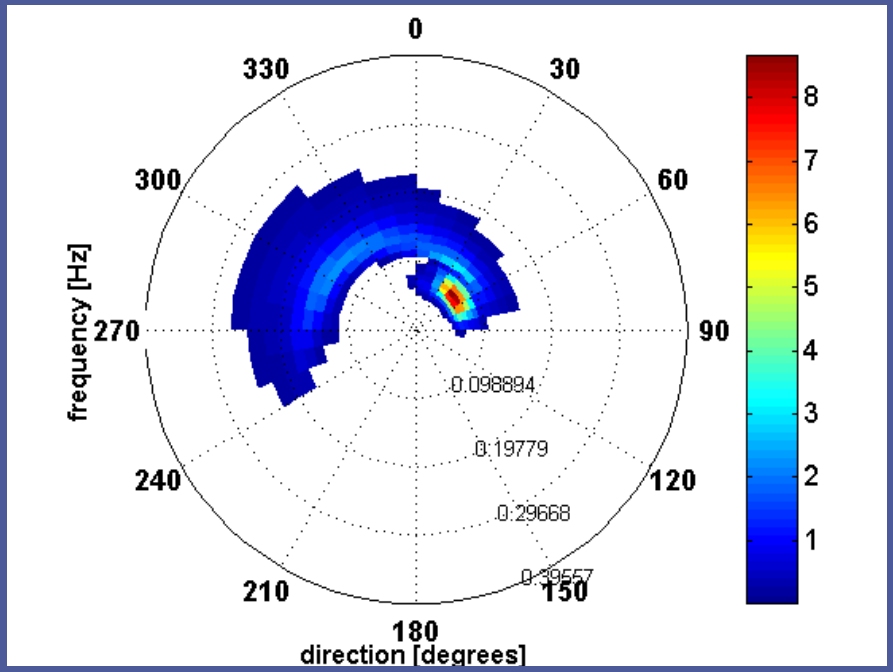
Assimilation of Altimeter and ASAR data in WAM



Jean-Michel Lefèvre and Lotfi Aouf, Meteo-France

This work has been partly supported by the French Space agency (CNES)

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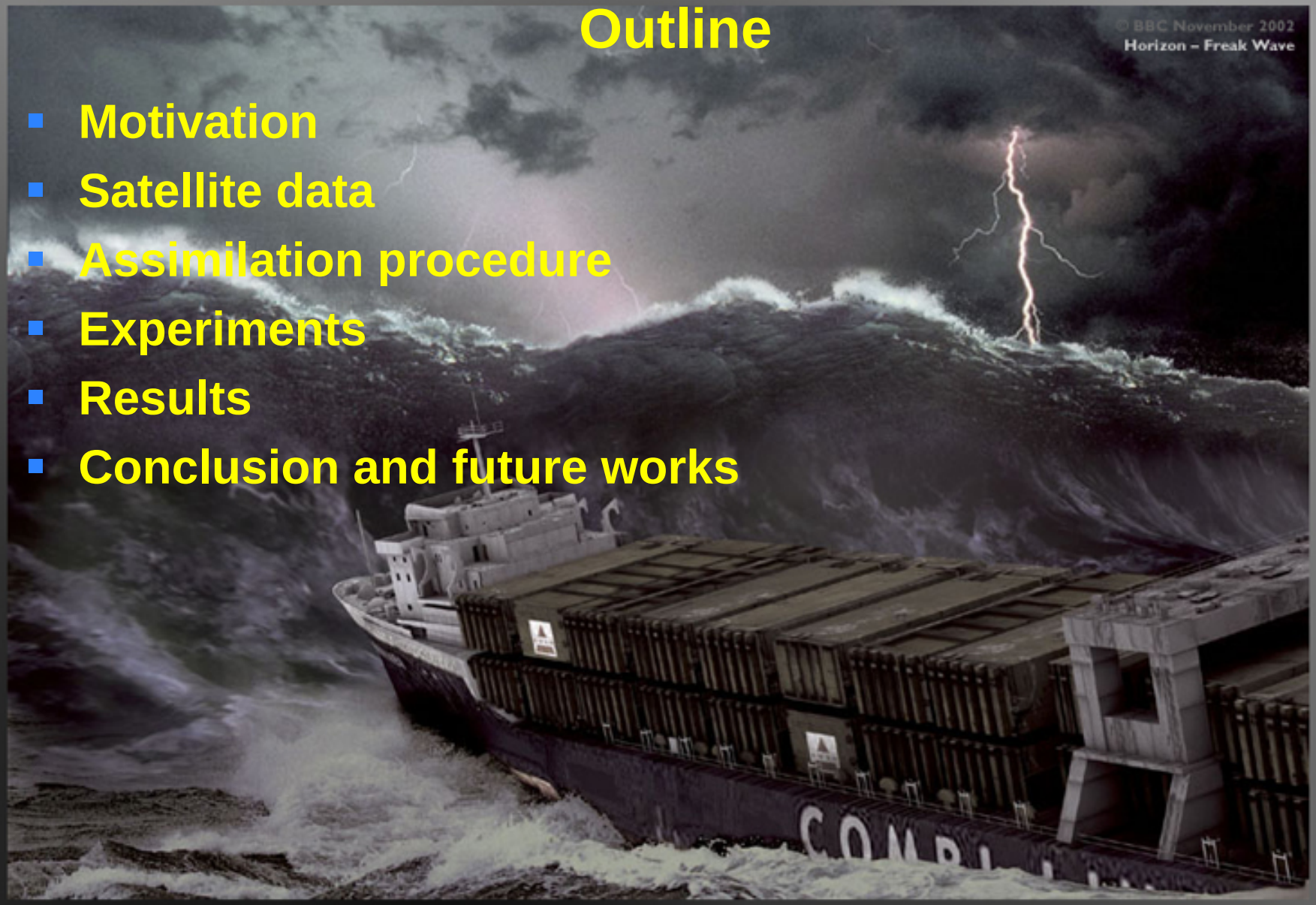
Outline



- Motivation
- Satellite data
- Assimilation procedure
- Experiments
- Results
- Conclusion and future works

Motivation

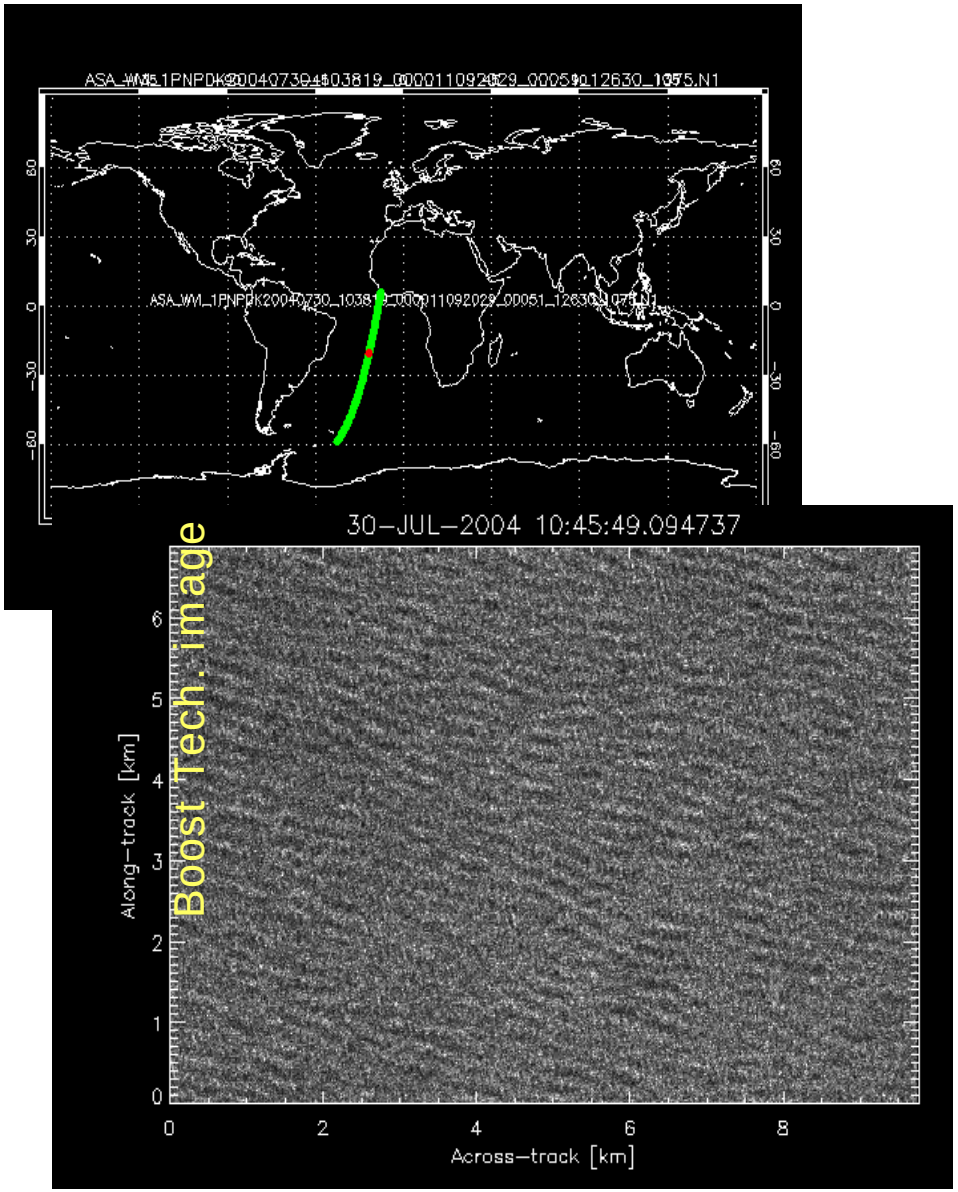
• Satellite wind/wave data are available in Near Real Time (NRT) on the GTS (Jason, ERS2) or on request from ESA (ENVISAT)

•Their accuracy can be similar (and even higher) than in situ-measurements (if adequately used, for comparable scales). But there is some limitations (Val Uncertainty Principle introduced par Hendrick !)

• They offer global coverage though there are some gaps when considering a typical time window of 6h, but the assimilation procedure should be able to propagate the satellite information.

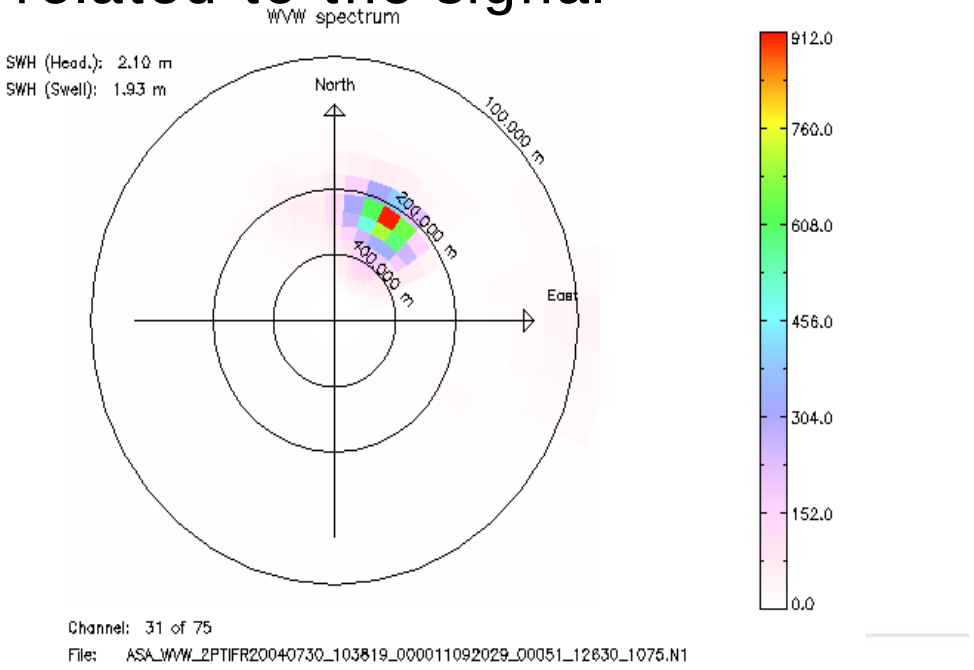
• Finally, the development of assimilation procedures should help to better define future satellite missions, by performing OSSE's.

The ASAR level 2 wave mode provides:



Geophysical parameters
- Partial Wave spectrum
- Wind speed estimate

+ many others parameters related to the signal



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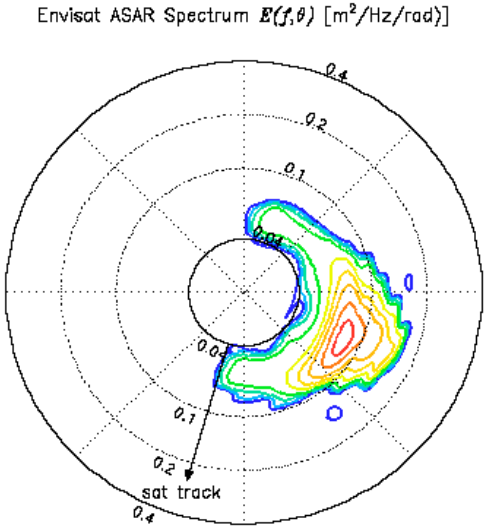
From Jian-Guo Li and Martin Holt

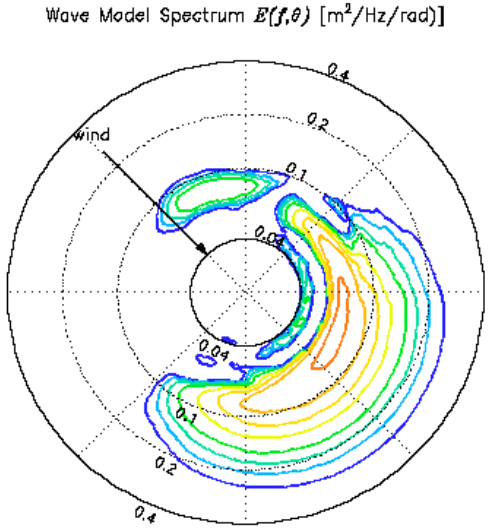
- 2-D energy spectrum;
- 1-D spectrum;
- 4-bin SWHs;
- SWH.

$$E(f) = \int_0^{2\pi} E(f,\theta)\,d\theta$$

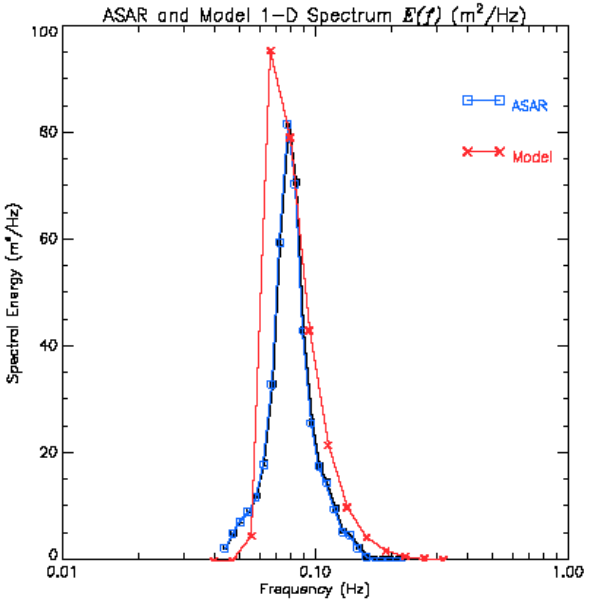
$$H_s(f_2 - f_1) = 4\left(\int_{f_1}^{f_2} df \int_0^{2\pi} d\theta \cdot E(f,\theta)\right)^{1/2}$$



Date: 2005/ 5/ 21, 6: 21: 46
Location: (−51.67N, 39.15E) LandFlag= 0
SWH Cal/Hdr= 6.30/ 6.51
Max WL at 255.3 m to 110.0 deg rel to N
ECMWF Wind 20.11 m/s from 45.00 deg rel to N
Shared Energy C_Levels [0.2, 0.5, 1., 2., 5., 10., 20., 50.,100.,200.] m²/Hz/rad



Date: 200505210630.
Location: (−51.94N, 38.75E)
SWH= 7.96 m
Max WL at 180.5 m to 125.4 deg rel to N
Wind 19.70 m/s from 315.7 deg rel to N



Azimuthal cut−off: 588.4 m, (0.05151 Hz)
ASAR Qp,BFI = 2.86, 0.0275
MODEL Qp,BFI = 2.23, 0.204

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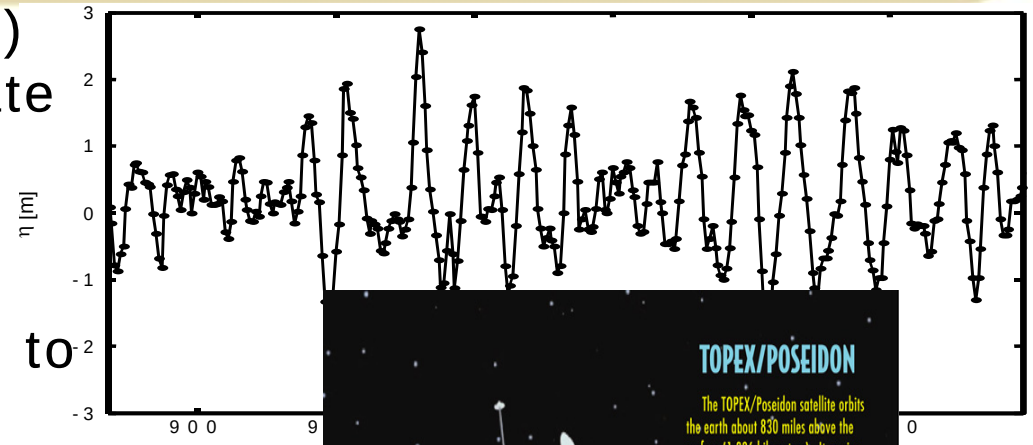
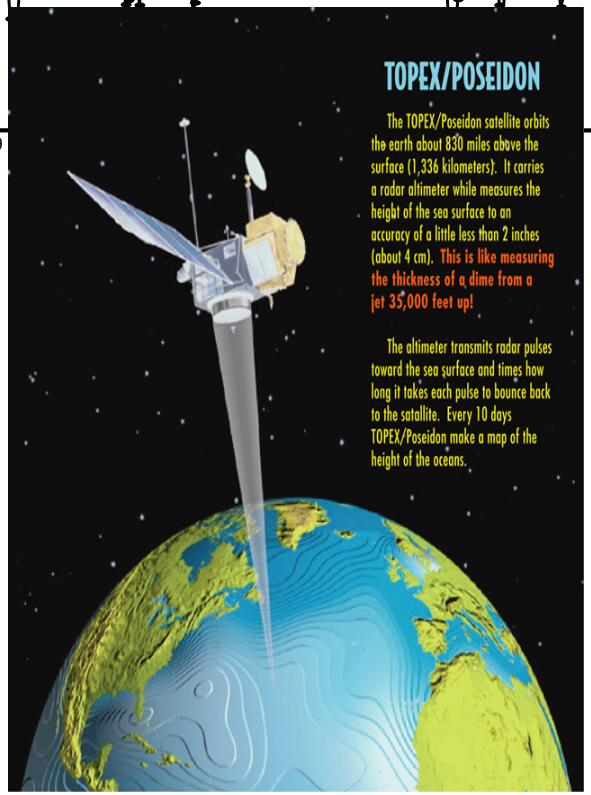
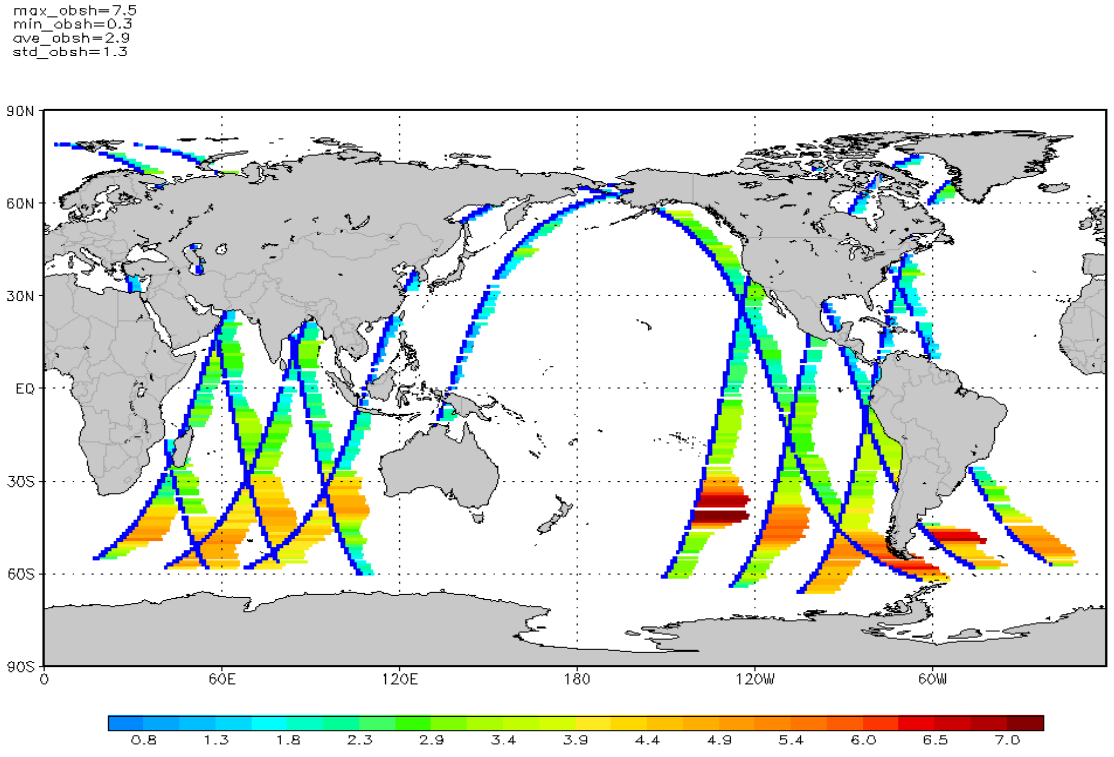
Altimeter products

-Significant Wave Height (total) inaccurate for very low sea-state
-Wind speed (U10), but very inaccurate above 20 m/S

+ Statistical quantities related to 1Hz SWH and U10







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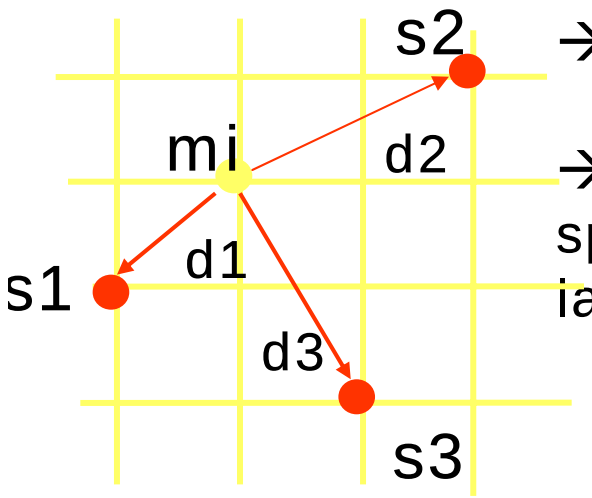
How the assimilation system works ?

• Assimilation of altimeter data following Lionello (92) with few improvements since



→ **Optimum Interpolation** of SWH

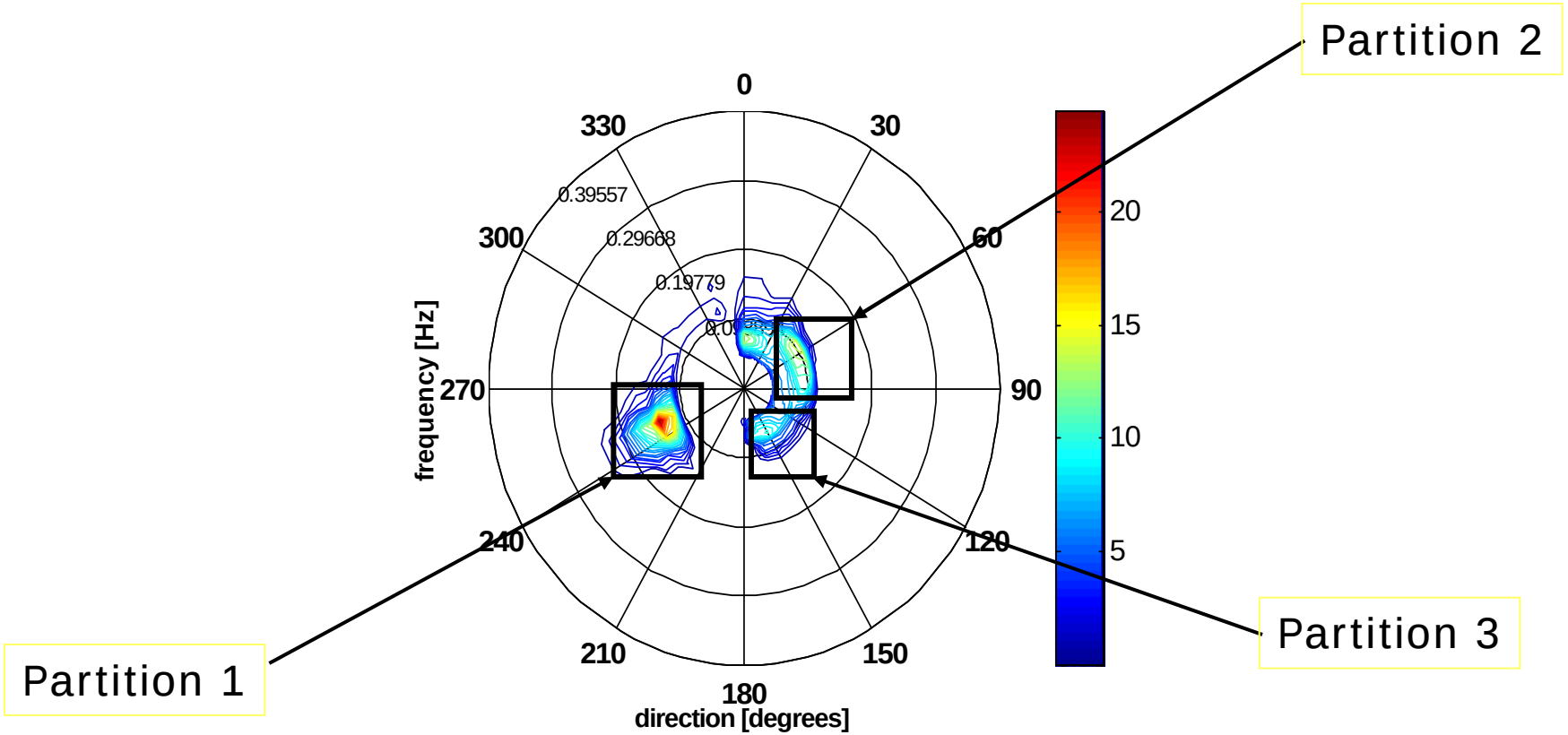
→ **Reconstruction** of the wave model spectrum based on assumptions , power laws or « conservative » parameters

• Assimilation of ASAR directional wave spectra (adapted from Voorrips)

→ **Decomposition** in wave trains and computation of related mean parameters

Partionning of wave spectra

- Decomposition of the wave spectra in partitions (first guess and observation)



Each partition is described by its mean parameters

→ **Cross-assignment** between first guess and observed partitions (km-ko < tuned value)

→ **Optimum Interpolation** of mean parameters for the selected partitions

→ **Reconstruction** of the analyzed wave spectra

Model and Assimilation set-up

- **Test runs set-up**

  - Wave model WAM-4 (global 1°in lat-lon), wave spectrum in 25 frequencies (0.044-0.39 Hz) and 36 directions

  - 6-hourly ECMWF wind fields

  - Assimilation every 3-hour (3h time-window)

  - Correlation length 250 km and distance of influence 600 km

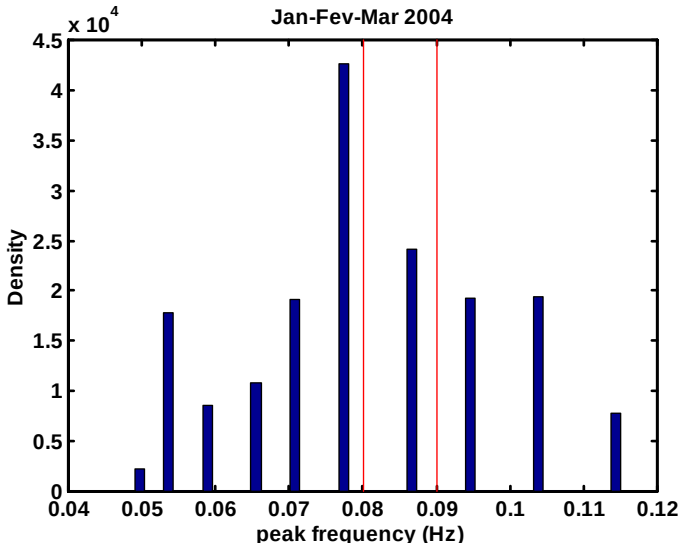
  - Assimilation period from 1 Jan 2004 to 1 April 2004

- **Quality control for ASAR wave spectra**

  → signal to noise ratio(3<r <200)
  → normalized variance of the image (1-1.7)
  → wind speed (2-17 m/s)

Runs description

→ **Combined assimilation** of **RA-2** altimeter data and **ASAR** wave spectra over a **3 month** period (1 Jan-1 April 2004) with two different wavelenght cut-off (200 m and 240 m corresponding to about 11.5 and 12.5 s respectively)



→ Run with assimilation of **RA-2 altimeter** wave height only

→ **Reference** run **without assimilation**

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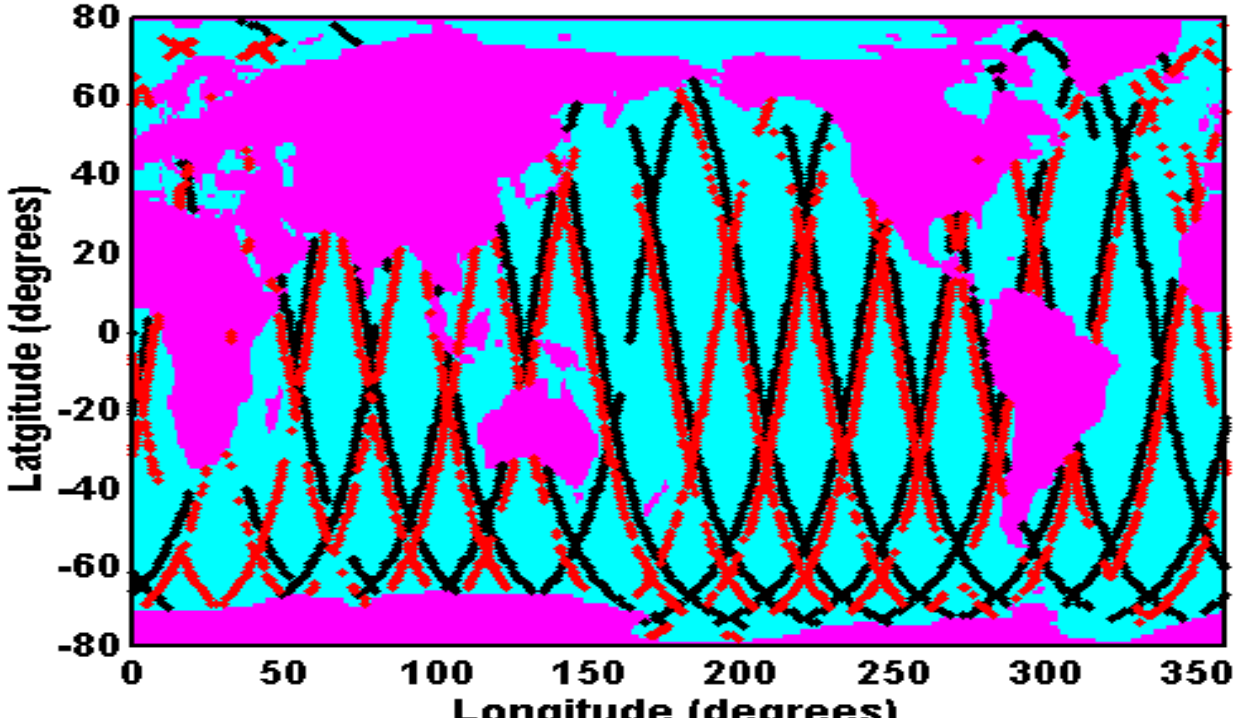
Daily data coverage for ENVISAT RA2 and ASAR

- RA2
- ASAR



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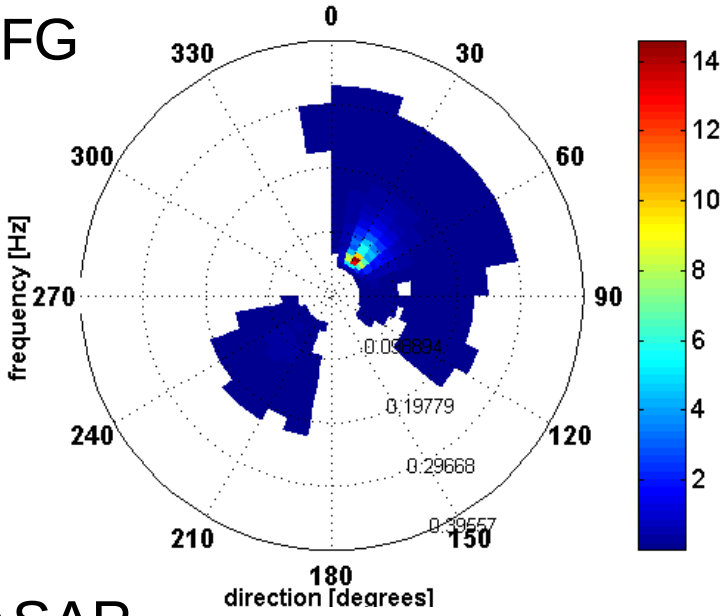
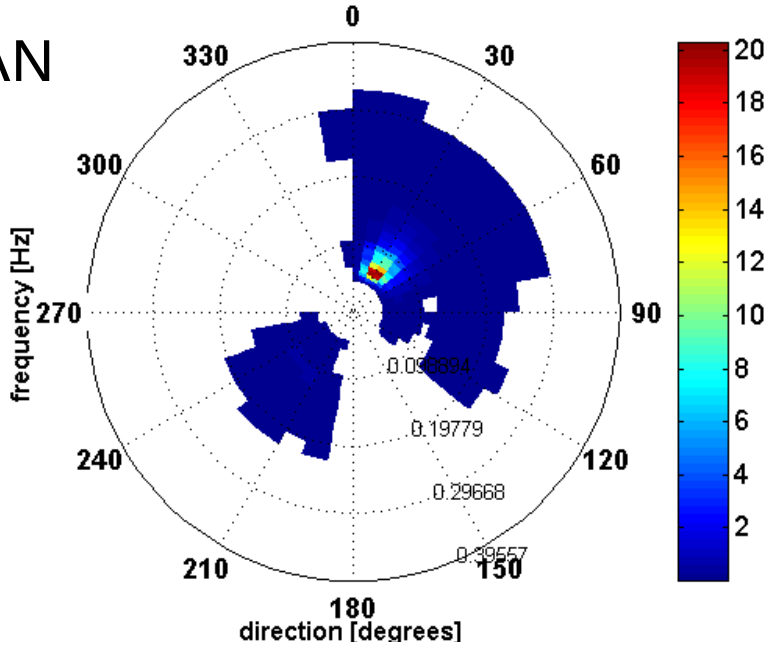
FG

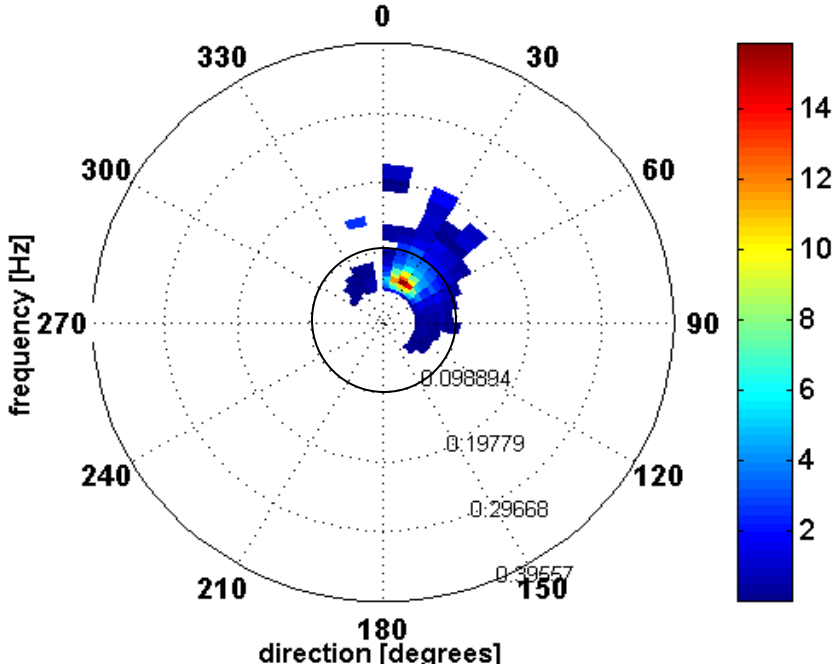


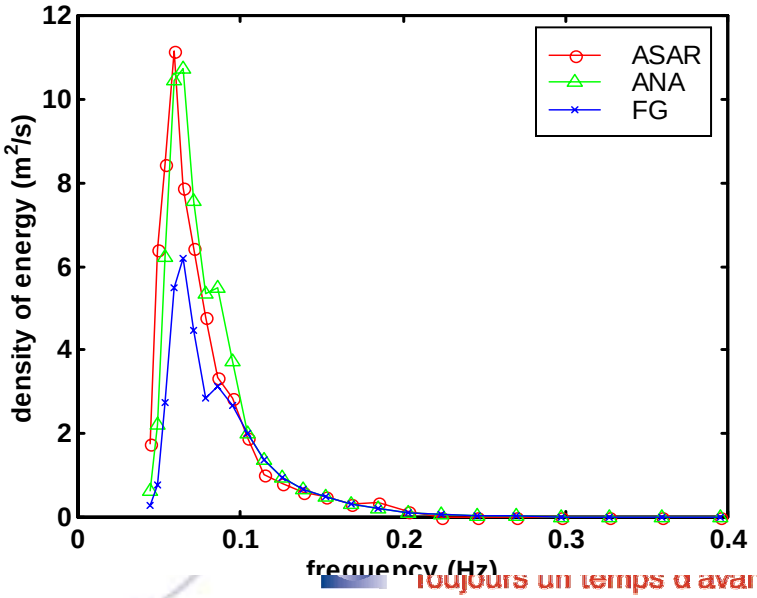
AN



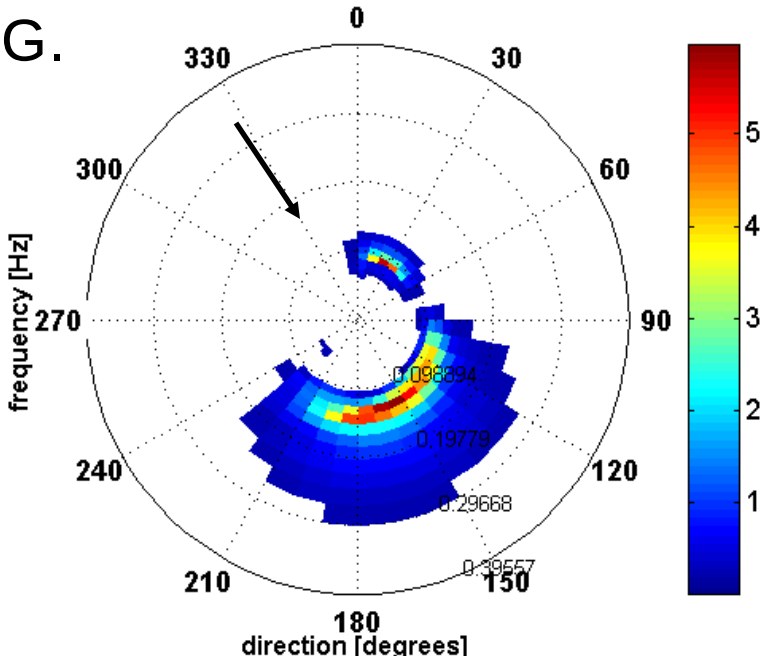
ASAR

Long swell travelling close to the azimuth direction





FG.



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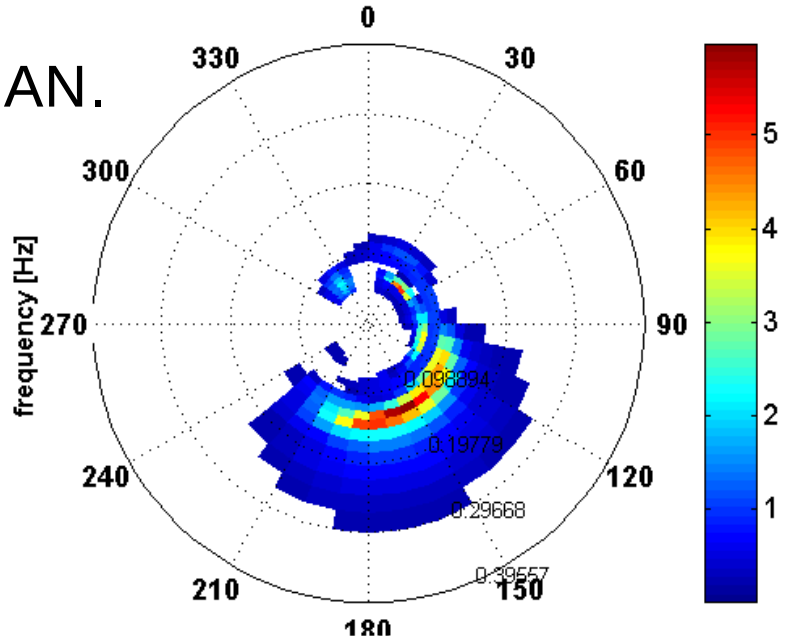
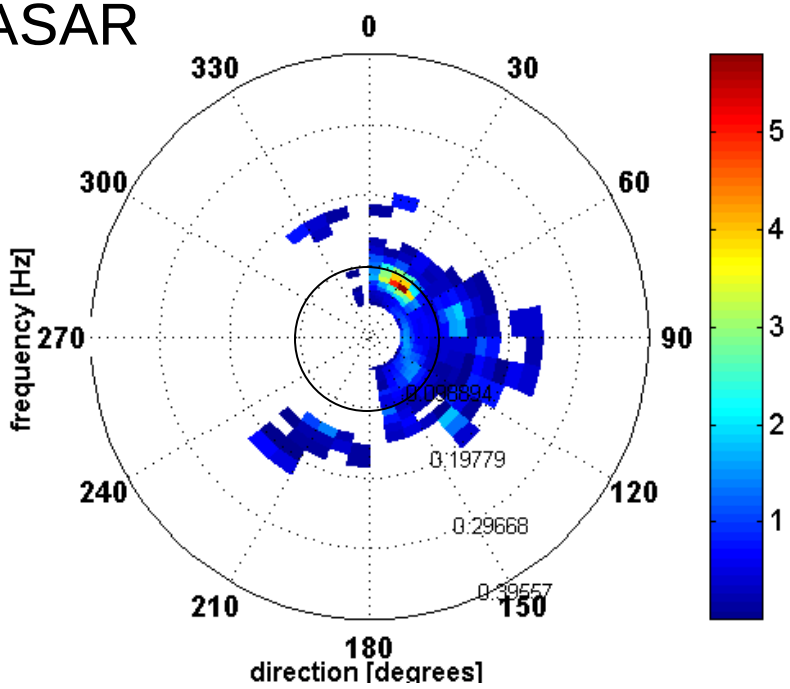
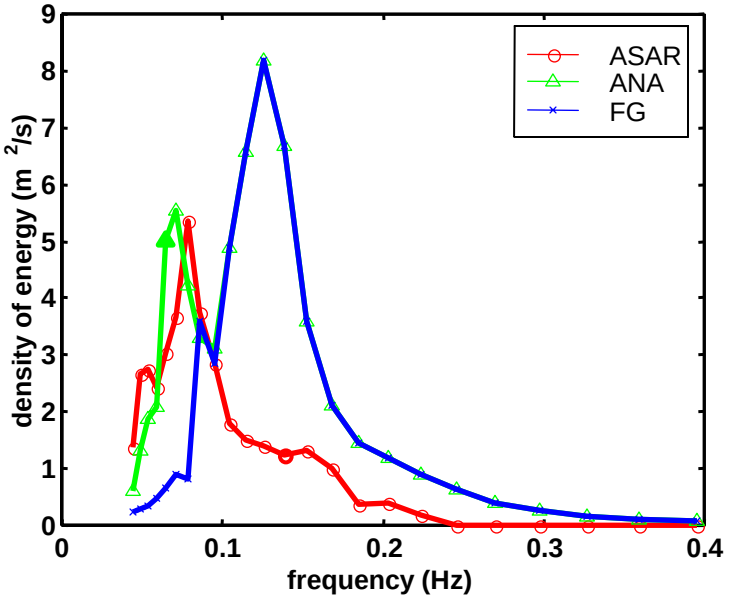


ASAR





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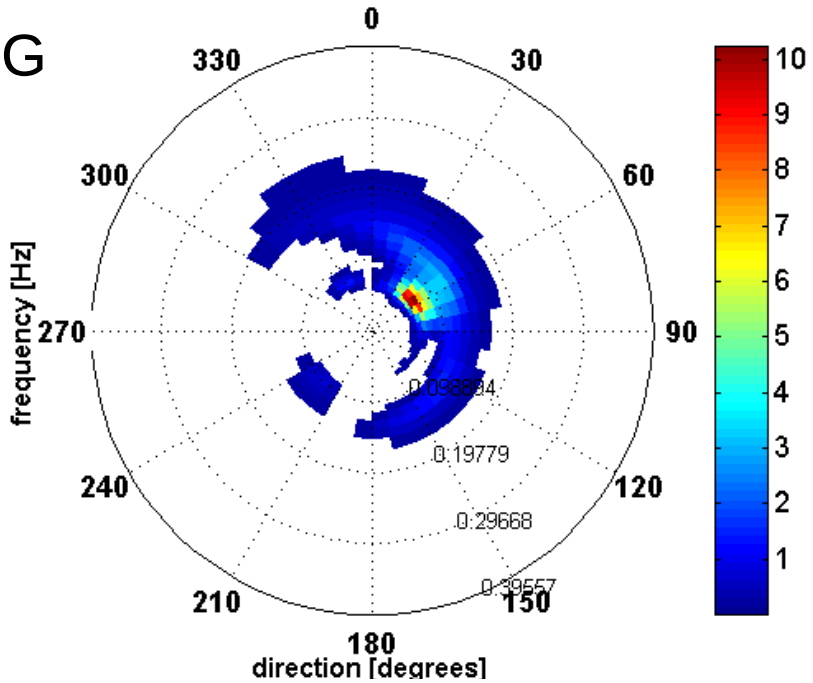
FG



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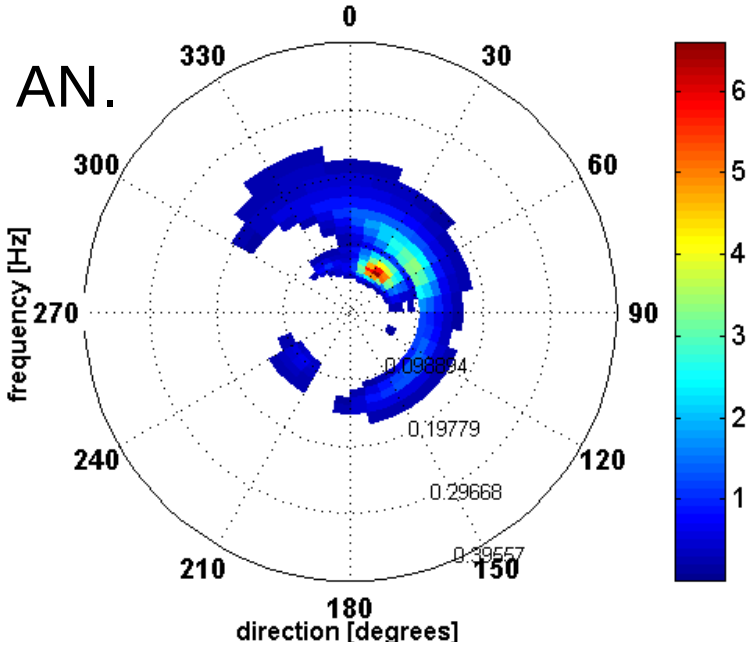
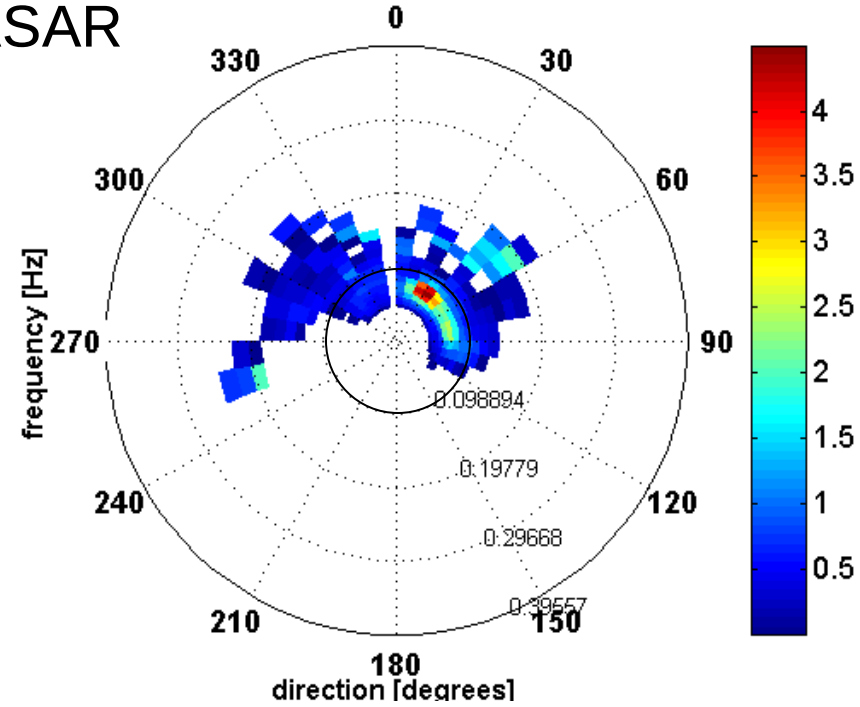
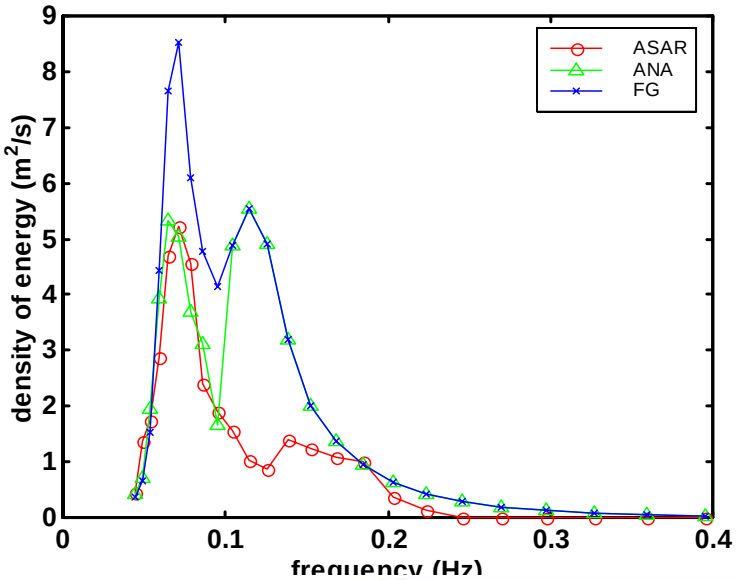


ASAR





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Impact study

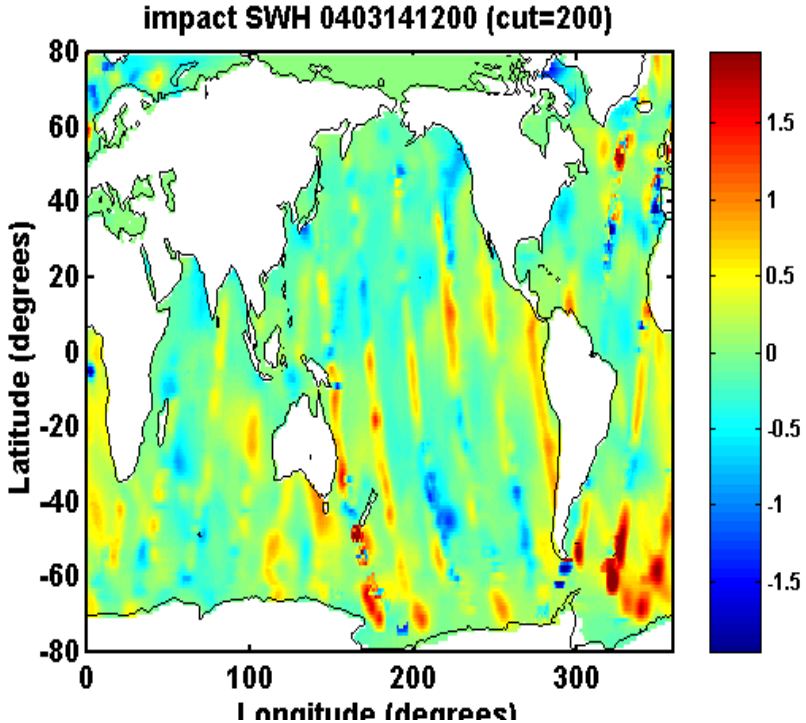
Combined assimilation of Ra-2 altimeter and ASAR data over three months :Jan-Feb-Mar 2004

- validation with Jason-1 altimeter and NDBC buoys data (significant wave height and mean wave period)

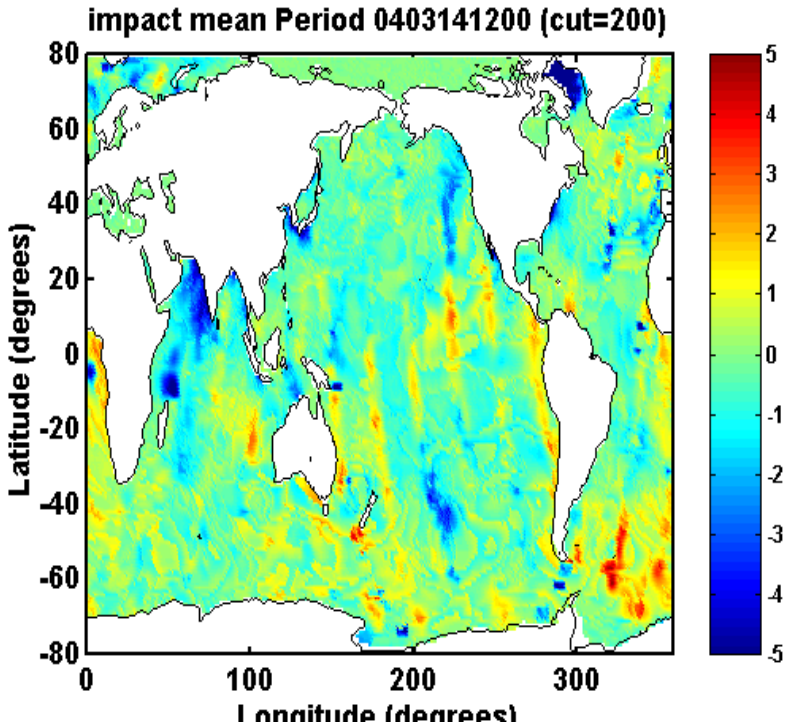
- comparison with the run of assimilation of Ra-2 wave height only

Impact of the combined assimilation

Significant wave height



Mean wave period



14 March 2004 at 12:00

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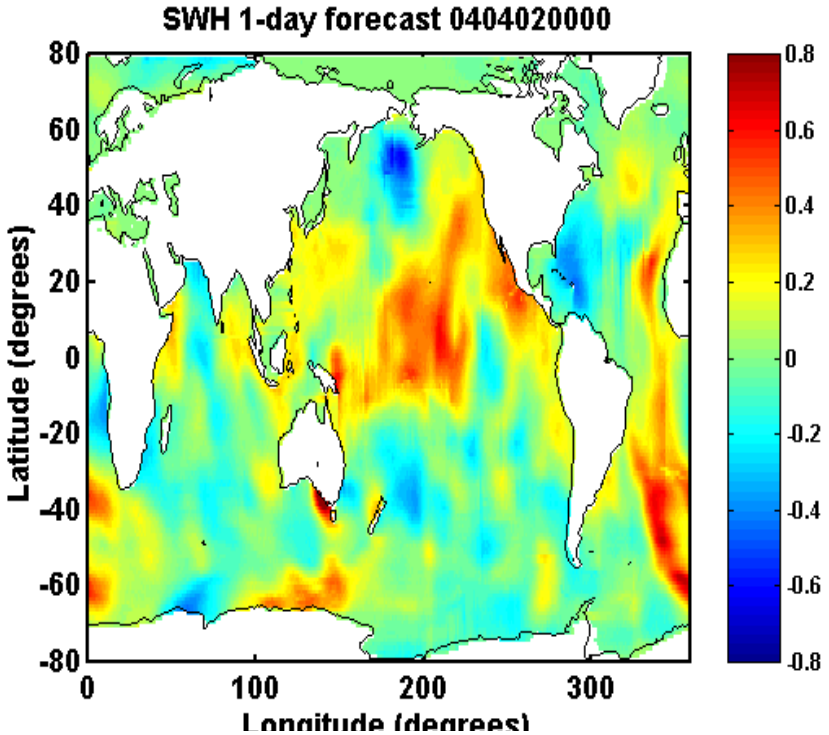
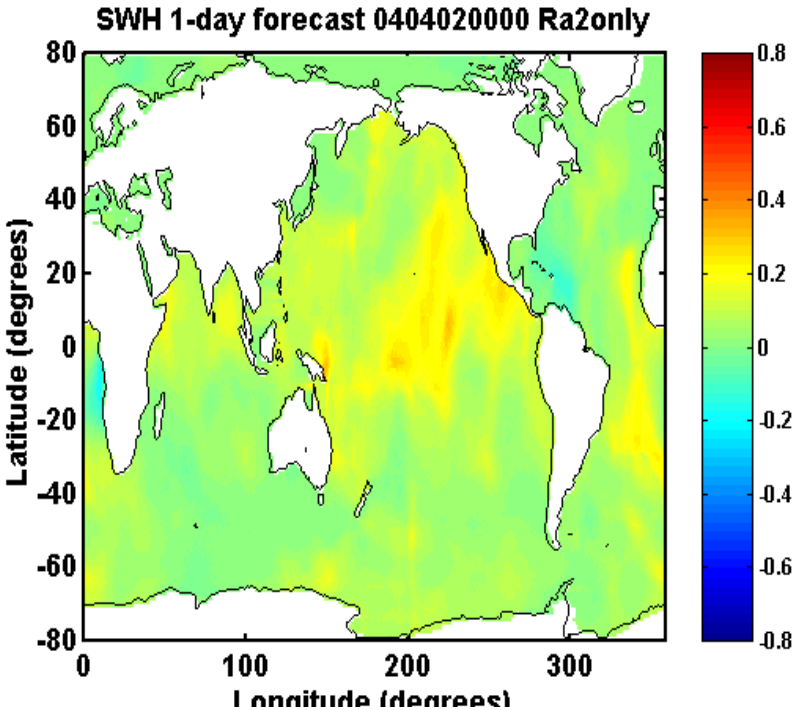
Impact of the combined assimilation

SWH Ra2 only





2 April 2004 at 0:00
1-day forecast

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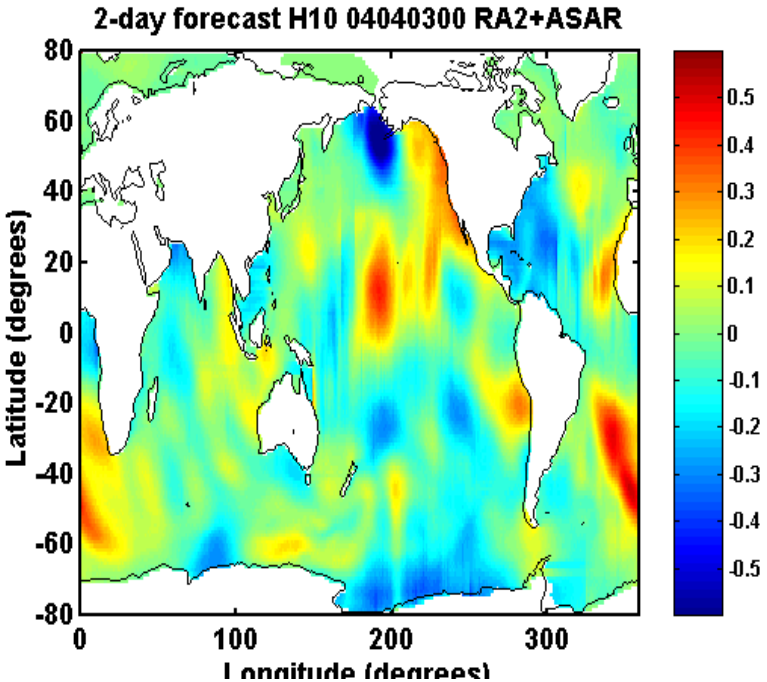
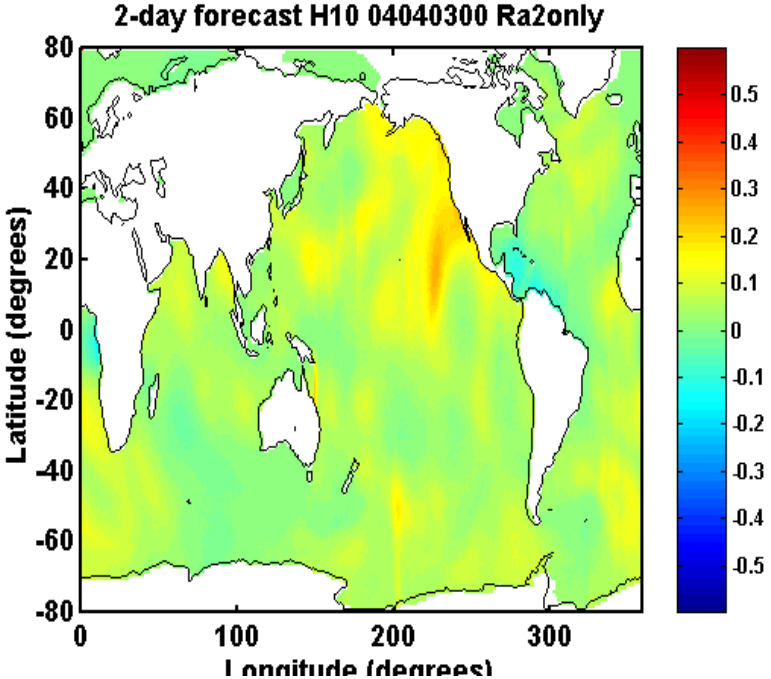
Impact for low frequency wave height H10
In the forecast period

RA2+ASAR



RA2 only



3 April 2004 at 0:00
2-day forecast

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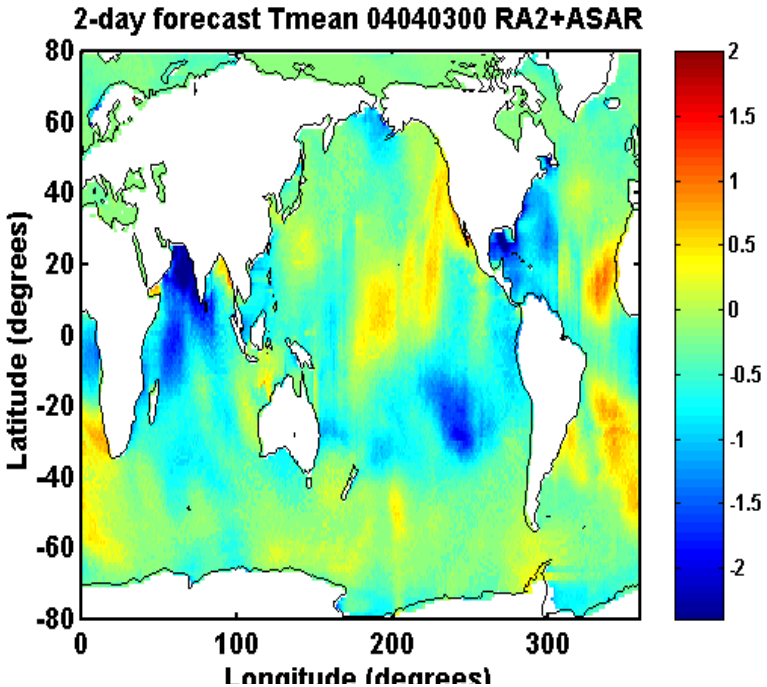
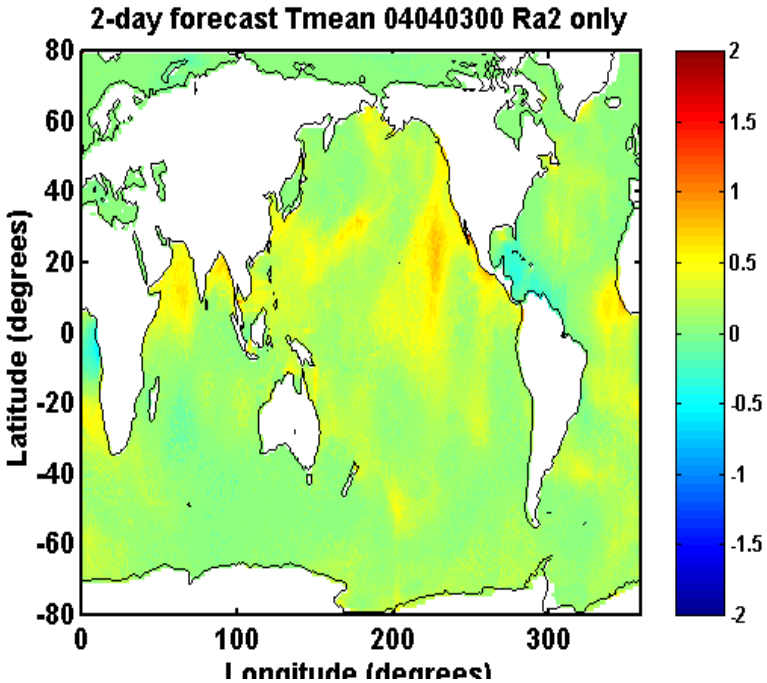
Impact for the mean wave period in the Forecast period

RA2+ASAR



RA2 only



3 April 2004 at 0:00
2-day forecast

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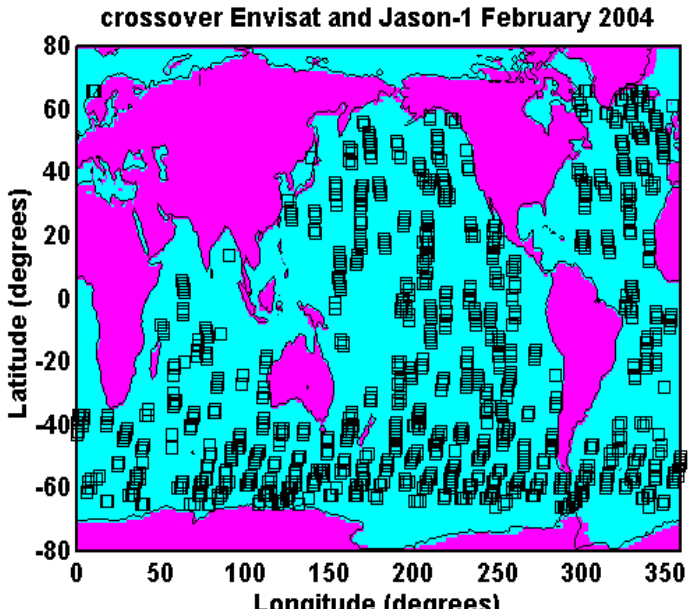
Using Jason-1 altimeter data as independent verification data set at crossovers points



Biais and RMS errors in meters

	Cut=240		Cut=200	
	MB	RMS	MB	RMS
ASSI-ASAR-Ra2	-0.05	0.31	-0.03	0.32
NOASSI	0.12	0.49	0.13	0.48
NB-OBS	17440		19369	

→ **Significant reduction of RMS error (AI) by 38 % et 33.2%**

Jan-Feb-March 2004

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Verification at all Jason-1 points

	MB	AI (%)	SI (%)
ASSI-ASAR-240-RA2	0.04	13.4	16.2
ASSI-ASAR-200-RA2	0.04	12.8	16.3
ASSI-RA2 only	-0.02	12.3	16.4
NOASSI	0.09	-	18.7
NB OBS	334374		

better skill for the combined assimilation with cut-off=240

Jan-Feb-March 2004

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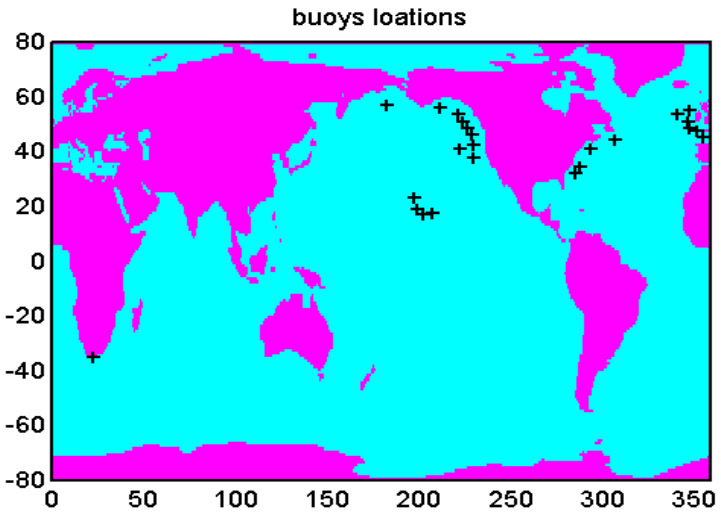
Verification at NDBC buoys locations for the mean wave period

Biais and RMS error in seconds (Tmean=9.5 s)



	Cut=240		Cut=200	
	MB	RMS	MB	RMS
ASSI-ASAR-Ra2	-0.09	1.71	-0.06	1.71
NOASSI	-0.26	1.80	-0.31	1.83
NB-OBS	6656			

RMS error reduced by about 5-7 %

Jan-Feb-March 2004

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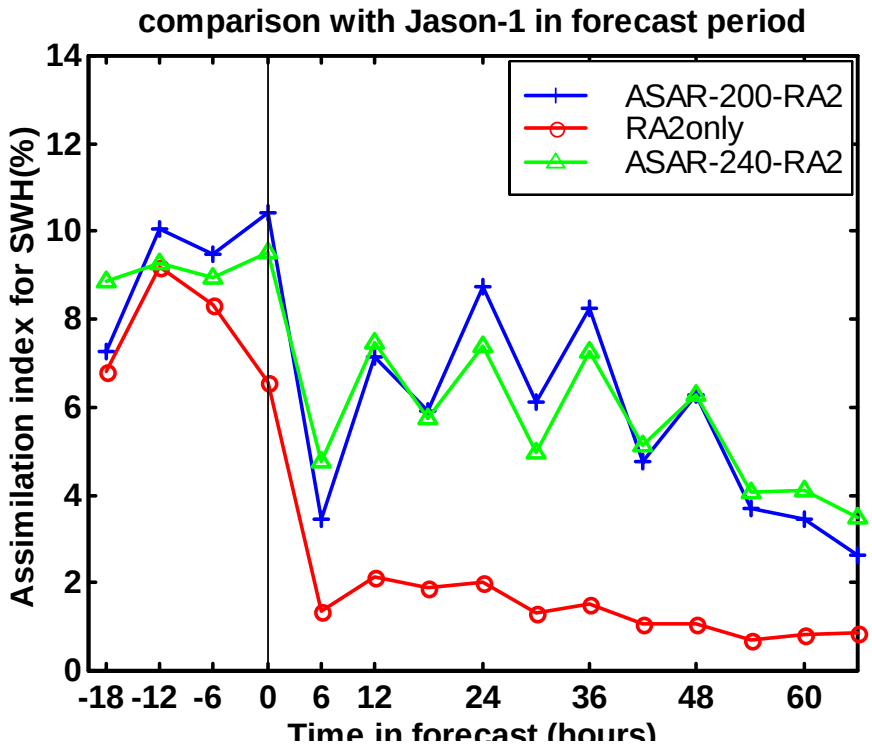
Comparison between combined assimilation of RA2 altimeter only in the forecast period

Comparison of SWH at all Jason-1 locations

reduction of RMS error in %



After two months of assimilation (Jan et Feb 2004) forecast period of three days

The spectral information induces a longer impact in The forecast period

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Concluding remarks and future works

- The combined assimilation of altimeter and ASAR data has significantly reduces the RMS error of SWH (~13 %) and mean period (~7%) when compared to no-assimilation. The improvement is not very large when compared to the run with RA-2 only,

but the improvement is kept much longer after the assimilation when using ASAR data.

- The wavelength cut-off is a key parameter for the assimilation system, so the implementation of a variable cut-off for each wave spectrum in the assimilation scheme will be investigated

- Additional combined assimilation runs for longer periods with upgraded ASAR level 2 wave products will be performed: ASAR products have been improved since.

- The dissipation term used in this study has been significantly improved in wam 4.5: we expect a larger impact when using this last WAM version