# Combined assimilation of S-1 and S-3A in the operational model MFWAM : Investigation on bias for SAR mode altimetry

*L. Aouf[(1)] and A. Dalphinet[(1)]*

*[(1)] Météo-France,*
*Département Marine et Oceanographie (DirOP/MAR)*

*Ocean Surface Topography, Science-Team (OSTST) meeting,*
*23-27 October 2017, Miami, Florida*

METEO FRANCE
Toujours un temps d'avance

# OUTLINE

1- Motivation

2- System and methodology

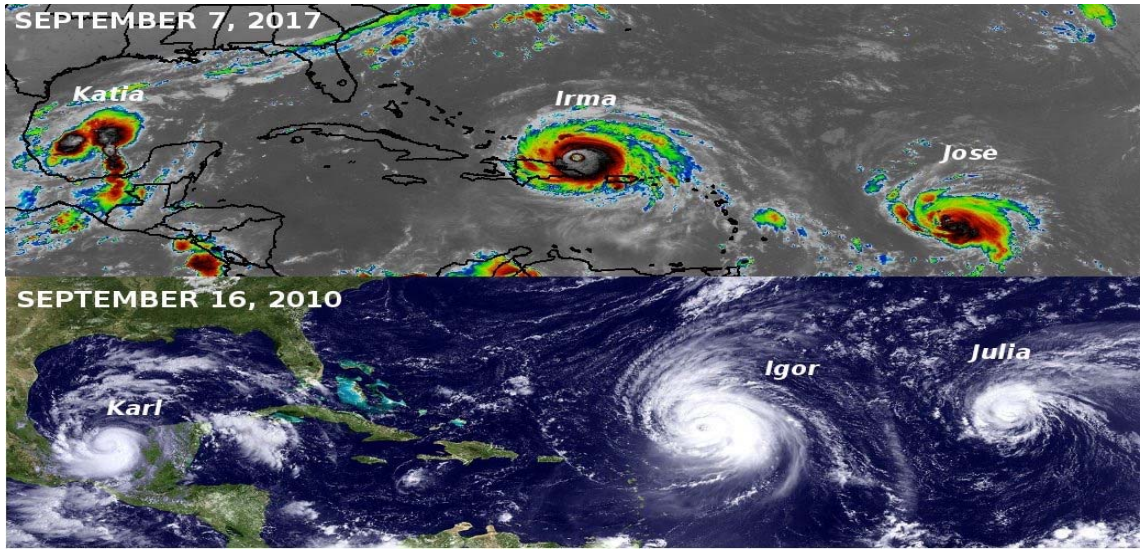
3- Wave climatology

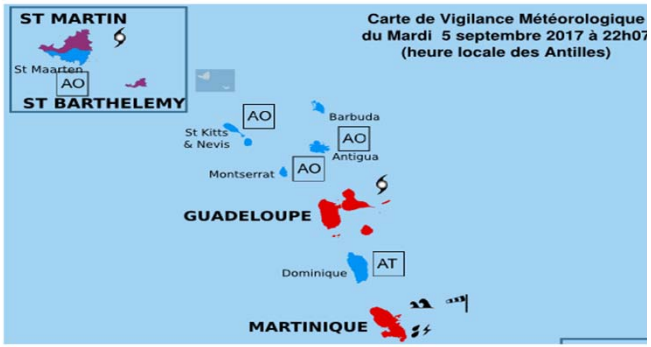
4- Results

5- Conclusions

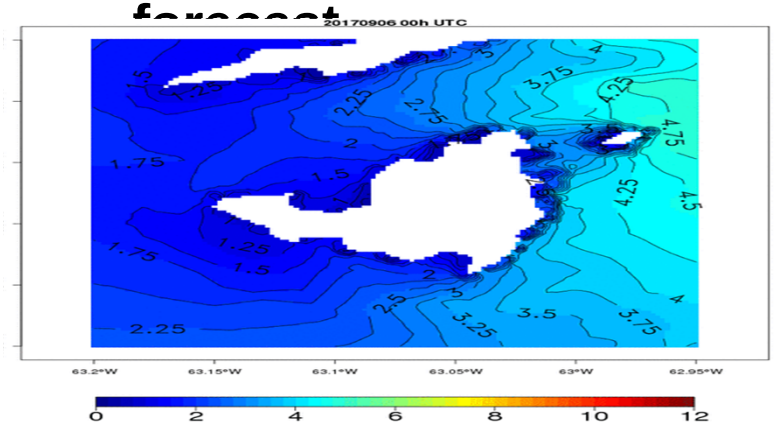
METEO FRANCE
Toujours un temps d'avance

# Highest level of waves submersion warning (Violet) For Hurricane IRMA (Sep. 2017)

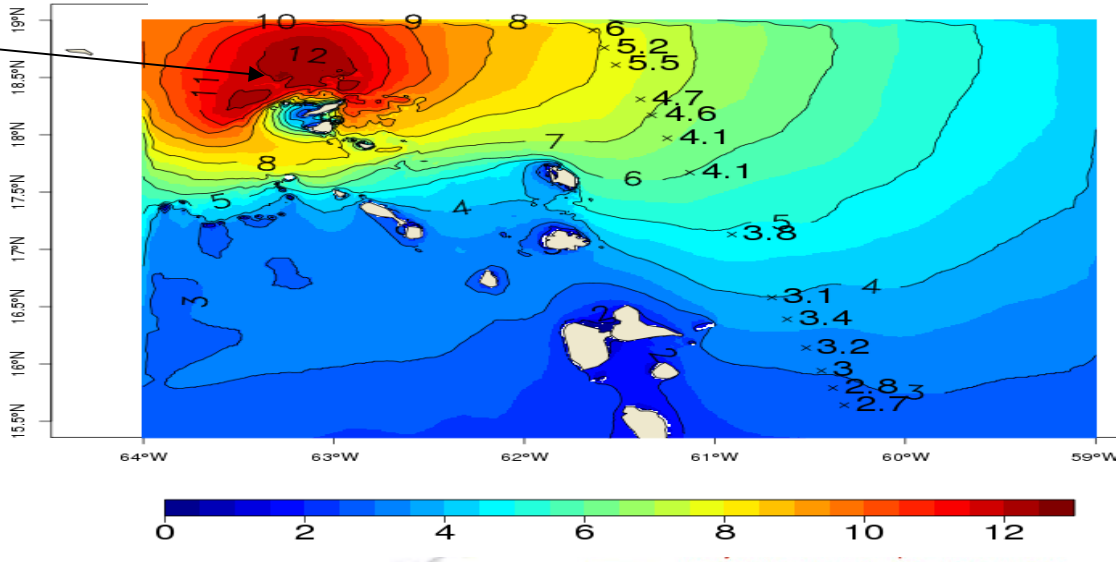


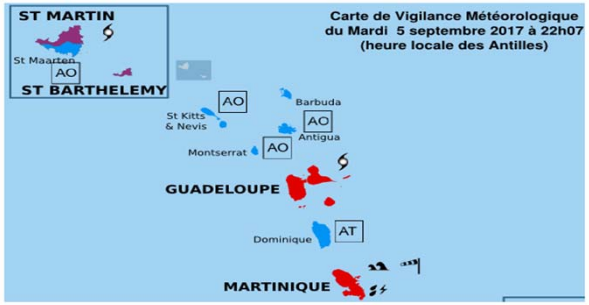

**12 meters of waves (SWH) near Saint Martin from the coastal model forecast**




**Significant wave height (m) on 6 Sep. 2017 at 13:00 UT**




# MOTIVATION



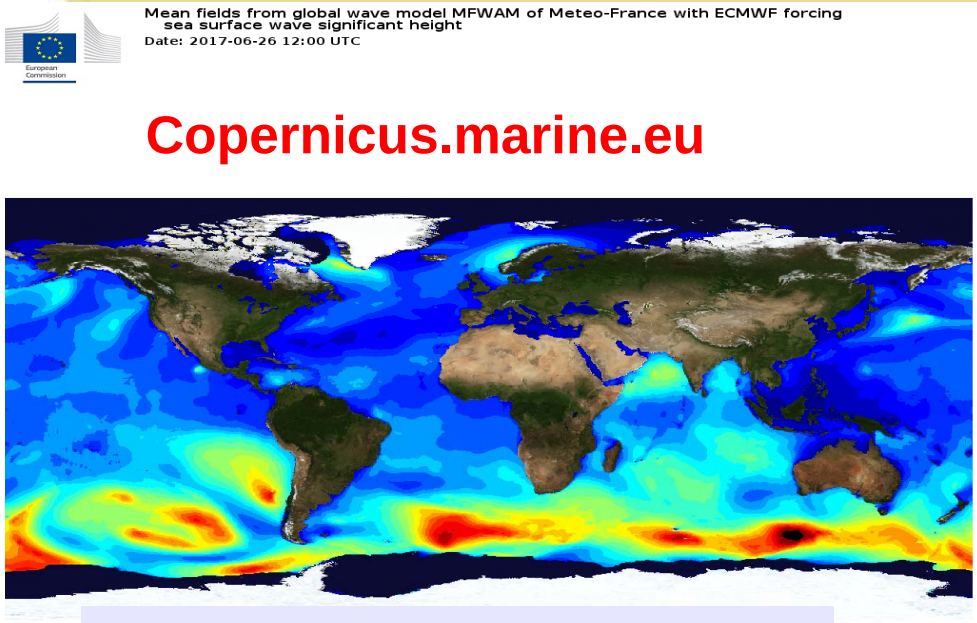

- **Are the SAR wave spectra from Sentinel-1 capable to remove partially or completely the bias of SWH from A. SAR model altimetry ?**

- **Continously Improving the operational wave forecasting system of Météo-France : global and regional scale reliable wave submersion warning (VVS)**

- **Ensuring the best wave products for the CMEMS Marine service (Global MFC)**

Damages caused by hurricane IRMA in Saint-Martin

# The global wave forecasting MFWAM CMEMS-MFC-Global

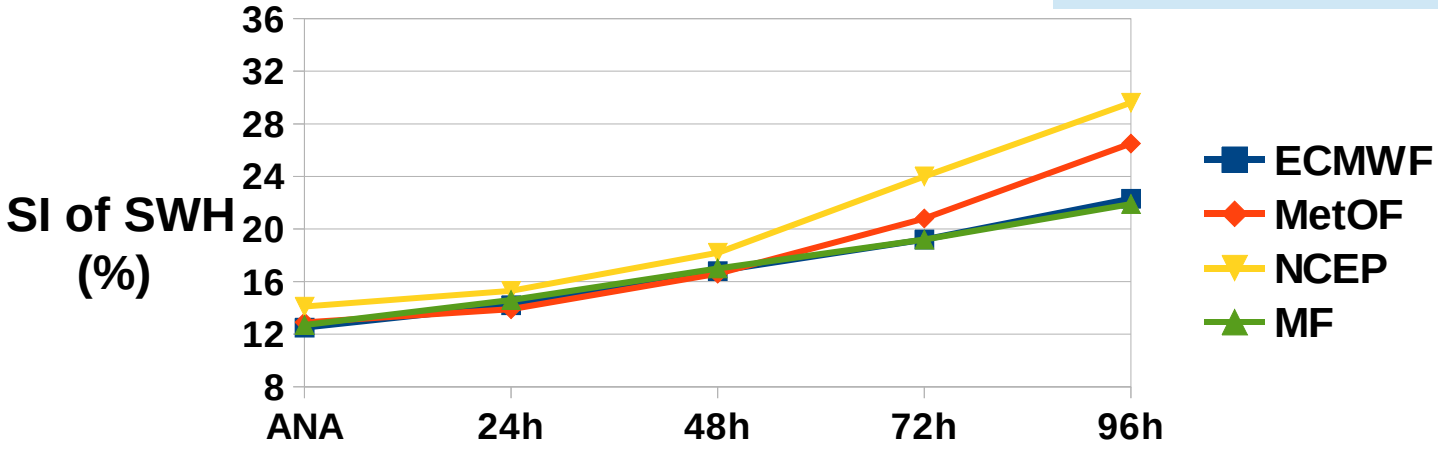



**Copernicus.marine.eu**

**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 ST4 physics (Ardhuin et al. 2010) and settings from Mywave project.**

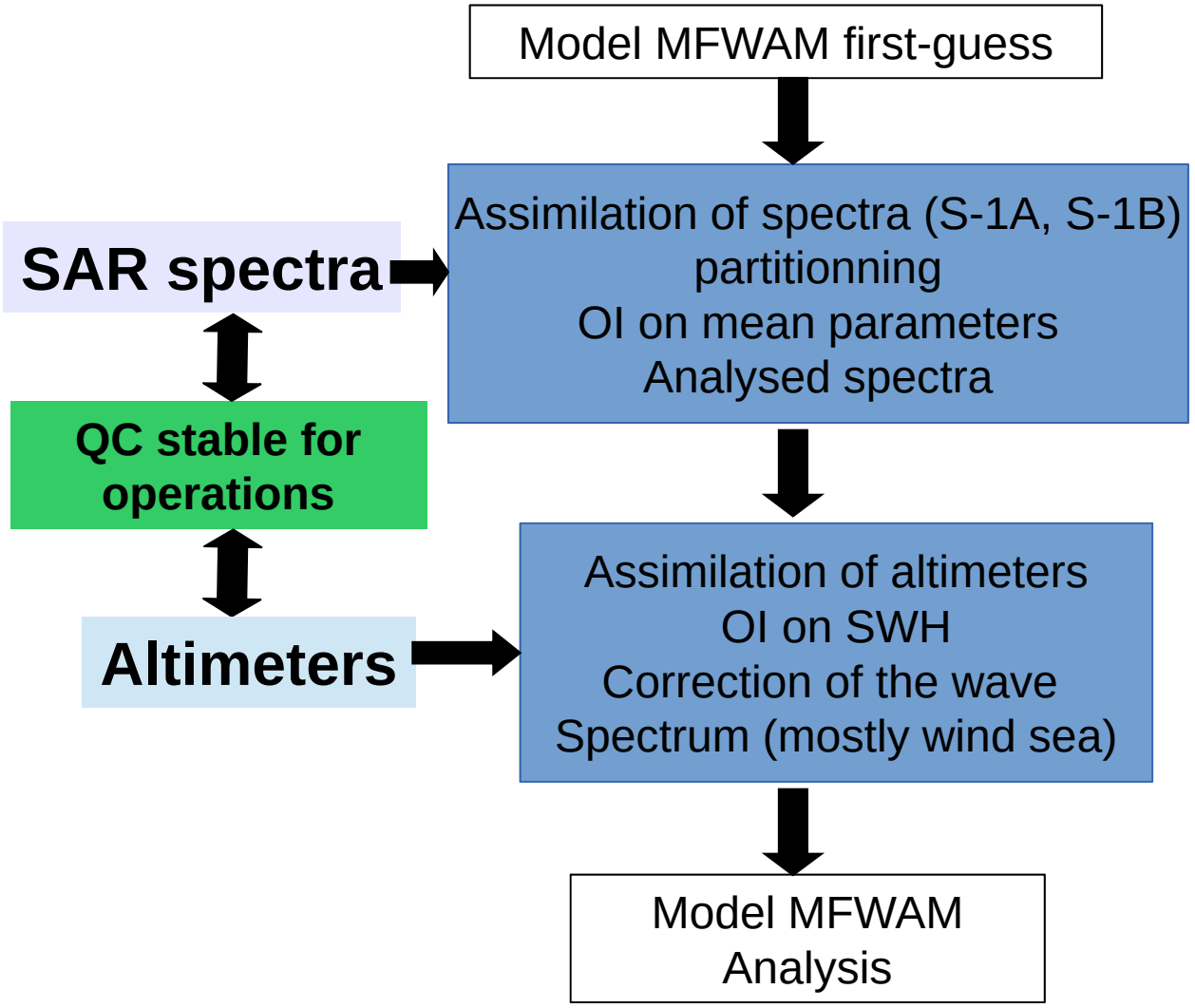
**In operations assimilation 6 hours:**
**Jason-2 (safe-mode)**
**SARAL since 10 December 2013**
**Cryosat-2 since 23 April 2014**
**Jason-3 since October 2016**




**JCOMM Intercomparison With buoys April 2017**

METEO FRANCE
Toujours un temps d'avance

# Description of combined assimilation system




**Use of SAR spectra From S1 in operations is expected end 2017**

# Methodology

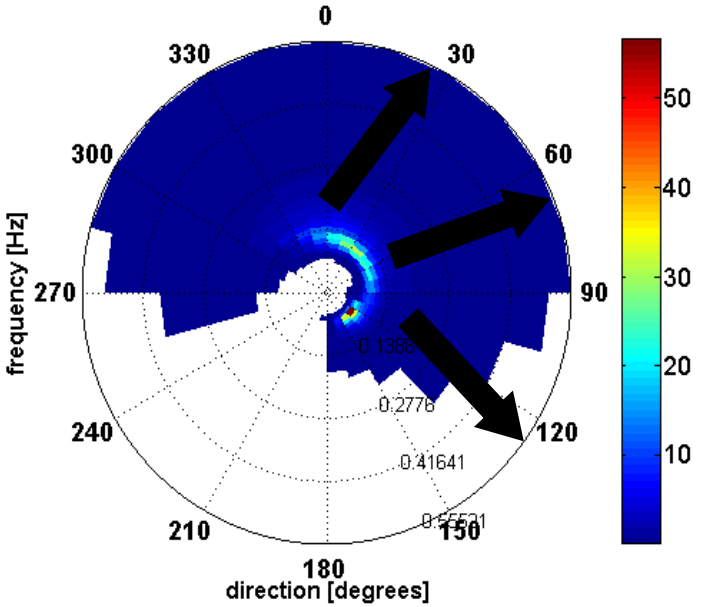
**1- waves climatology for swell dominant (primary swell) regime (2015-2016)**

**- Identifying ocean areas highly affected by primary swell**
**- Estimating the occurence of primary swell depending on mean parameters (height and period)**

**2- performing combined assimilation with S3A altimeters and SAR wave spectra from S-1A and 1B, typically for southern winter May-June-July 2017 (intense storms generating swell systems)**

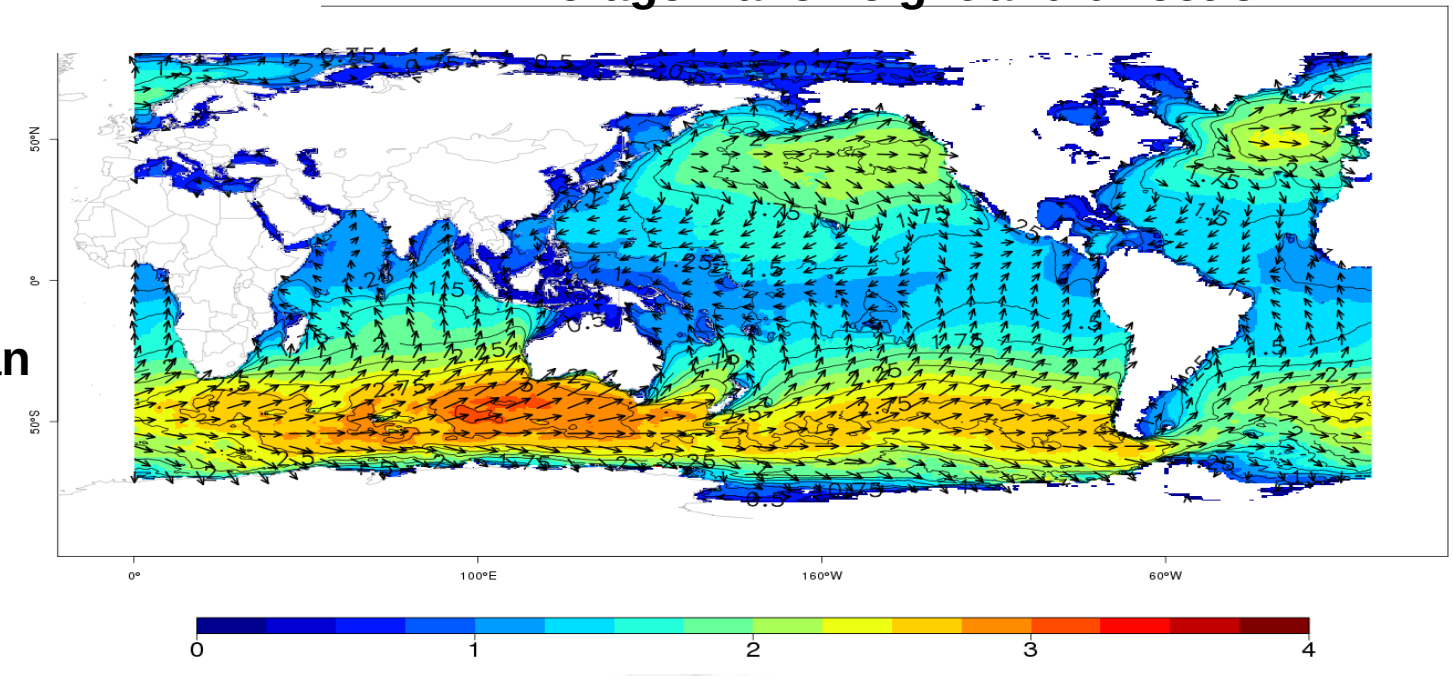
**3- validation of the results with altimeters and buoys and analysis on the bias of SWH**

# Global wave climatology for primary swell 2015/2016




The primary swell is the most energetic swell partition (dominant swell) : wave height, mean period and direction

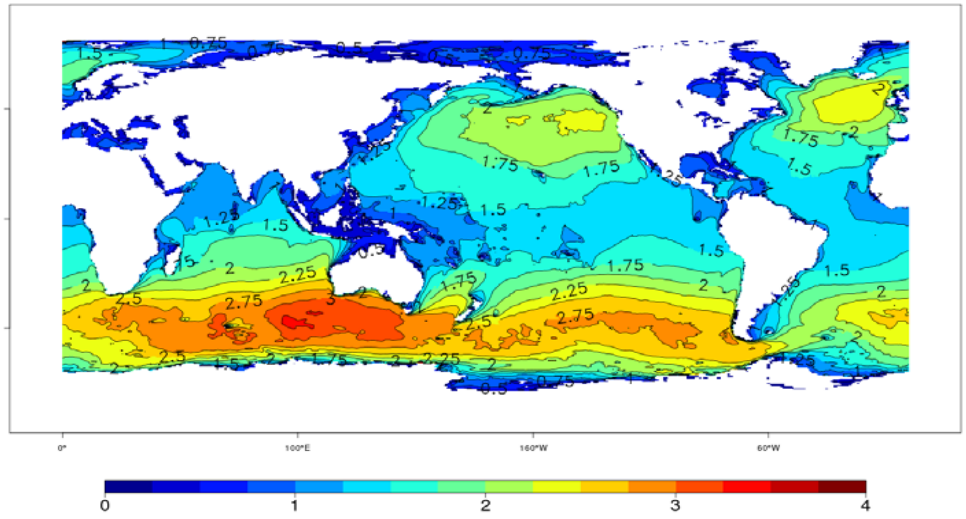
**Primary swell regimes over all ocean basins**
**Average wave height and direction**



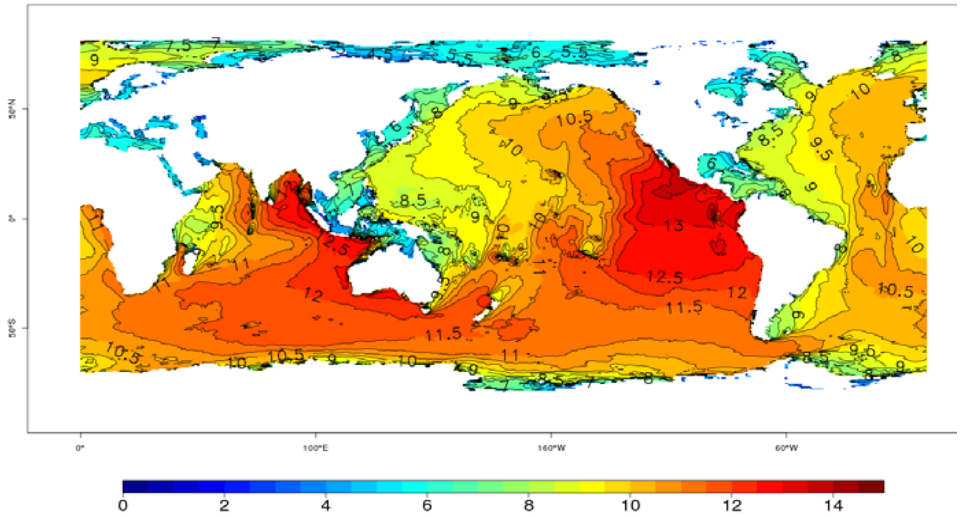

**Southern ocean**
**NE Pacific ocean**
**N-NE Atlantic ocean**

# Primary swell climatology from the model MFWAM : Average mean parameters (2015-2016)

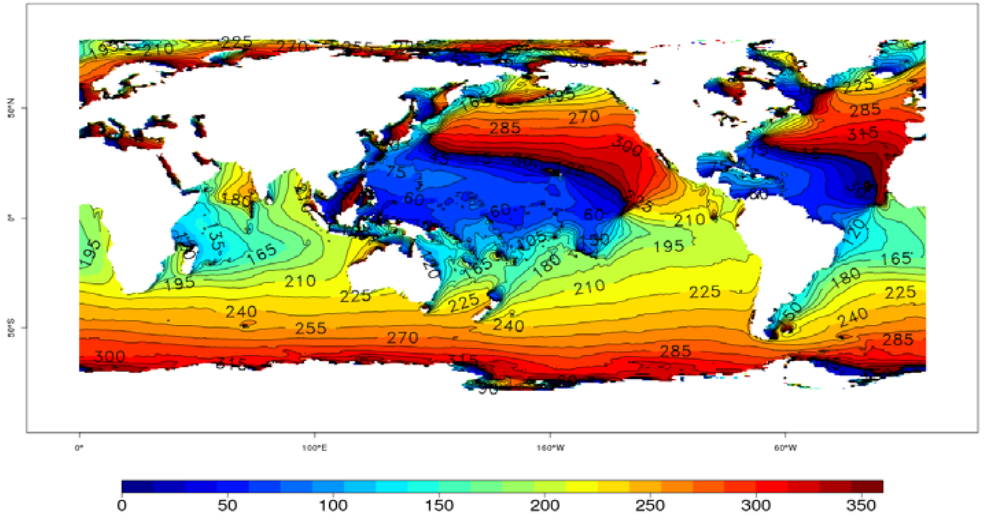
**Swell wave height**




**mean period**




**mean direction**



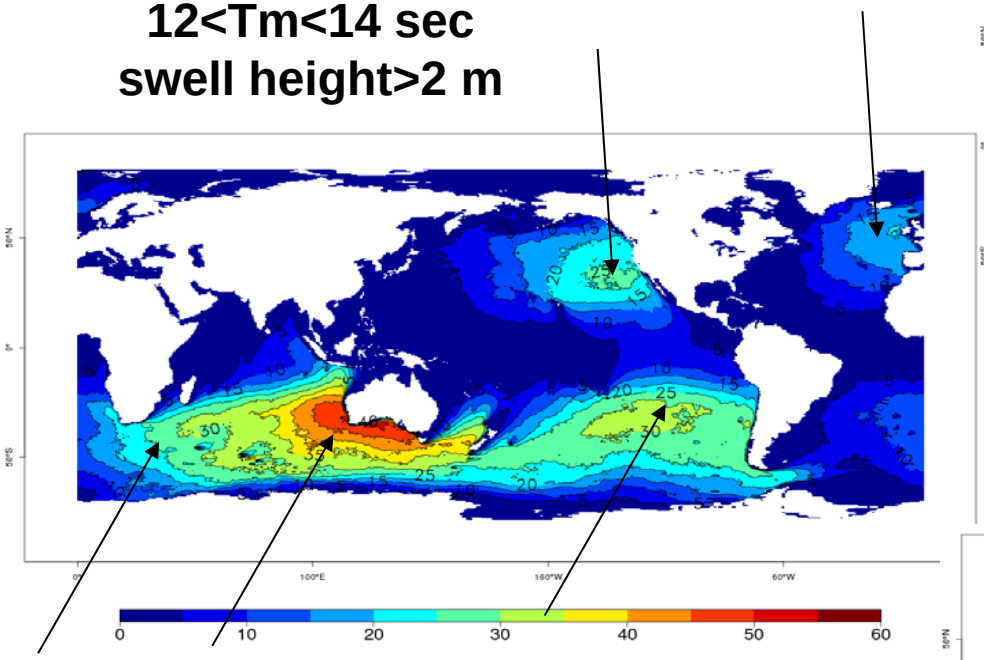

Swell of mean period ranging between 12-14 sec : potential affecting the SAR mode retrieval

METEO FRANCE
Toujours un temps d'avance

# Classification of swell reglme : occurence in %

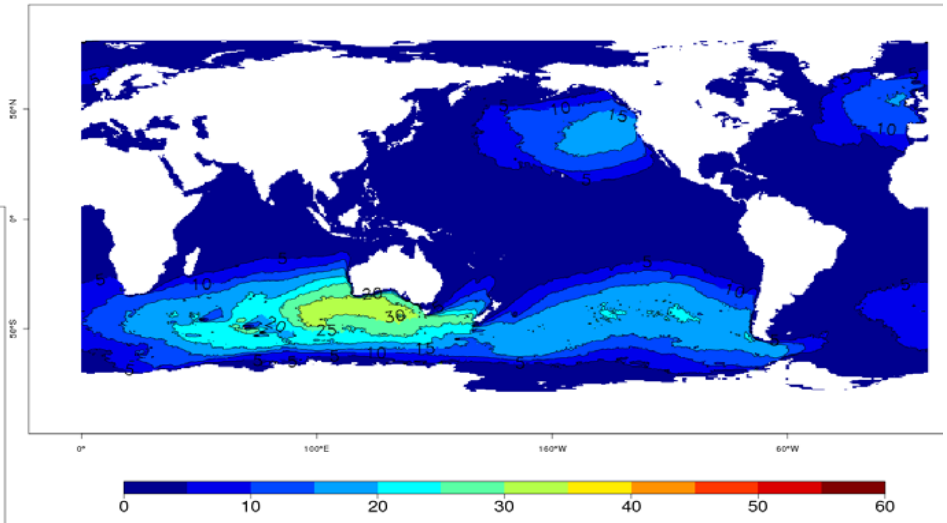
The occurence indicates the percentage of observing such swell regime depending on height and mean period over years 2015 and 2016

**12<Tm<14 sec**
**swell height>2 m**

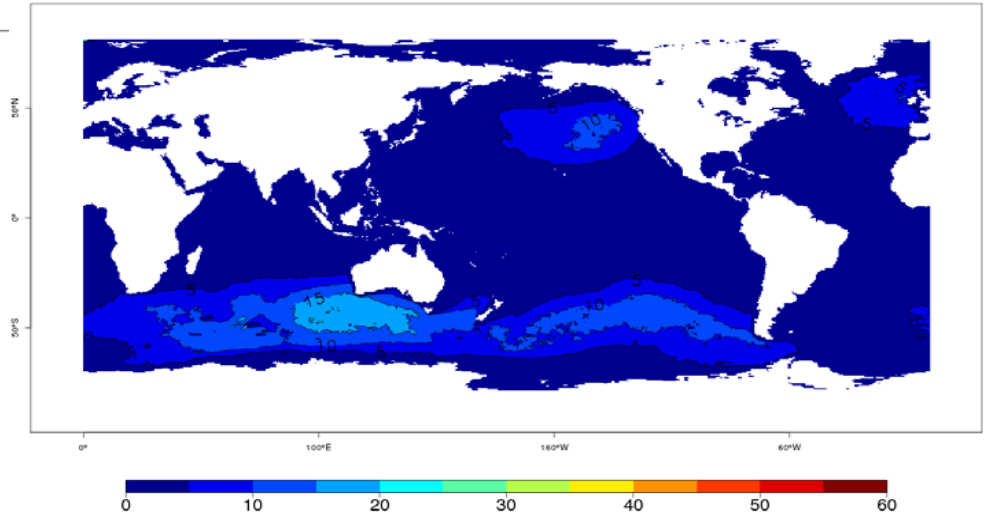



Ocean areas such as Agulhas, south of Australia and south-east pacific have more than 30 % of occurence

**12<Tm<14 sec**
**SH>3 m**

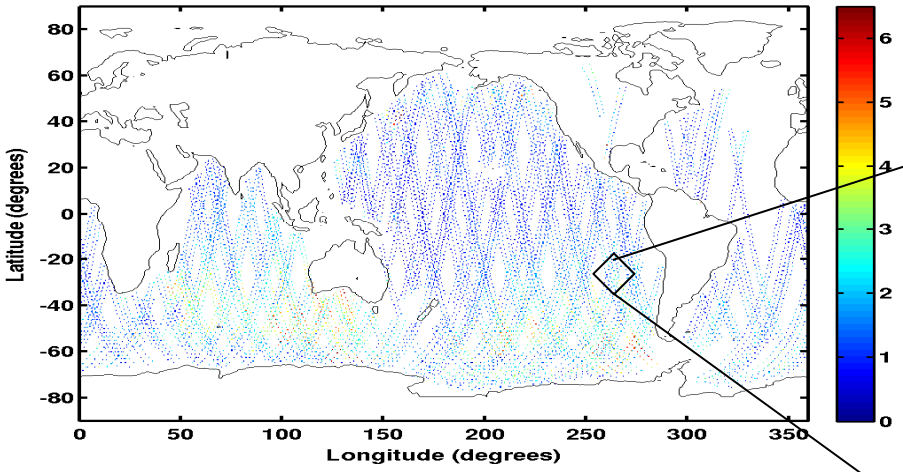



**12<Tm<14 sec**
**SH>4 m**

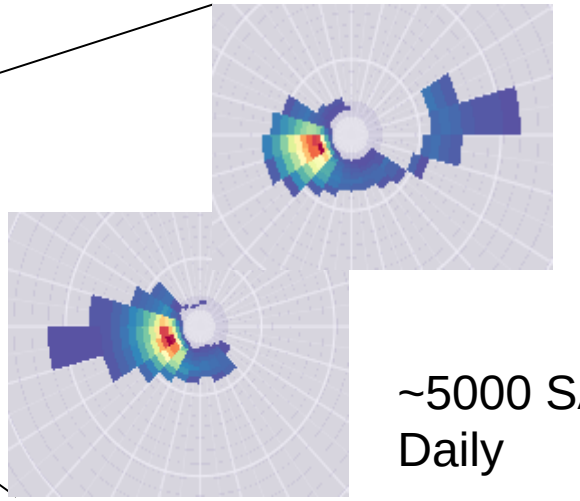


# Daily coverage altimeters wave data and SAR wave spectra from S-1A and 1B

## S1A and S1B daily orbit tracks

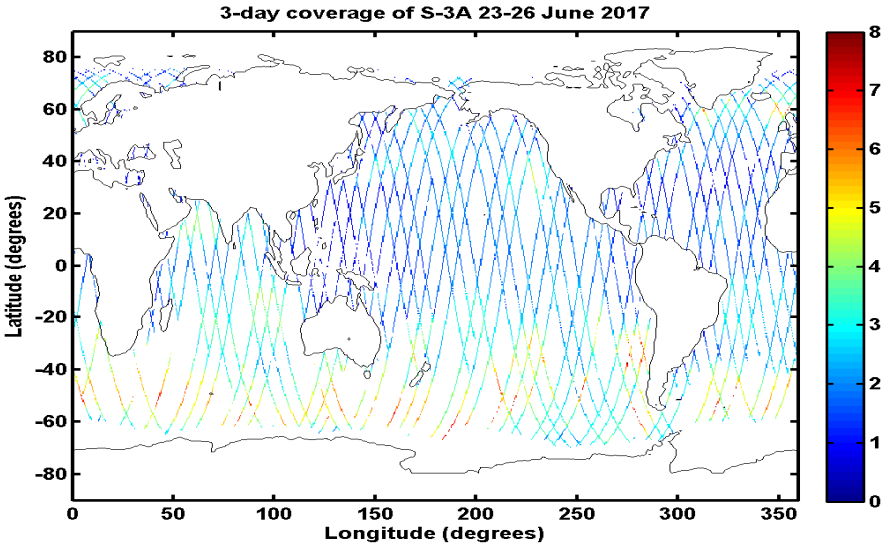



Spectral resolution of 60 frequencies and 72 directions : QC implemented



~5000 SAR spectra Daily

**SAR wave spectra capture waves with range between 200 to 800 m of wavelength**




3-day coverage of S-3A (23-25 June 2017)

METEO FRANCE
Toujours un temps d'avance

# 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)**

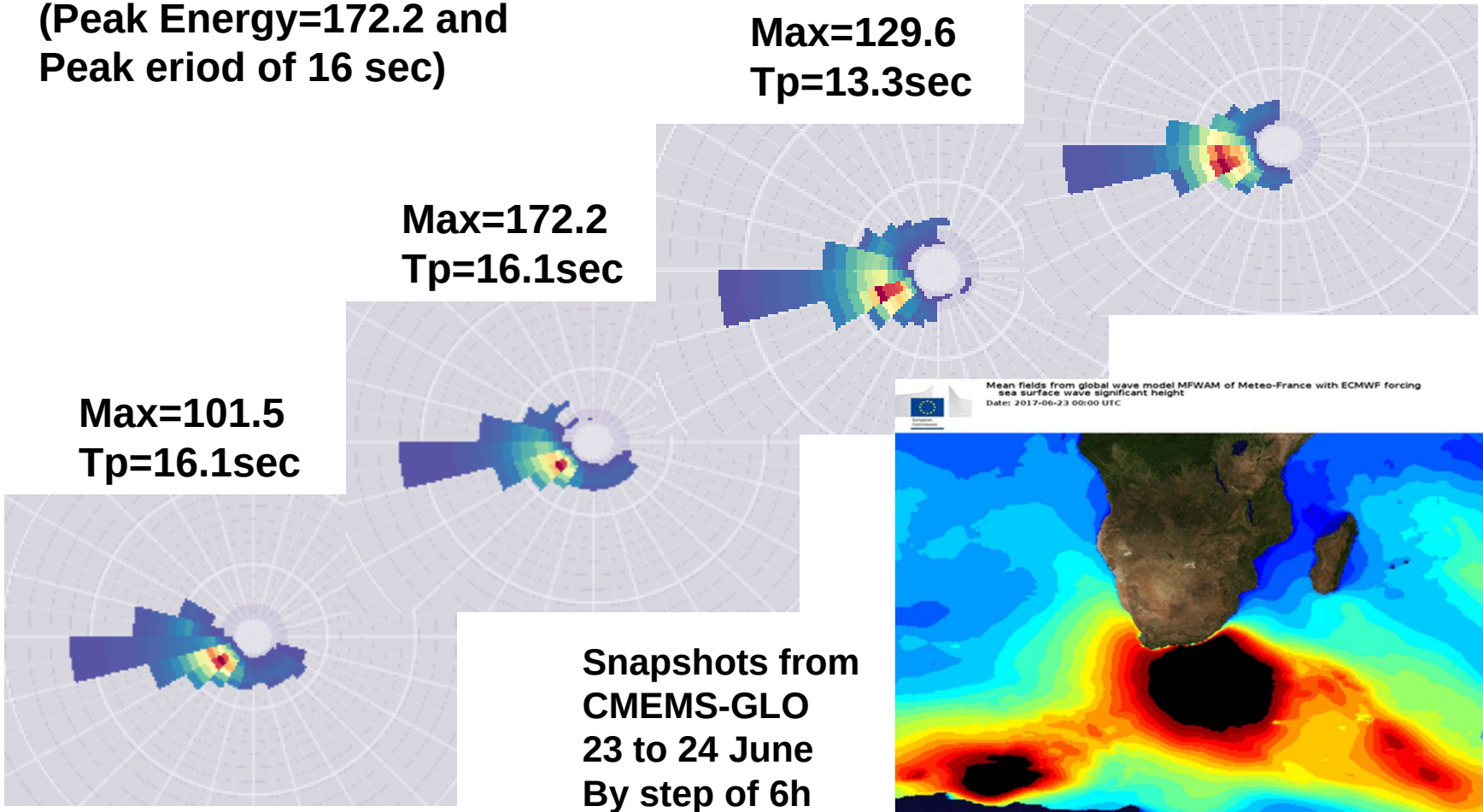
**S1 in the peak of the storm**

**Max=115.1**
**Tp=13.1sec**

**Max=129.6**
**Tp=13.3sec**

**Max=172.2**
**Tp=16.1sec**

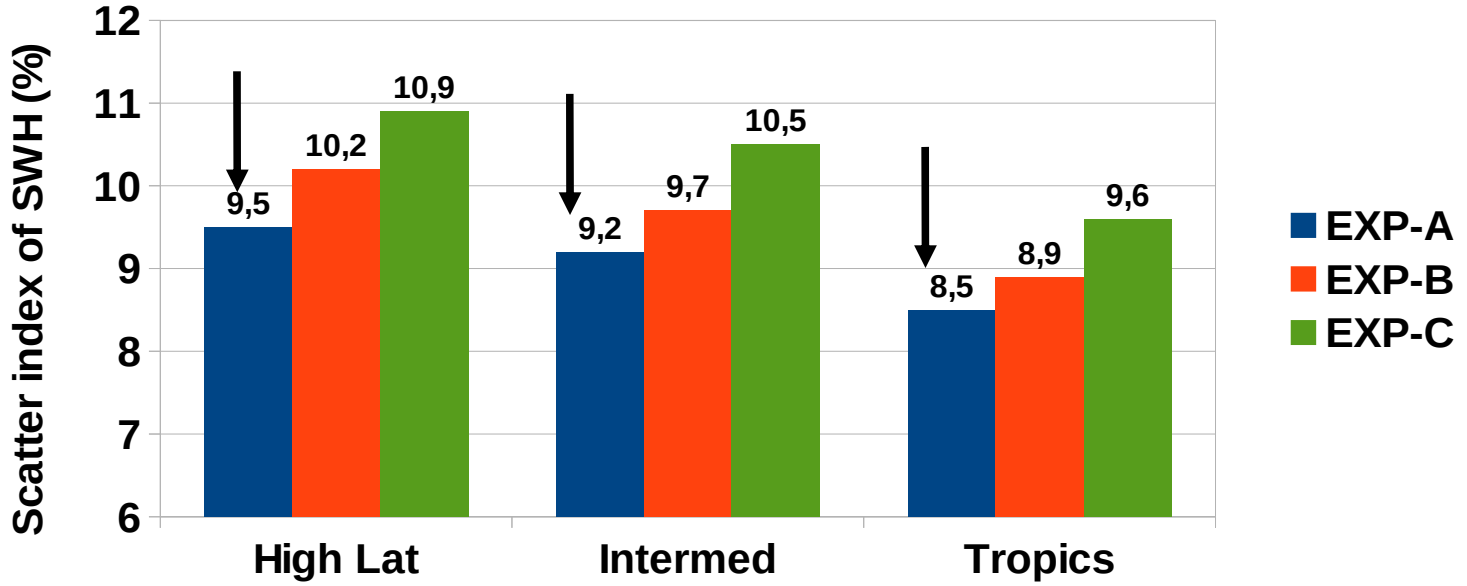
**Max=101.5**
**Tp=16.1sec**



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

# Impact of combined assimilation of altimeters and SAR spectra on SWH

**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-D | No assimilation | | | | | | |

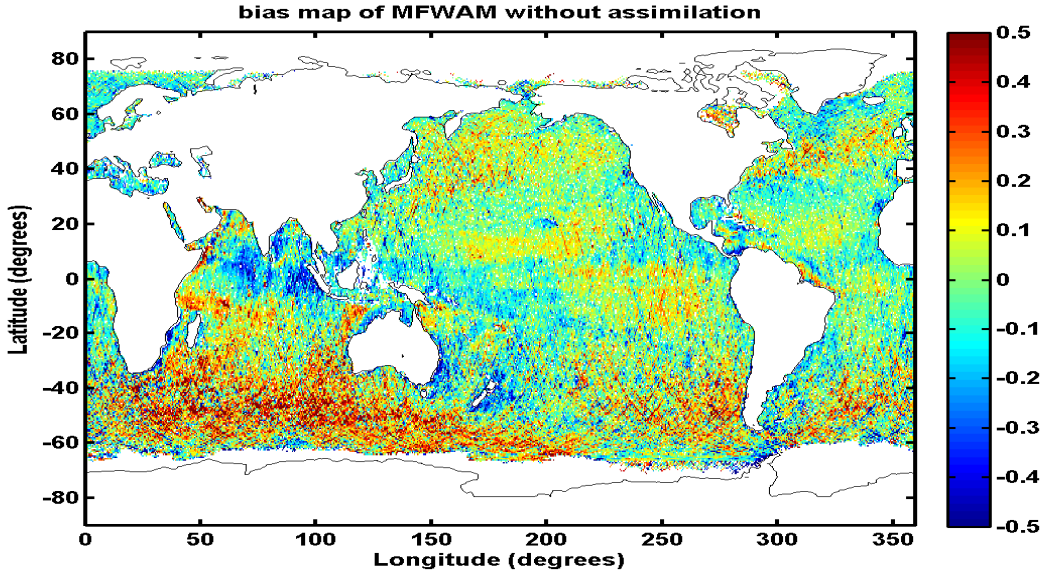
**High Lat |⍰|> 50°**
**Intermediate lat 20°<|⍰|<50°**
**Tropics |⍰|<20°**

**At least 1 altimeter is kept for the validation**

**Period of May-June-July 2017**

METEO FRANCE
Toujours un temps d'avance

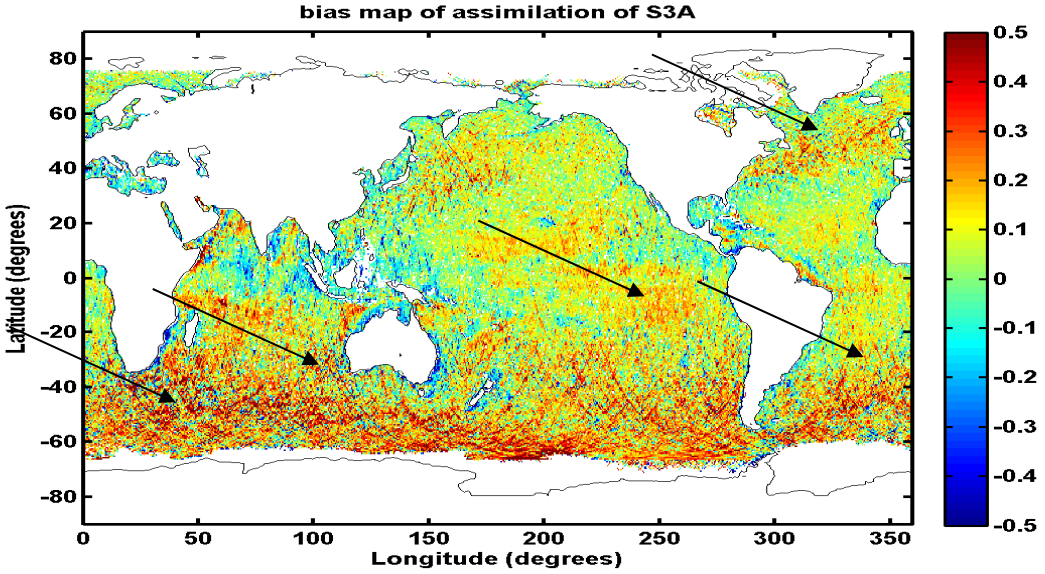
# Bias maps of SWH (The story)
# the assimilation of SWH from S3A




**without assimilation**

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

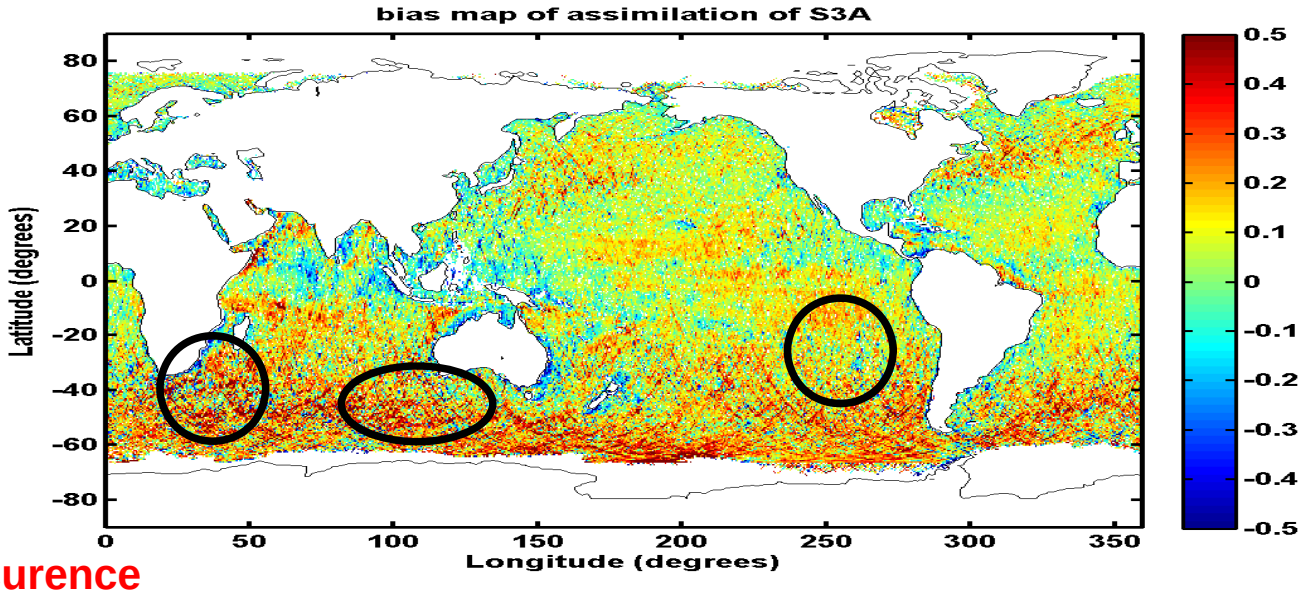
**MFWAM+S3A**




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

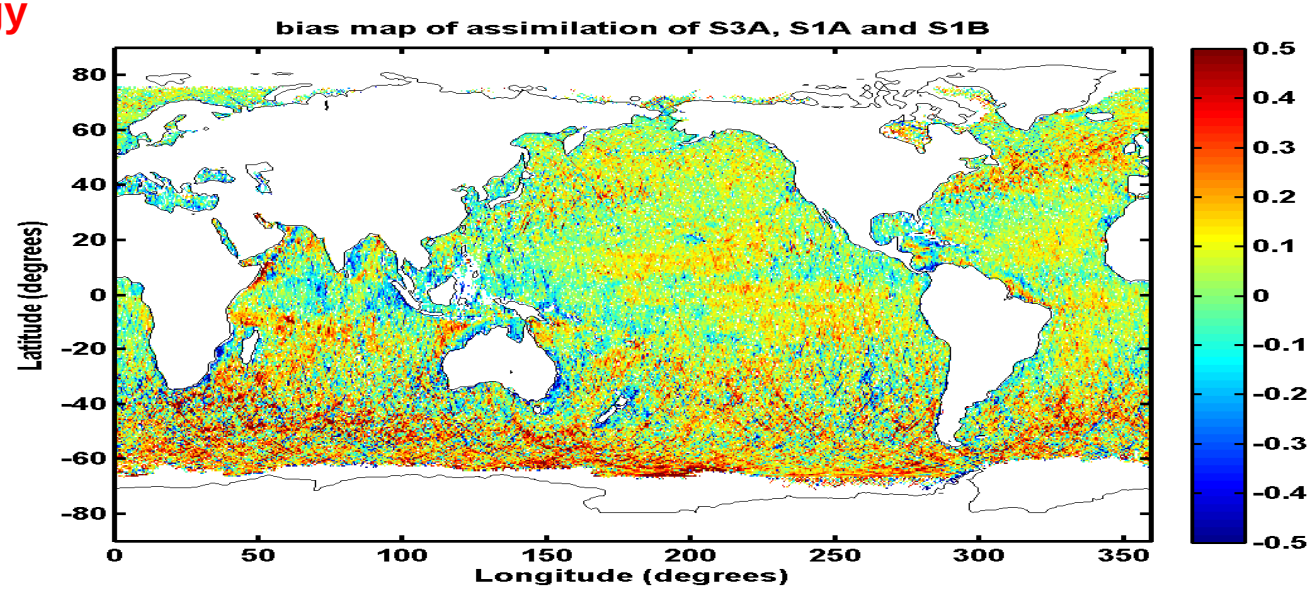
# Global bias map during the southern winter

**Assimilation of S3A**



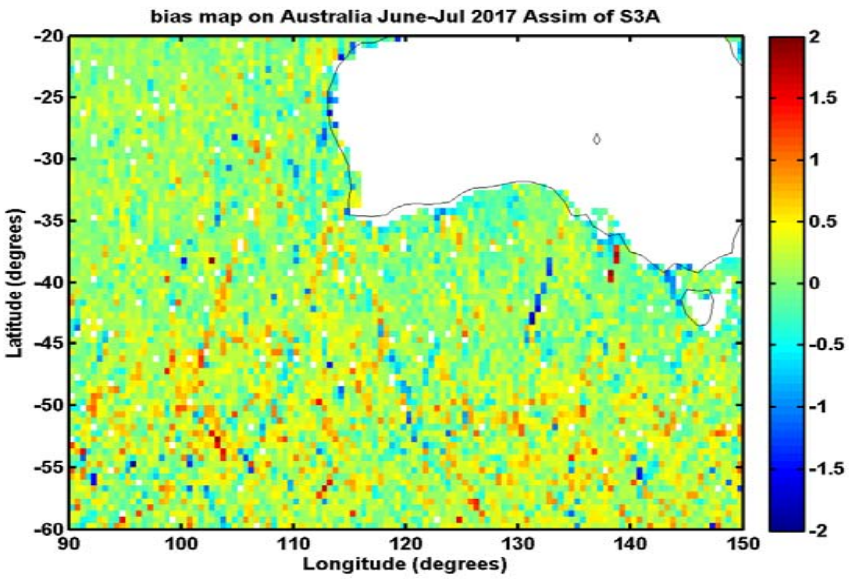

**The increase of bias is consistent with the occurence given by the climatology**

**Assimilation of S3A, S1A and S1B**

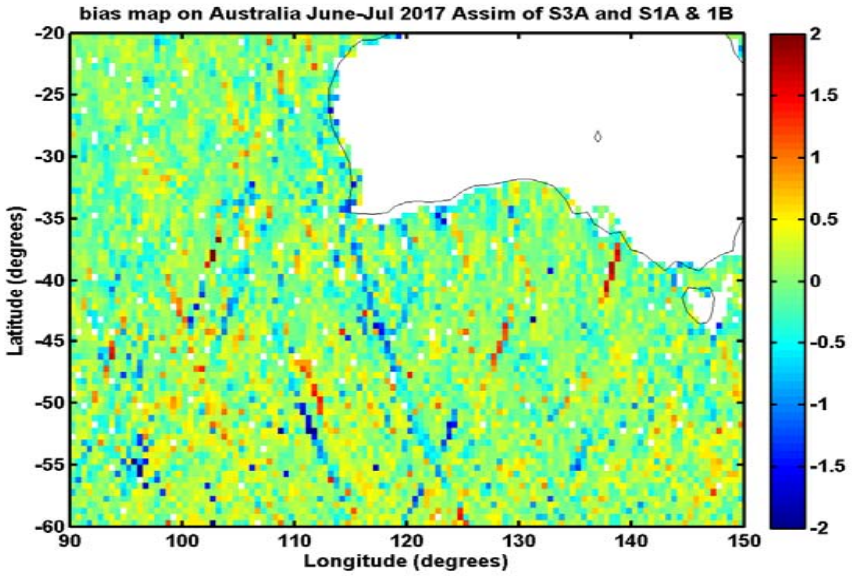


# Bias reduction when using S-1A and 1B : zoom on southern ocean

Assimilation of S3A

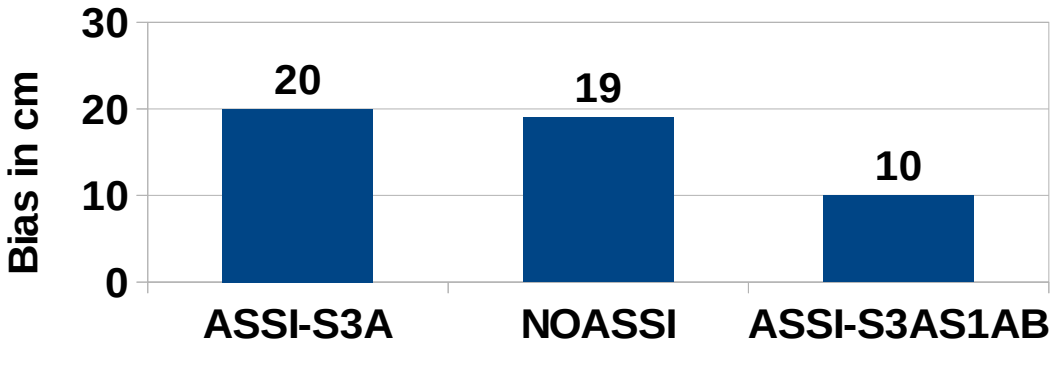



Combined assimilation of S3A and S1



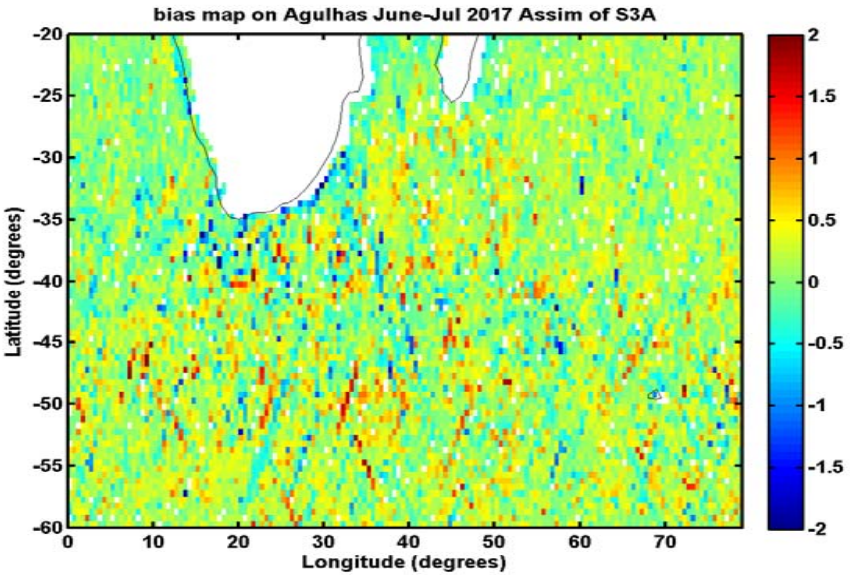

**During southern winter June-July 2017**

**Strong reduction of SWH bias (~50%) in south Australia**

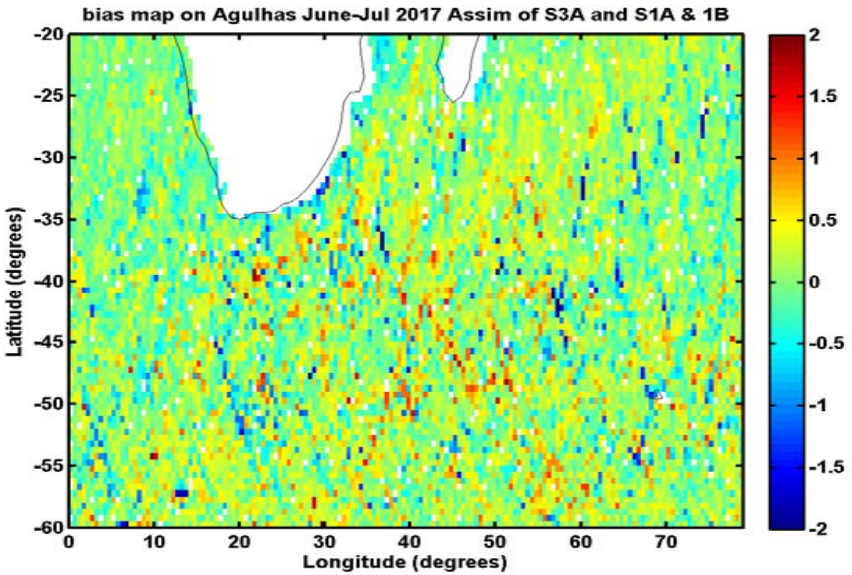


# Bias reduction when using S-1A and 1B : Focus on Agulhas area

Assimilation of S3A

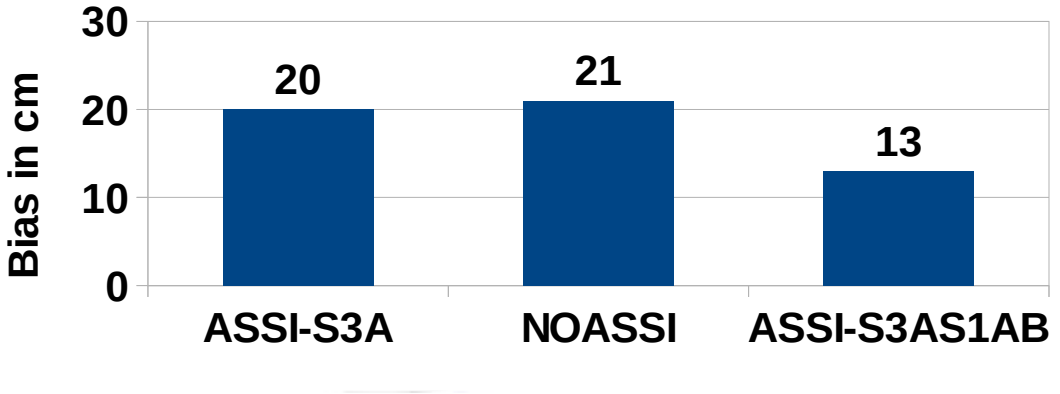



Combined assimilation of S3A and S1

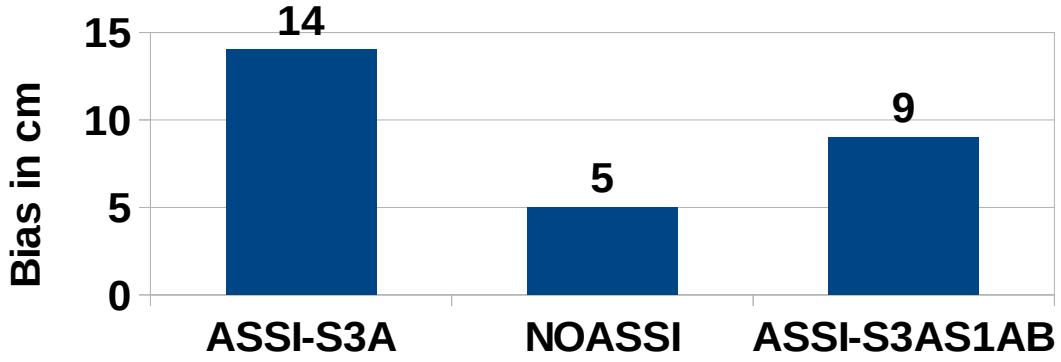



**During Southern winter June-July 2017**

**SWH bias reduces from 20 to 13 cm when using SAR spectra from S1A &1B**



# Validation with SWH from Stratus buoy

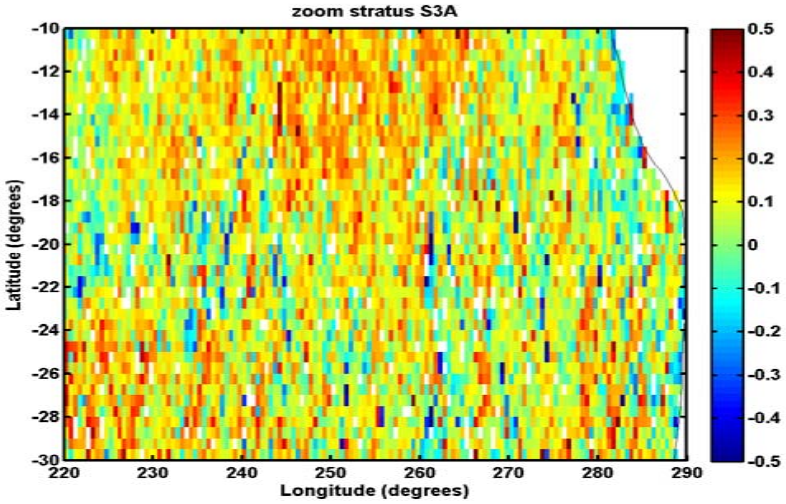


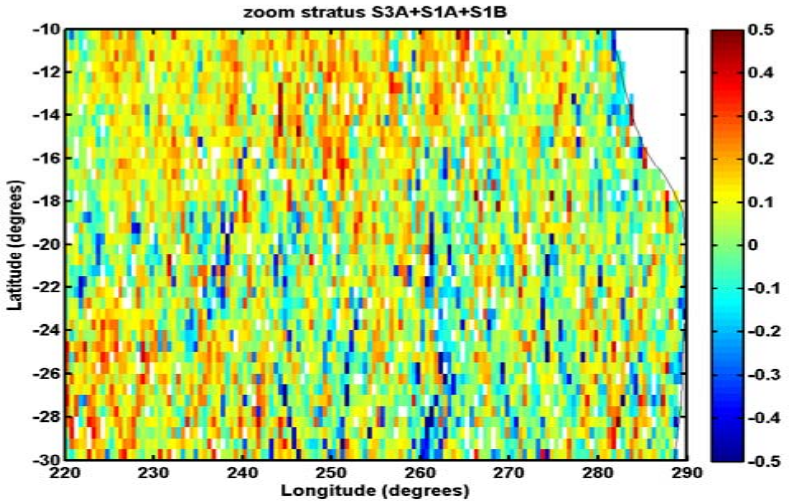


Stratus

**Same trend : bias of SWH is reduced when using SAR Wave spectra from S1A and S1B**

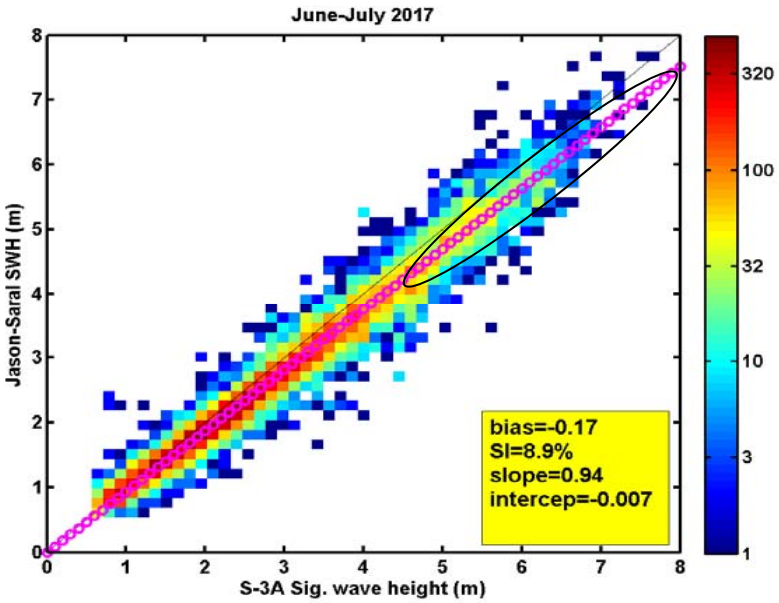
Bias maps from altimeters validation



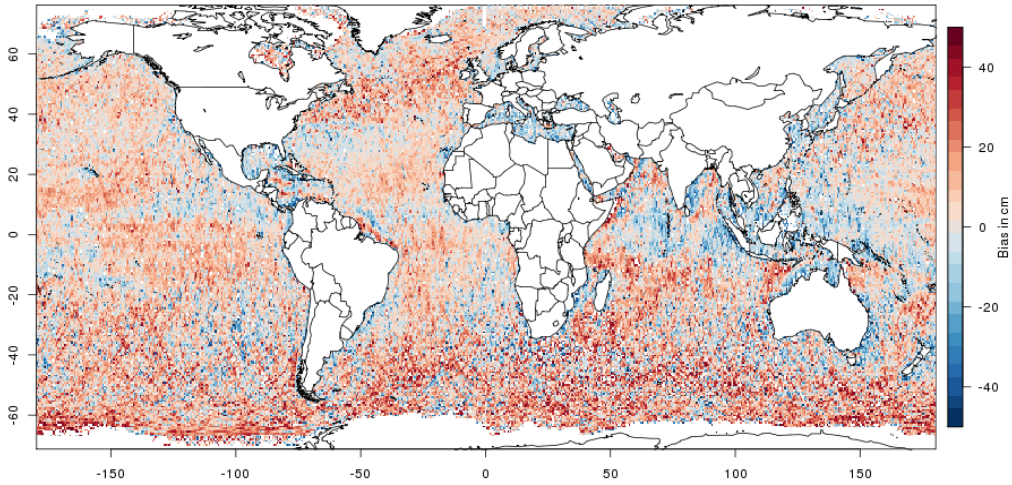
# Testing on bias correction for S-3A

**Comparison between S3A and Ja-3 and Saral at crossovers tracks**

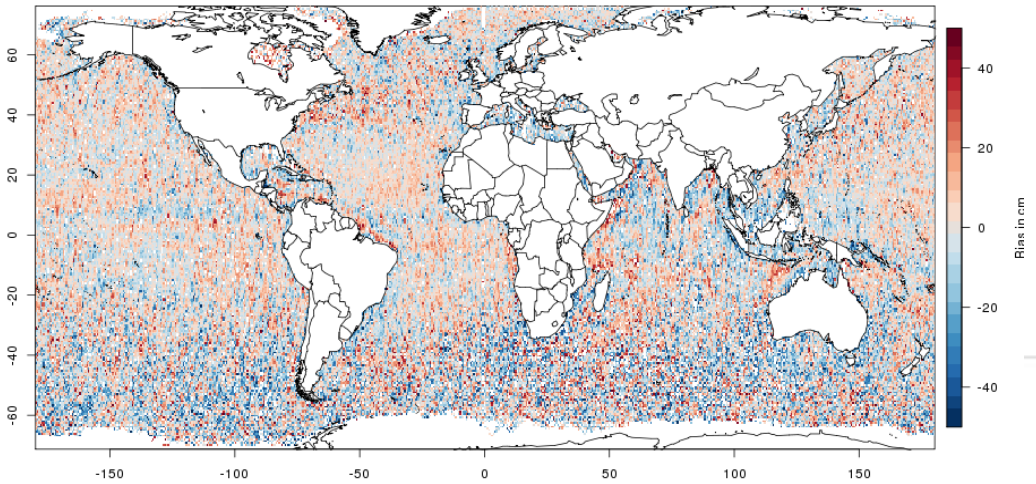



**Assimilation run with correction on S3A has been performed.**

**before**




**Improvements after using correction**



# Conclusions

- **Yes : the combined assimilation is efficient for removing partially the SWH bias of S3A.**

- **Ocean areas identified by the wave climatology are highly consistent with using SAR wave spectra from S-1A and 1B**

- **In the frame of Copernicus marine service (CMEMS-global) the S3A and S-1A S-1B will be included in the assimilation system the end of 2017.**

- **Looking forward for evaluating waves products issued from the LR-RMC processing (F. Boy).**