The impact of combined assimilation of altimeters data and wave spectra from S-1A and 1B in the operational model MFWAM

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1st International Workshop on Waves, Storm Surge and Coastal Hazards, 10-15 September, Liverpool

OUTLINE

1- Motivation

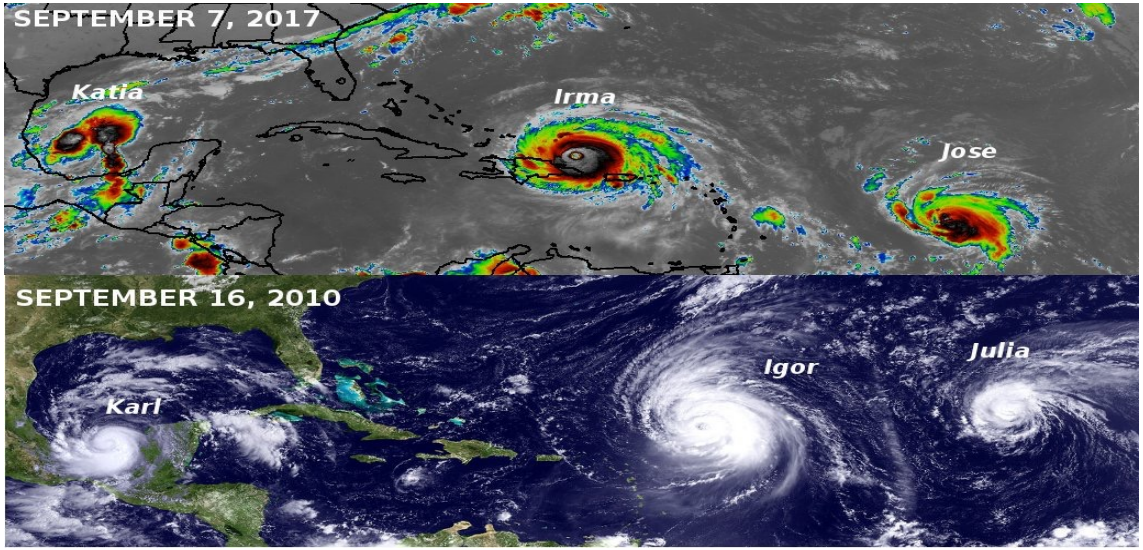
2- The system and satllite data

3- Results and validation with independent data
- Story of bias
- Re-localization

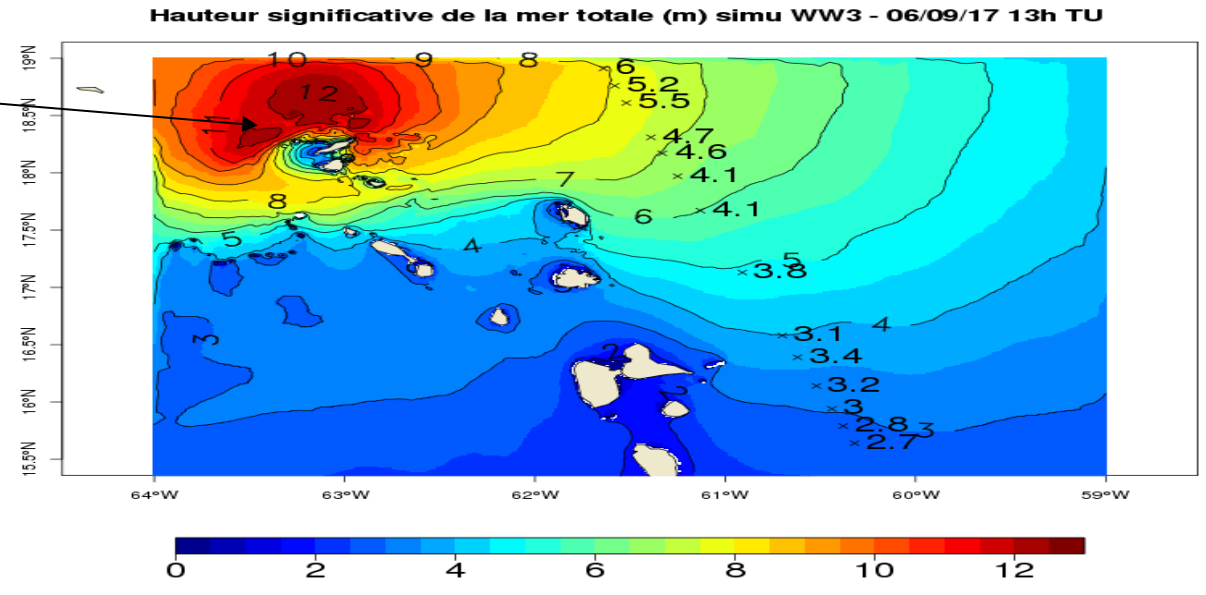
4- Storm cases

5- Conclusions

Highest level ov waves submersion warning (Violet) For Hurricane IRMA



12 meters of waves near Saint Martin from the coastal model forecast



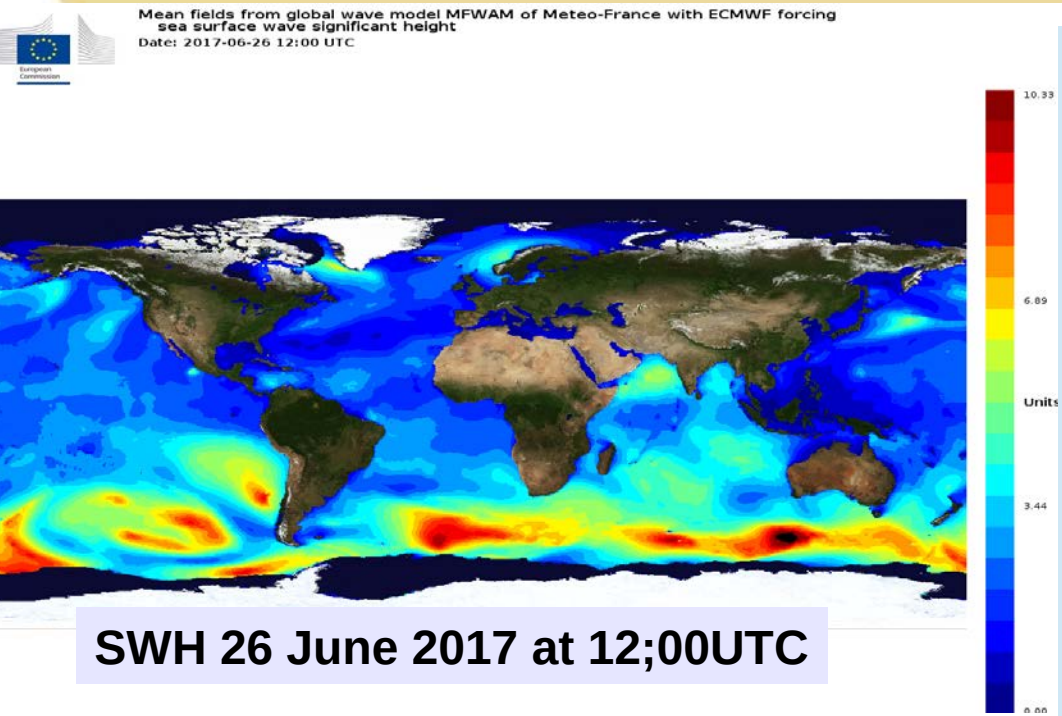
MOTIVATION

- **Improving the wave forecast and in particular directional properties in the operational MFWAM at global and regional scale : reliable wave submersion warning (VVS)**

- **Preparing the assimilation of satellite data in the frame of CMEMS-Global (design V4 : end of 2017) : Sentinel-1 and**
- **Sentinel-3 copernicus missions**

- **Assessing the impact of using altimeters and SAR wave spectra (S-1A & 1B) and evaluating the impact of SAR mode altimetry from S-3A**

The global wave forecasting MFWAM



SWH 26 June 2017 at 12;00UTC

Global wave model MFWAM (0.2°) forced by ECMWF winds.

- MFWAM is based on IFS-38R2 code with the source terms developed in Ardhuin et al (2010) and setting from Mywave project.

In operations assimilation 6 hours:

Jason-2 (safe-mode)

SARAL since 10 December 2013

Cryosat-2 since 23 April 2014

Jason-3 since October 2016

SI of SWH (%)

JCOMM Intercomparison With buoys April 2017

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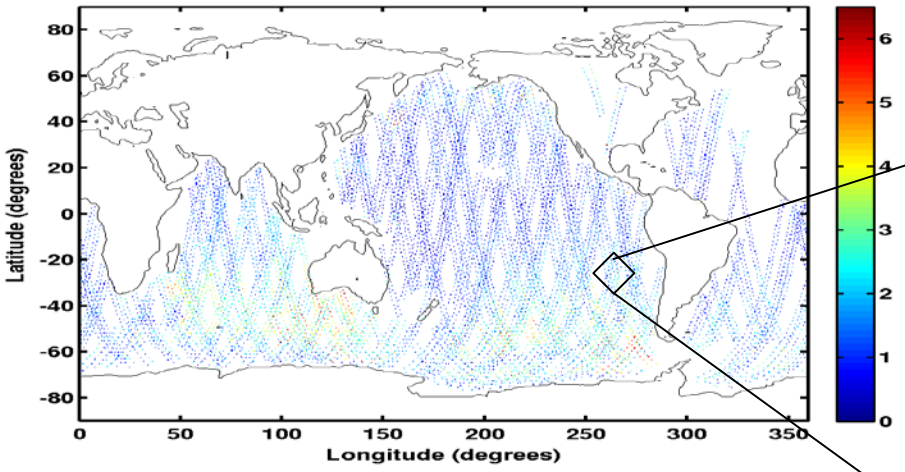
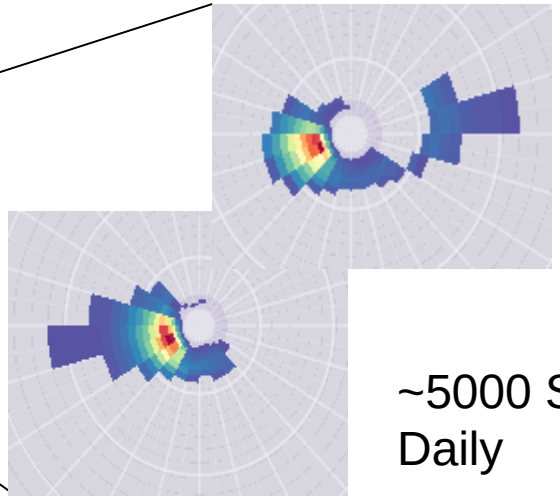
Daily coverage altimeters wave data and SAR wave spectra from S-1A and 1B

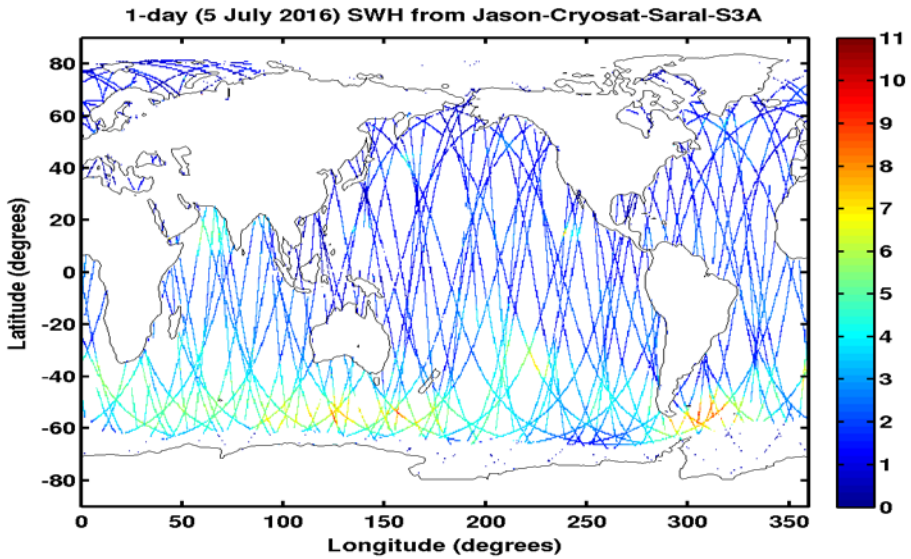
S1A and S1B daily orbit tracks



Spectral resolution of 60 frequencies and 72 directions : QC implemented



~5000 SAR spectra Daily



couverture journalière en données altimétriques (Jason-2 & 3, Cryosat-2, Saral et S-3A)

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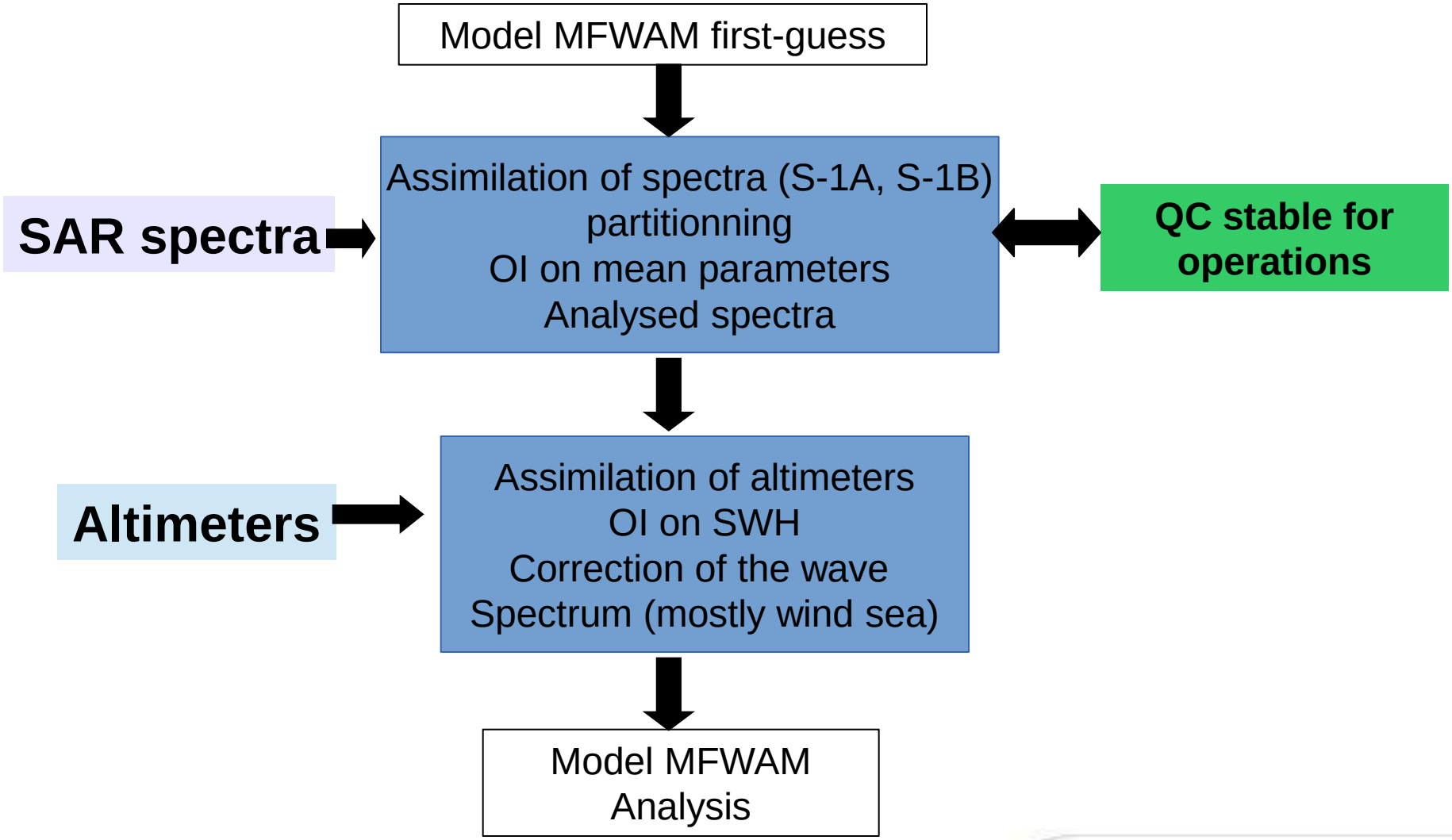
Description of combined assimilation system



Assimilation experiments

☐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 3-day forecast ECMWF winds).

Focus on two seasons : Sep-Oct-Nov-Dec 2016
May-June-Jul 2017

☐Performed runs :

- runs with combined assimilation Altimeters + SAR spectra from S-1A and S-1B
- run with S3A altimeters and SAR spectra from S-1A and S-1B
- Baseline run without assimilation

☐The validation of results has been performed with alimeters wave heights (not assimilated) and buoys.

Impact of the combined assimilation of S-1A and S-1B Spectra and altimeters : Sep-oct-Nov-Dec 2016

Best performance when using Ja2-Saral-Cr2 and S1A, S1B

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

SI is improved after the asimilation of S-1A and S-1B spectra

Validation with altimeter HY-2a

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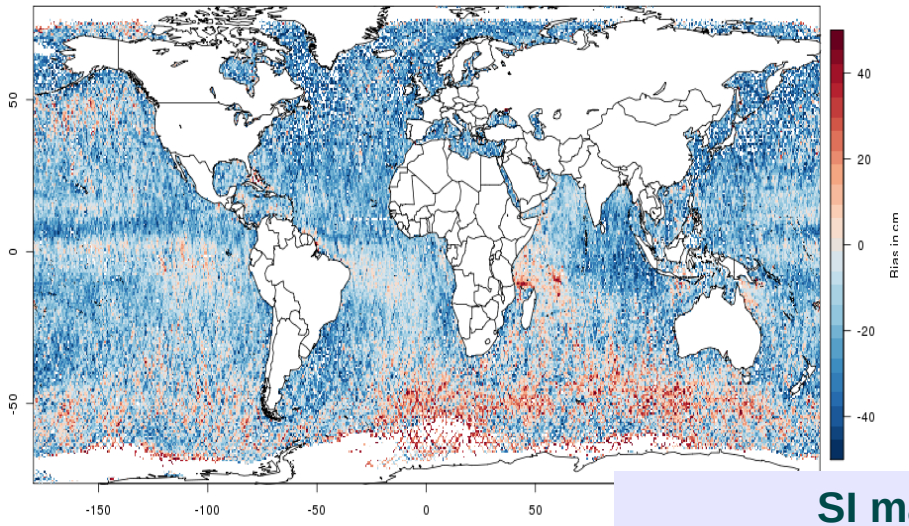
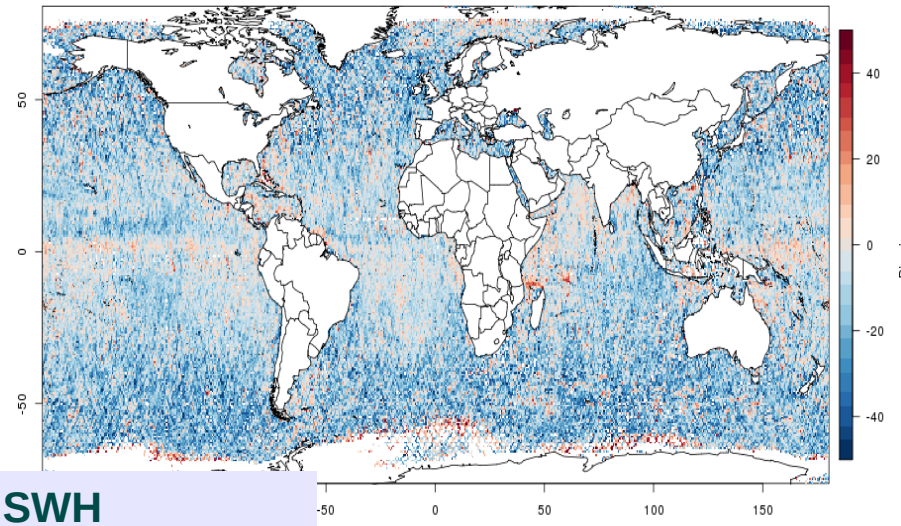
Combined assimilation of SAR spectra from S1A and S1B and altimeters (Ja2,Saral and CR2)

Without assimilation

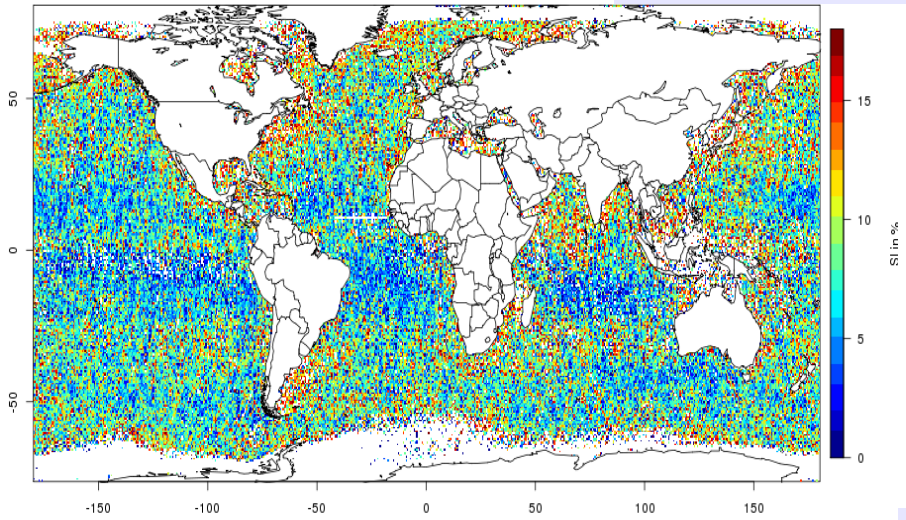
Bias map of SWH
(Significant bias reduction)

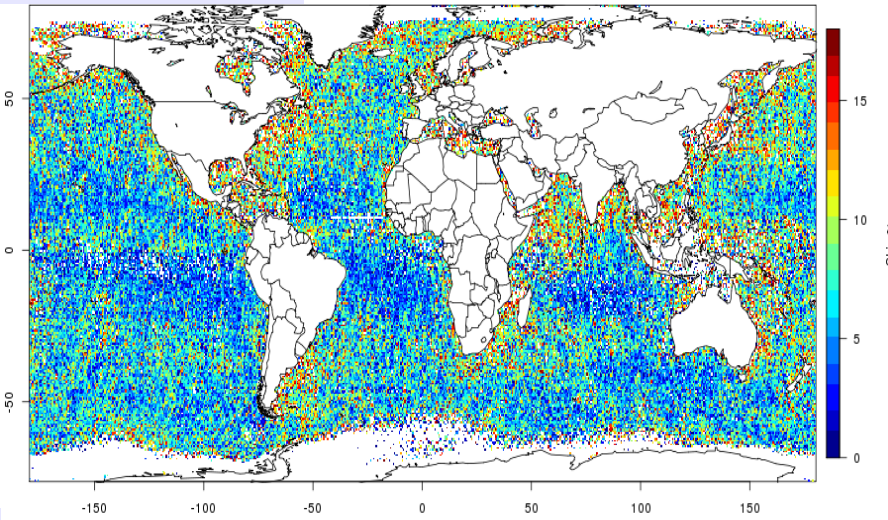
With assimilation





SI map of SWH
(globally improvement by ~16 %)





Validation with independent Hy-2A
(Sep-Oct-Nov-Dec 2016)

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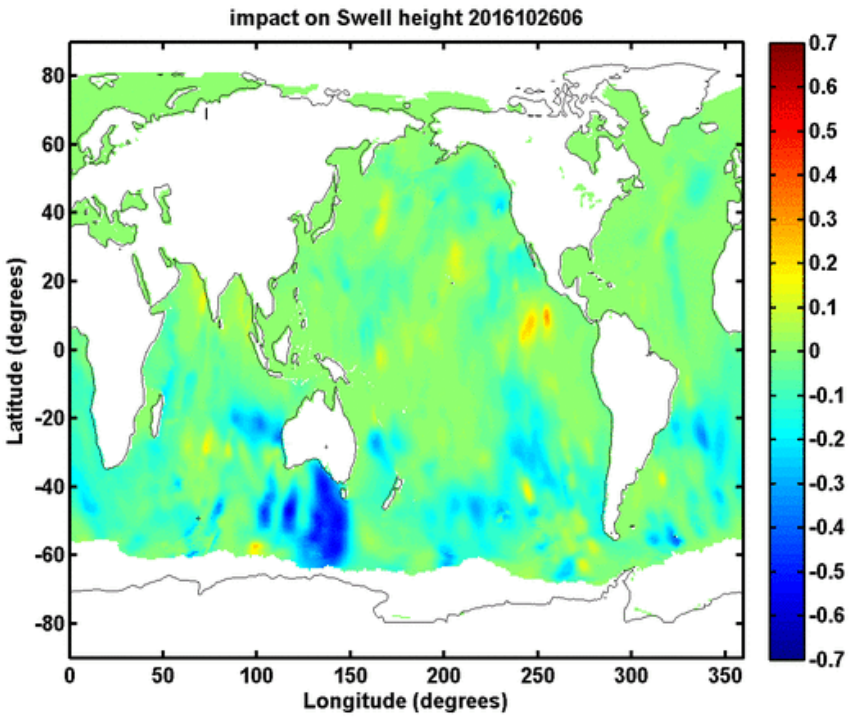
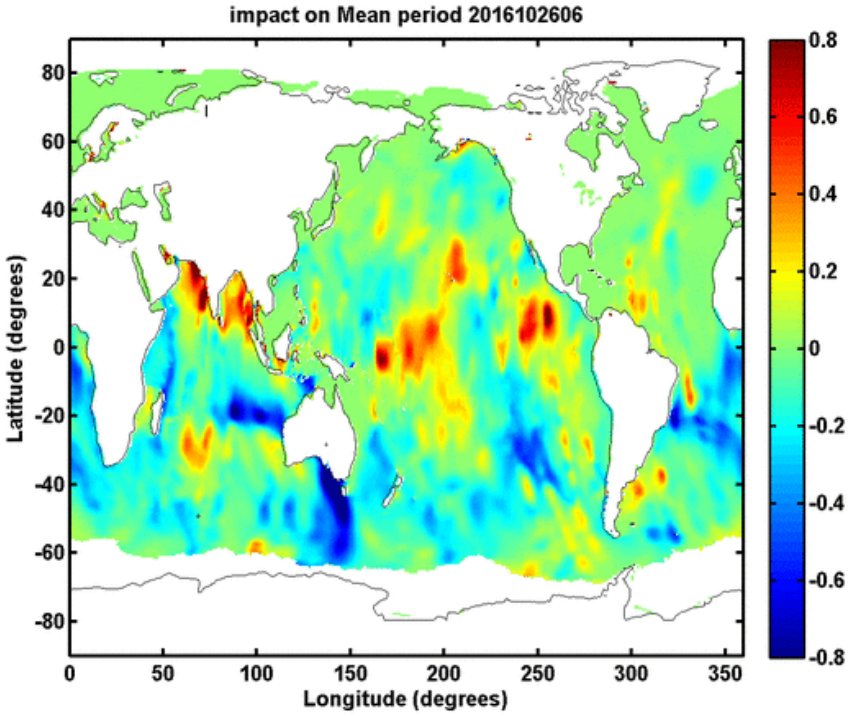
Impact of the assimilation of sentinel-1A and 1B in the forecast period

Swell wave height



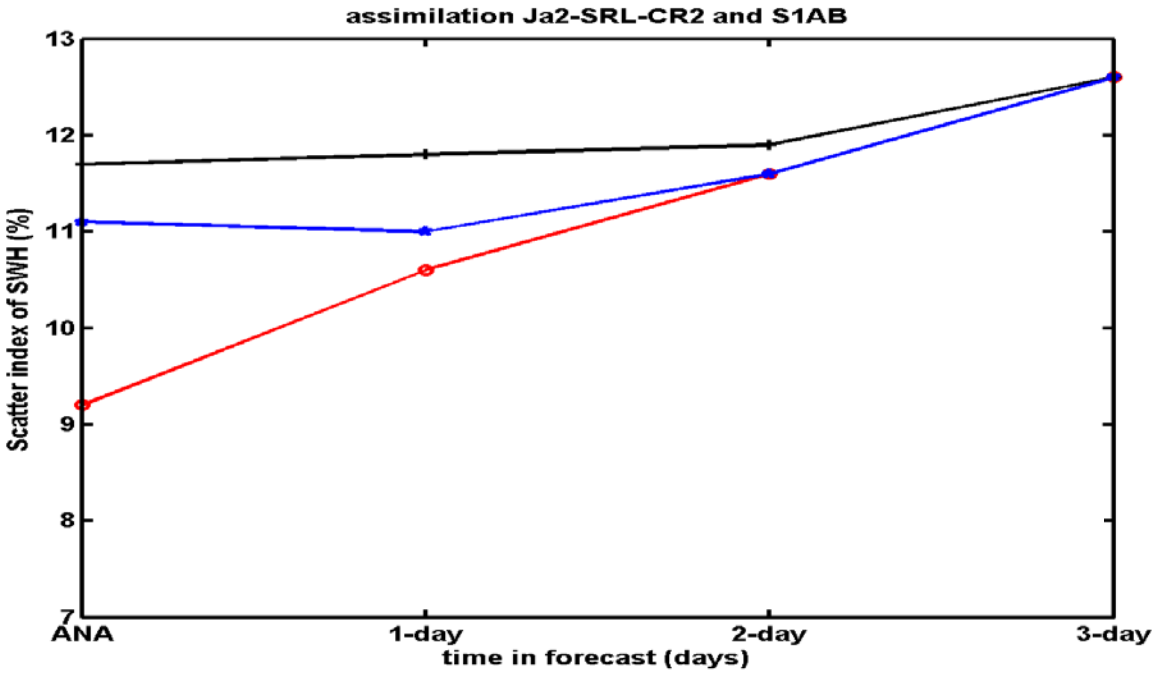
Mean wave period



Difference of wave parameters with and without assimilation of S1A
Snapshots with a step of 6 hours in the period of forecast starting on 26 October 2016 at 06:00 UTC until 28 October at 0:00

The impact of the assimilation in the forecast period

Normalized Scatter index of SWH (%)



Black line : MFWAM without assimilation

Blue line : MFWAM with S1A and S1B

Red line : MFWAM with altimeters (JA2+CR2+SRL) and S1A+S1B

Validation with Jason-2 and Saral

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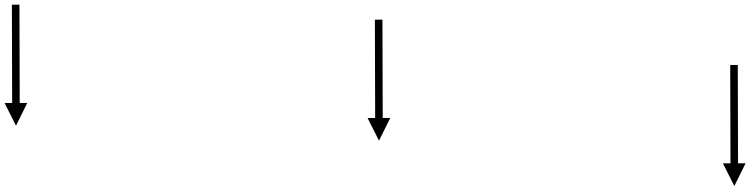
Impact of increasing number of altimeters and SAR spectra on Sig. Wave Height

The best performance on SWH when using 4 altimeters with SAR spectra (SI <10%):



Experiments description:

EXP-A	Ja-2	Ja-3	SRL	CR2	S3 A	S1A	S1B
EXP-B	Ja-2	Ja-3	SRL	CR2	S3 A	S1A	S1B
EXP-C	Ja-2	Ja-3	SRL	CR2	S3 A	S1A	S1B
EXP-D	No assimilation						

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

At least 1 altimeter is kept for the validation

ly 2017

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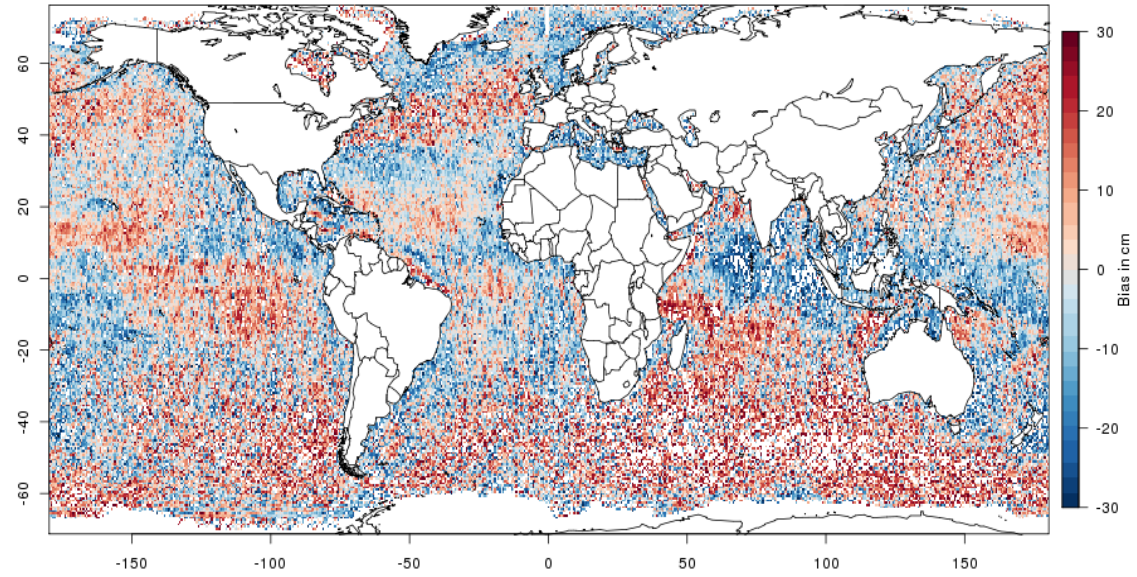
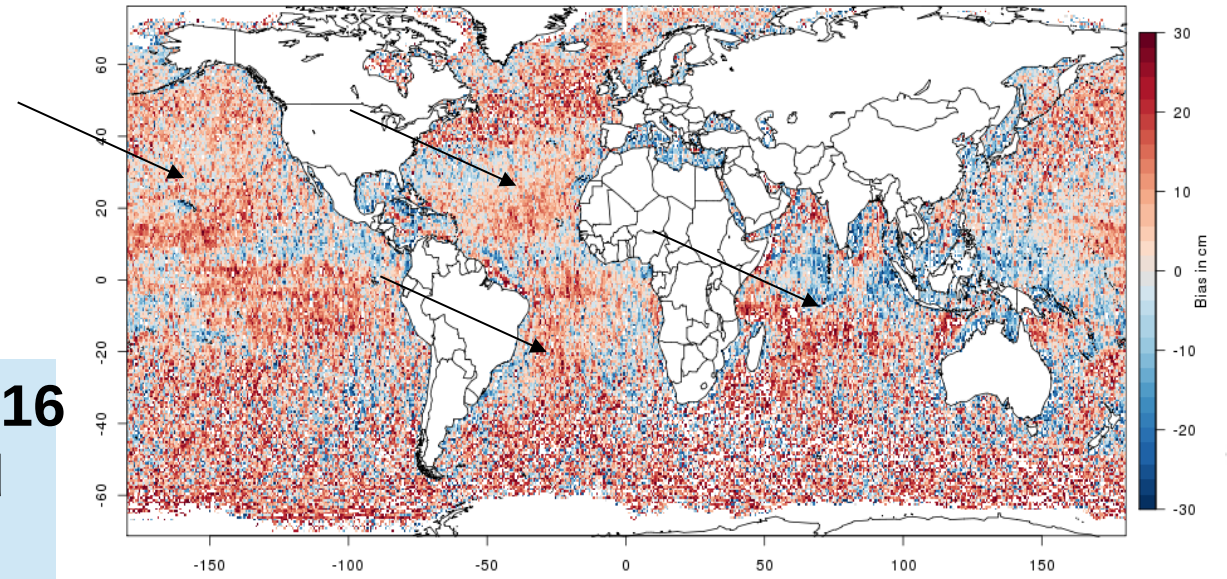
Bias maps of SWH (The story)
the assimilation of S3A and S1A and S1B spectra



without assimilation

Sentinel-3A increases the bias of SWH after the combined assimilation. Bias induced possibly by swell effect on the retrieva of SAR altimetry

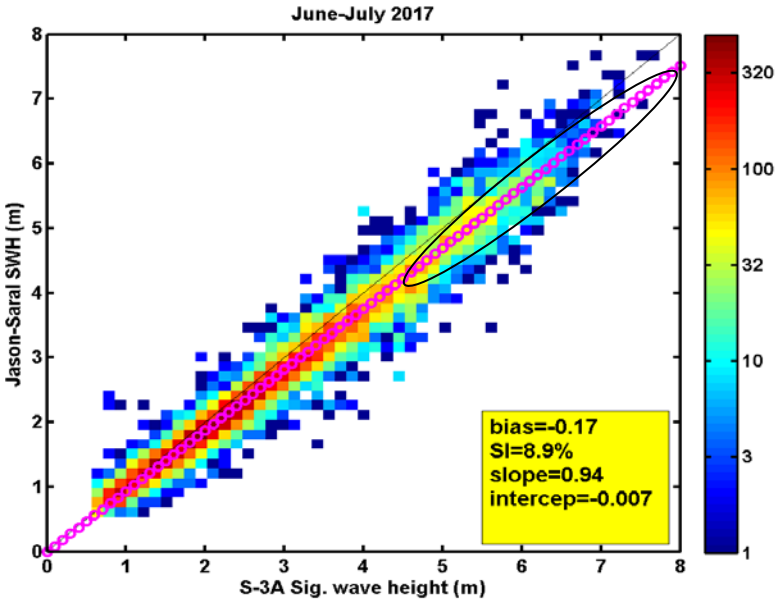
MFWAM+S3+S1A+S1B

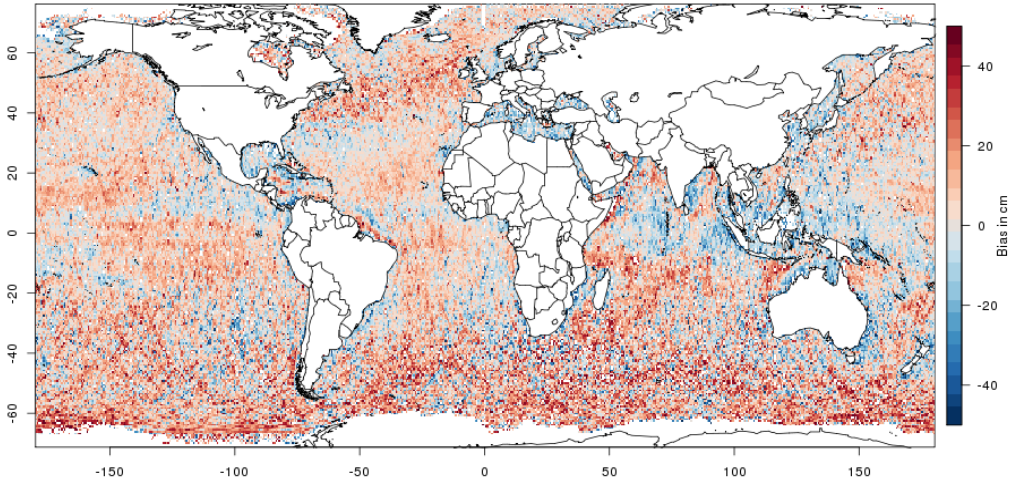


Period of May-Jun-Jul 2016
Validation with JA3 and Saral

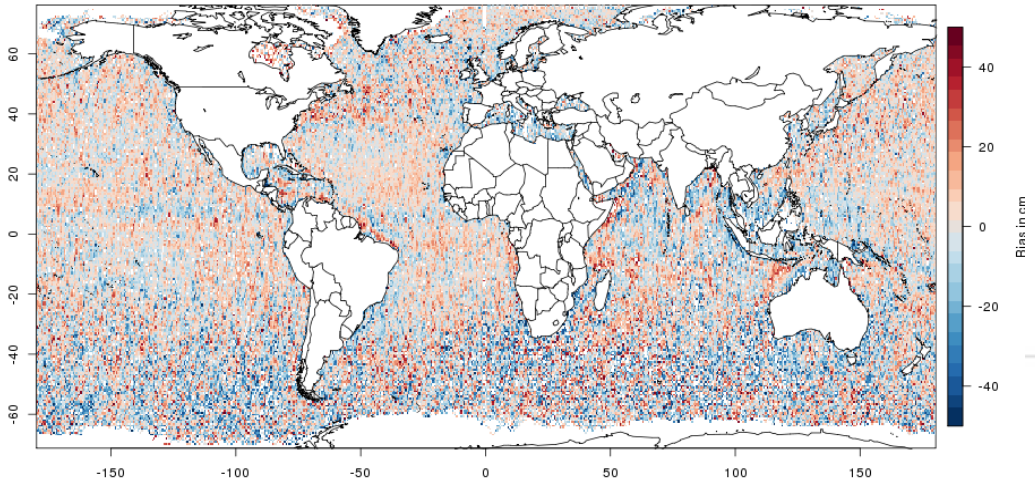
Testing on bias correction for S-3A

Comarison between S3A and Ja-3 and Saral at crossovers tracks



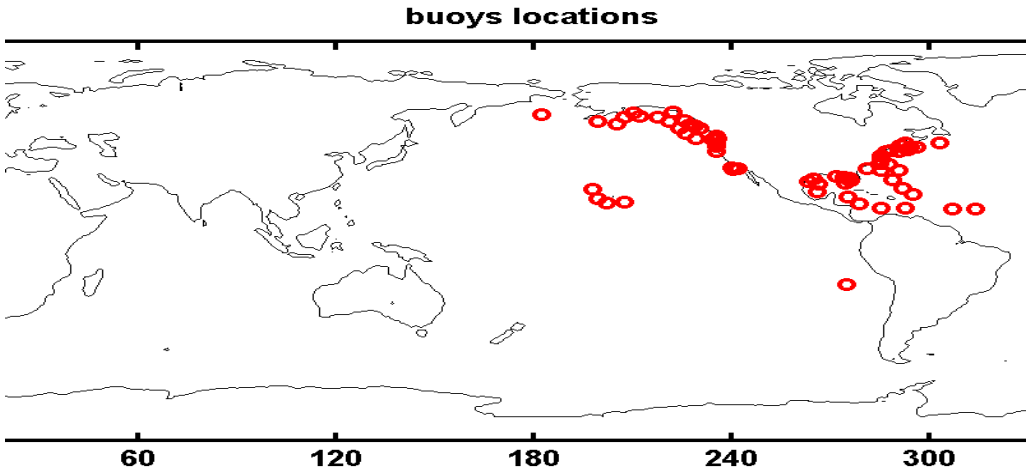


Improvements after using correction



Assimilation run with correction on S3A has been performed.

Comparison with buoys : thanks to NDBC and J. Bidlot for buoys data archive



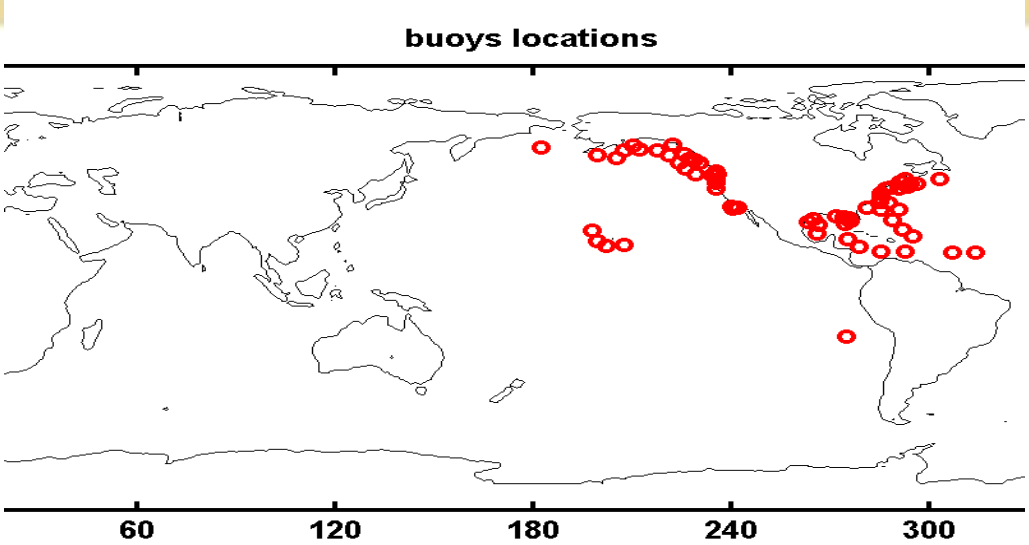
Validation of SWH for the period : Sep-Oct-Nov-Dec 2016

SI is improved for all wave Systems. CAT4 is improved Thanks to SAR spectra

CAT1 : Tp > 6 sec
CAT2 : Tp > 8 sec
CAT3 : Tp > 10 sec
CAT4 : Tp > 12 sec

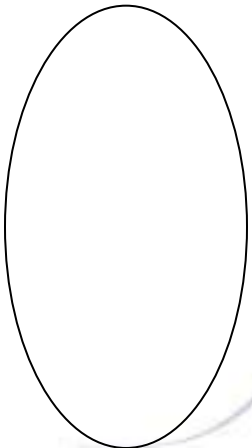
Comparison with buoys : Peak period

Period of Sep-Oct-Nov-Dec 2016



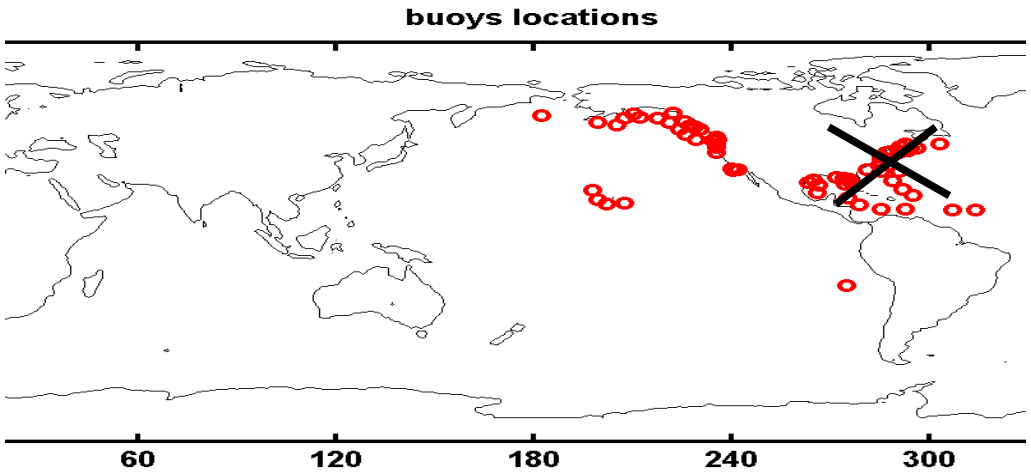
Validation of Peak period Tp

SI is well reduced and the Improvement is enhanced for CAT4 thanks to S1A and 1B



CAT1 : Tp > 6 sec
CAT2 : Tp > 8 sec
CAT3 : Tp > 10 sec
CAT4 : Tp > 12 sec

Comparison with buoys : May-June-Jul 2017
Winter in the southern ocean



Validation of Peak period Tp on Pacific buoys

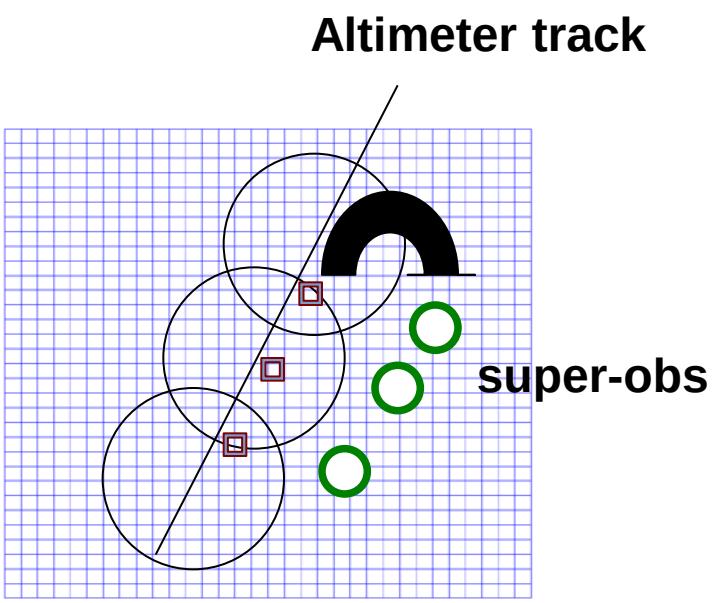
Significant improvement of SI in particular for long swell (CAT4) Dominant system

CAT1 : Tp > 6 sec
CAT2 : Tp > 8 sec
CAT3 : Tp > 10 sec
CAT4 : Tp > 12 sec

The use of re-localization technique for global 0.2°

Decreasing the grid resolution of the wave model induces less impact for grid points at 0.5°.
The re-localization uses the altimeter observed points to get super-obs at 0.5°, and then will be considered as Input for the assimilation.
The advantage is increasing the number of data and allow a more efficient Assimilation.

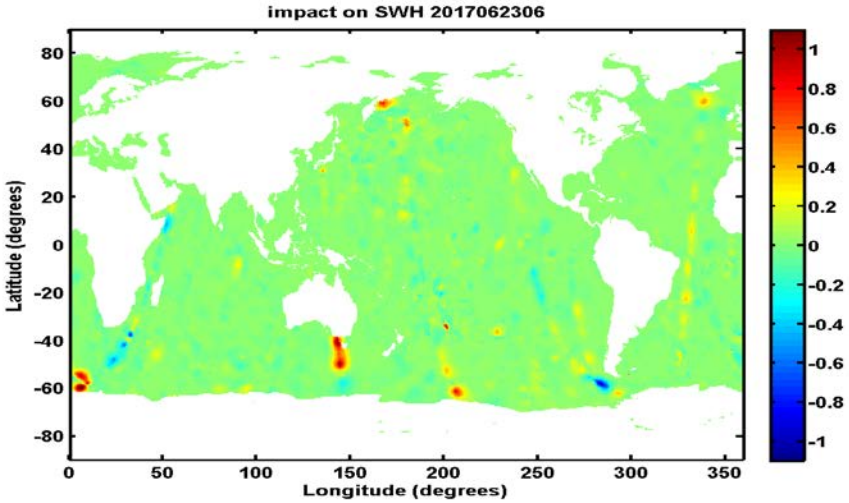
Test run for June 2017 has been tested with operational MFWAM of grid resolution of 0.2°.



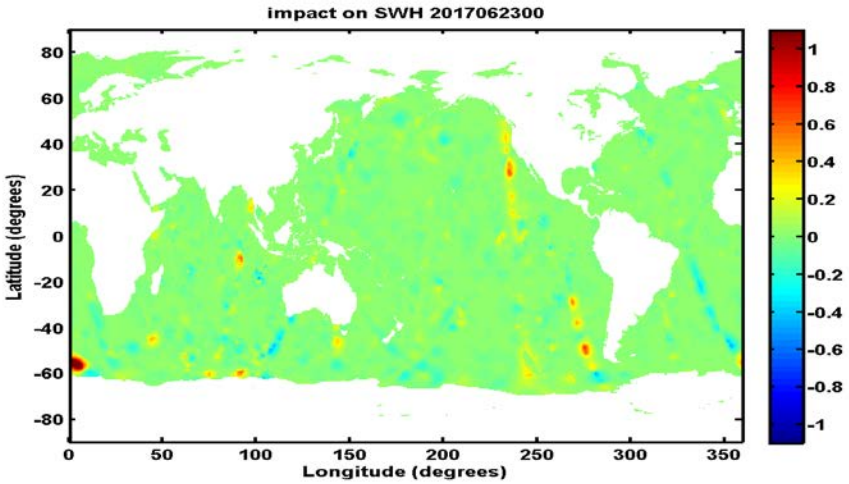
The impact of re-localization technique

Difference of SWH with and without re-localization

23 June 2017 at 0:00



23 June 2017 at 06:00



Better SI when using the re-localization technique (roughly improved by 5%)

Validation with Saral

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Storm in southern ocean on 23 June 2017 : Warning for swell at La Réunion

Sentinel-1A and 1B tracking the long swell generated by the storm Off shore of South-Africa (Peak Energy=172.2 and Peak eriod of 16 sec)

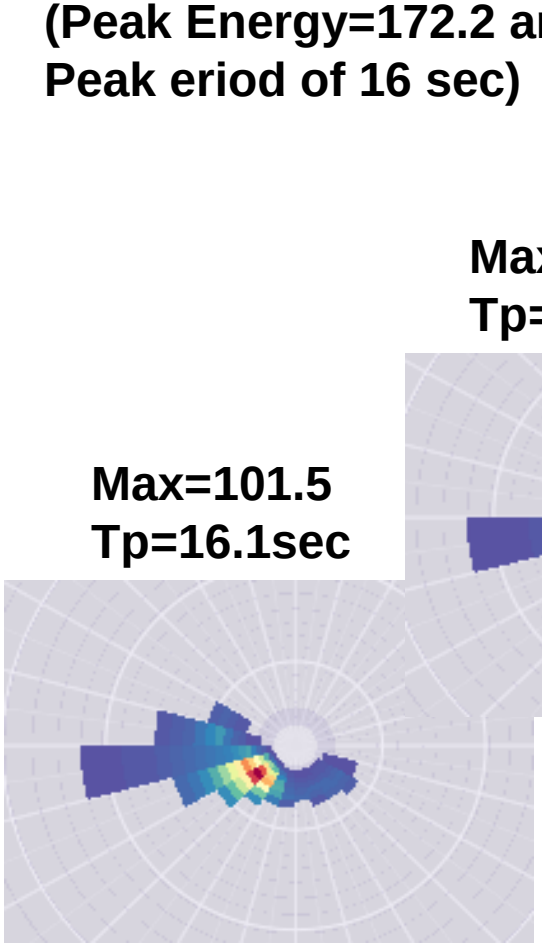
S1 in the peak of the storm

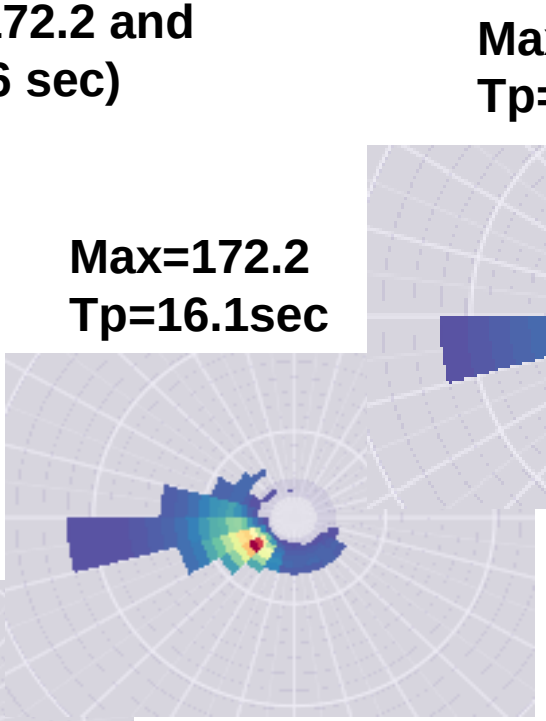
Max=115.1
Tp=13.1sec

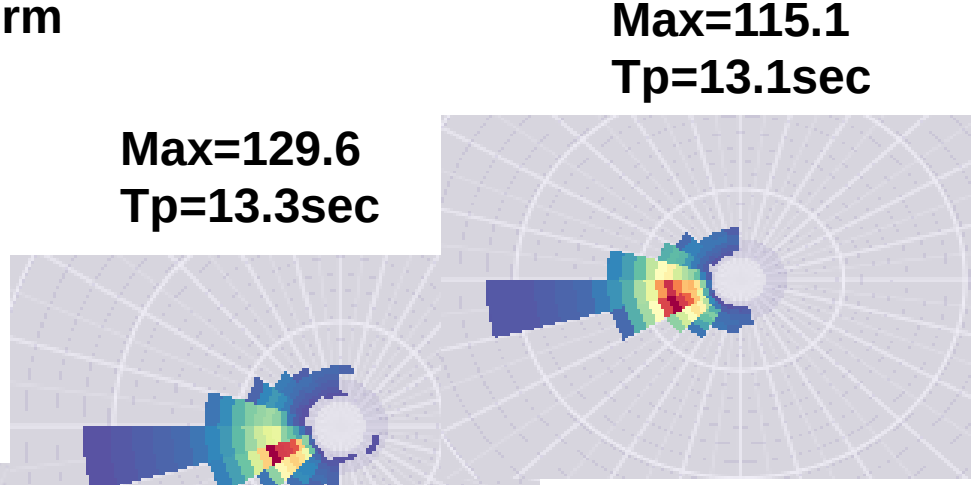
Max=129.6
Tp=13.3sec

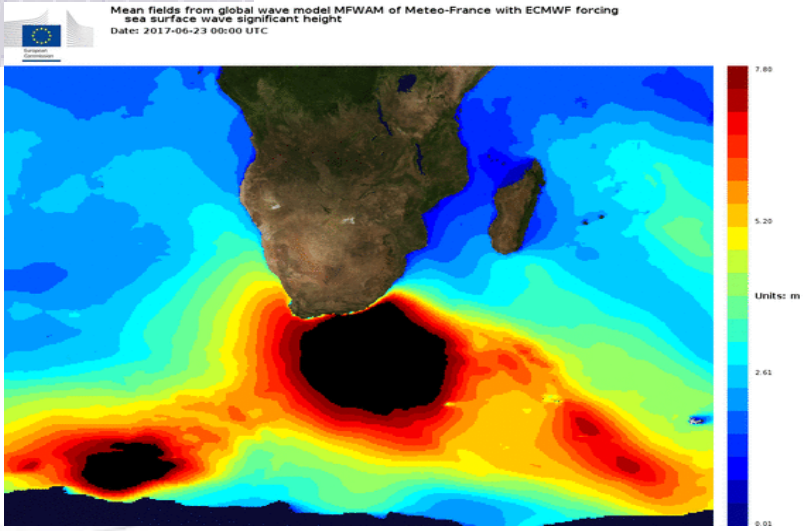
Max=172.2
Tp=16.1sec

Max=101.5
Tp=16.1sec







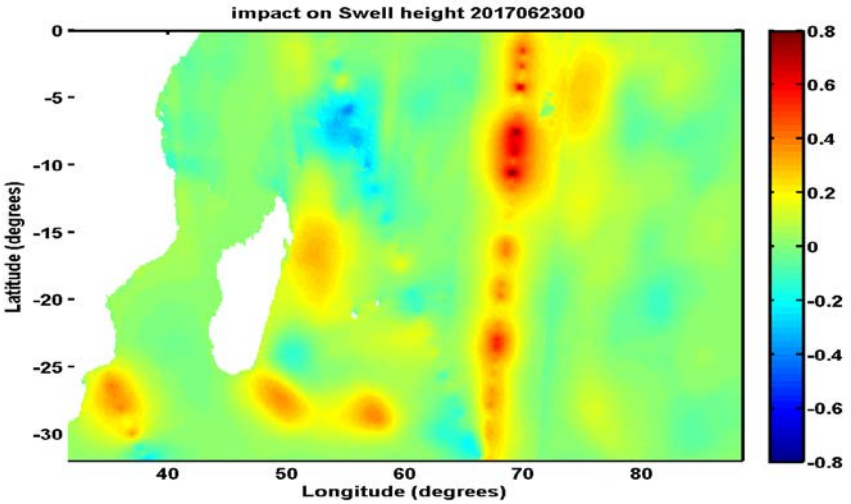


Snapshots from CMEMS-GLO 23 to 24 June By step of 6h

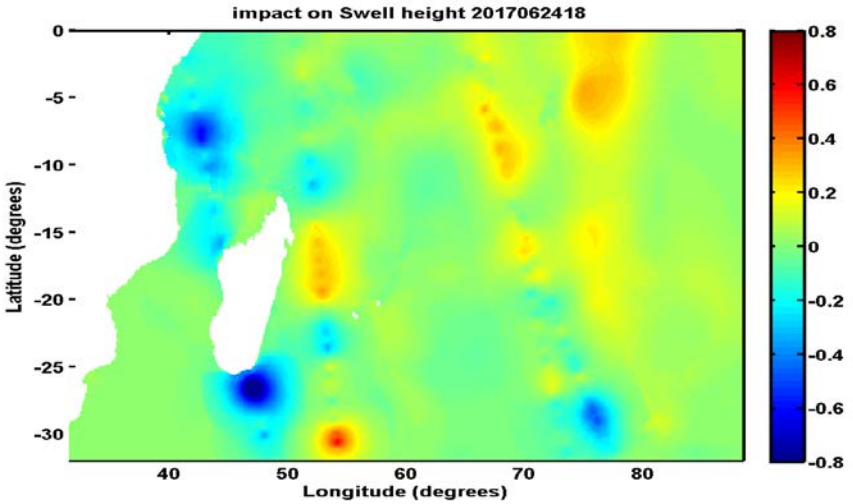
Impact of combined assimilation in regional MFWAM (10 km) for La Reunion : swell warning in 23 June 2017

Difference of swell height with and without combined assimilation

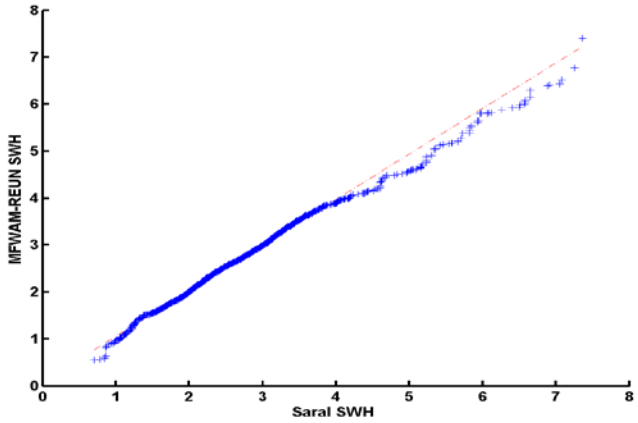
23/06/2017 at 0:00



24/06/2017 at 18:00



Comparison with saral during the storm



Saral

The combined assimilation Improves the scatter index of SWH by 14 % during the storm

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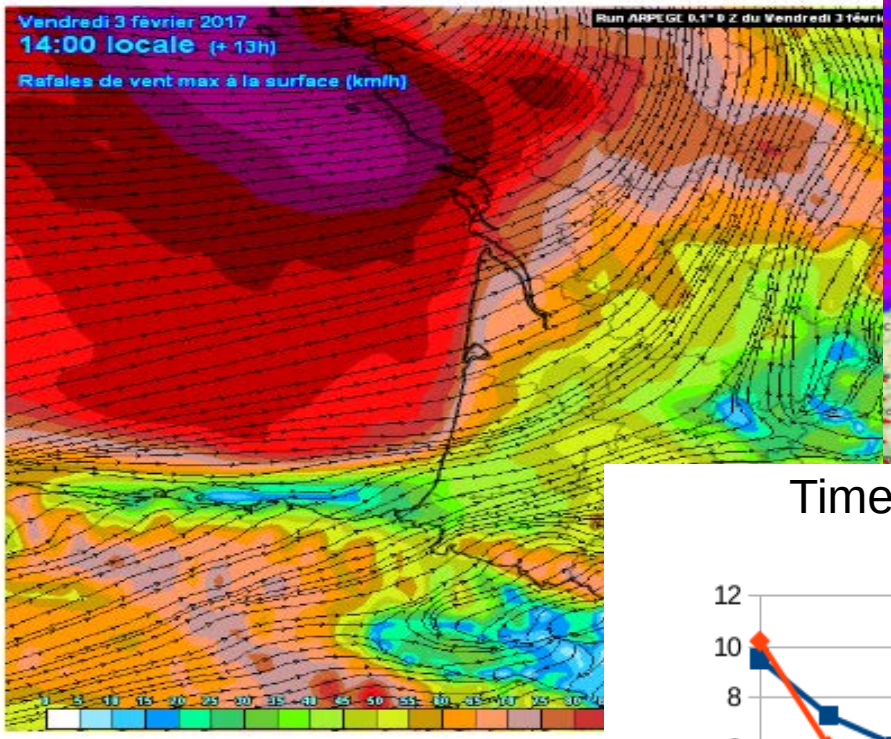
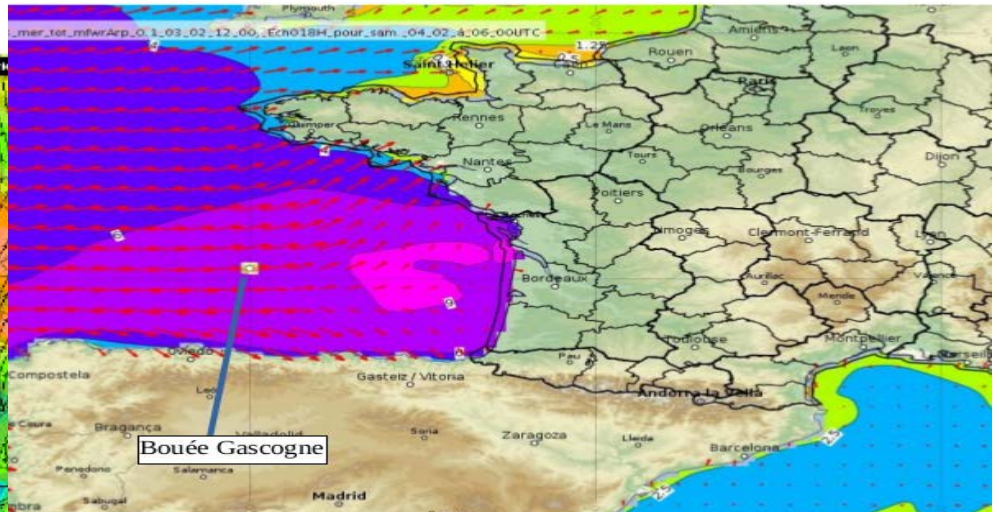
Storm cases Kurt and Leiv in early february 2017

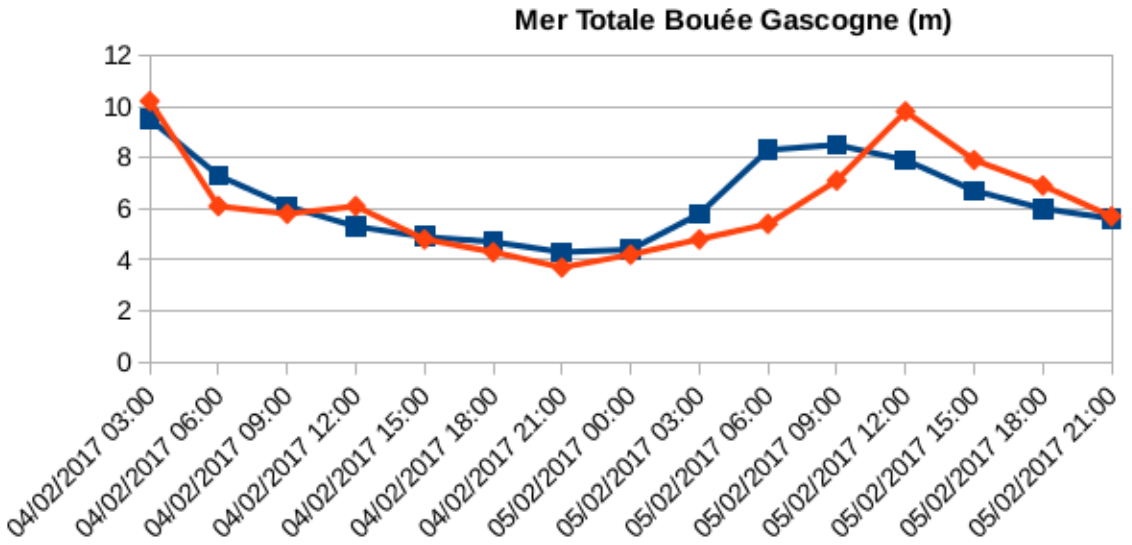
Winds from ARPEGE system



SWH from MFWAM-ARP-01 on 04/02 at 06:00

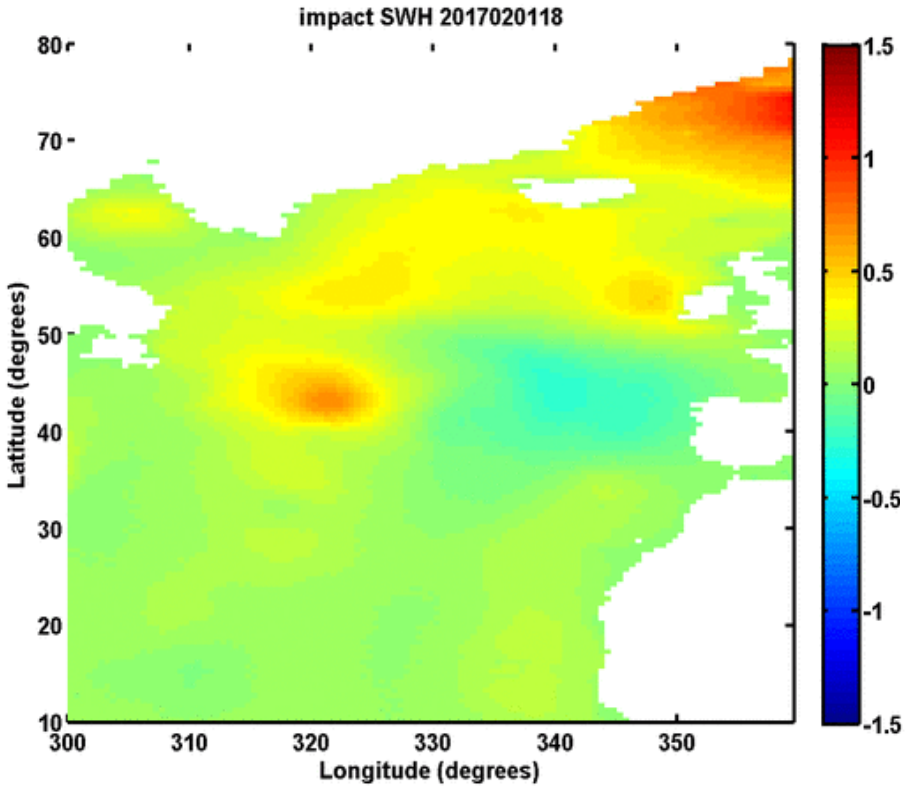


Time series of SWH from MFWAM-ARP-OPER

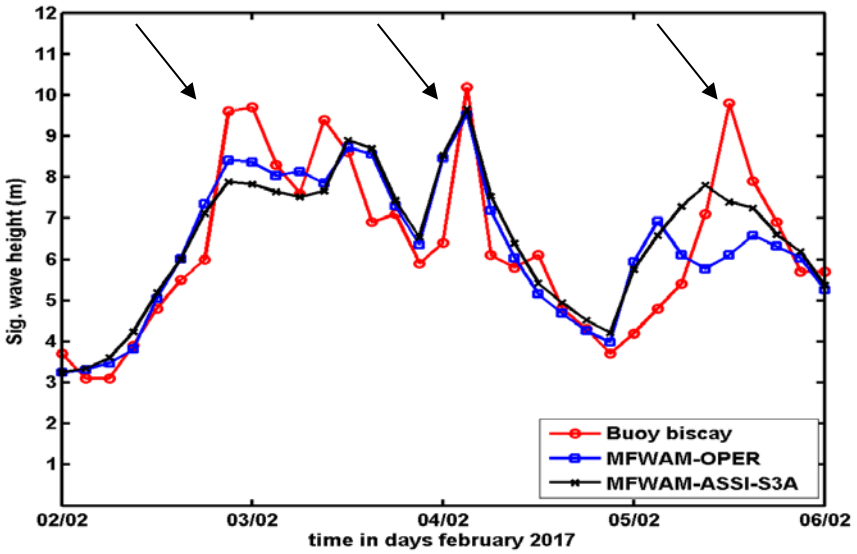


Maximum wind from the atmospheric system ARPEGE : 130 km/h (gulf of biscay 3 feb. 2017)

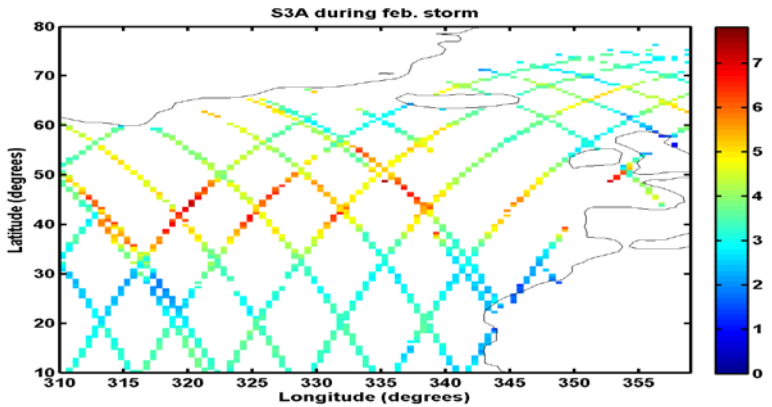
S3A watching storms Kurt and leiv (February 2017)



Validation at buoy biscay



6-hourly difference of SWH with and witho Assimilation of S3A from 01/02/17 at 18:00 04/02/17 at 0:00 (UTC)



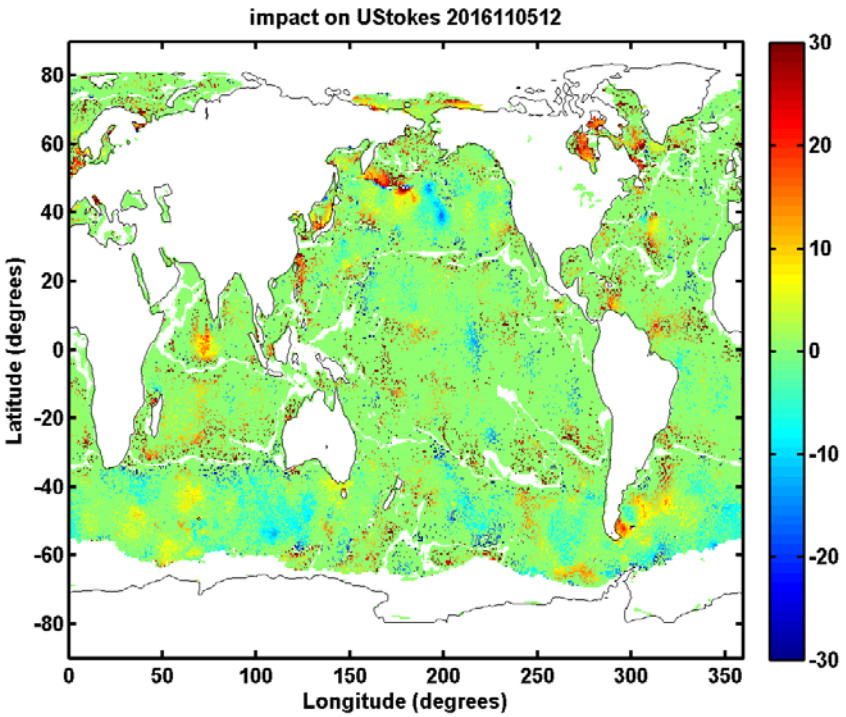
The black line : with S3A

Blue line : operational MFWAM

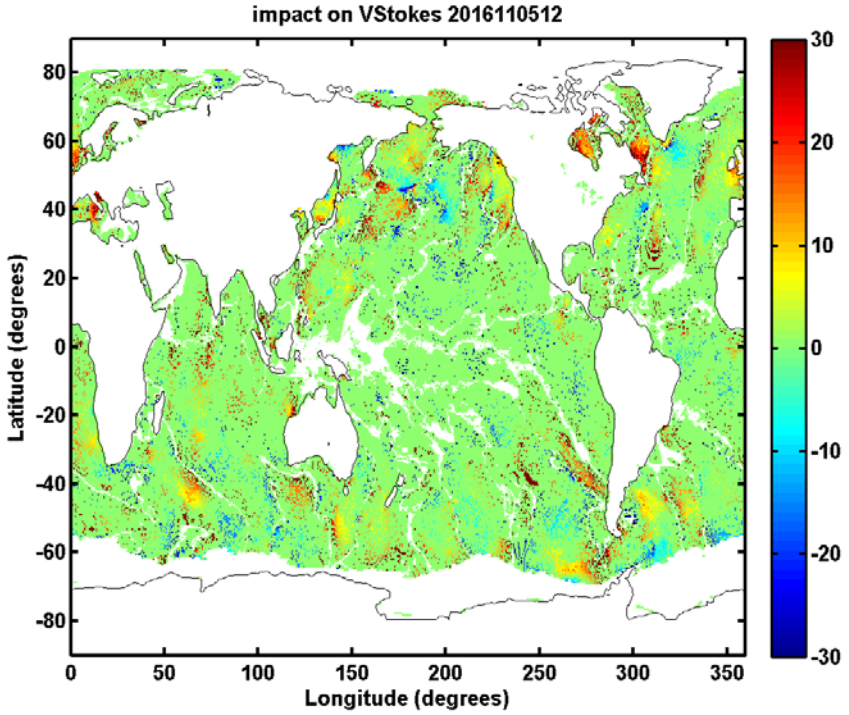
Red line : biscay buoy

Impact of the combined assimilation (Altimeters+S-1A and S-1B) on Stokes drift

U-Stokes



V-Stokes



The maximum impact can reach ~30 % of the initial component

5 November 2016 at 12:00 UTC

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Conclusions

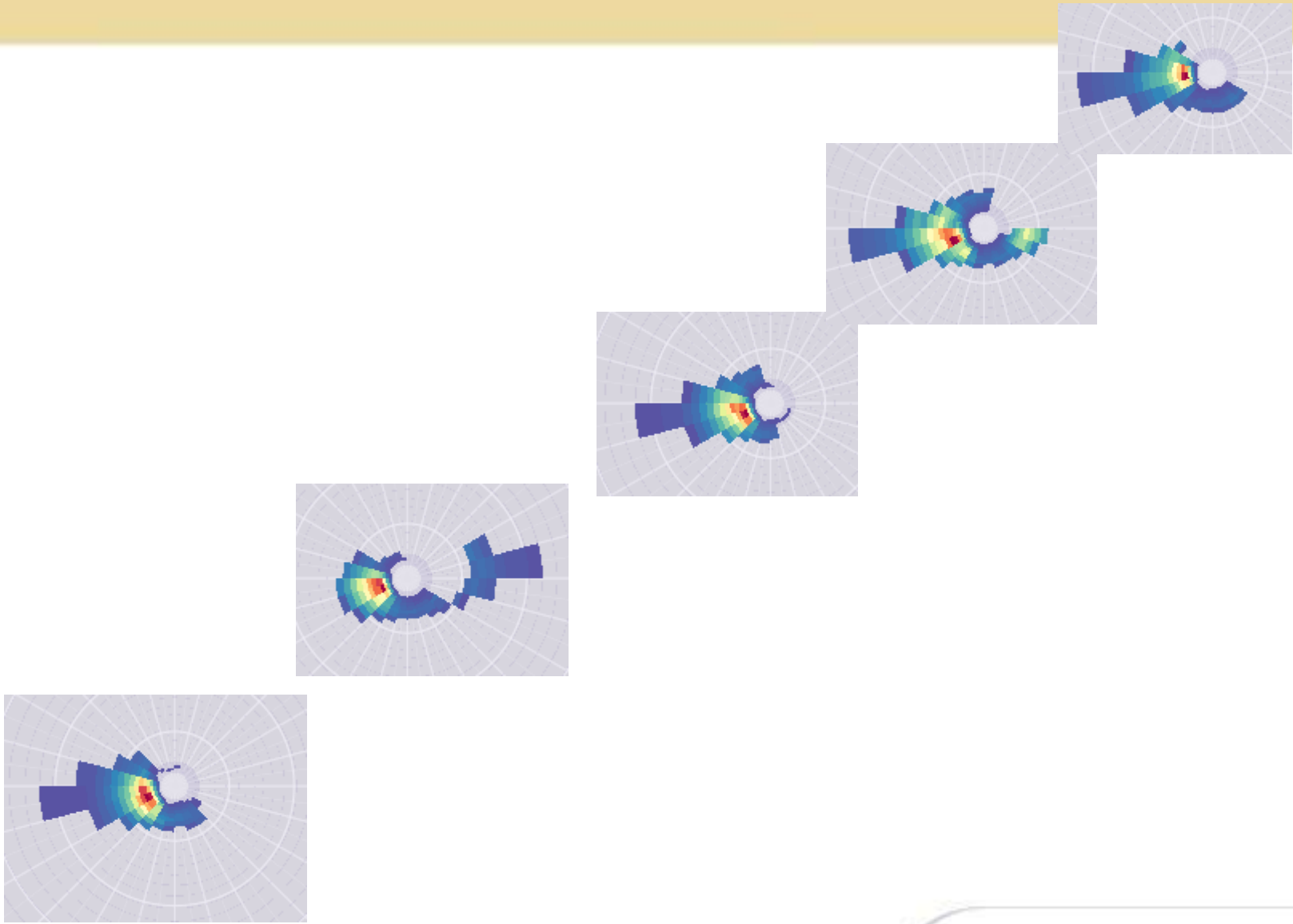
☐The combined assimilation has been successfully evaluated for long period and It will be used in operations (CMEMS-GLO V4) when S1A and 1B get through the GTS system.

☐The use of S3A data shows significant improvement on scatter, however a strong bias has been identified possibly because of swell effect on the retrieval (work is ongoing for the CALVAL team)

☐Re-localisation technique shows good skill to enhance the impact of the assimilation (SI globally of 8%) 

☐Using both altimeters and SAR spectra works efficiently to reduce uncertainties during storm cases.

☐CFOSAT mission : Launch next June 2018 (wave spectra,SWH and winds from scatterometer



METEO FRANCE
Toujours un temps d'avance