On the signature of swell for the Cryosat-2 SAR-mode wave data

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Aknowledgements to François Boy, Nicolat Picot, Thomas Moreau

OUTLINE

1- Motivation

2- CR-2 SAR mode Data

3- Assimilation of SAR-mode and P-LRM

4- Discussions on swell signature (CR-2 SAR vs MFWAM)

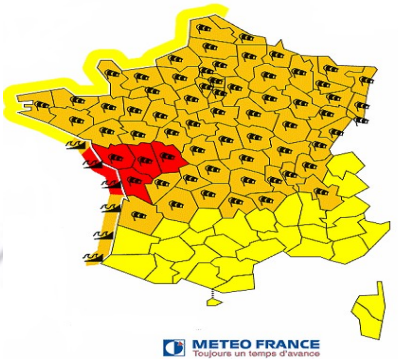
5- Conclusions

MOTIVATION

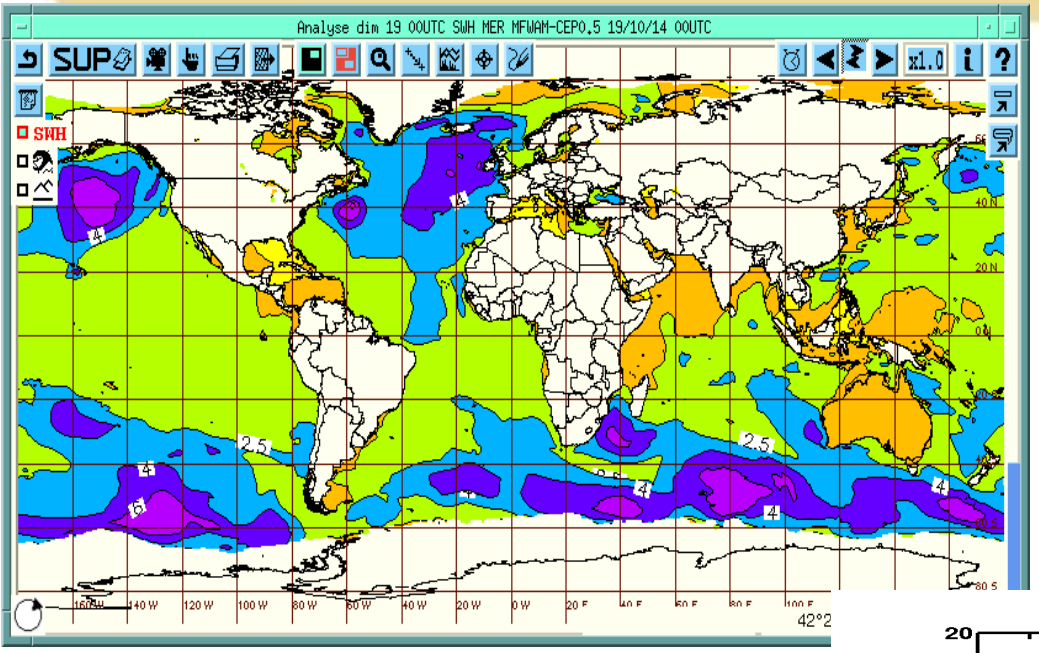
- **The assimilation of altimeters is a strong component of the operational wave forecasting system of Météo-France : accuracy and efficiency of the wave submersion warning (VVS)**

- **Preparing the use of new altimeter data (SAR-mode) in the assimilation system (Sentinel-3 soon).**

- **Evaluating the Impact of using altimeters SAR-mode regarding to P-LRM data in the wave model MFWAM**



Operational global wave forecasting system at Météo-France



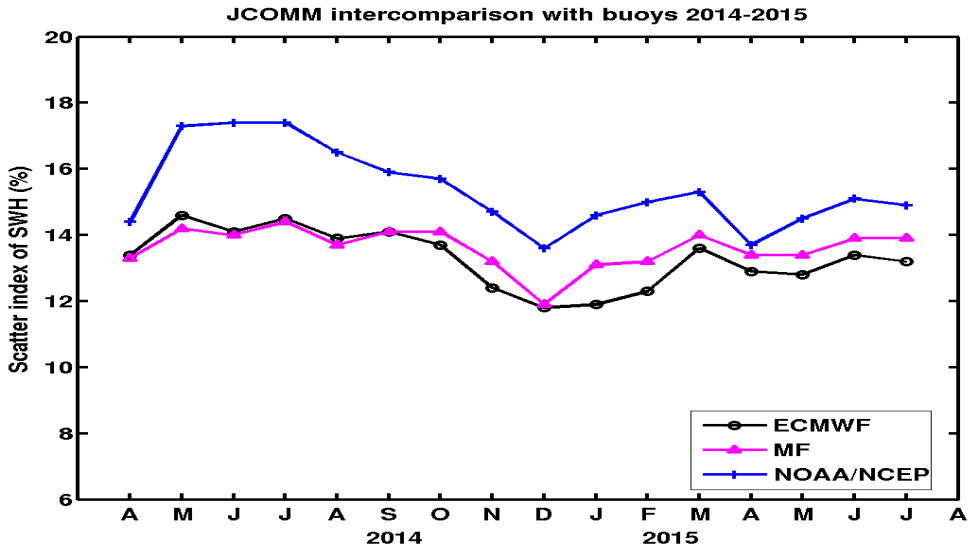
Snapshots of SWH on 19 October 2104 at 0:00 (UTC)

Two global wave models MFWAM (0.5°) forced by analyzed ARPEGE and ECMWF winds

The model was upgraded since november 2014 with improvements from the work in Mywave project.

In operations assimilation 6 hours:

- Jason-2
- SARAL since 10 December 2013
- Cryosat-2 since 23 April 2014



Performance of analysis from operational wave models (JCOMM/WMO)
by J. Bidlot
SI of SWH (comparison with buoys)

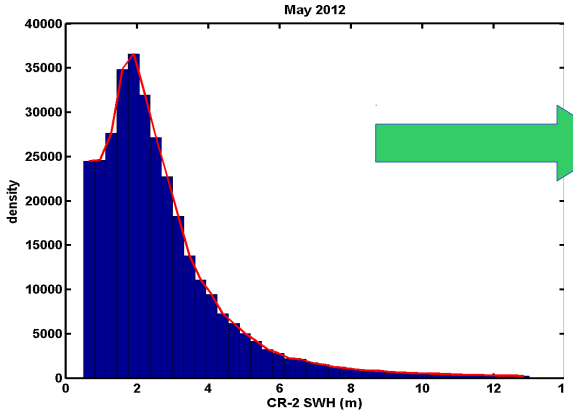
2014 2015

Cryosat-2 wave data

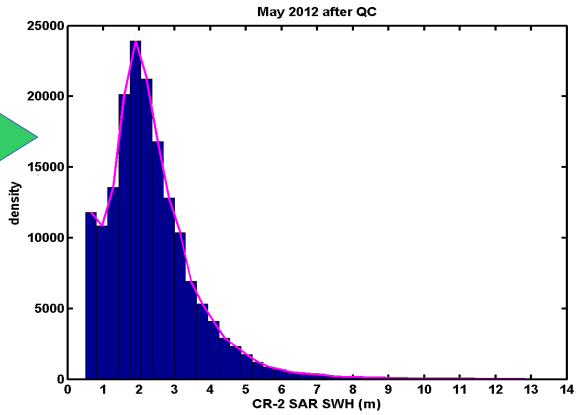
- Two sets of wave data are used in this study. Both SAR mode and P-LRM data are provided :
  - May-Jun-Jul-Aug-sep 2012 (Processing V13)
  - Nov-Dec-2013-Jan-Feb-Mar 2014 (more recent data Processing V14)

- Quality control procedure is processed :
  - threshhold on SWH,σ0 and flag of surface type,...

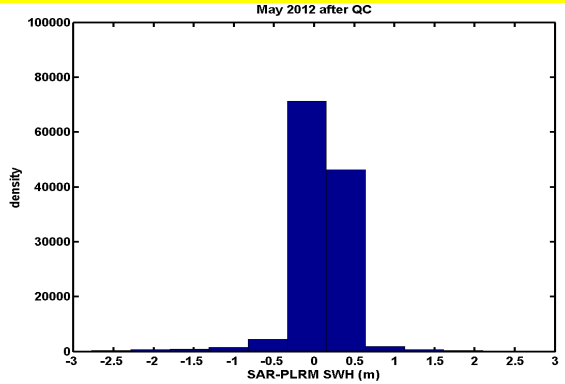
Histogram of SWH before QC



After QC



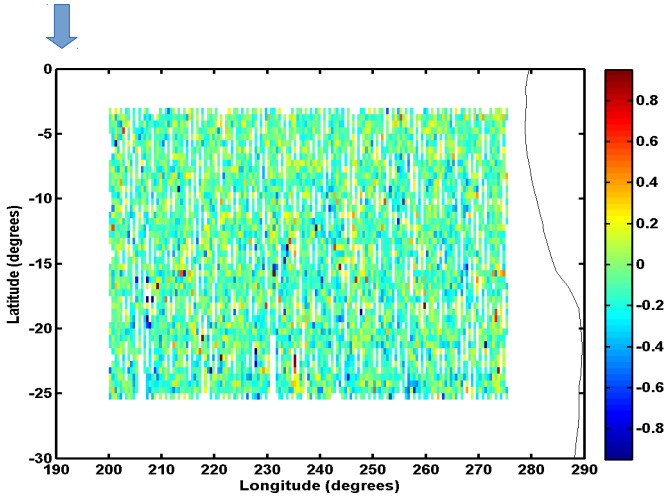
Histogram of difference SAR-PLRM SWH after QC

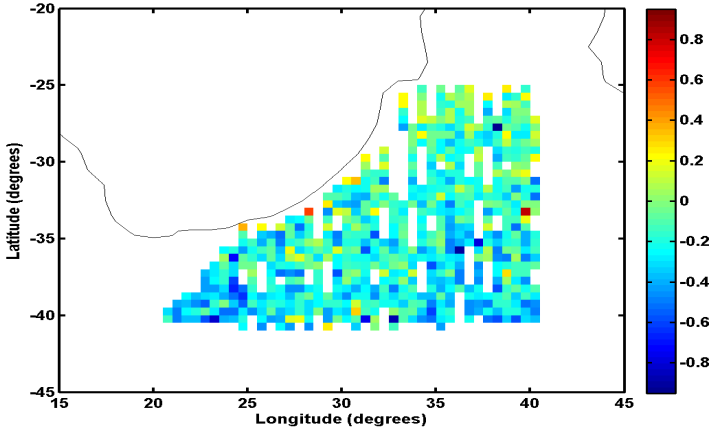


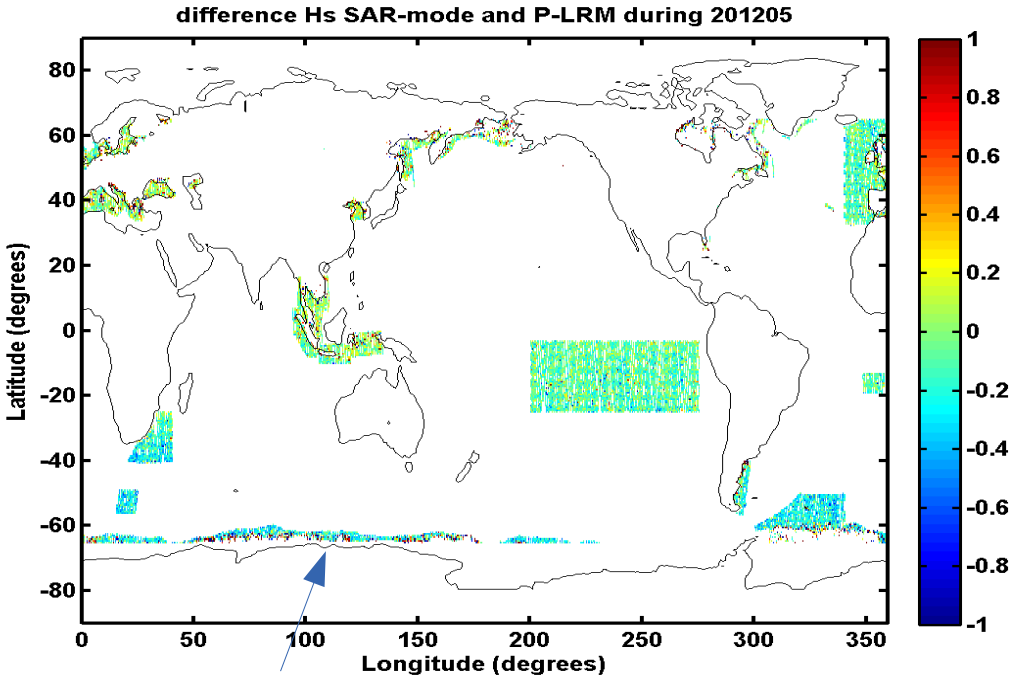
The assimilation system

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

East-Pacific zone







Data for latitudes > 60°S are not included in the system. Large difference with First guess will reject the data.

Zoom on Agulhas zone

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Methodology

- Assimilation runs have been performed with the wave model MFWAM every 6 hours for both period (2012 and 2013-2014)
  Model resolution is of 0.5° and wave spectrum in 24 directions and 30 frequencies :

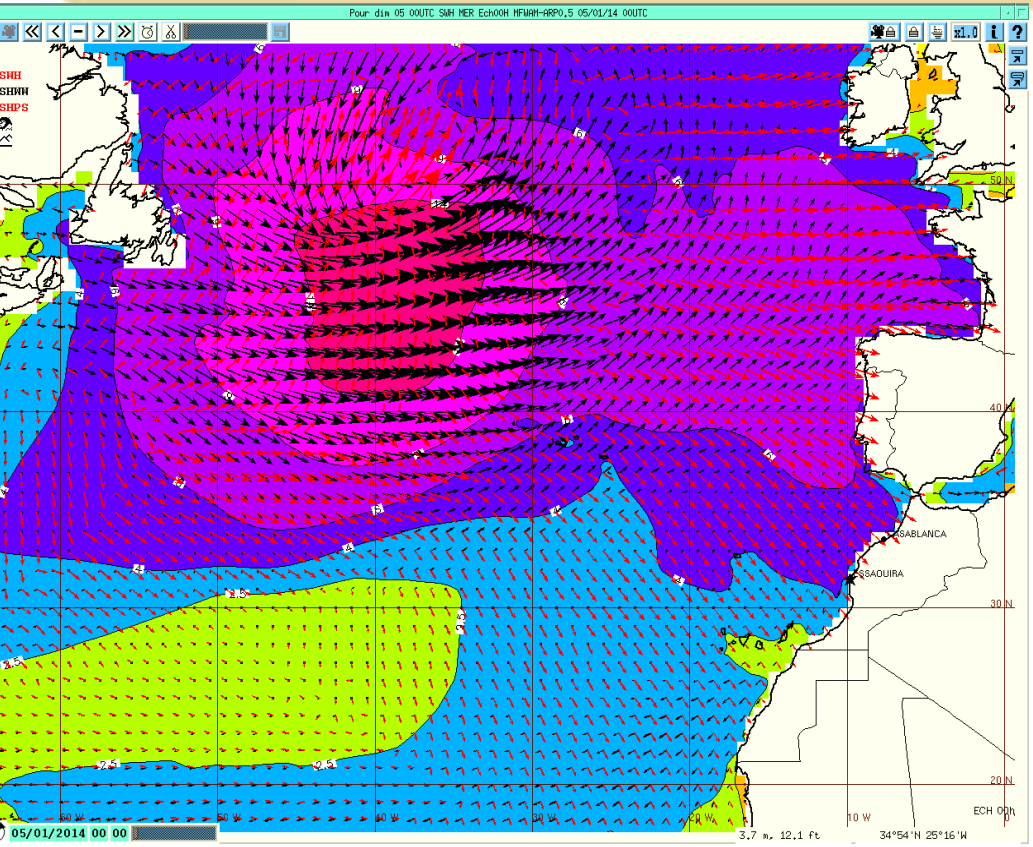
  - Run with assimilation of CR-2 SAR mode
  - Run with assimilation of CR-2 P-LRM
  - Baseline run without assimilation

- Validation of the results with independent altimeters (Ja-1, Ja-2 and Saral)

- Comparison between CR-2 wave data (both SAR mode and P-LRM) with :

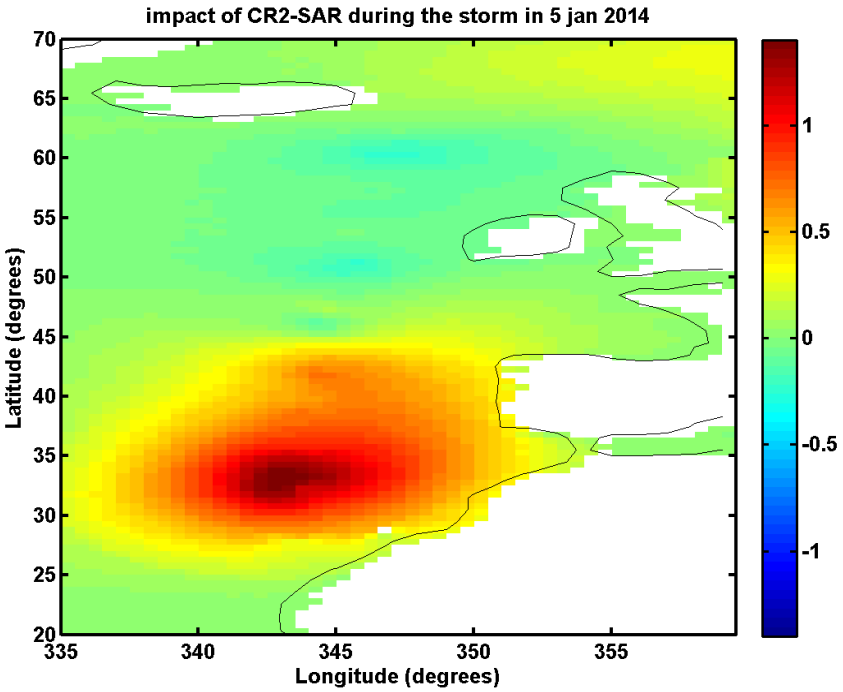
  - Operational MFWAM (from Météo-France data base)
  - Baseline run of MFWAM (grid 0.5°)

Impact of the assimilation of CR-2 SAR mode Storm HERCULES beginning of Jan. 2014



Long swell propagating to the Morrocan coast : SWH of 7 m and 18 sec of period (powerful swell)

SWH



Difference between MFWAM with and without assimilation of CR2

January 5 2014 at 0:00 (UTC)

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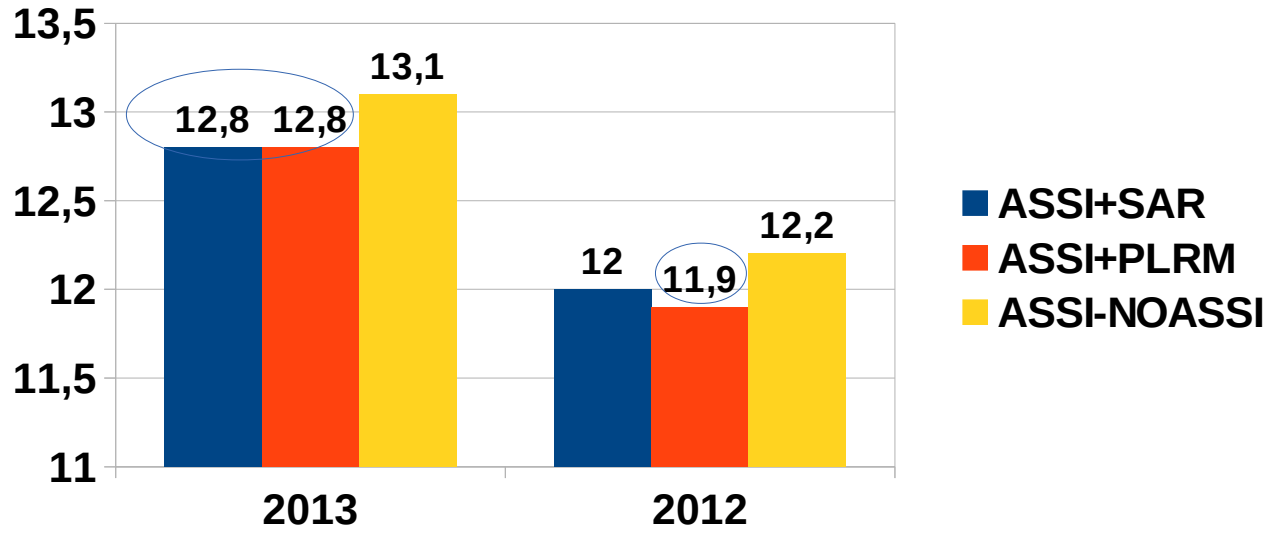
Results of the assimilation on global scale

Scatter Index for SWH



Bias in cm 0 -2 -1 0 -2 -1

Comparison for 2013 : Ja-2 and Saral
2012 : Ja-1 and Ja-2

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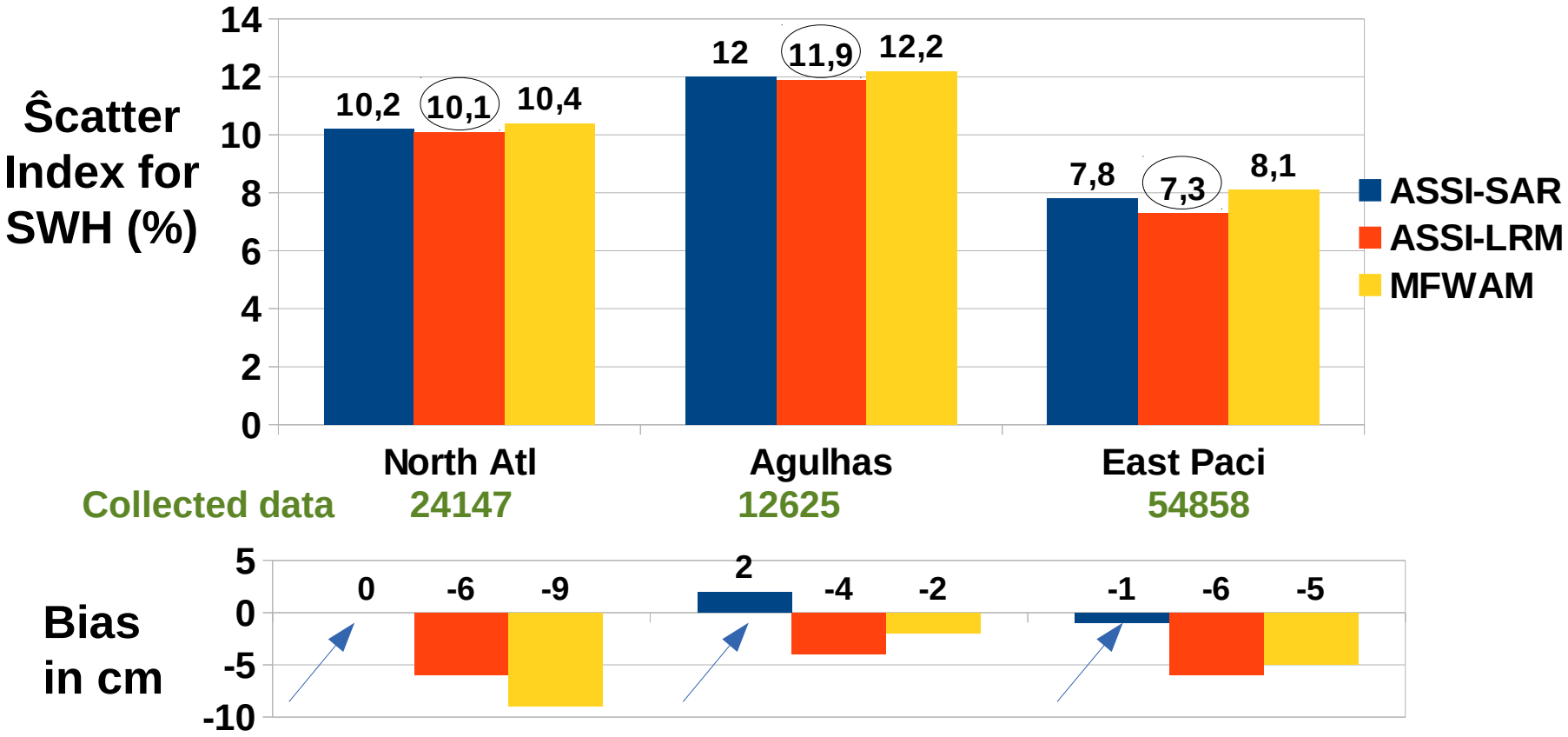
Impact of the assimilation of CR-2 for 2013-2014 data
Focus on three regions



SAME TREND FOR DATA OF 2012

Bias is slightly larger after the assimilation of P-LRM in north atlantic

Comparison with Jason-2 and Saral

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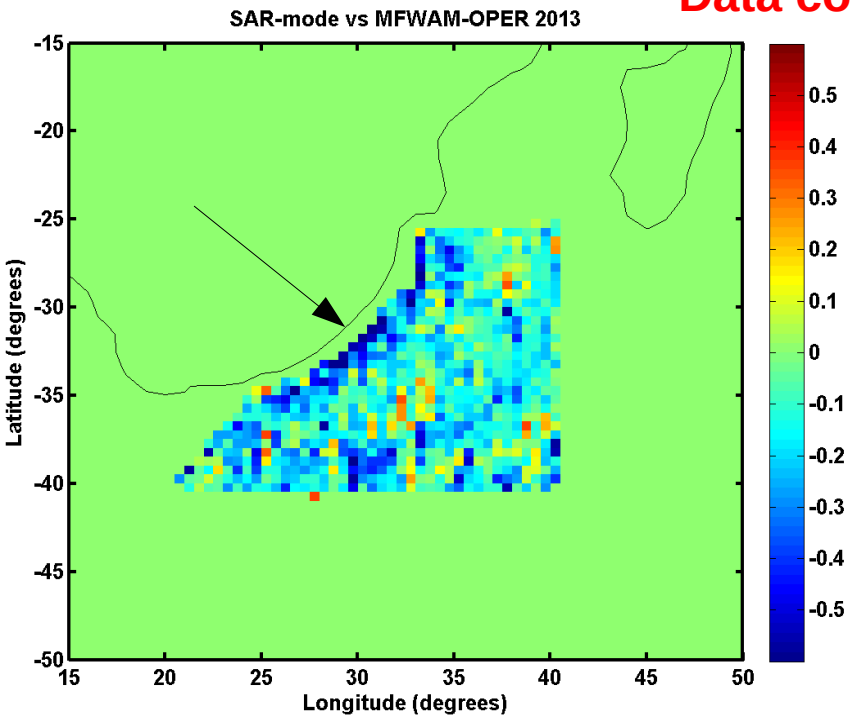
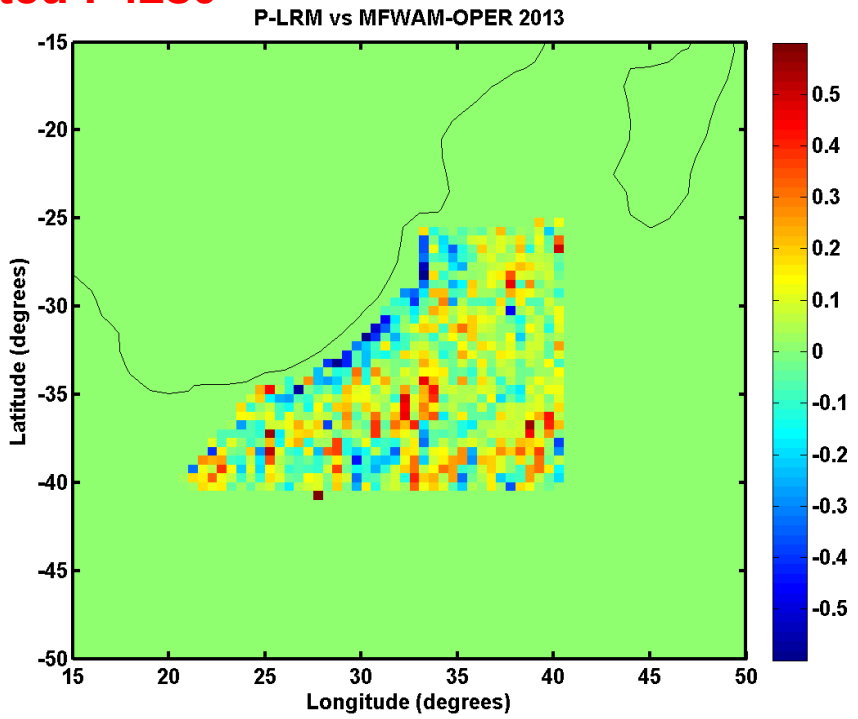
CR-2 SAR and P-LRM vs Operational MFWAM
Significant wave height

Mean bias over 5 months
Data collected : 4280

SAR-mode



P-LRM



Bias = -0.14
SI = 12,0%
Slope =0.93
Intercept =0.05

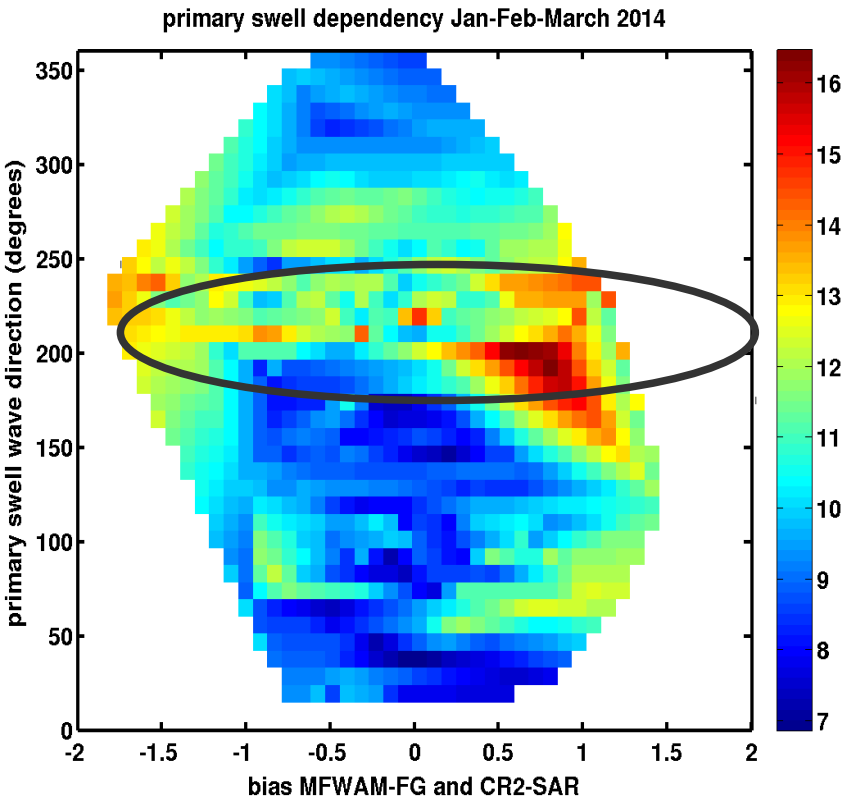
Better scatter index for the SAR-mode but with strong bias on SWH

Bias = 0.03
SI = 12,6%
Slope =0.97
Intercept =0.12

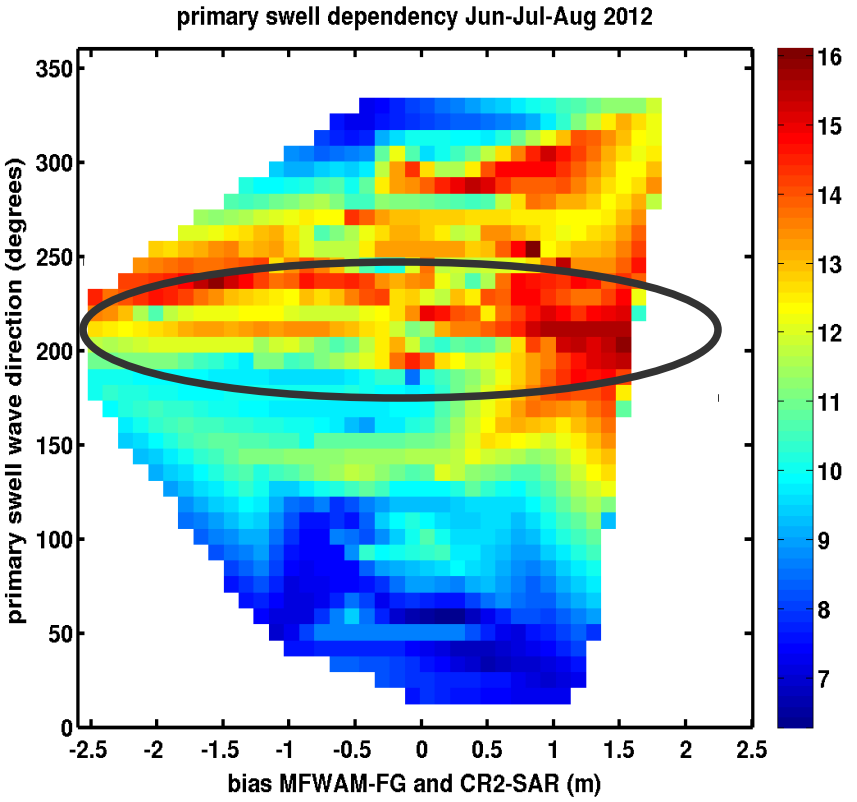
Agulhas period 2013-2014

bias between MFWAM and CR2-SAR-mode depending on the period and direction of primary swell

The coming direction of the waves (WMO ref.)



Data jan-feb-mar 2014



Data jun-jul-Aug 2012
Winter more swell are generated

The colors show the period (in sec) of the primary swell from MFWAM
A swell of 16 sec correspond of roughly ~400 m of wavelength

Agulhas region

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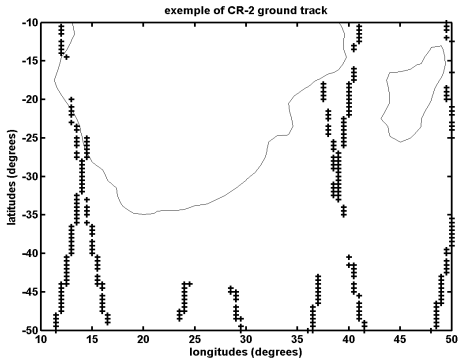
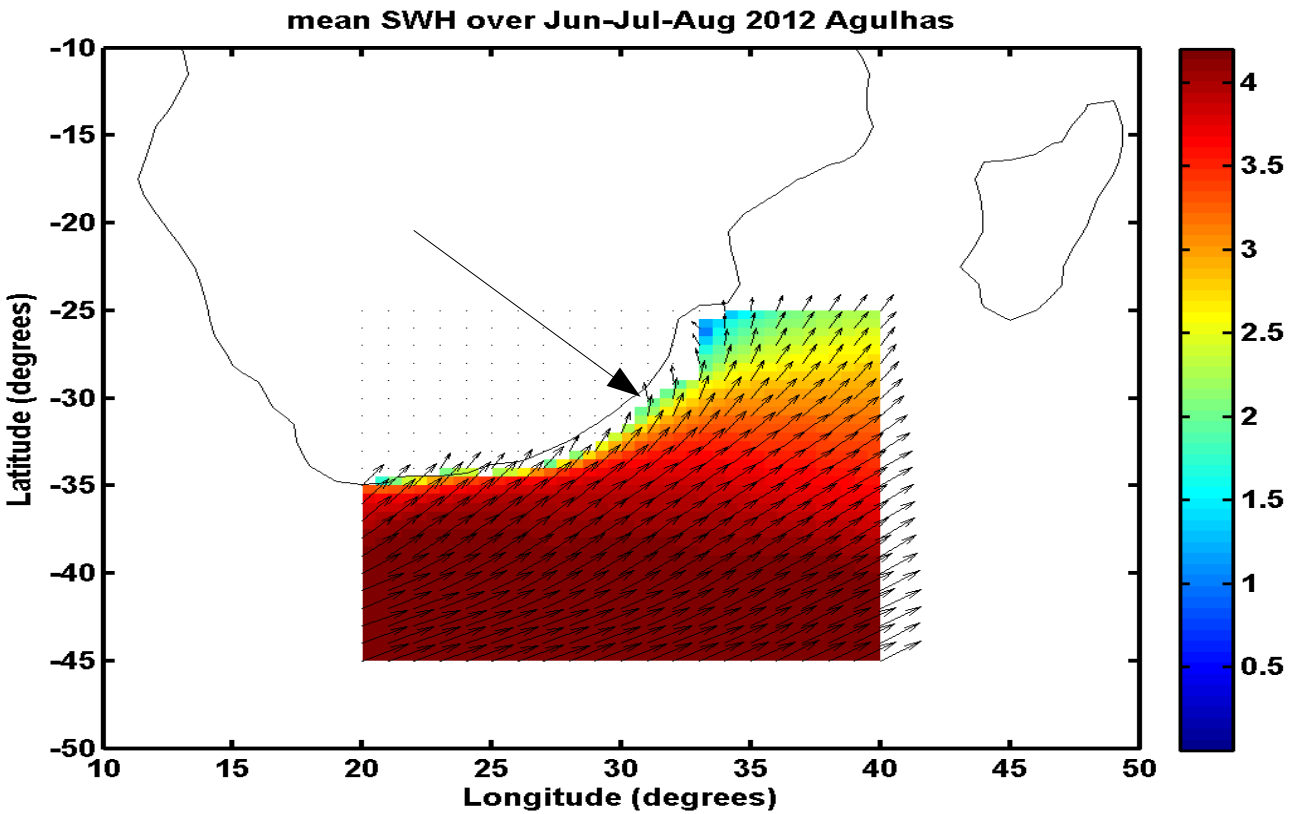
Mean significant wave heights over Jun-Jul-Aug 2012



Exemple of CR-2 Ground track direction



The arrows indicate the mean direction of primary swell
Mainly swell regime oriented from south-west and turning from south near the east coast of south-Africa.

Swell regime in the Agulhas zone

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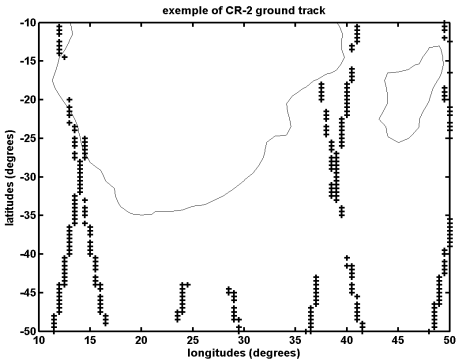
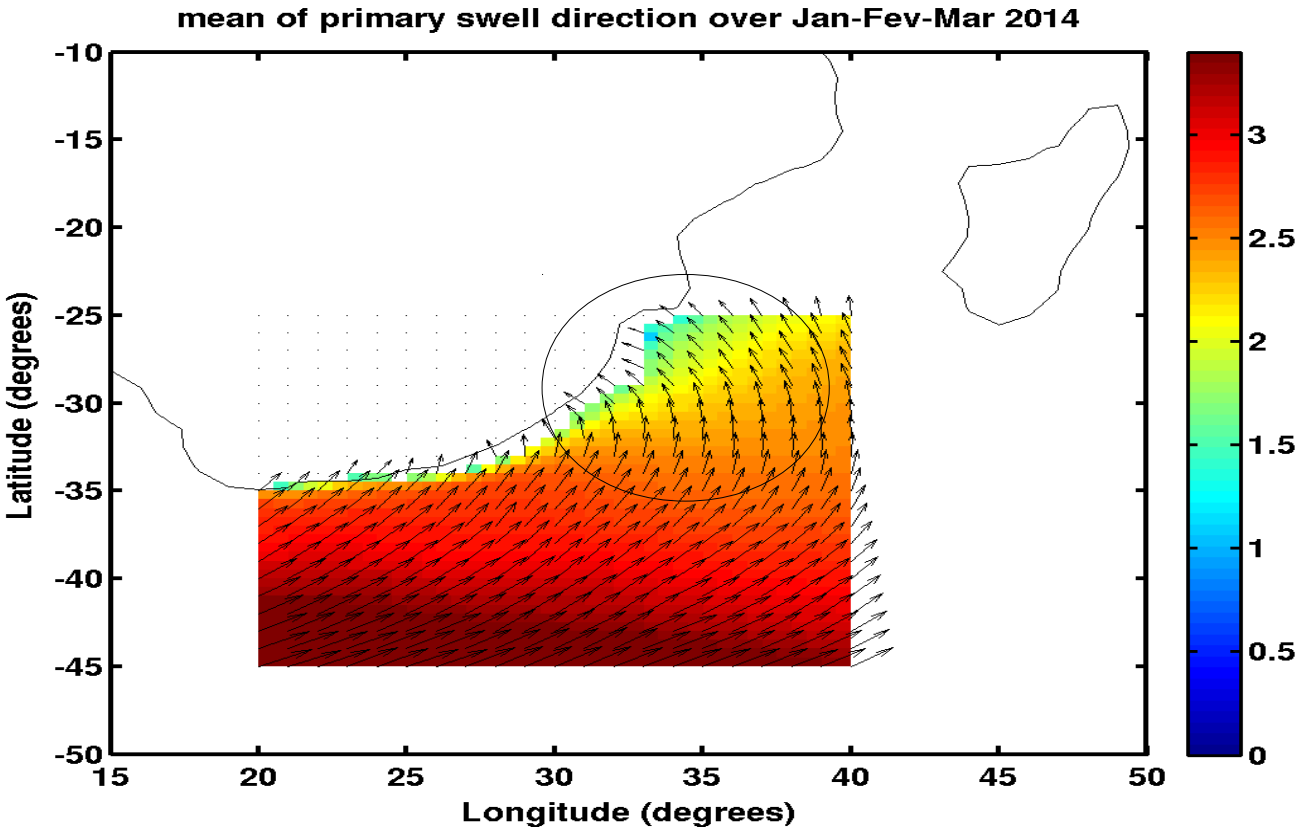
Mean significant wave heights over Jan-Feb-Mar 2014



Exemple of CR-2 Ground track direction



The arrows indicate the mean direction of primary swell
Same regime as in winter but with smaller mean of SWH and more extended zone for swell oriented from south.

Swell regime in the Agulhas zone

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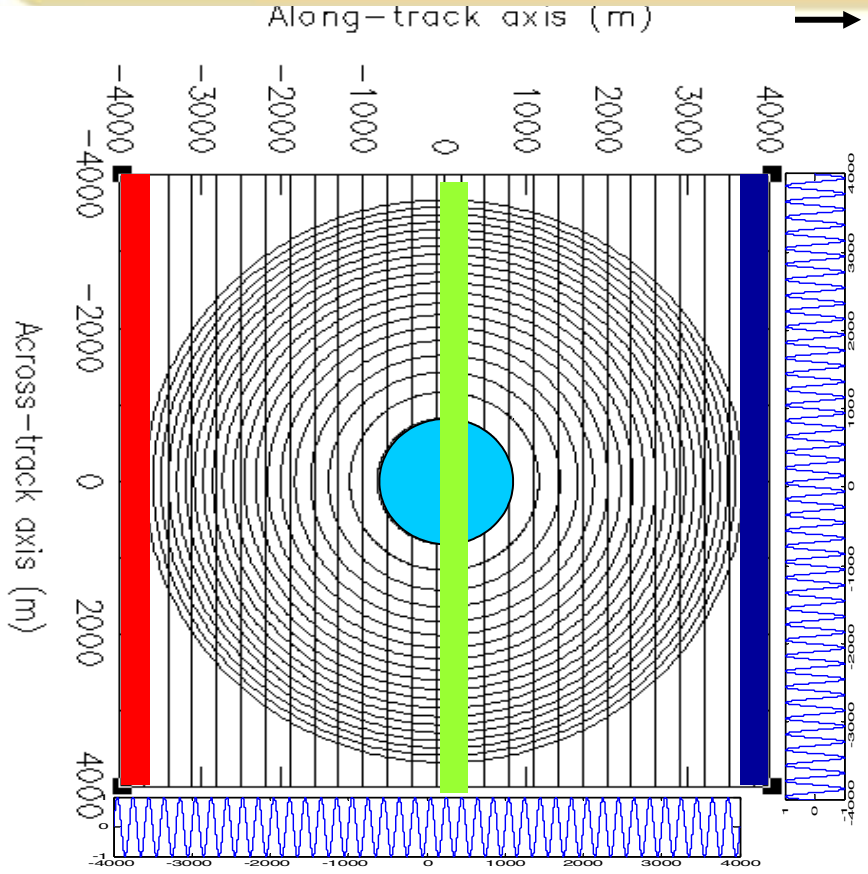
SAR-mode and SWELL

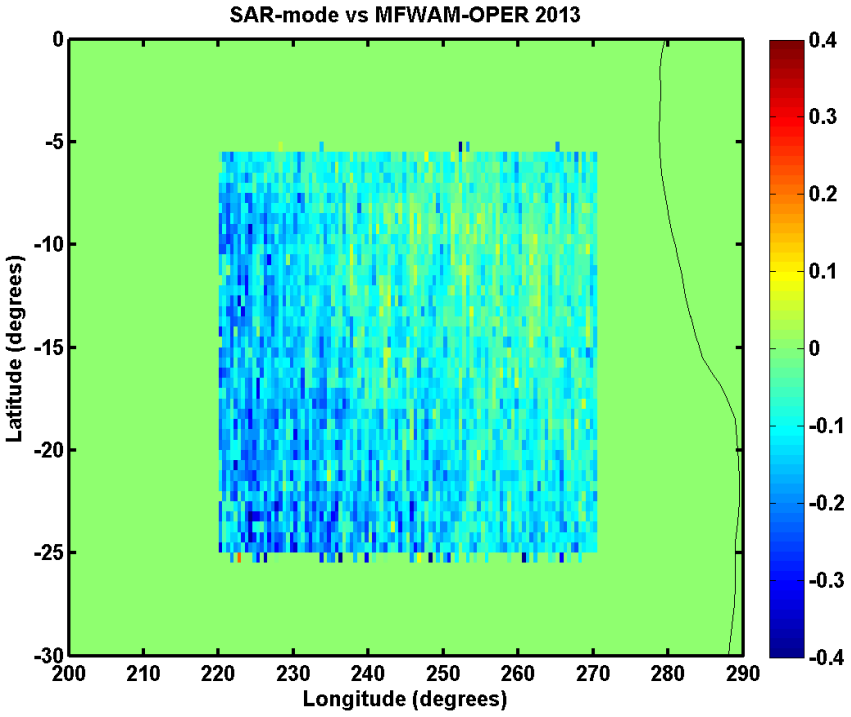


- **Hypothesis for explaining differences « bias » between LRM and SAR mode SWH in high swell conditions**
- **Conventional altimetry :**
  - **No dependency on swell direction**
  - **Range spreading due to swell is averaged out due to the large surface of range gate**
- **SAR altimetry**
  - **Anisotropy of swell direction with respect to Doppler cells : swell orientation affect the waveforms**
  - **The surface spanned by a range cells are much smaller than in conventional altimetry : range spreading due to cell will modulate the individual waveforms**
  - **the re-tracking does not account for swell direction/amplitude/wavelength and « biases » may results when re-tracking in LRM and SAR**

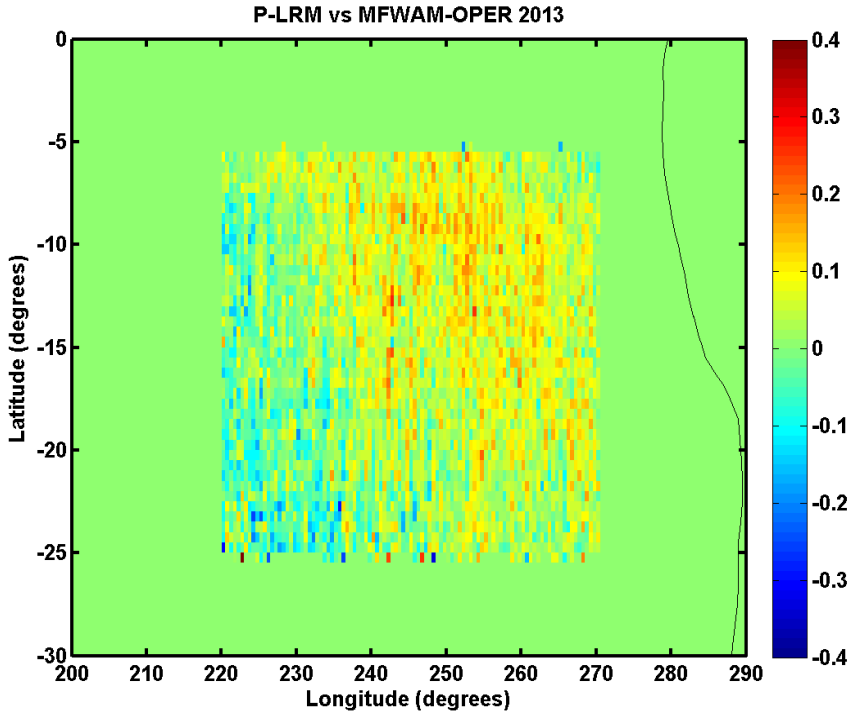
CR-2 SAR and P-LRM vs Operational MFWAM

Mean bias over 5 months
Data collected : 21970

SAR-mode



P-LRM



Bias = -0.10
SI = 5,8%
Slope =0.93
Intercept =0.03

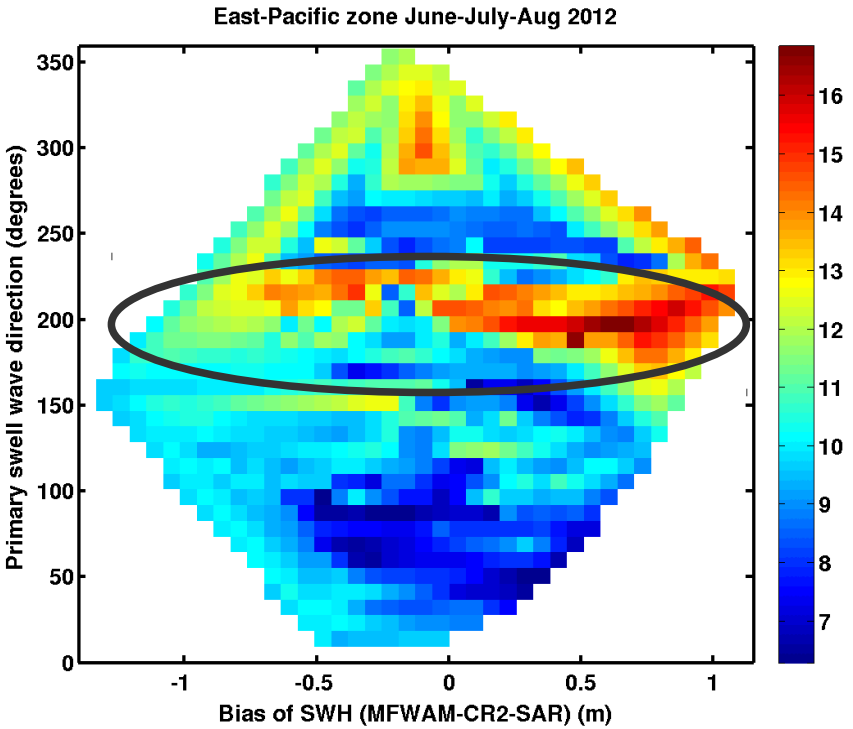
Better scatter index of SWH and strong bias

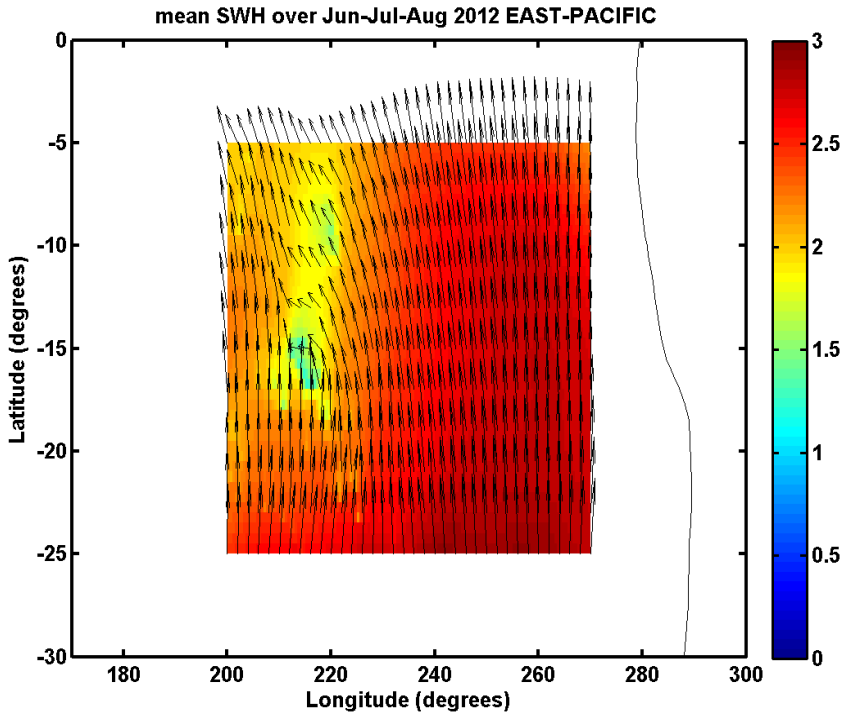
Bias = 0.03
SI = 6,4 %
Slope =1.02
Intercept =-0.02

East-Pacific period 2013-2014

bias between MFWAM and CR2-SAR-mode depending on the period and direction of primary swell

The coming direction of the waves





Data jun-Jul-Aug 2012

The arrows show the mean direction Of the primary swell mainly from south

The colors show the period (in sec) of the primary swell from MFWAM
A swell of 16 sec correspond of roughly ~400 m of wavelength

East-Pacific region

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Conclusions

- The impact of the assimilation of CR-2 SAR mode is almost as good as the P-LRM's one. Larger impact for data in 2012 than 2013.

- The bias of SWH is slightly better after the assimilation of CR-2 SAR Mode : comparison with Ja-1, Ja-2 and Saral.

- The comparison with MFWAM has revealed a bias for SWH of CR-2 SAR mode induced by long swell. The bias is enhanced when the swell is propagating close to the satellite ground track angle.

- Big challenge is on the way for taking into account the long swell in the SAR-mode retrieval. Works are on going with teams from CNES, Thales and CLS.