

SWIMSAT: A satellite mission proposed to measure sea state, including spectral properties of ocean waves

Danièle HAUSER, CETP/IPSL/CNRS

With contribution of the 26 Cols

- SWIMSAT is a project proposed to ESA, in response to the Call for Opportunity Missions of the Earth Explorer Program
- Not selected in 2002 (ranked 4th , only 3 selected)
- Considered in the GAMBLE project, as one of the possible future missions with radar altimeter

SWIMSAT Objectives

Measure the spectral properties of the surface waves (wavelength and direction)

⇒ improving wave forecast models (assimilation)

⇒ contribute to all studies which require a precise knowledge of sea-state

- Physics of the waves and impact of the waves on the air/sea exchanges
- Climatology of surface waves and wind
- Influence of long-waves on the inversion of remote-sensing observations (topography from altimeter, wind from scatterometer, salinity from radiometer)
- Formation/destruction of sea-ice, coastal processes, ocean mixed layer

Limitation of existing observing systems for wave observations

Altimeters => only total energy of the waves and wind speed, but **no information on spectral properties** of surface waves

Imaging radar (SARs) on satellite: difficulties to use SAR inverted products (wave spectra) because of **filtering and distortion effects** due to the surface motion

- SAR measurements still not widely used in the engineering or forecasting community
- However, some improvements are expected with ENVISAT

but information on surface waves will remain limited to long wavelength (> 200-250m).

Status

- Feasibility of the concept studied since 1994 (support of CNES and Alcatel Space Industry)

Assessed with airborne measurements (ROWS, RESSAC, STORM) since 1985

Specification and performance in *Hauser et al, 2001* (VAGSAT version proposed in 1998)

- Improvements in the concept proposed in 2002 for SWIMSAT
- SWIMSAT Proposed (January 2002) in response to the Announcement of Opportunity (for the Earth Explorer Program)
 - 2 PI (D. Hauser and S. Lehner) and 26 Col from 19 research groups, mainly in Europe
- Assimilation studies started in 2000
- Evaluation from ESA in 2002: not selected in the 3 first (4th!!)

Main characteristics of the instrument and mission

Payload:

Ku-Band radar(13.6 GHz)

Nadir looking (like a standard altimeter)
+ 5 beams at small incidence (2, 4, 6, 8, 10°)

Beam aperture (2x 2°), range resolution 0.5 to 0.75 m

Conical scans over 360° in azimuth (only the transmitting horns are in rotation)

Real aperture radar avoiding the main limitations of SARs: no smearing effect due to velocity bunching

Power/weight: 190 Watt, 75 kg

Orbit:

450 to 500 km

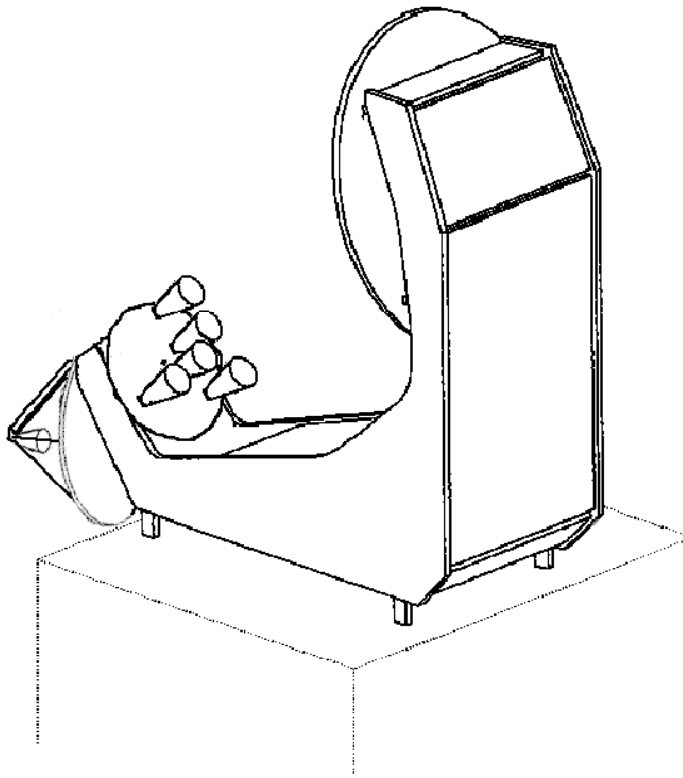
Near-polar to ensure a coverage from 83 S to 83 N

Sun-Synchronous is possible but not mandatory

Platform:

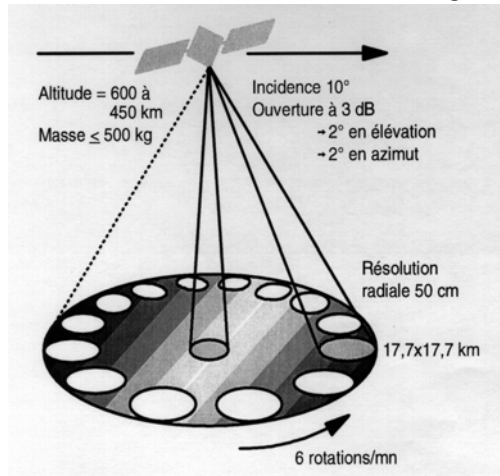
Compatibility with PROTEUS (CNES), but other choices are possible

Antenna design (Alcatel Space Industry)

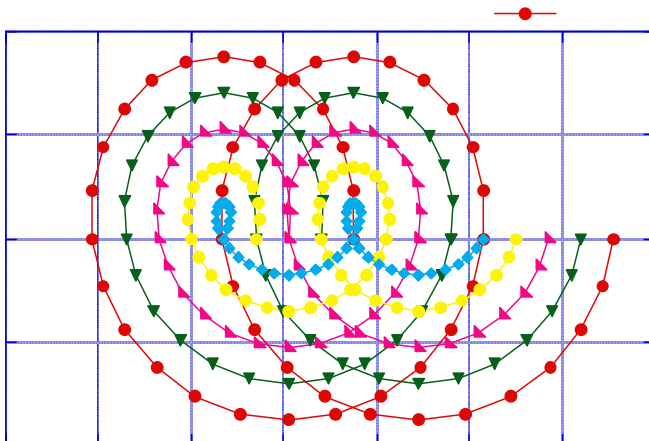


Geometry of observation

For incidence 0 and 10°



For incidence 2 to 10°



Expected geophysical products

⇒ Directional spectra should be obtained at scales less than 50 x 50 km (wavelengths from about 70 m to about 400 m).

Significant slope (H_s/λ_p)

⇒ Probability density function of wave slopes (through the analysis of $\partial\sigma_0/d\theta$)

⇒ Wind speed and significant wave height from nadir looking

⇒ tentatively: wind speed and direction from combined measurements at different incidence angles

**Expected performances (From simulation studies,
taking into account noise sources)**
(Hauser et al, JAOT 2001)

=> SWIMSAT should be capable of measuring wave spectral properties at a 50 x 50 km scale :

-under wind-sea condition, provided the dominant wavelength is greater than about 70 m

-in swell conditions, provided the significant wave height is greater than 1.5 to 2 meters, depending on wind.

The inversion process should provide :

- Accuracy of about 10% in wave height (calculated over the range of waves which can be retrieved).
- Resolution in direction: 15° after the averaging
- Resolution in wavelength: about 20% of the wavelength

Assimilation studies (simulations)

Collaboration with Météo-France (Aouf, Lefèvre)

Aouf et al, JAOT, submitted 2003

■ Wave model WAM cycle 4 :

- Global scale (1x1 degrees)
- Wave spectrum discretization in 24 directions and 25 frequencies (0.04-0.41 Hz)

■ Assimilation code (Voorrips et al. (1997) adapted by Aouf (2001))

- Partitioning : wave train decomposition
- Optimal Interpolation

■ Parameters of the assimilation scheme

- Area of impact=1000 km
(additional tests with 600 km)
- Correlation length=500 km
(additional tests with 250km)
- Assimilation time step 3 hours

■ Two sets of results

1) Synthetic SWIMSAT data :

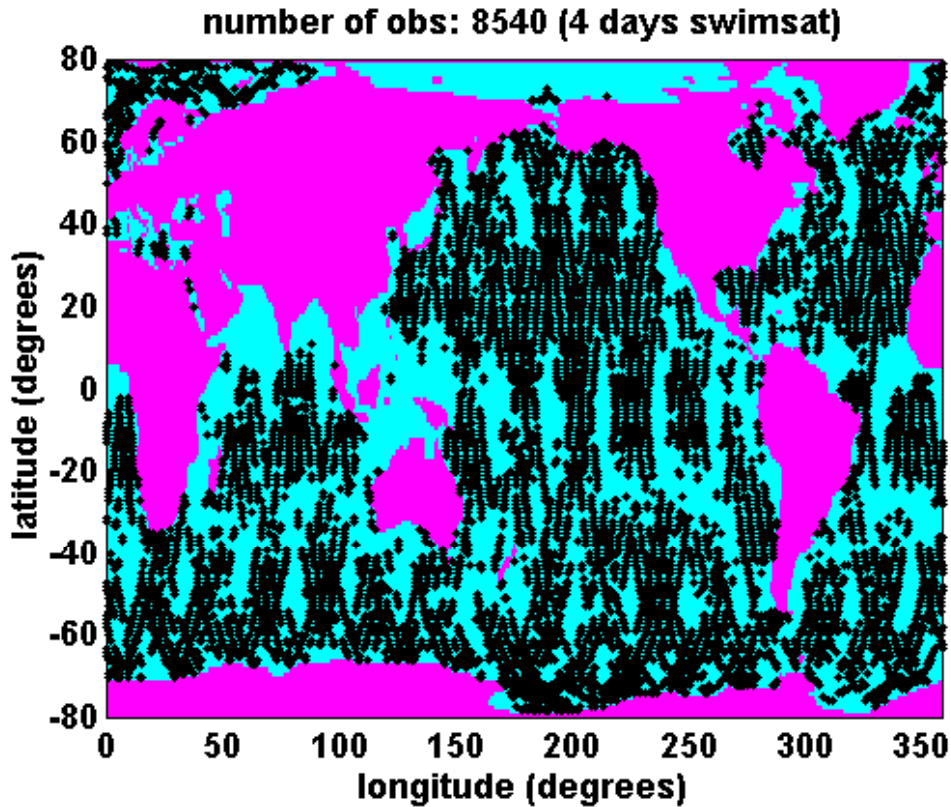
- Run without assimilation (analyzed wind field)
 - => **Synthetic Observations** along SWIMSAT orbits with repeat cycle of 17 days
- Disturbance of the wind field :
Forecasted wind field 4 days before+ random noise
- New wave field is generated => **First guess**

2) Preliminary tests with real data (ENVISAT)

Not presented here

Assimilation simulation

Coverage for 4 days of assimilation



Observation locations for 4 days assimilation of SWIMSAT synthetic

Main results on the simulations

Impact of assimilation, - “assimilation index”

% of improvement of the assimilation compared to no assimilation

Scores one day after the end of assimilation period

100% => run with assimilation=observation,

0% => no impact of assimilation

- **on the total Hs** => similar for SWIMSAT and for standard altimeter data (10-12%)
- **on H_{10}** (Hs limited to waves with periods over 10 s) => larger than on total Hs and larger for SWIMSAT (20%) than for standard altimeter (16%)
- **on mean wave frequency** => larger for SWIMSAT (about 16%) than for standard altimeter (about 12%)
- deteriorates rapidly when **the cutoff** is larger than 150 m (case of a SAR)

=> Spectral data (SWIMSAT case) brings more information in the assimilation than standard altimeter data (Hs), and avoids problems due to the cutoff of the SARs

CONCLUSIONS

- Feasibility of SWIMSAT demonstrated (confirmed by airborne systems)
- Interest for forecasting demonstrated (assimilation studies) -demonstration with ENVISAT data still under progress.

SWIMSAT should be taken into account in a multi-mission prospective.

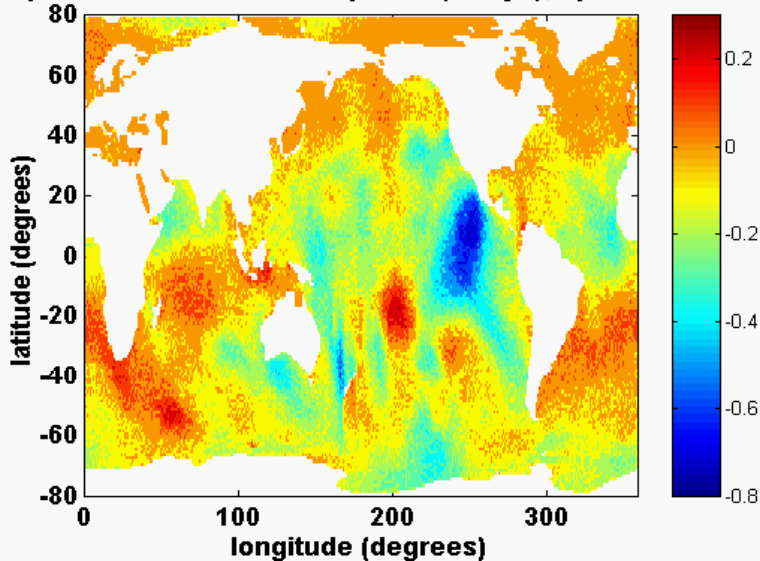
Would allow to combine

- a complement (with rough corrections for orbit determination) to precise altimeter missions
- a standard altimeter mission for Hs and U
- a configuration (low incidence multi-beam scanning) allowing to measure spectral properties of ocean waves (and other information on sea-state)

Assimilation simulation

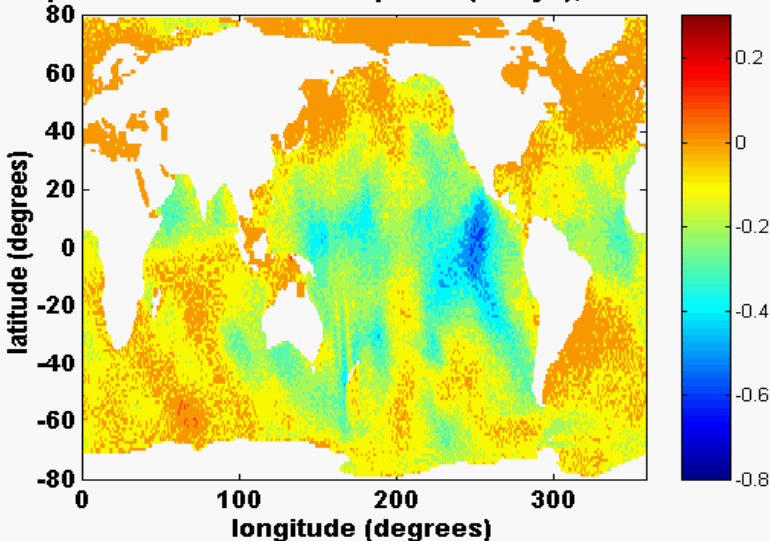
Difference (in meters) of the significant wave height between the run WITH and WITHOUT assimilation, 2 days after the end of the simulation period

impact for SWH in forecast period (2 days); spectral info



With spectral
information
(SWIMSAT)

impact for SWH in forecast period (2 days); altimeter



Without spectral
information
(altimeter case)

Assimilation simulation

Statistical analysis: comparison between model with assimilation (spectral info and altimeter case) and observations (synthetic data)

Assimilation Index (AI) defined by:

$$AI (\%) = \frac{rms_{NOA} - rms_{WA}}{rms_{NOA}} * 100$$

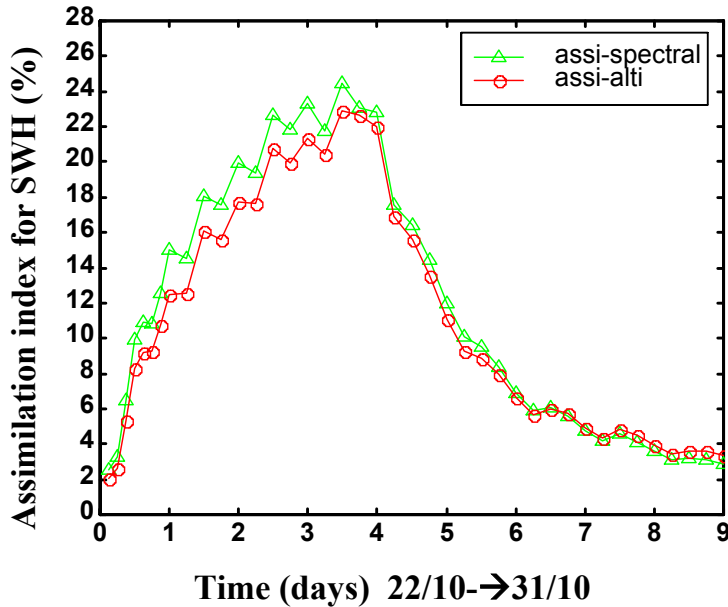
Where the rms deviation is calculated between observed parameters (synthetic here) and modeled parameters

NOA: NO Assimilation

WA: WITH Assimilation

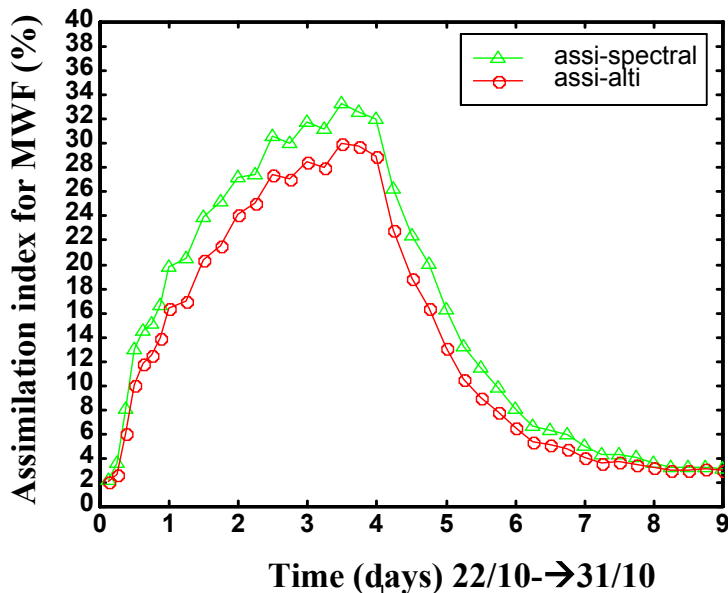
Assimilation simulation

Statistical analysis: comparison between model with assimilation (spectral info and altimeter case) and observations (synthetic data)

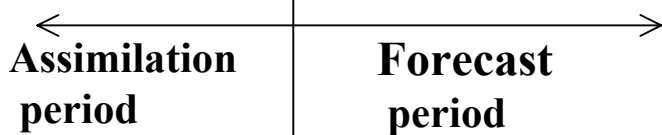


Assimilation index for significant wave height

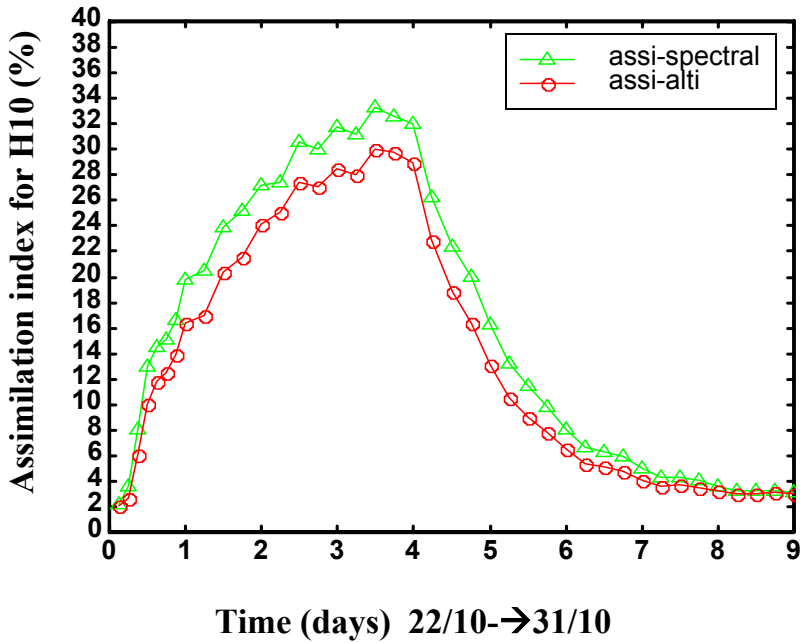
green line: spectral info
red line: altimeter case



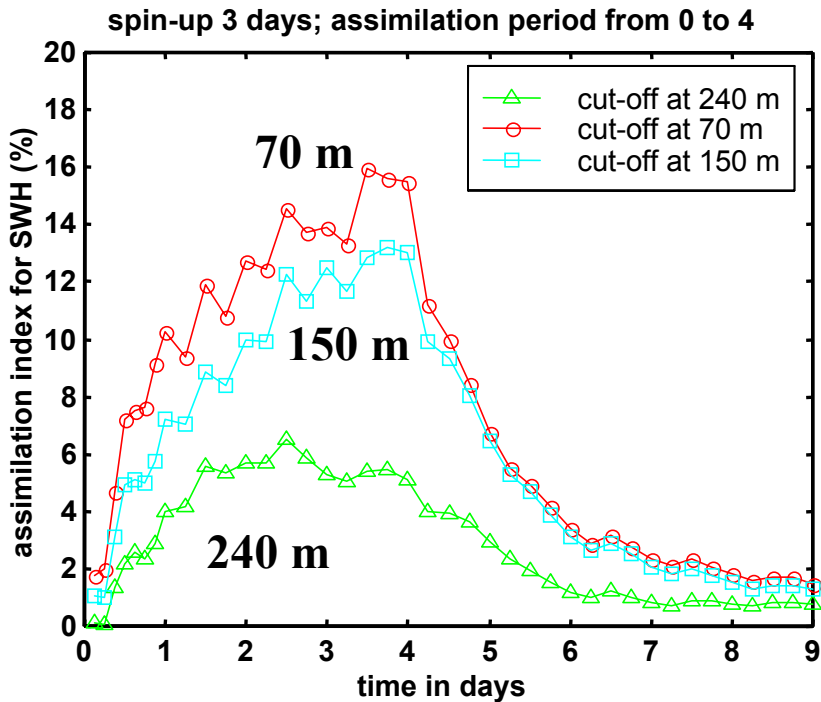
Assimilation index for mean wave frequency



Assimilation simulation: Impact on swell wave height and cut-off effect



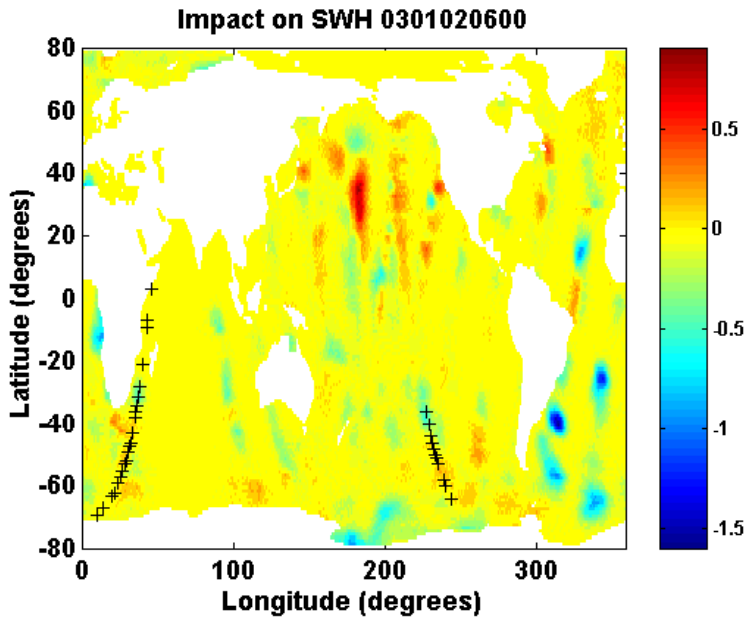
Assimilation index
for swell wave
height (H10)



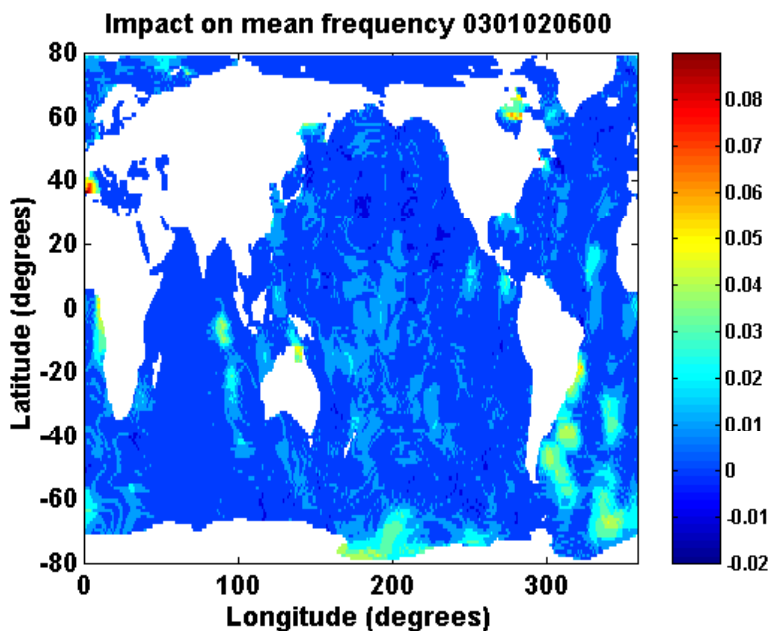
Cut-off effect on
the assimilation
index for SWH

Assimilation of real data (ENVISAT ASAR wave spectra), impact during assimilation period

Assimilation from
1 to 6 January, 2003
(cut-off of 0.1 Hz)

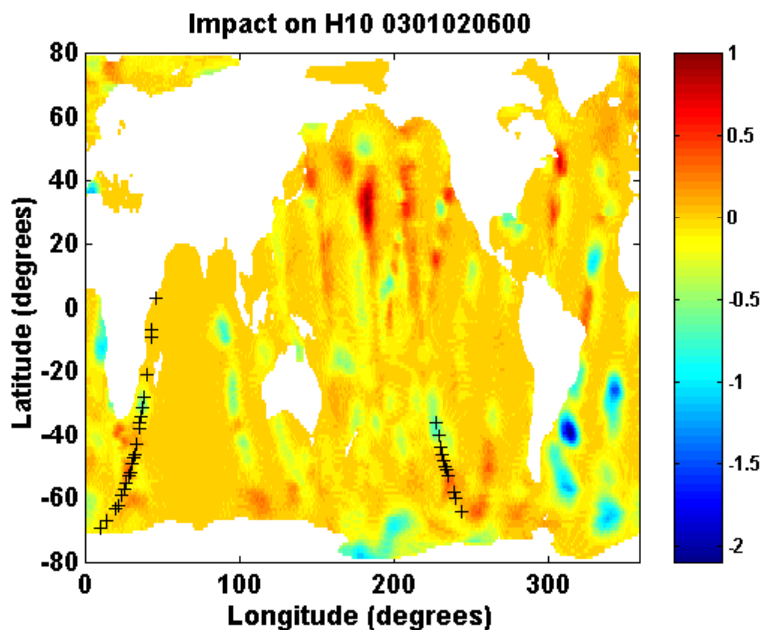


Impact on significant
wave height
January 2 at 6:00



Impact on mean
wave frequency
January 2 at 6.00

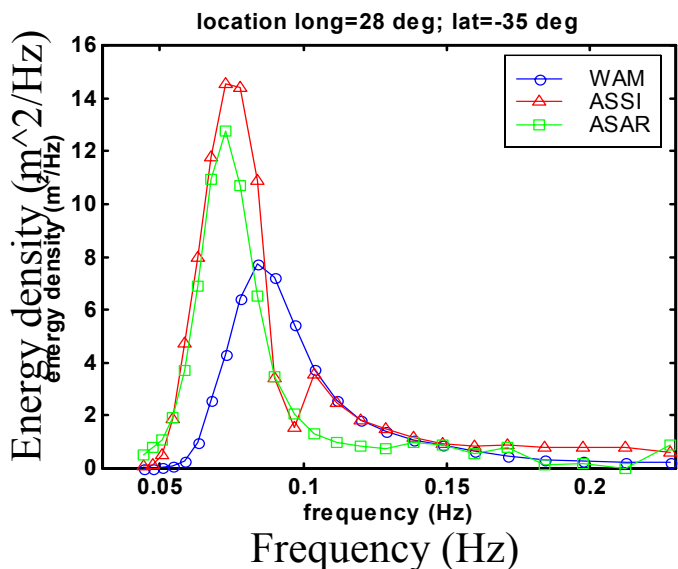
Assimilation of ENVISAT: impact during assimilation period



Impact on swell
wave height (H10)
January 2 at 6:00

Statistical analysis on model and ASAR swell wave height H10

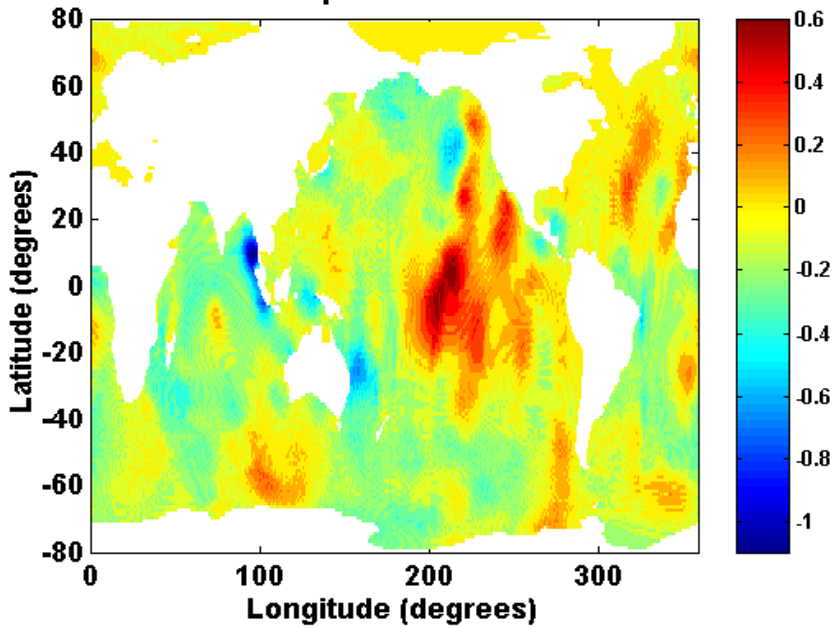
	Mean bias (m)	RMS (m)
WAM with assimilation	0.30	0.84
WAM without assimilation	0.41	1.14



First guess, observed and
analyzed 1D spectrum
on January 1, 2003 at 9:00
location is 28°E and 35°S

Assimilation of ENVISAT:
Impact 1 day after assimilation

forecast period 0301070000



Impact on H10 in
forecast period
January 7 at 0:00
(1 day after the end of
assimilation)