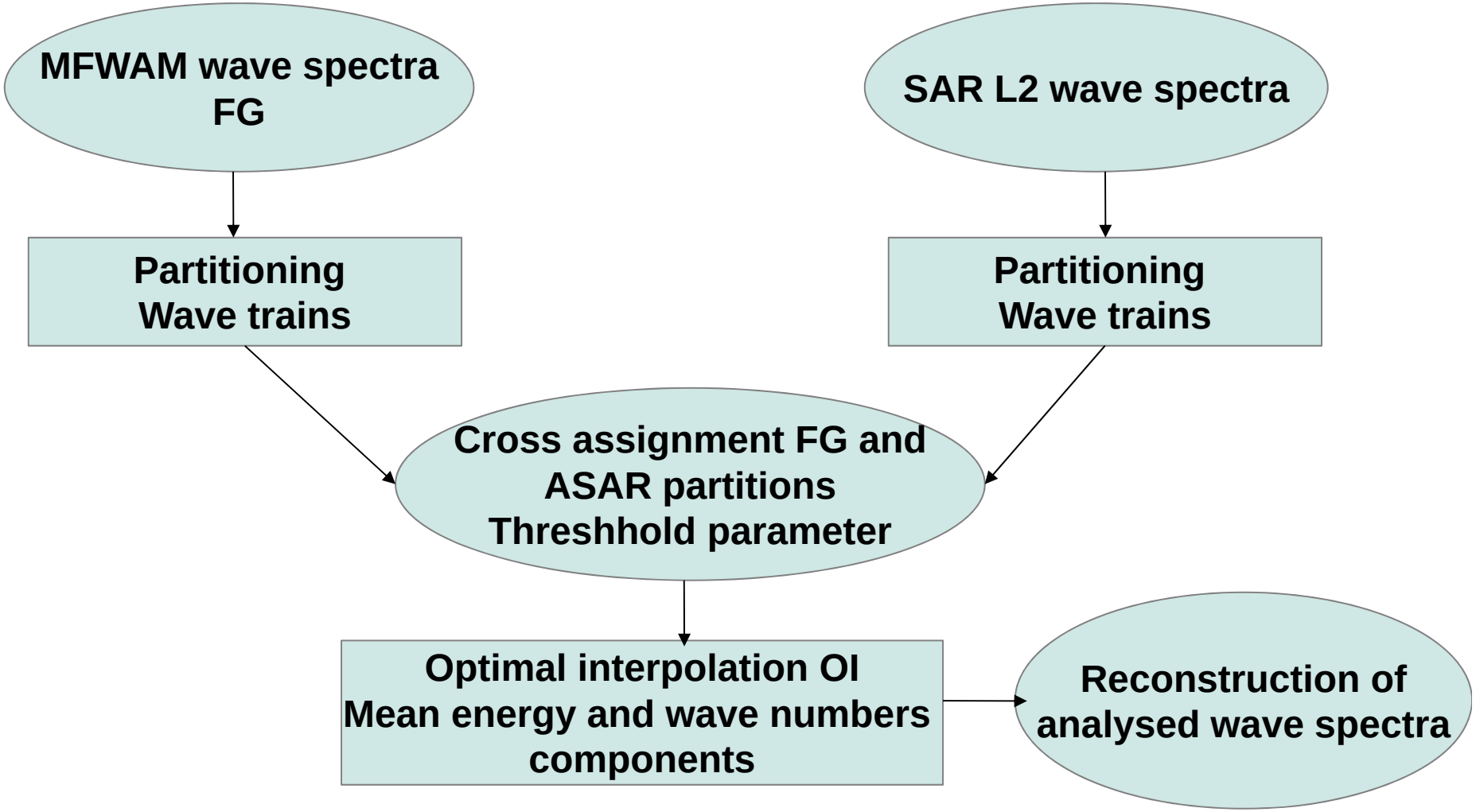
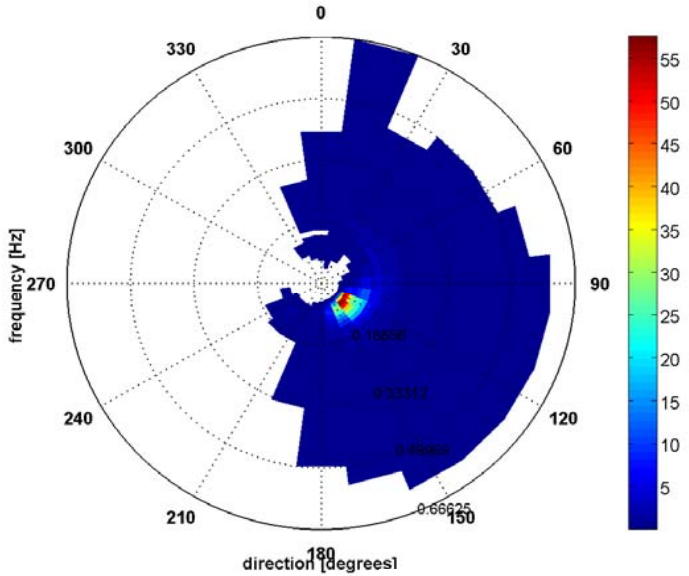
Description of the assimilation of SAR wave spectra

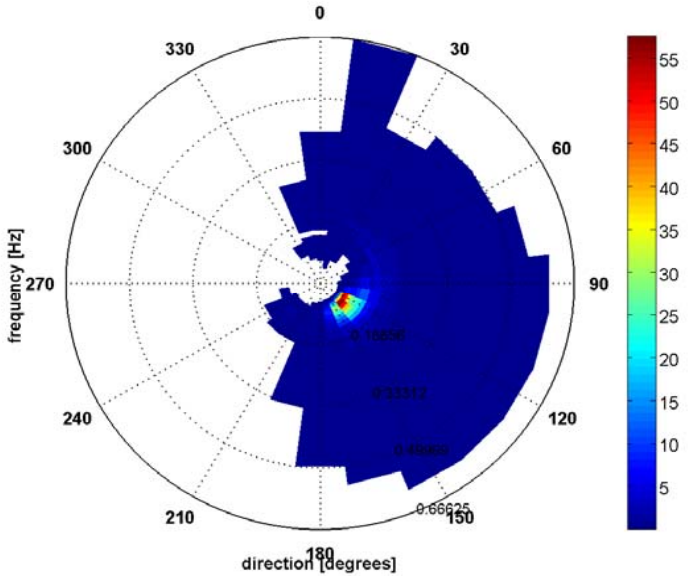


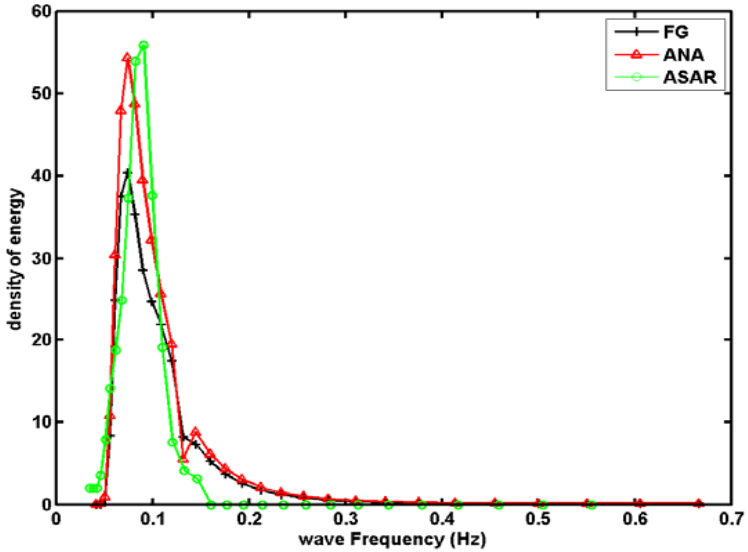
Results on the assimilation in MFWAM-UPGRADE

First guess



Analysis





The 1D wave spectrum :
Green line : SAR
Red line : Analyzed MFWAM
Black line : First guess

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Description of test runs

- Assimilation runs are performed from cycle 236 until 253 (24 August 2015 until 11 september 2015)

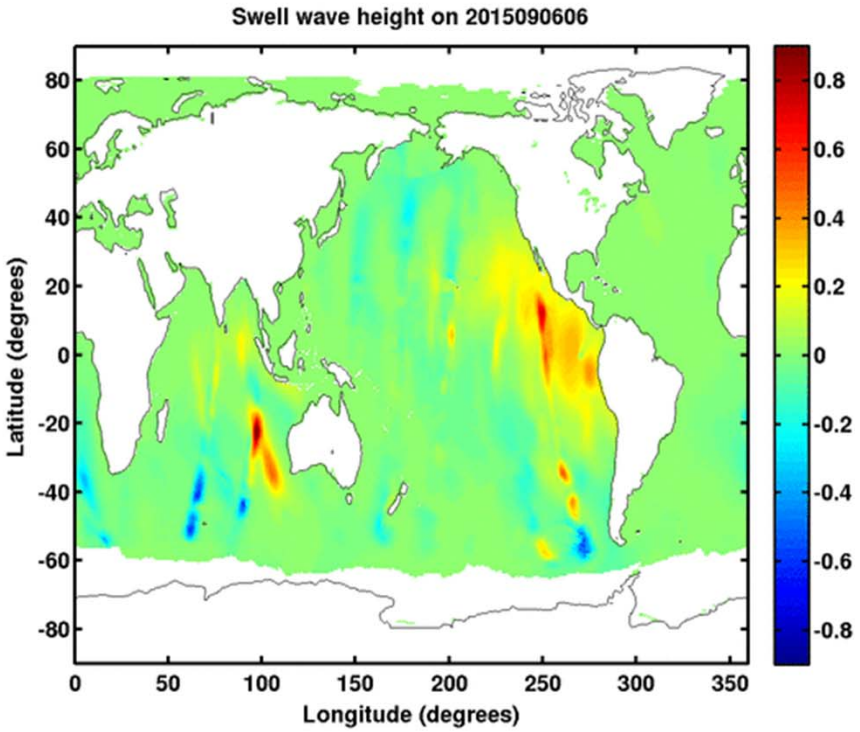
- The model MFWAM with grid size of 0.5° and the wave spectrum in 24 directions and 30 frequencies (starting 0.035Hz). The model MFWAM is driven by 6-hourly ECMWF analysed winds)

- Assimilation runs (from cycles 236 until 253 : 24 Aug to 11 Sep. 2015) :

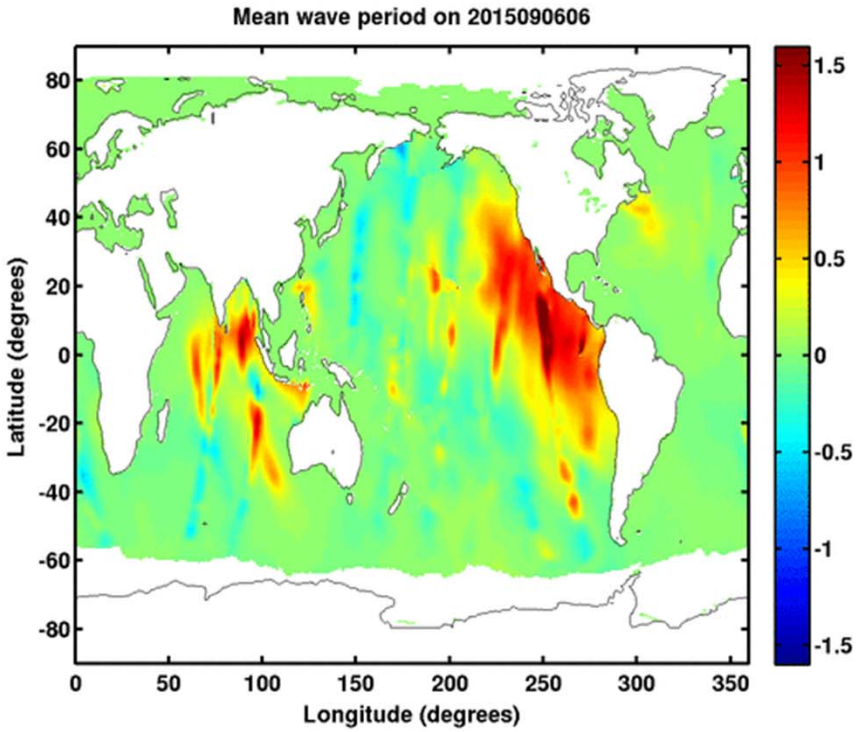
Runs with SAR	Run with altimeters	Run with SAR and altimeters	Baseline run
Assimilation with S1A (WM-1)	Assimilation with Saral and Cryosat-2	Assimilation with S1A (WM-1 & 2), Saral and Cryosat-2	Without assimilation
Assimilation with S1A (WM-2)			
Assimilation with S1A (WM-1 & 2)			

Impact of the assimilation of sentinel-1A (WV 1 &2) in the forecast period

Swell wave height



Mean wave period



Difference of wave parameters with and without assimilation of S1A Snapshots with a step of 6 hours in the period of forecast starting on 6 september 2015 at 0:00 UTC until 8 september at 0:00

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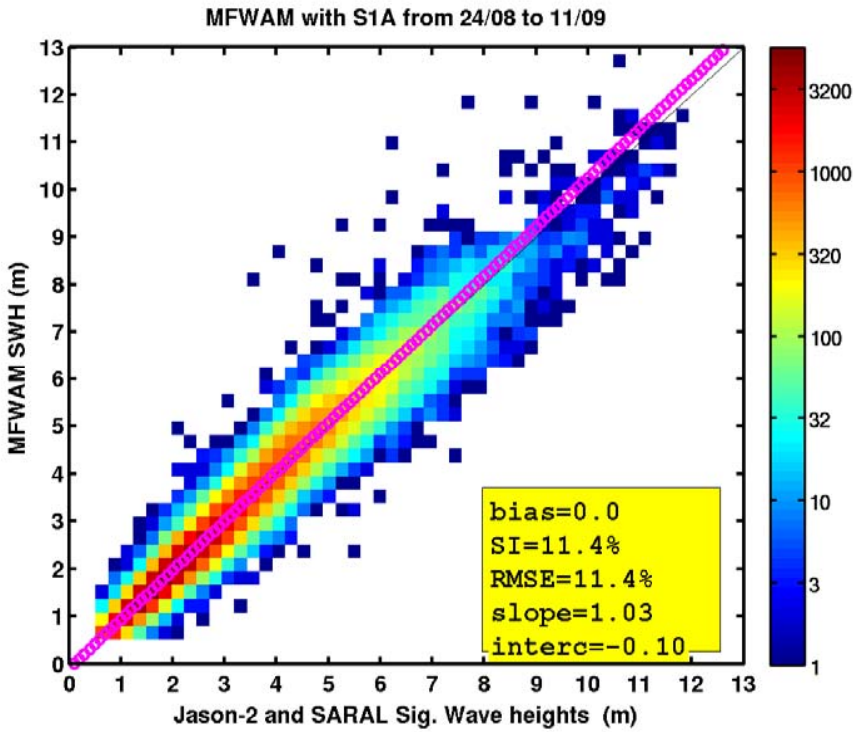
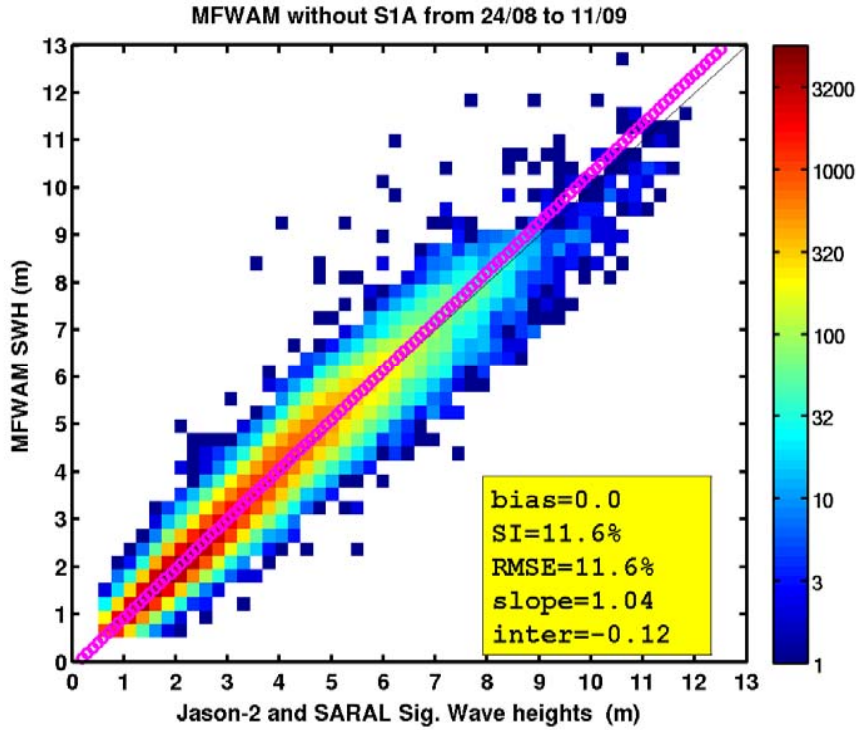
Validation of the assimilation of S1-A wave spectra
Significant wave heights

MFWAM-ASSI-S1A

Better slope

MFWAM-NOASSI





Bias = 0.0
SI = 11.4%
RMSE = 11.4%
Slope = 1 .03
Intercept = -0.10

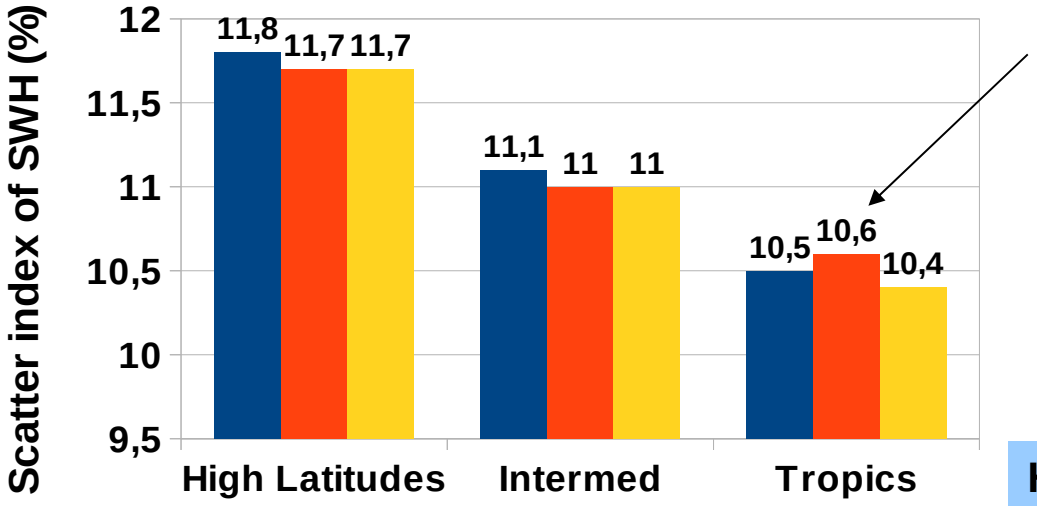
Scatter index is slightly improved by 1.5 %

August 24 au September 11, 2015
Comparison with SARAL and JA2

Bias=0.0
SI=11.6%
RMSE=11.6%
Slope=1.04
Intercept=-0.12

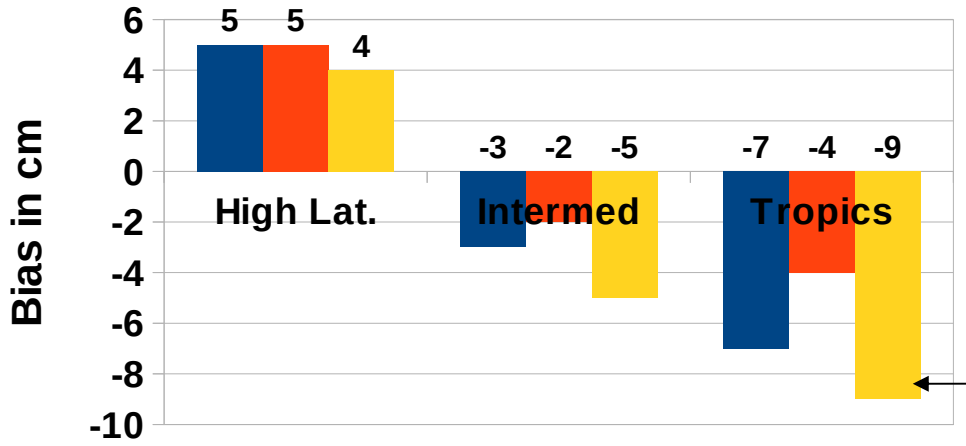
Impact of the assimilation of S1-A depending on the incidence angle of Sentinel-1A WM

Statistical analysis



WV-1 slightly degrades in the tropics

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



WV-2 increase the bias

Validation with Jason-2 and SARAL

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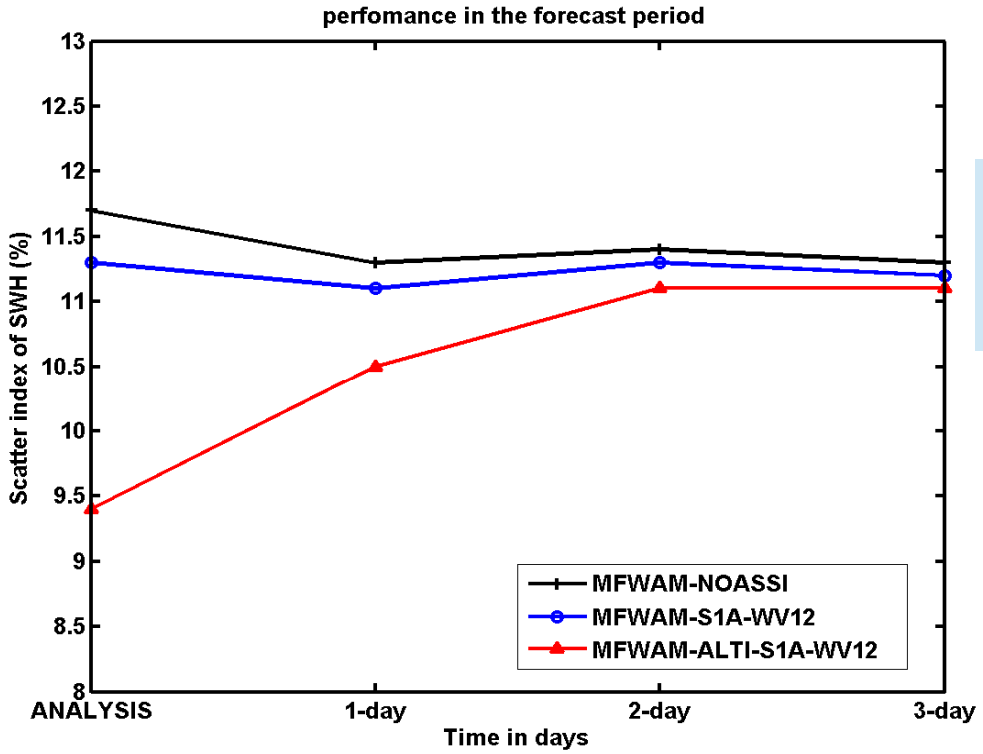
The impact of the assimilation in the forecast period

Normalized Scatter index of SWH (%)



The impact remains efficient after 2-day forecast

Black line : MFWAM without assimilation

Blue line : MFWAM with S1A

Red line : MFWAM with altimeters (CR2+SRL) and S1A

Validation with Jason-2 and Saral

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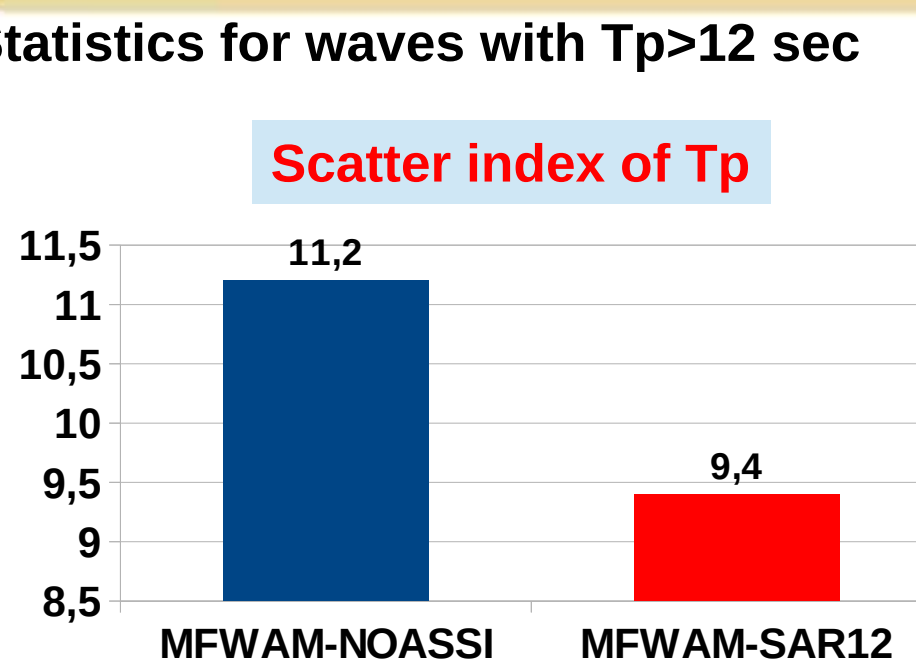
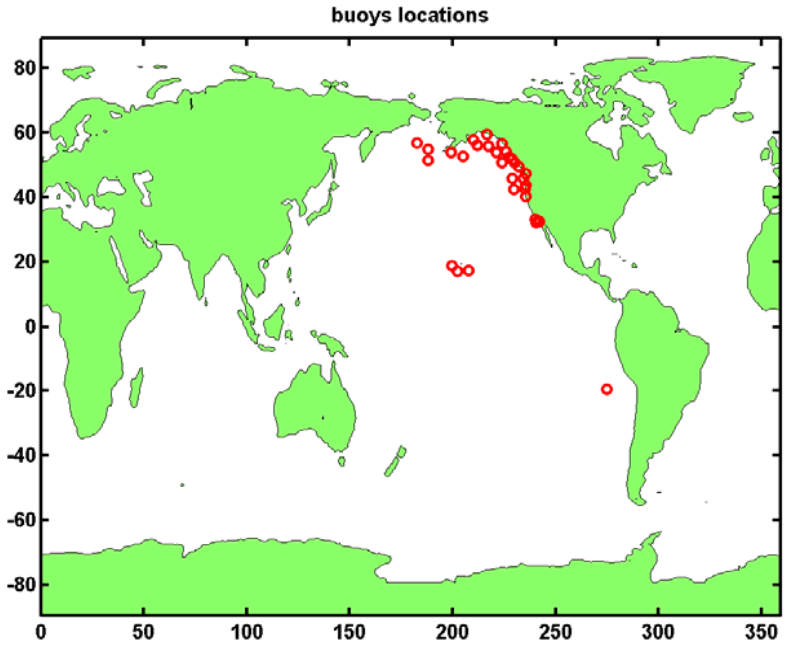
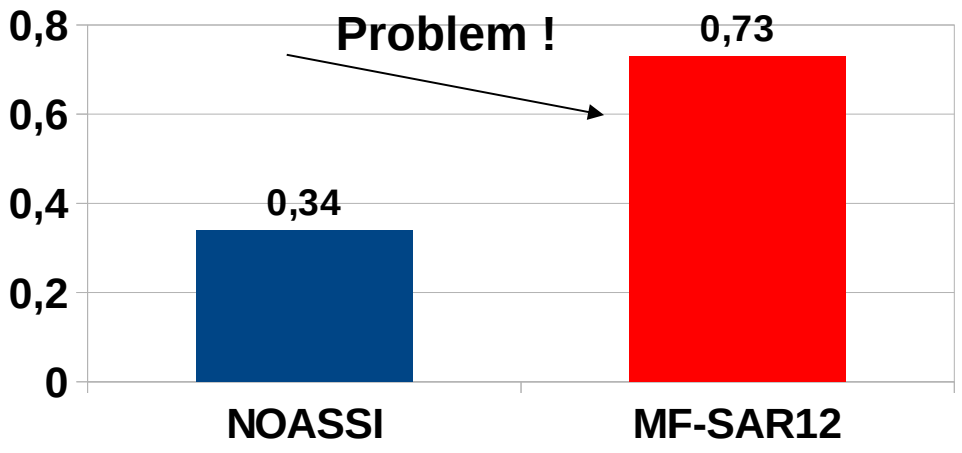
Validation on peak period in pacific ocean
Thanks to NDBC

Statistics for waves with Tp>12 sec



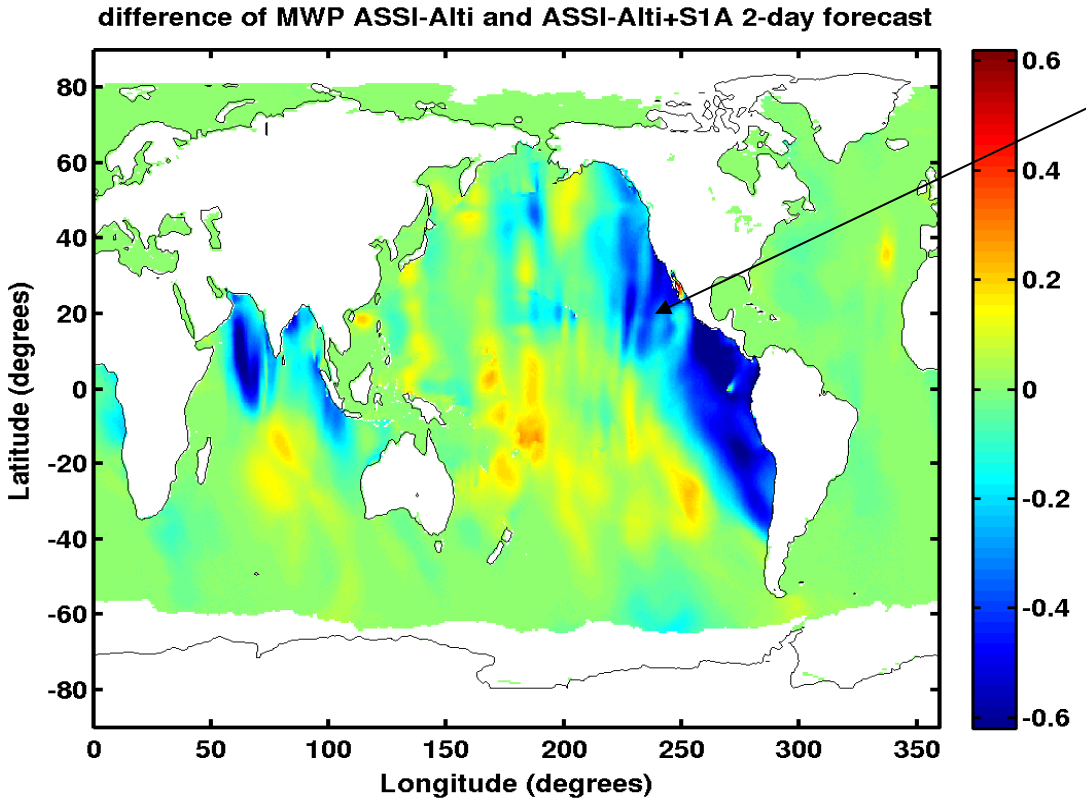




Scatter index is well reduced by 16 %, but bias is increased

24 Aug. until 11 Sep. 2015

The impact of assimilation of wave spectra from S1A In the forecast period



Strong hurricane Activity (hurricane LINDA)

2-day forecast after the end of the assimilation

Difference between mean wave period (in sec) of runs with assimilation of altimeters only and the one with altimeters and S1A wave spectra

8 September 2015 at 0:00 UTC

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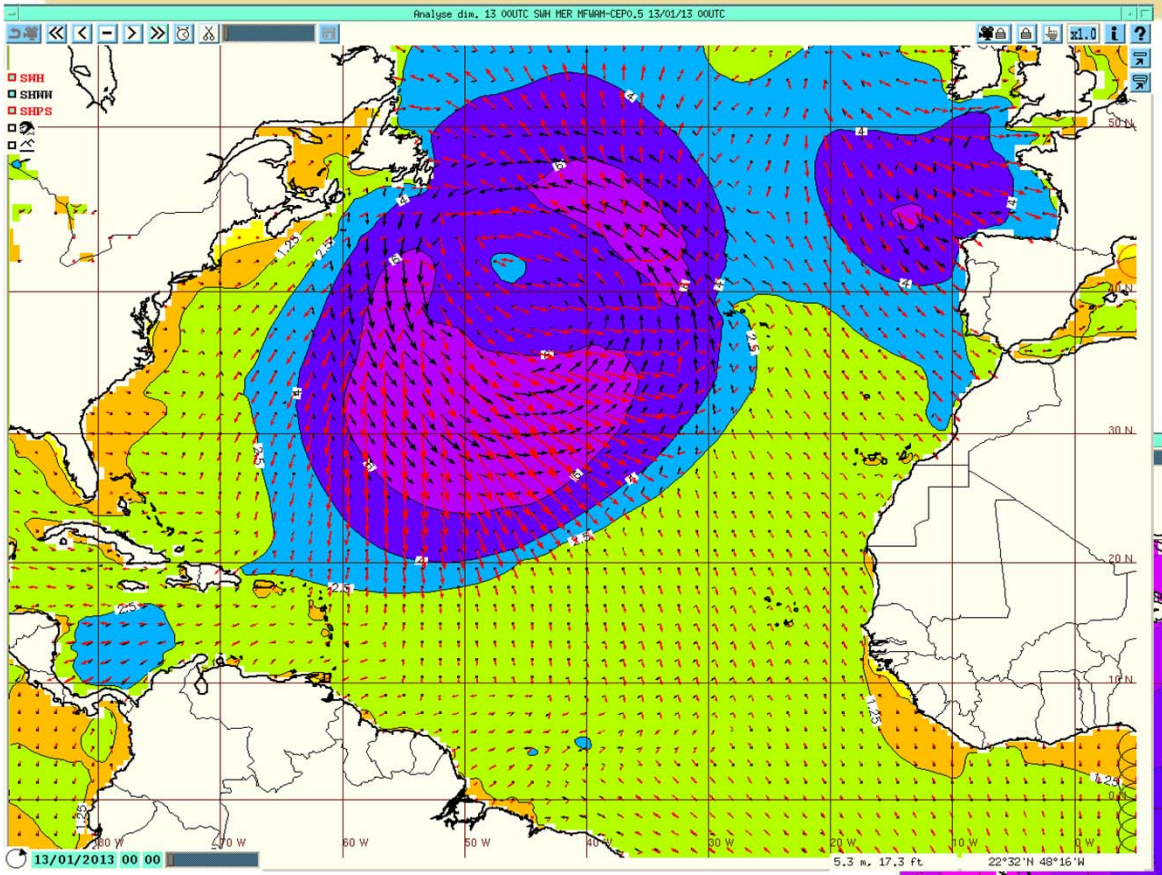
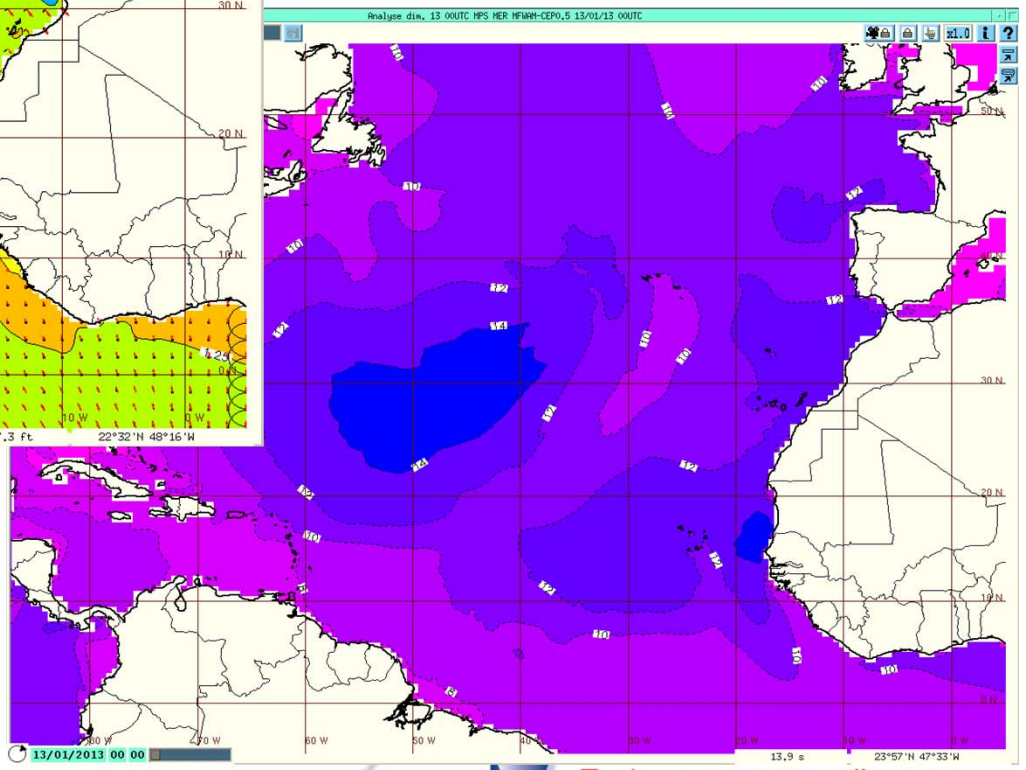
The swell case propagating from north towards the west indies (Antilles-Guyane 13 au 16 janvier 2013)

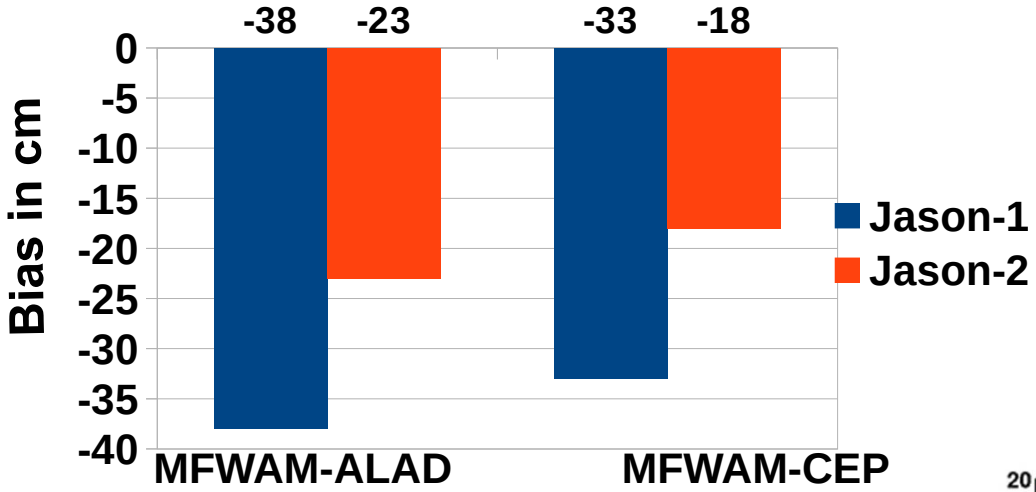


Sig. Wave height

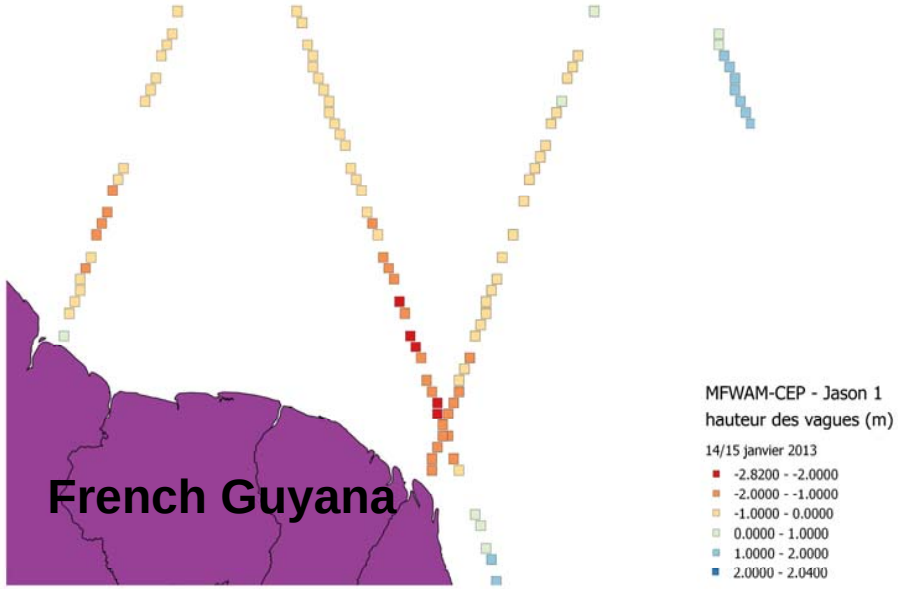
Mean wave period
Swell of 14 sec in Guyana

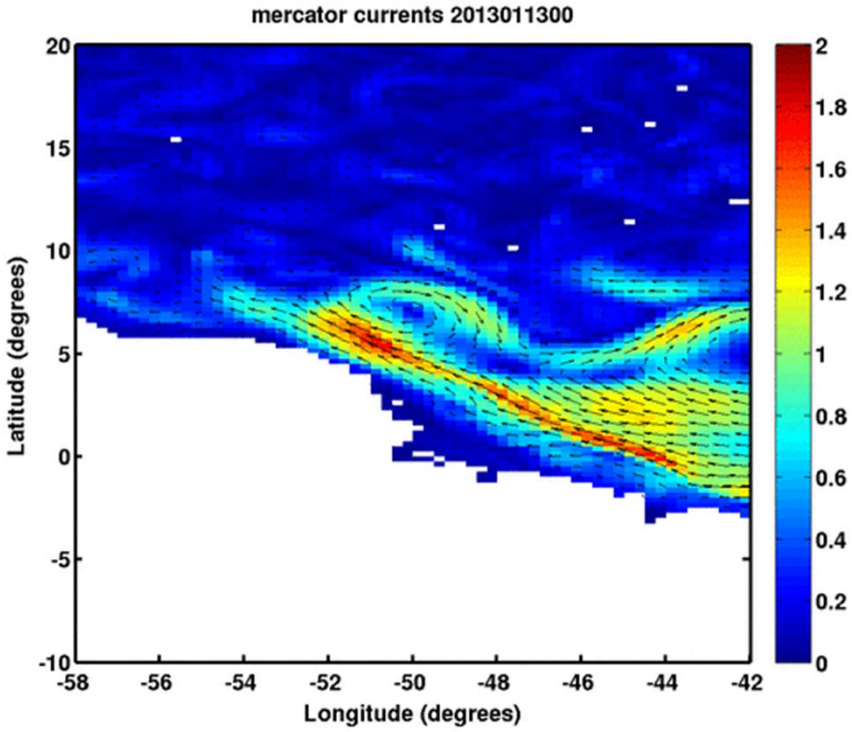


Errors in wave forecast on 13-16 January 2013 : consequence on Wave submersion warning



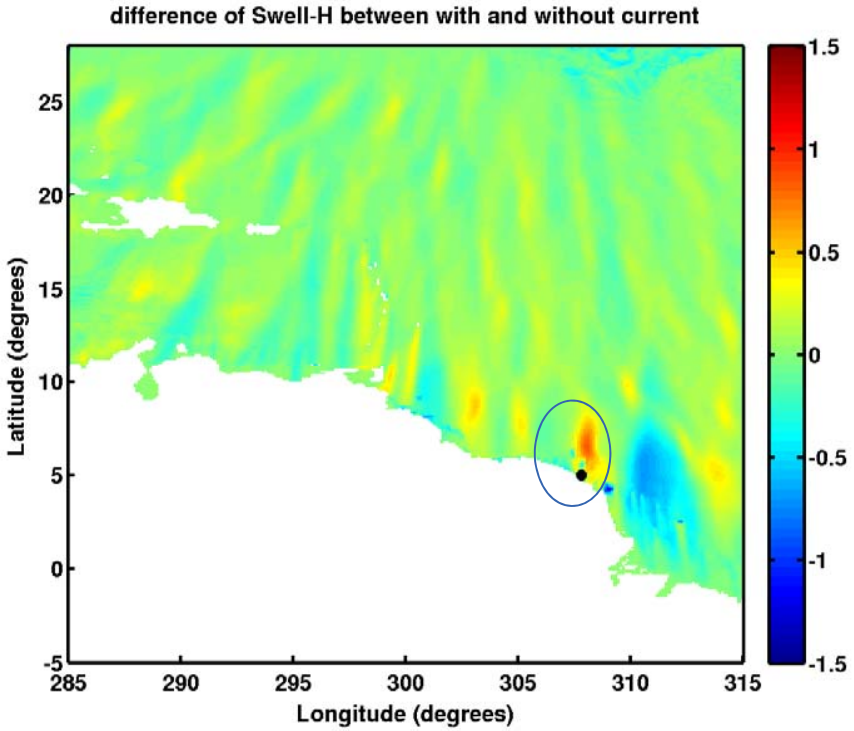
Two sources of errors :
1- Underestimation of the winds In the tropics
2- Strong surface current (Ascending Brazilian currentl)



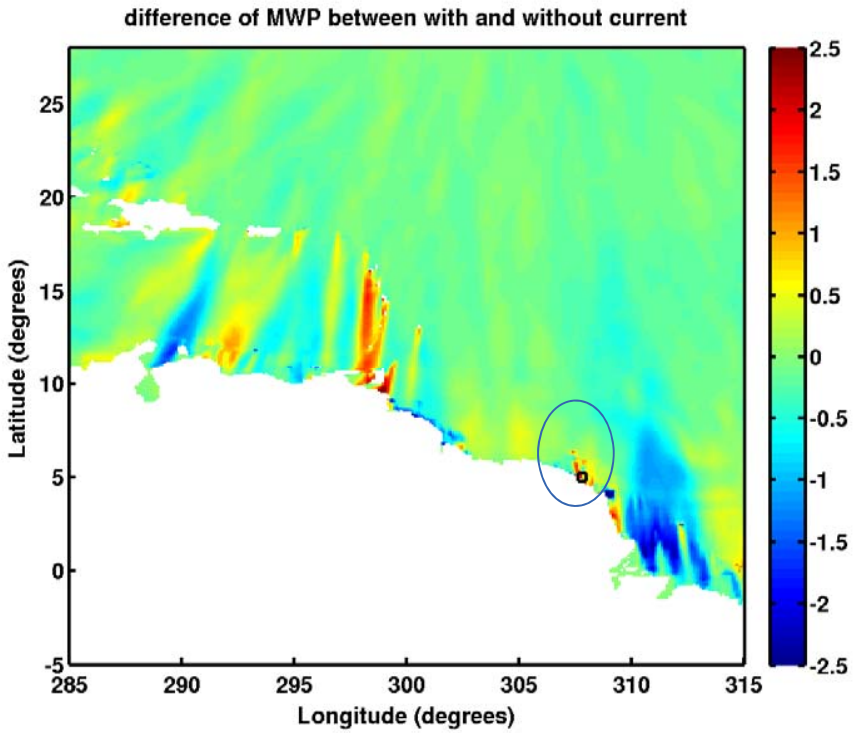


Impact of using Mercator surface currents In nested MFWAM-ANTI (regional west indies)

Swell wave height



Mean wave period



Difference of wave parameters from regional nested MFWAM-ANTI With and without Mercator currents

The currents induce a significant increase on the swell wave height off shore Cayenne indicated in black dot (Guyane)

15 January 2013 at 0:00 (UTC)

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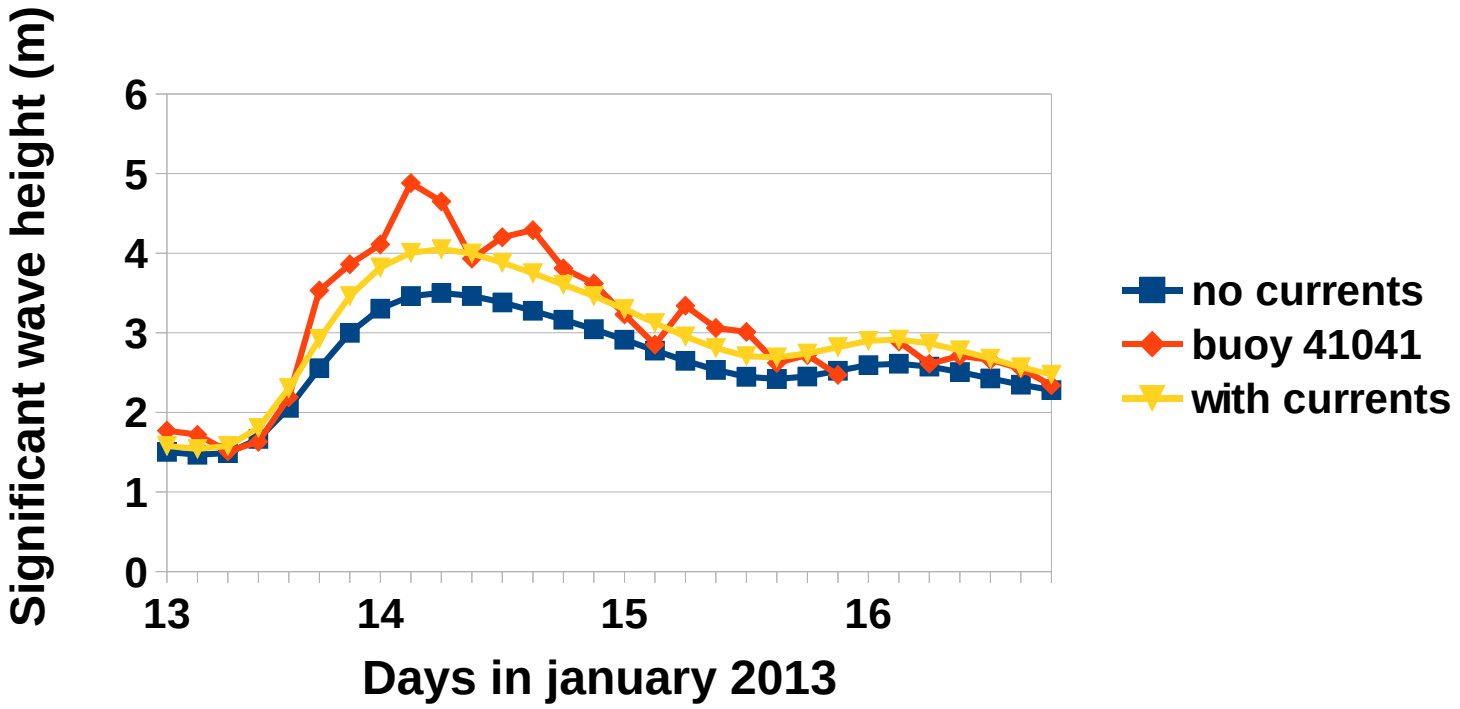
Validation with NDBC buoy 41041 (East of Martinique)
Thanks to NDBC buoy data



➡ **Improvement after the use of Mercator currents in regional MFWAM-West-indies**

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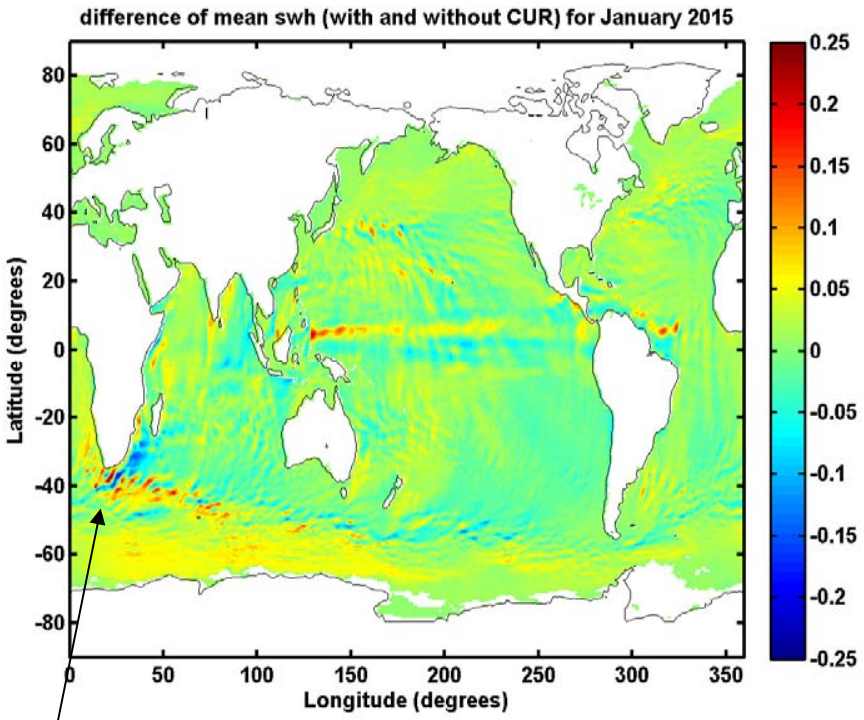
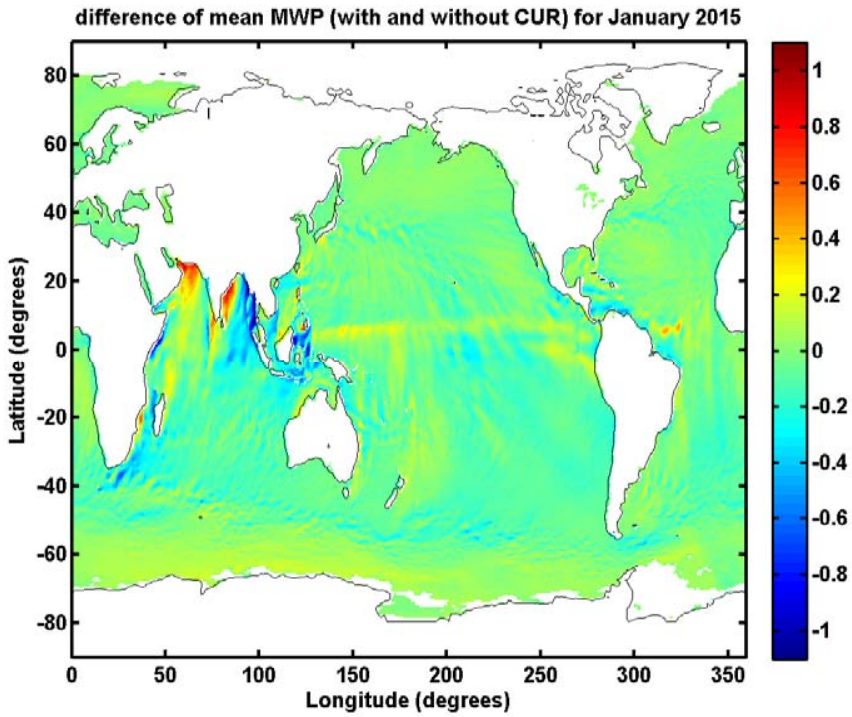
Impact of Mercator currents on MFWAM
January 2015

Significant wave height



Mean wave period



Difference of mean wave parameters with and without Mercator-NEMO currents

Comparison with altimeters shows improvement by ~10 % on Scatter index in the Agulhas and Benguela ocean area

Mean of 6-hourly output over January 2015

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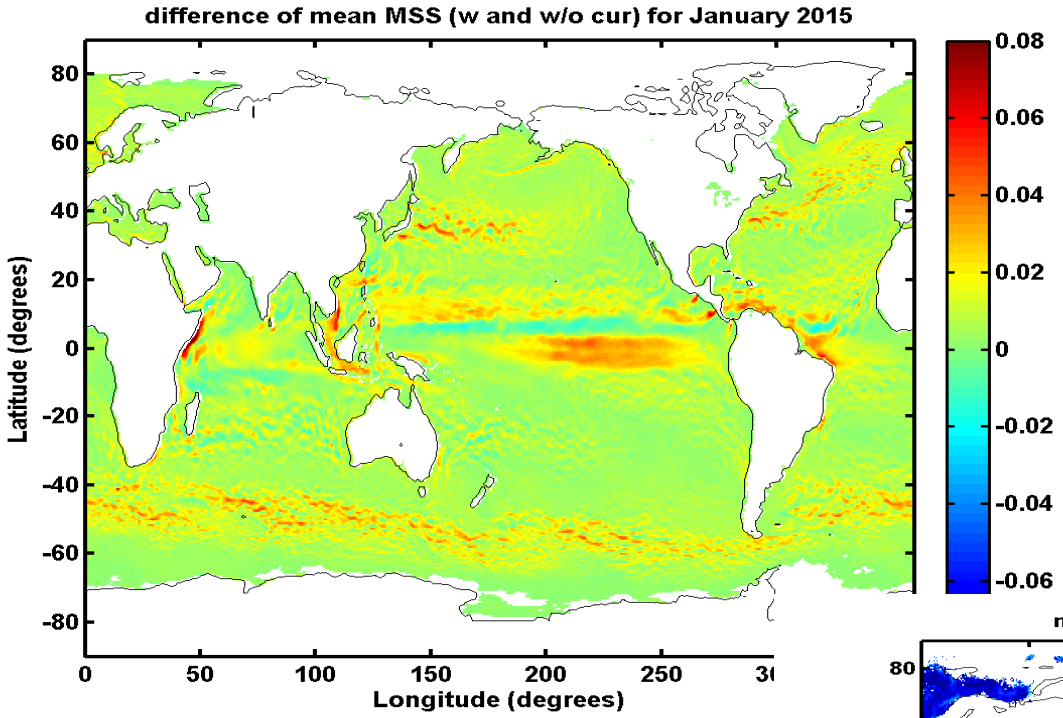
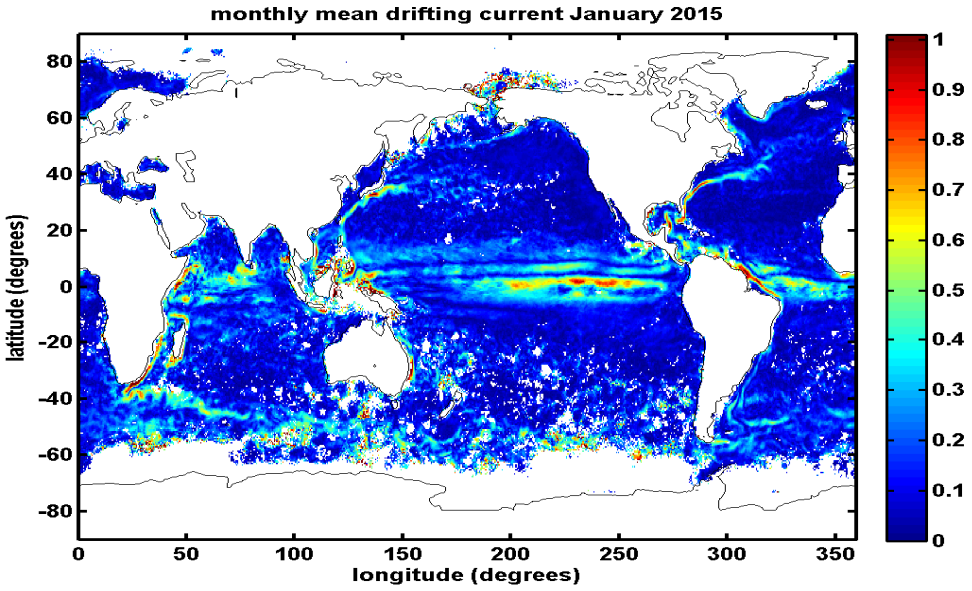
Impact of wave/current interaction on the Mean Square Slope (MSS)



Difference of mean MSS with and without forcing of currents

The MSS is significantly modified in strong current regions and in the tropics.

Monthly mean of drifting current January 2015 from AOML (Rick Lampkin)



Mean of 6-hourly output over January 2015

Conclusions

→ The impact of the assimilation of both wave mode incidence (1&2) indicates a positive and small improvement in the analysis (in reference to altimeters)

→ The wave spectra from the WM-1 slightly degrade the analysis in the tropics. The MTF for the retrieval needs to be improved (recommandations sent to ESA)

→ The impact of the assimilation is enhanced in the forecast period for hurricanes and storm events.

→ Works are ongoing for more testing and adapting the assimilation scheme.

→ The use of Mercator/NEMO currents in MFWAM improves the sea state forecast : the challenge of coupling in Copernicus programme