

**Wave forecasting and Satellite data:  
Research and Development Activities at Météo-France**

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# Operational production

- Global wave model VAG\_GLOBE , 1° resolution, 3 days forecast, 4 runs per day, ERS2 altimeter data assimilation, ARPEGE winds
- Global wave model VAG\_TROPIQUE, 1° resolution, 3 days forecast, 1 runs per day, ERS2 altimeter data assimilation, ARPEGE\_TROPIQUE winds
- Regional Wave model VAG\_MEREUROP, 0.25° resolution, 2 days forecast, 4 runs per day, Shallow water, ARPEGE winds, nested in VAG\_GLOBE
- Coastal Wave model VAG\_COTIER, 0.1° resolution, 2 days forecast, shallow water, 4 runs per day, Shallow water, ALADIN winds, nested in VAG\_MEREUROP
- Others when required by the Navy

# Research and developpement activities

## Wave modelling

- VAG, WAM, WAVEWATCH\_3, SWAN

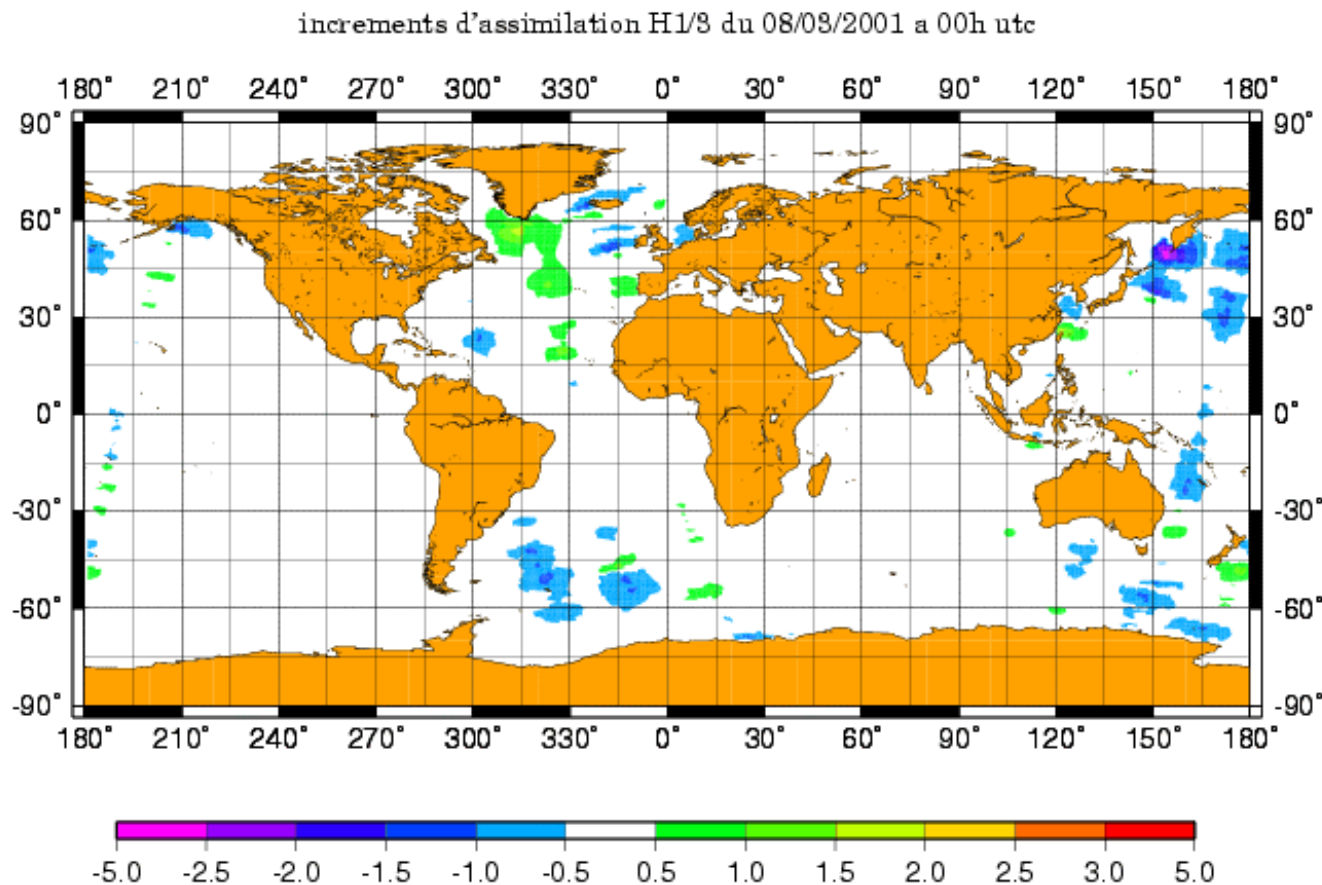
## Calval activities

- JASON Altimeter
- ENVISAT Altimeter
- ENVISAT SAR

## Data assmilation

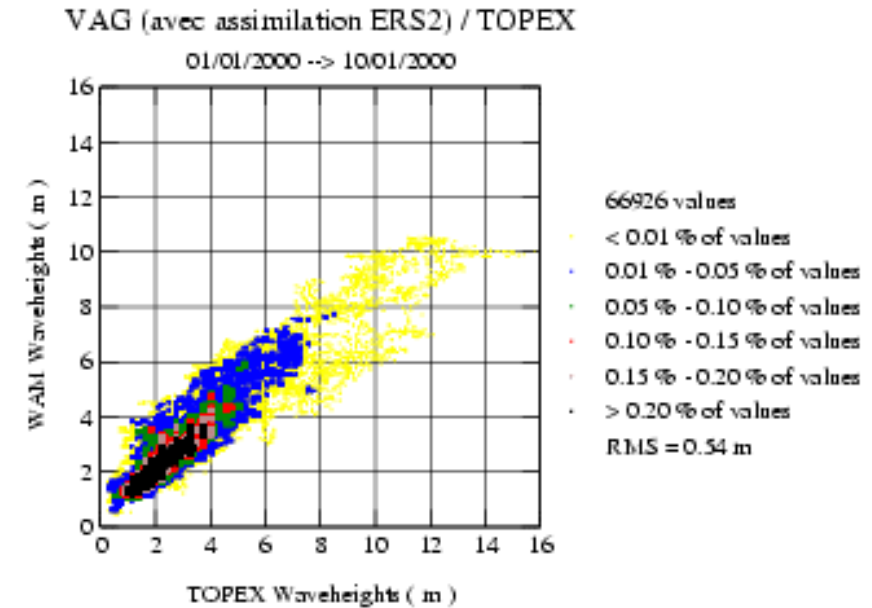
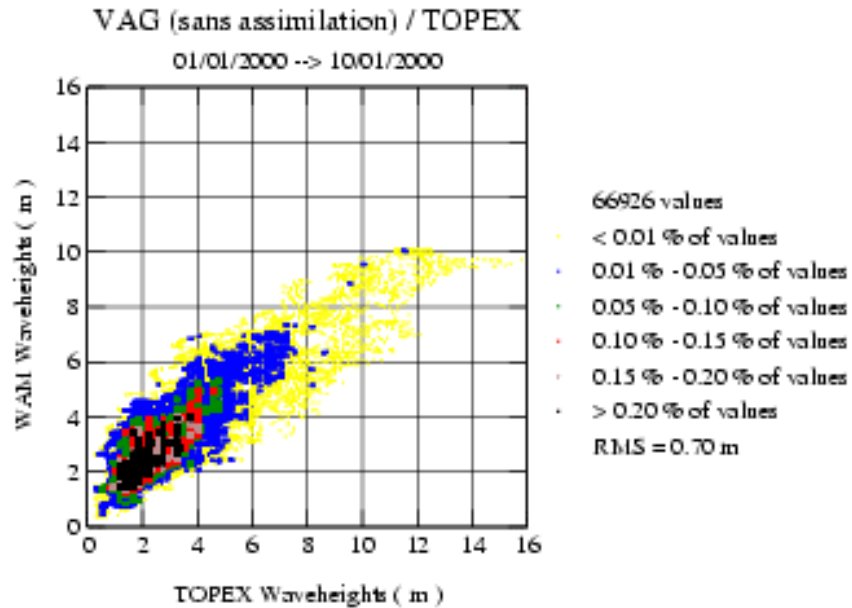
- Radar Altimeter
- Synthetic Aperture Radar
- Real Aperture Data

Figure 2. Analyses Increments (Analysis minus First Guess) from the assimilation of ERS2 altimeters wave height valid for March 03 2001 at 00 UT: only Increments larger than half of meter are represented.



6 hours window. Improvement is found when 3 hours window is taken. How many altimeters are required !

Comparison of model SWH with TOPEX SWH: left panel without assimilation, right panel with assimilation of ERS2 SWH for a ten days period over the whole globe.



Reduction of the error  
on the analysis with :


One altimeter :

Two altimeters :

Three altimeters :

More (OSSE's) :

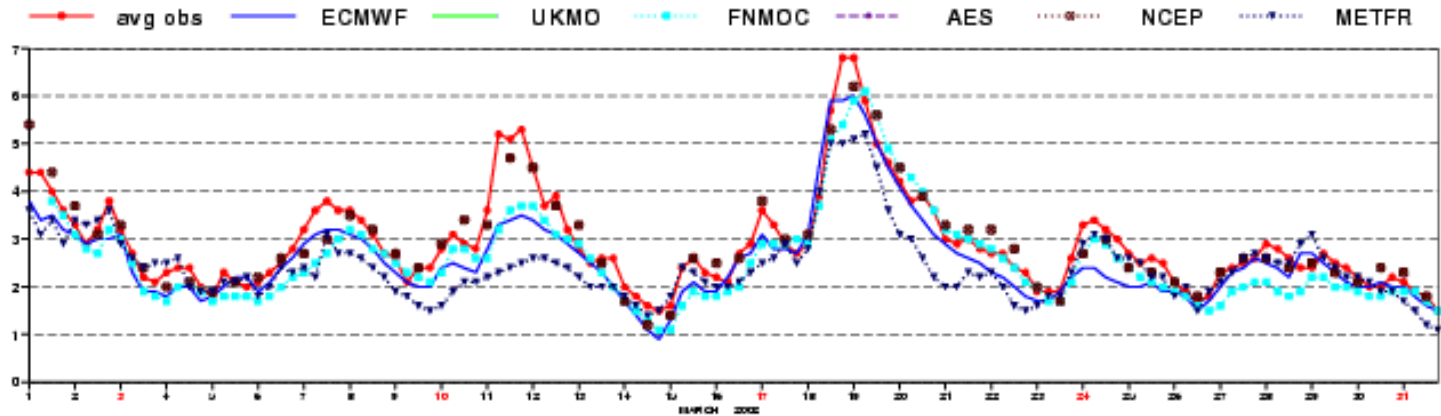




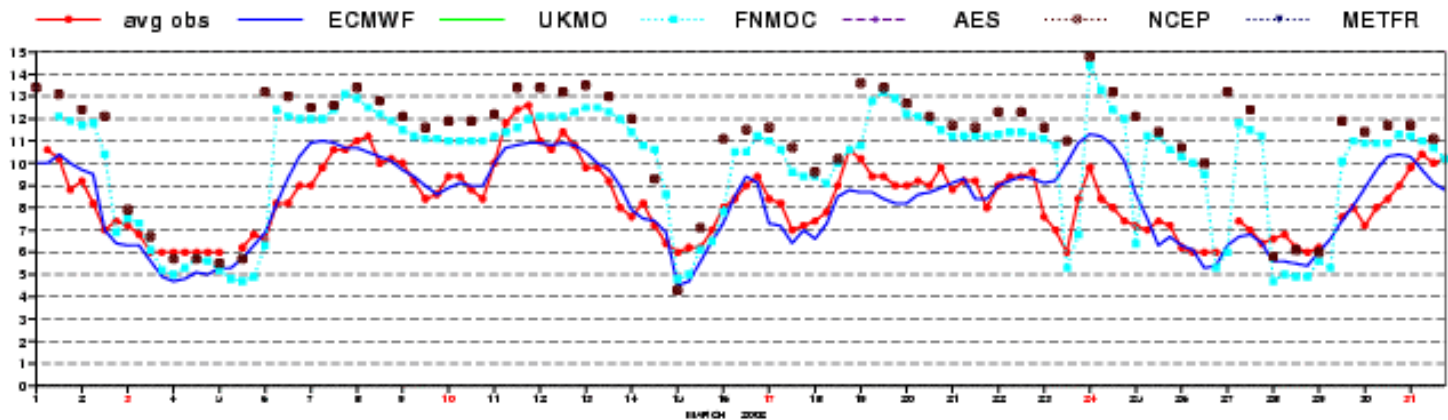
Forecasting high swell :  
work performed in collaboration with A.  
kortcheva (NIMH Bulgaria) and S.  
Stephanescu (NIMH Romania)

# Forecasting high swell

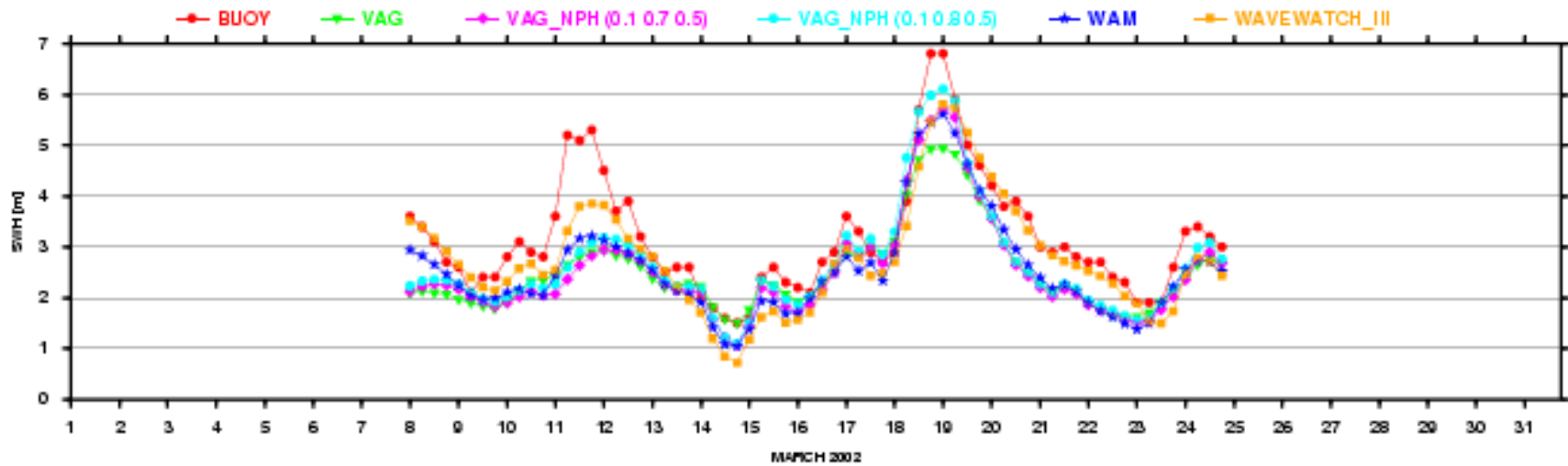
Analysed significant wave height and averaged buoy data at buoy 62001



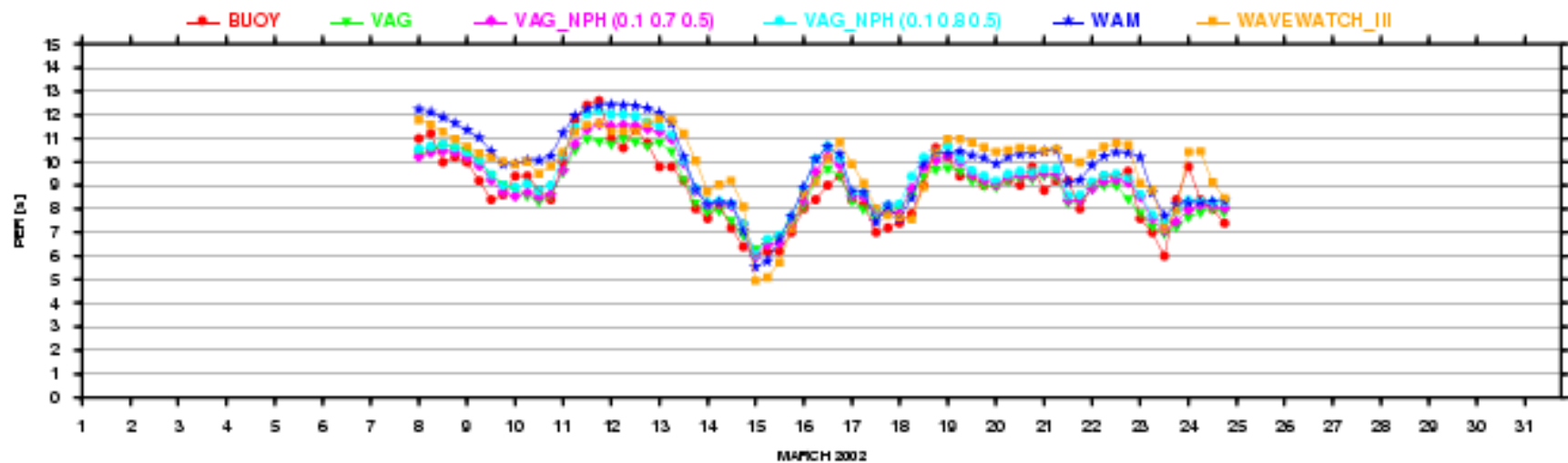
Analysed peak period and averaged buoy data at buoy 62001



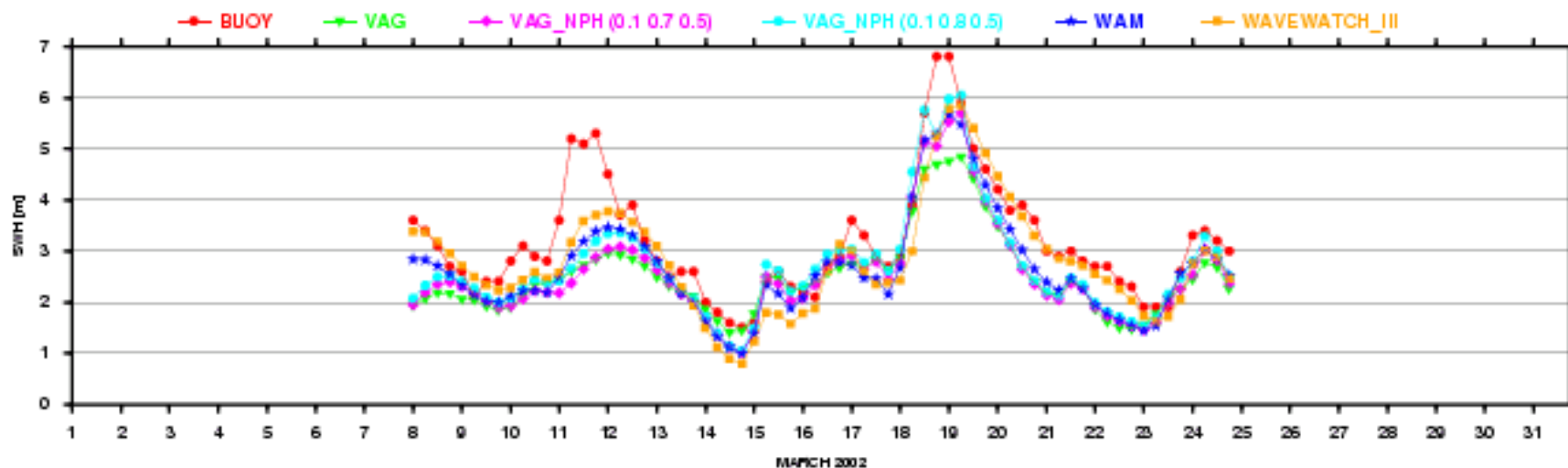
### Hindcasted significant wave height (resolution 1°x1°, wind ECMWF) and averaged buoy data at buoy 62001



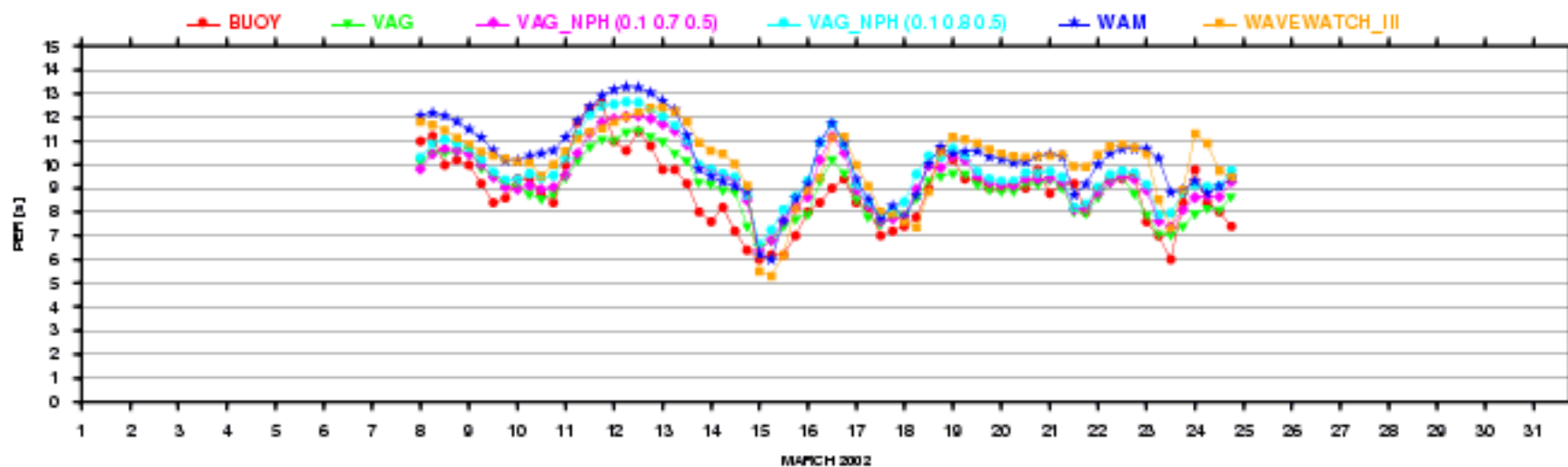
### Hindcasted mean period (resolution 1°x1°, wind ECMWF) and averaged buoy data at buoy 62001



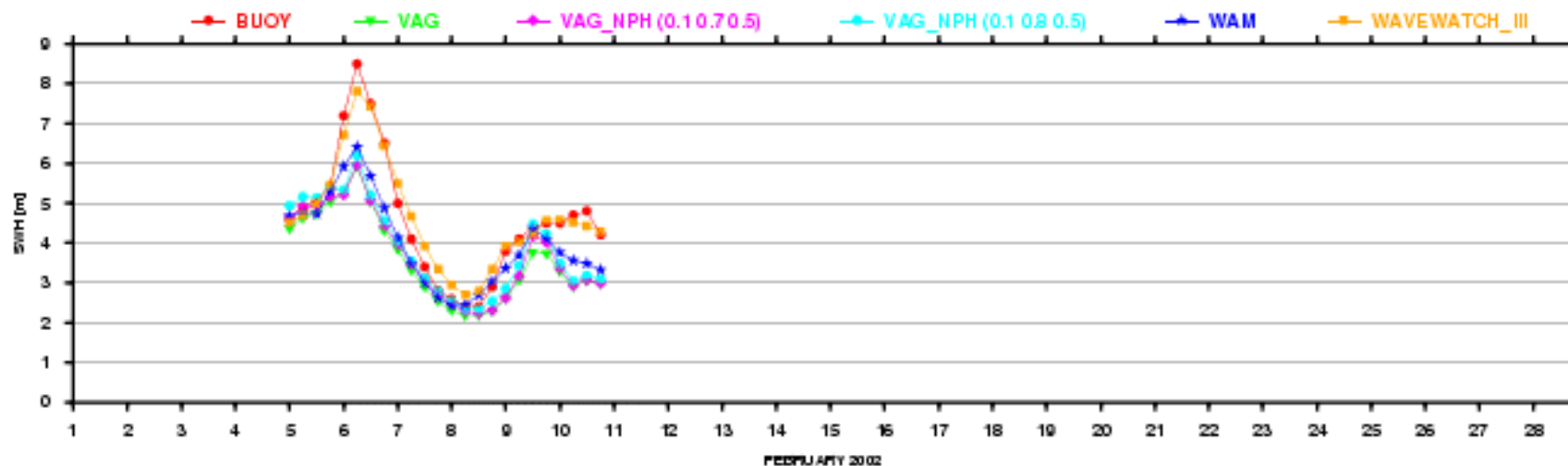
### Hindcasted significant wave height (resolution 1°x1°, wind ARPEGE) and averaged buoy data at buoy 62001



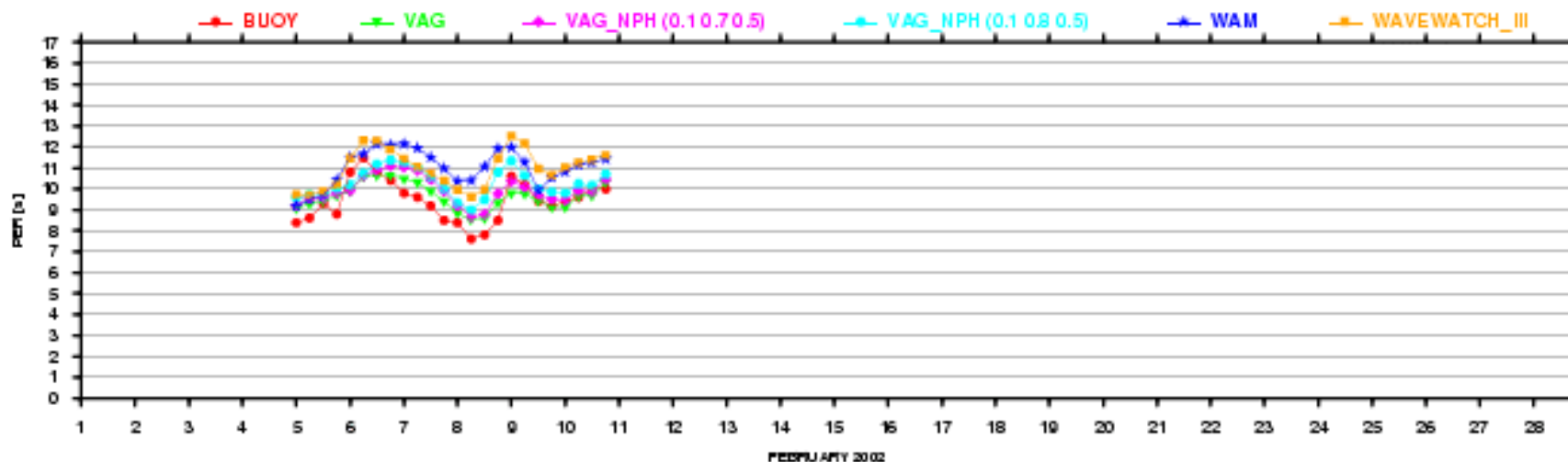
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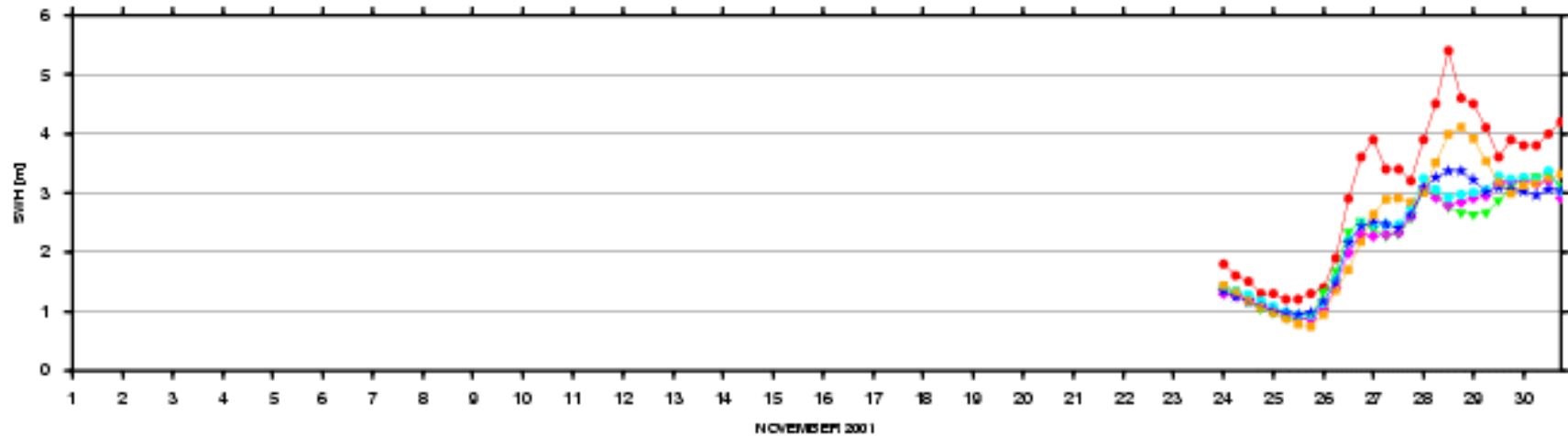


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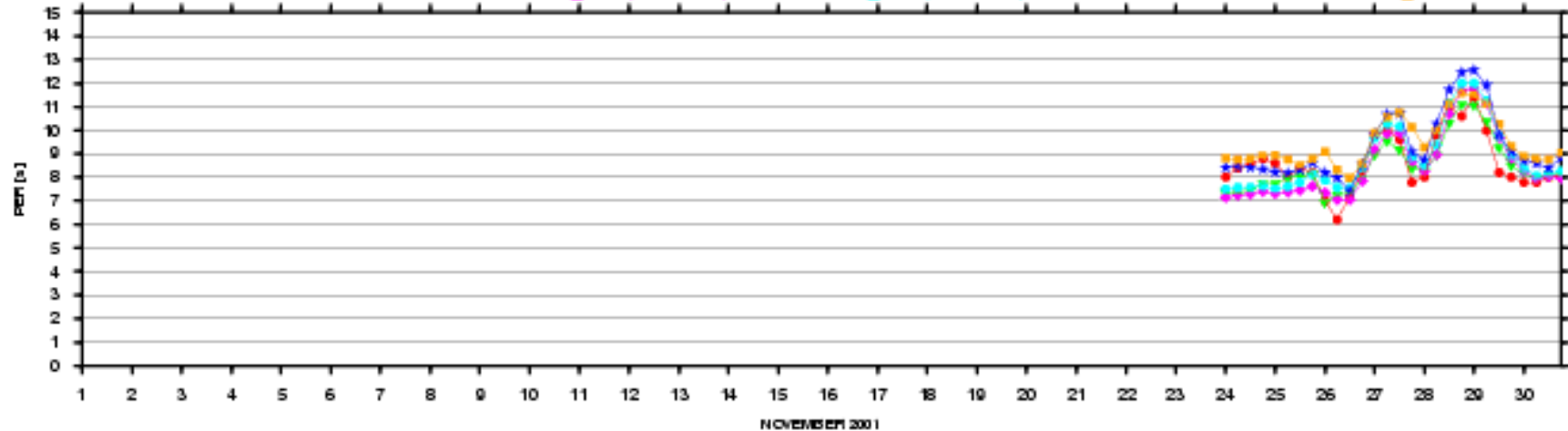
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— BUOY — VAG — VAG\_NPH (0.1 0.7 0.5) — VAG\_NPH (0.10.80.5) — WAM — WAVEWATCH\_III

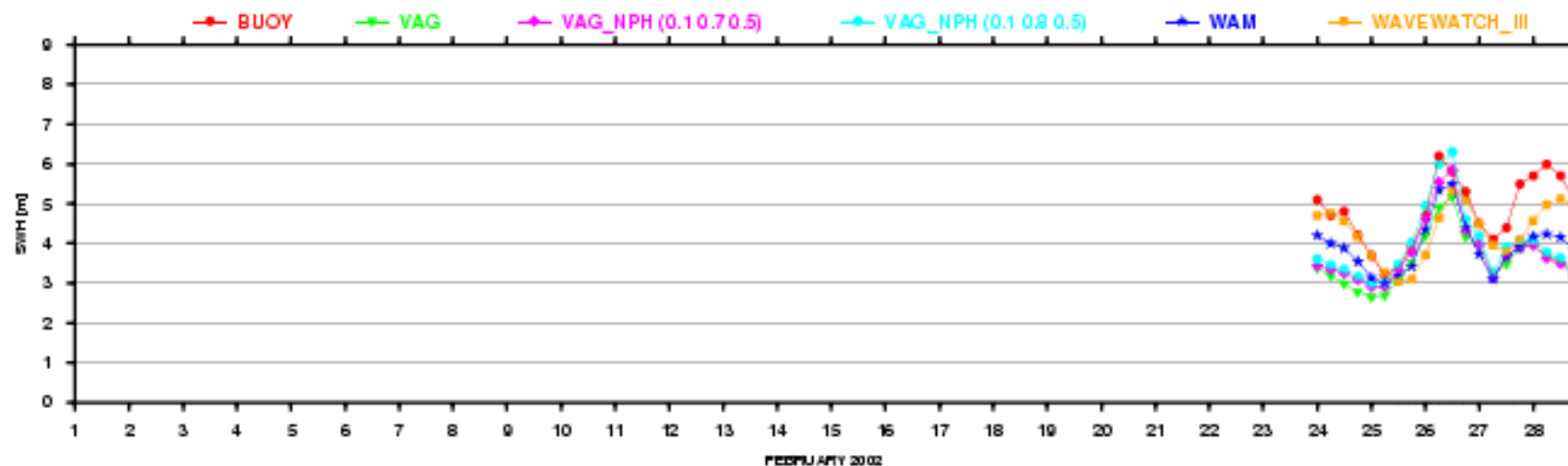


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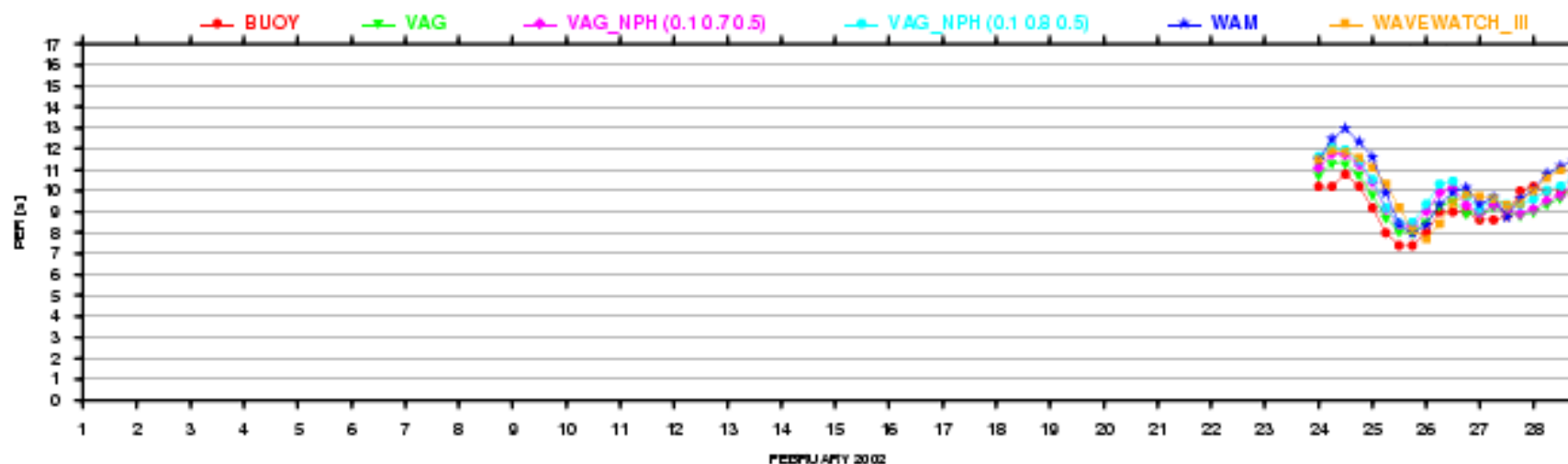
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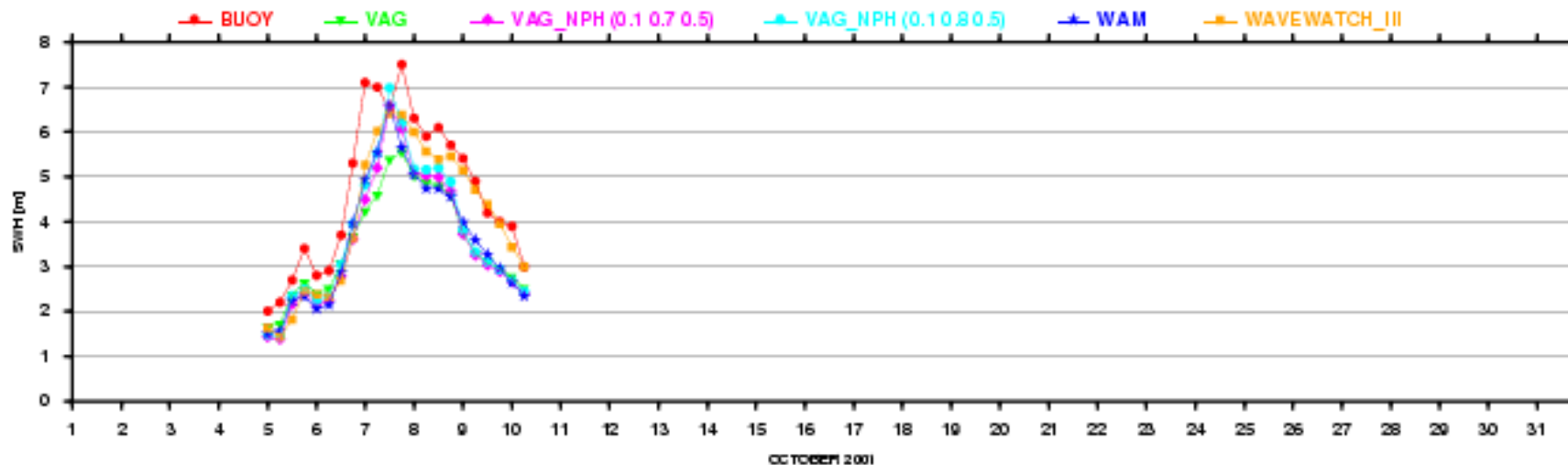
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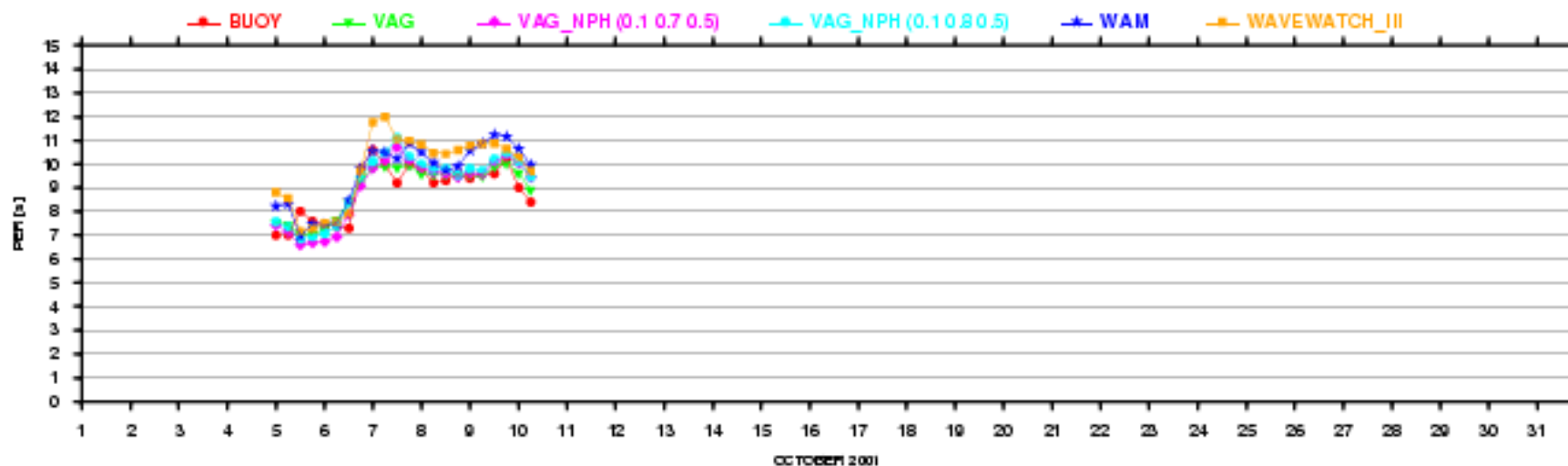
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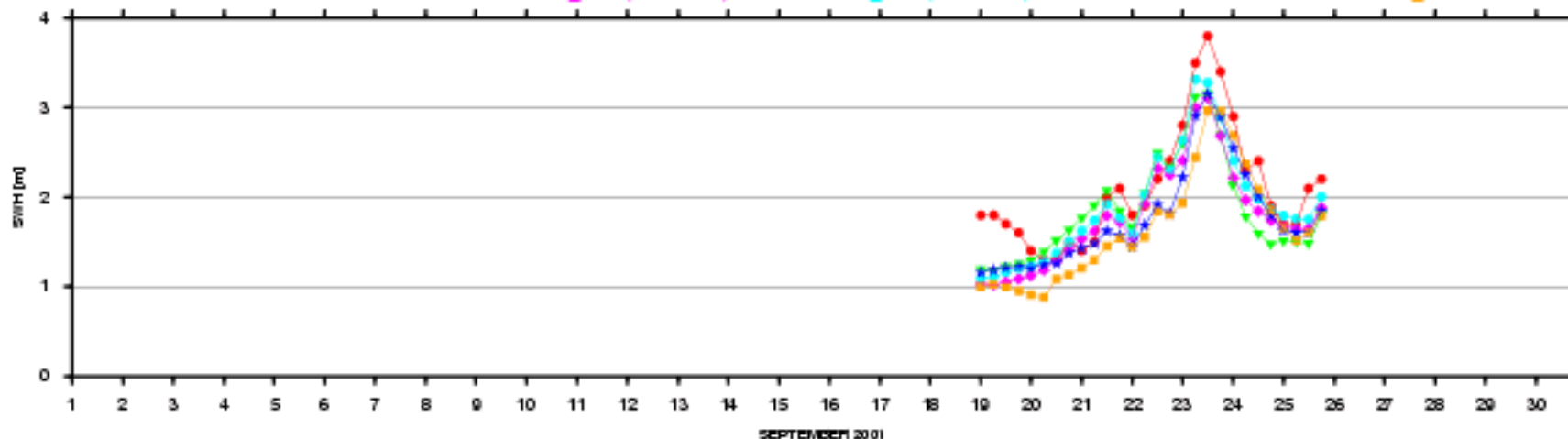


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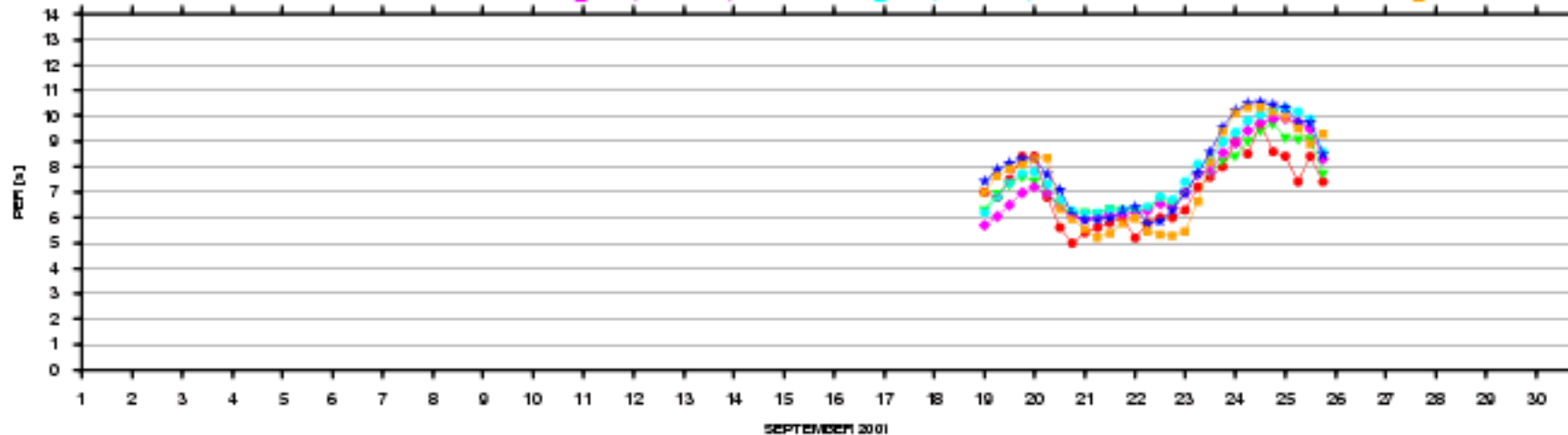
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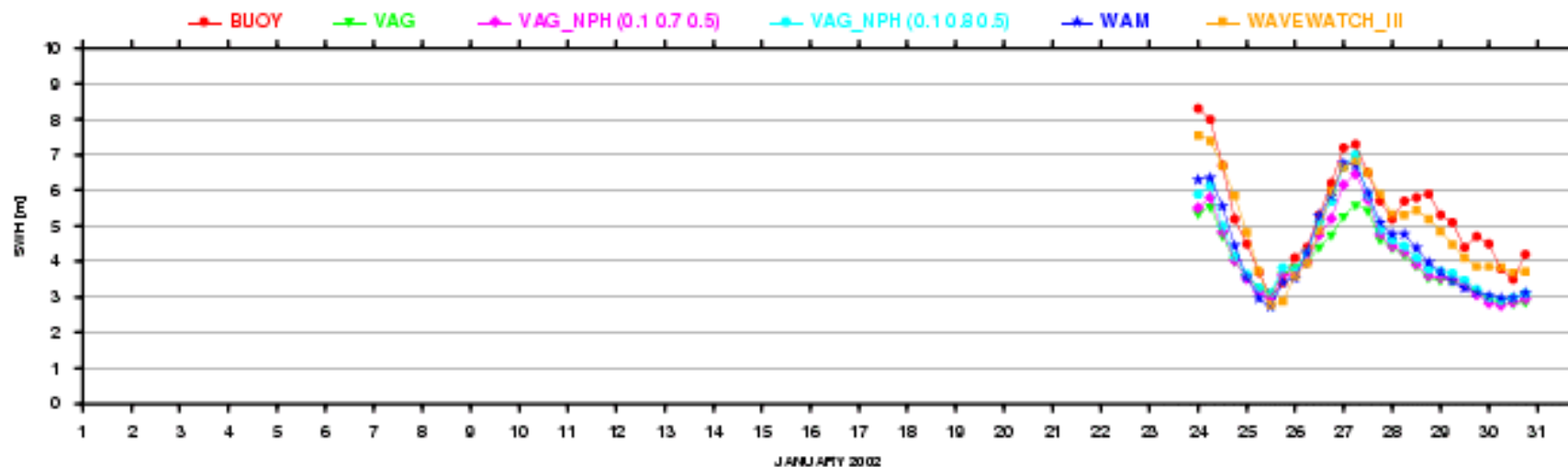


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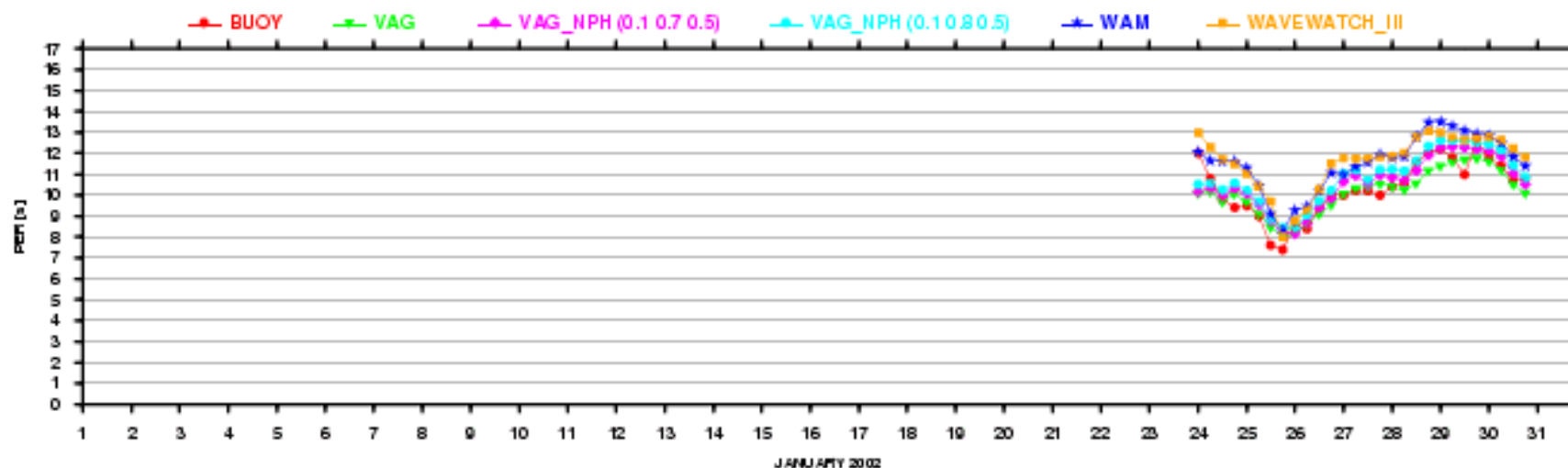
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## Hindcasted significant wave height (resolution 1°x1°, wind ECMWF) and averaged buoy data at buoy 62001



## Hindcasted mean period (resolution 1°x1°, wind ECMWF) and averaged buoy data at buoy 62001



- When comparing hindcast results with the operational runs, we found that the improvement due to the assimilation of ERS2 altimeter data did not change much the results at the buoy in most cases.
- Other altimeters or instruments are clearly needed to compensate some models (wind and wave) deficiencies

SES's : Lotfi Aouf (Supported by CNES) , D. Hauder (CETP) and J-M Lefèvre

**Real aperture radar system at Ku-band (13.6 GHz)**

scanning in incidence (0 à 10° every 2°)

Conical scanning of 360°.(in azimuth)

**Nadir look** : similar use as an altimeter (wind/Hs)

**Off-nadir look** : estimation directional wave spectrum (complement SAR)

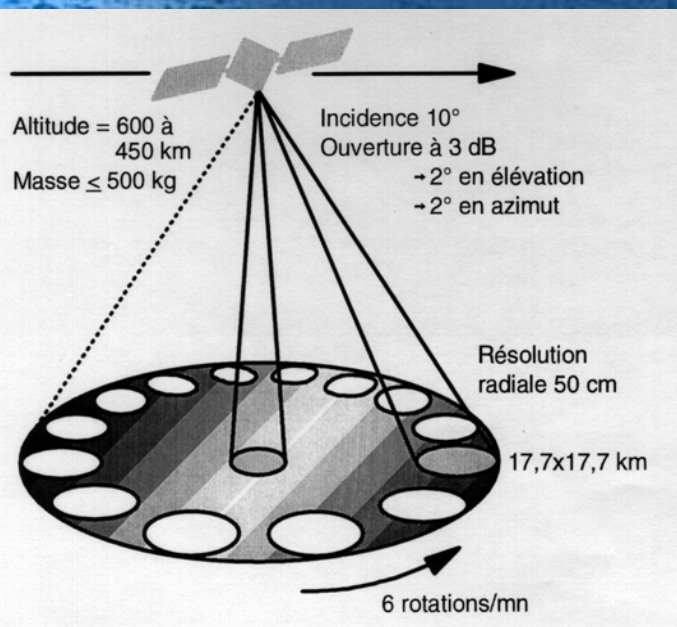
50-70 m wavelength for wind sea; minimum detectable wave height of 1 m for swell

➡ Better than SAR (limited to long waves 200 m wavelength)

• **Angle of incidence combination**

various spatial scales (50x50 km; 90x90 km)

access to other parameters (wave slope)



# Assimilation study

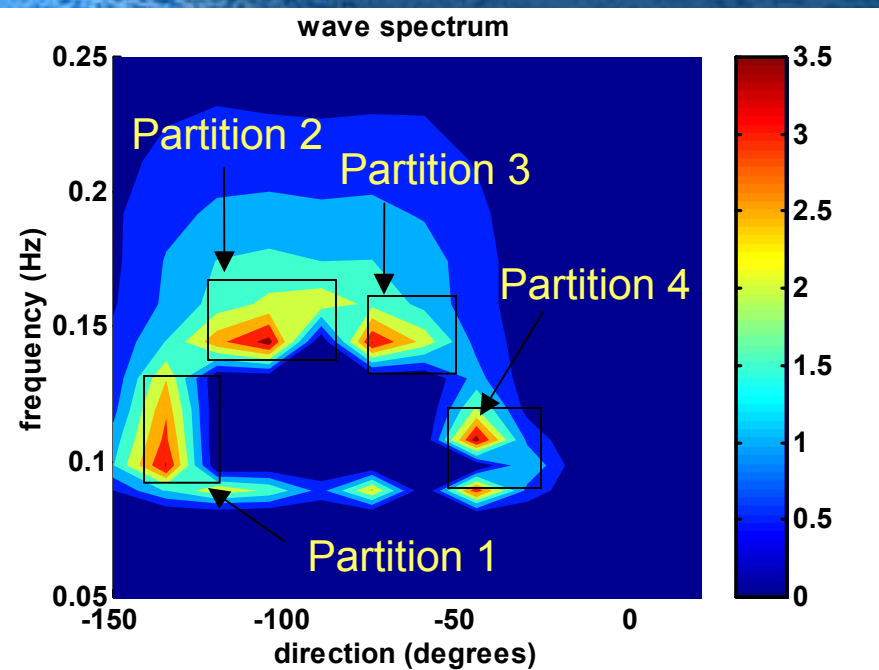
## Motivations

Estimation of the impact on wave height of the assimilation of spectral information comparing to the altimeter case

## Assimilation method (Voorrips et al. 1997)

### 1) Concept of partitioning

- Estimation of mean wave parameters for each partition of the spectrum
- ### 2) Cross-assignment between partition of the first-guess and the observations same wave system (wind sea, swell,...)





### 3) Optimal interpolation of partitions

Spreading function of the correction

→ 
$$W = \sigma_o \sigma_f \exp\left(-\left(\frac{d}{\lambda_c}\right)^{1.5}\right)$$

d : distance of influence of the observation

$\lambda_c$  : correlation length

Where the error variance for observation and first guess :

→ 
$$\sigma_f = \sigma_o = 0.02 + 0.35E$$

Optimal analyzed parameters :

→ 
$$X^a = X^f + \sum_i^N W_i (X_i^o - X_i^f)$$

4) Analyzed directional wave spectrum : collecting analyzed partitions

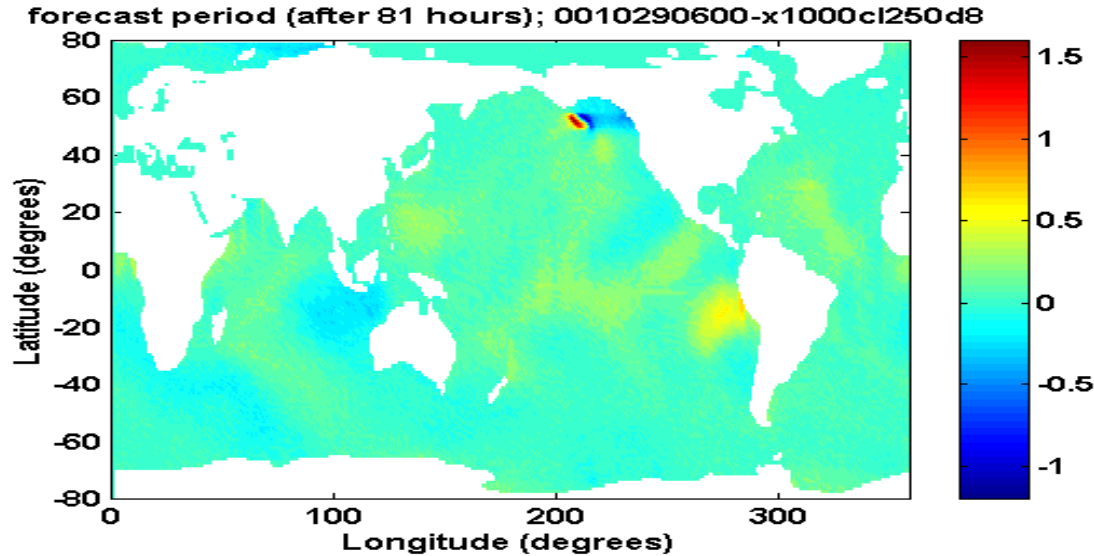
5) Correction of the wind at the sea surface  
use of empirical wave growth relations

# Simulation

- Wave model WAM cycle 4 : global scale (1x1 degrees)  
(wave spectrum discretized in 24 directions and 25 frequencies (0.04-0.41 Hz))
  - observations location —→ SWIMSAT track (17 days)
  - SWIMSAT synthetic spectra : run without assimilation  
(analyzed wind field ECMWF)
  - Perturbation of the wind : —→ forecasted wind field (4 days + error)  
—→ Generation of new wave field (first-guess)
  - Run with assimilation of synthetic directional spectra (time window 3 or 6 hours)

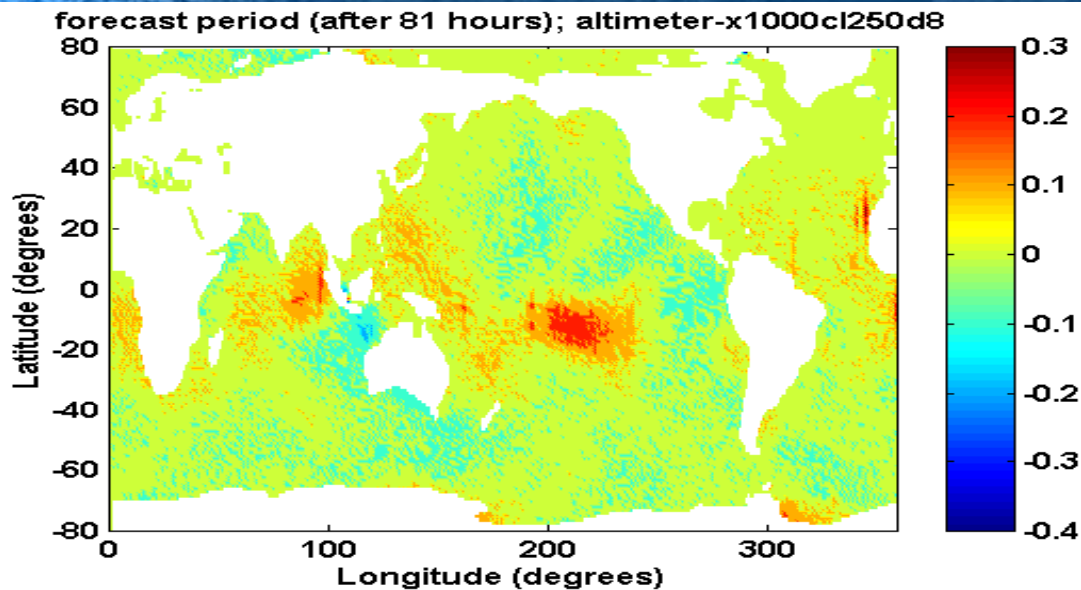


# Impact on wave height



After 3,5 days

Forecast period  
 $d = 1000 \text{ km}$ ;  $\lambda_c = 250 \text{ km}$



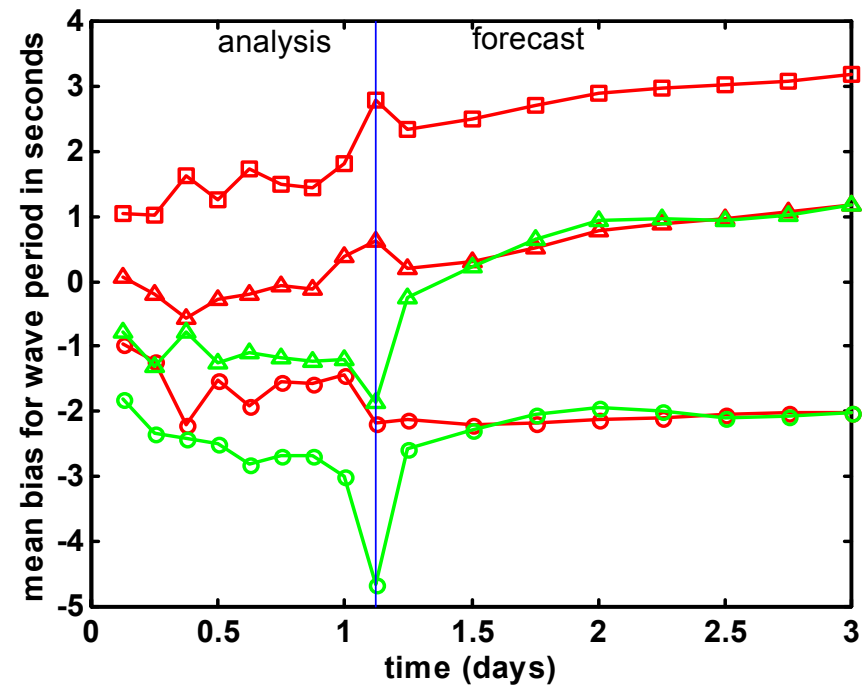
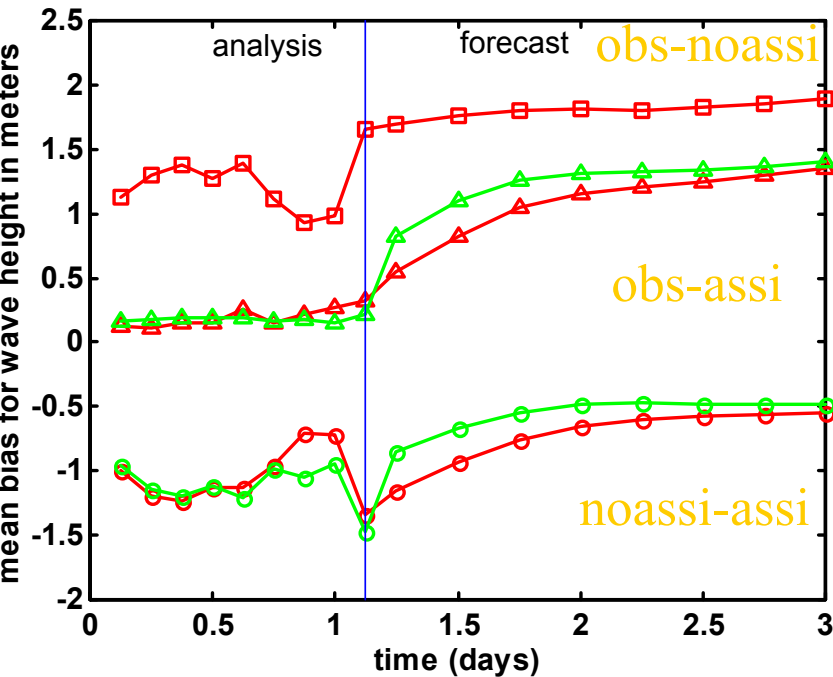
Altimeter case => less impact  
after 3,5 days

# Assimilation period of one day



For significant wave height

For mean wave period

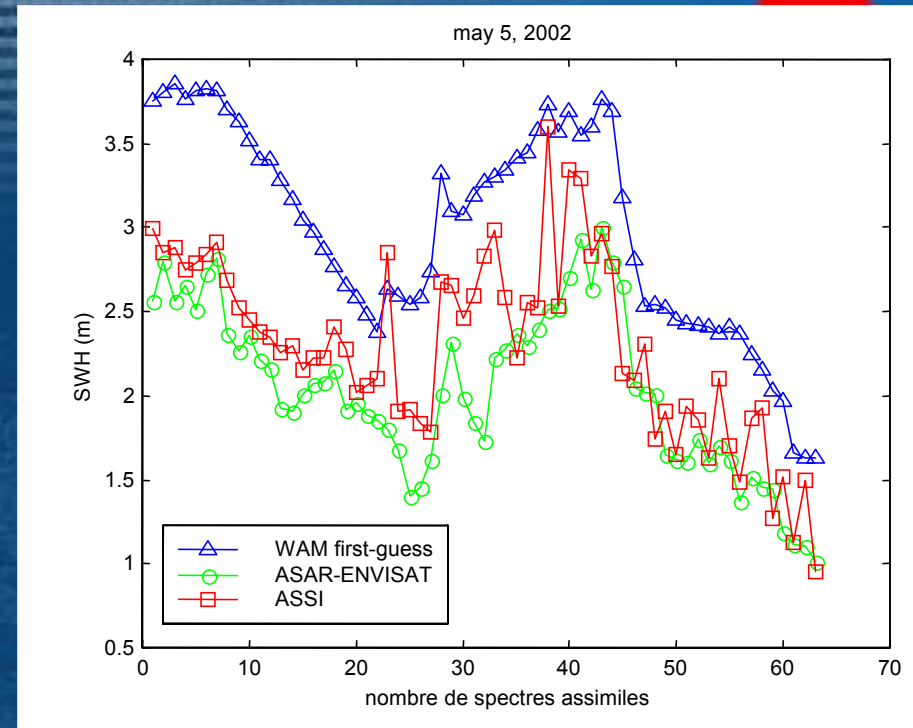
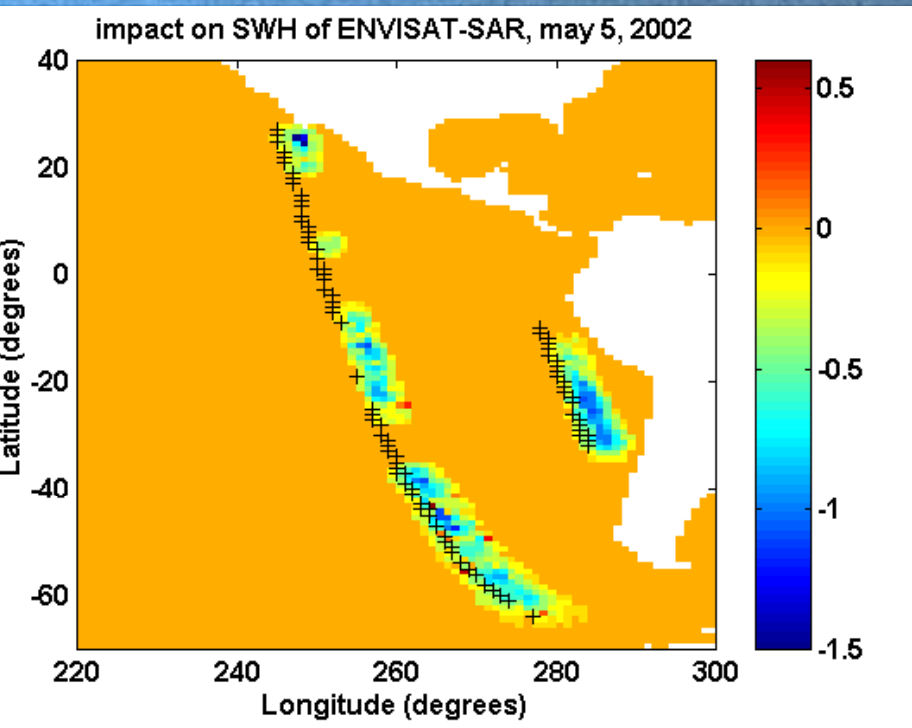


red : with spectral information

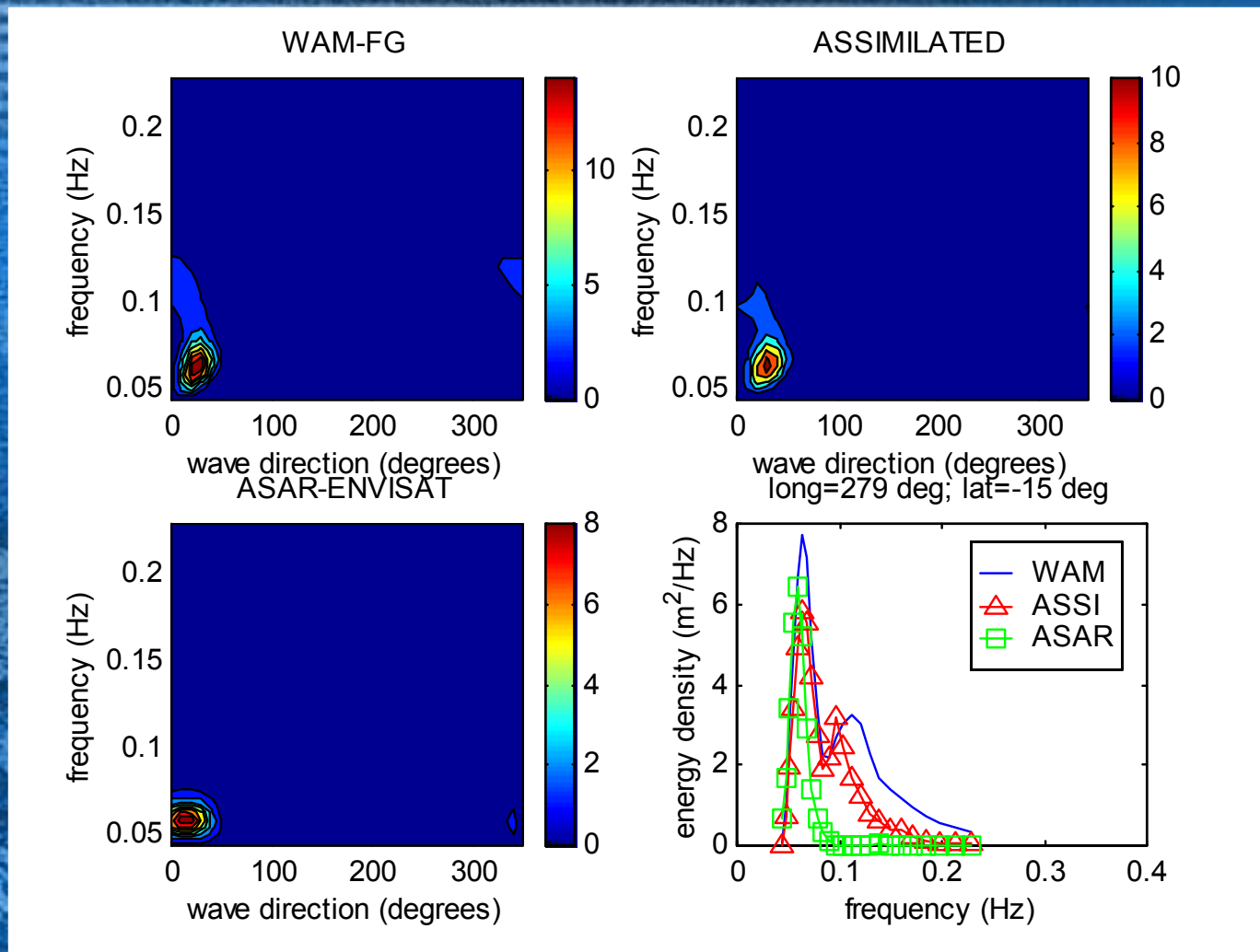
green : with altimeter type

Wind perturbation : 4 days forecast X 0.5

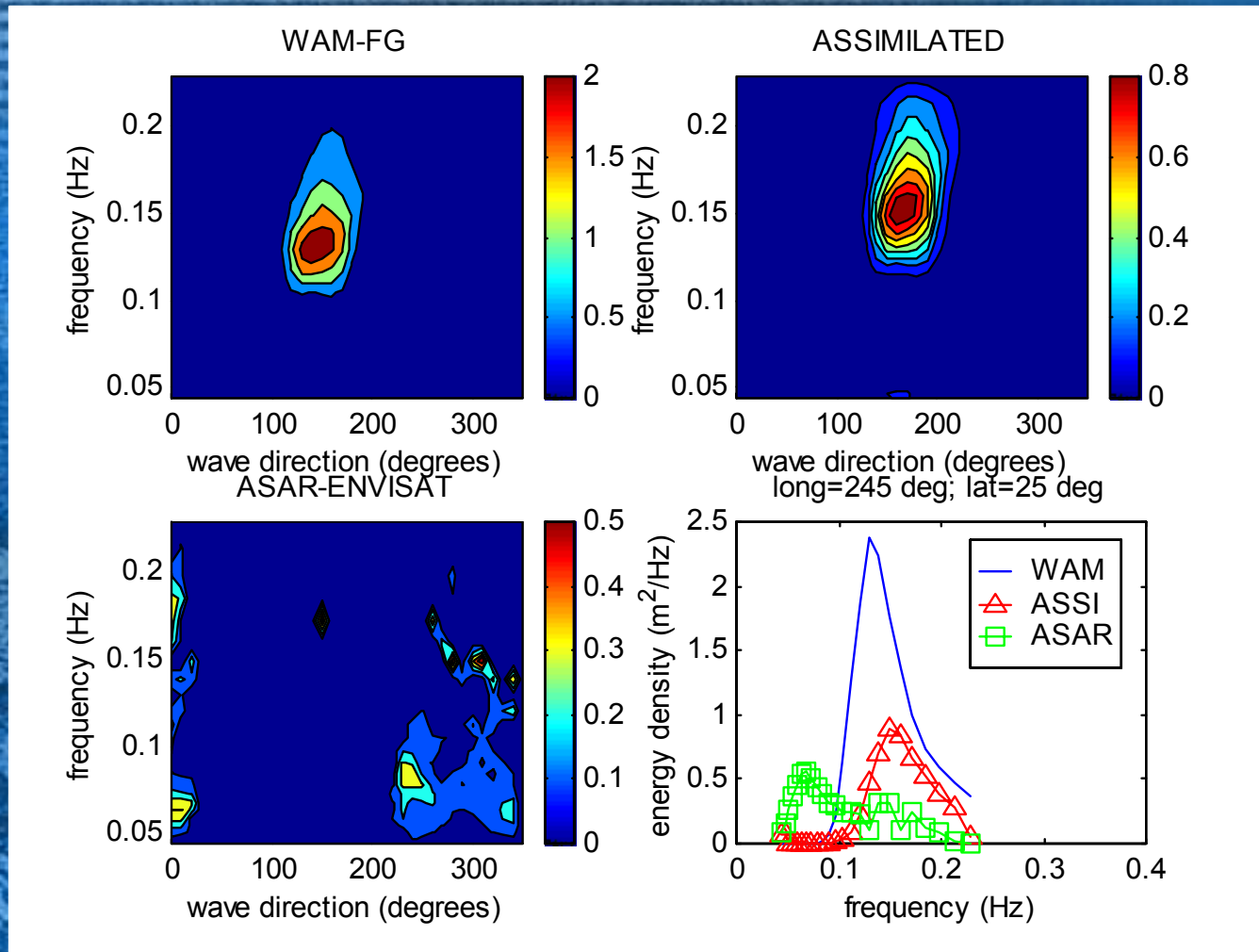
# Assimilation of ENVISAT ASAR Data



- assimilation of level 2 ASAR data in WAM wave model
- impact of the assimilation on the SWH field is shown on the left figure
- impact of the assimilation on the SWH along track is shown on the right figure



- The wind sea present in the WAM first guess is not seen by the ASAR but is built by the assimilation scheme (ASSI)
- The swell energy is slightly reduced according to the ASAR observation



- but some problems arises when the ASAR spectrum is too complex
- Still some work to face such problems

Work has been performed in order to tune of the assimilation scheme and to do assimilation experiments, in particular

- to determine form of the error correlation function,
- to tune correlation length, distance of influence of the observation,
- to introduce a frequency-dependent error correlation function (for wind sea and swell)
- to investigate the sensitivity of the results to the wind field perturbations (random errors, forecasts)
- To Introduce in WAM the OI scheme used in VAG for altimeter only (which has a few modifications from the original WAM)

## Still working on

- tuning of the partitioning parameters
- tuning cross assignment
- introduction of a frequency cut off (SAR-SWIMSAT)
- introduction of a minimum energy threshold

# What we plan to do

- Estimation the impact of using simulated swimsat data
- Tuning of the OIP scheme for the ASAR data
- Estimation the Impact of using several altimeters (ERS2, TOPEX, GFO)

# What could be done in 2003 (depending on external support)

- OSSE's for the optimization of the altimeters orbits
- OSSE's combining several altimeters+instrument providing spectral information (SAR or SWIMSAT type)
- Estimation of the impact of the assimilation of calibrated/validated ASAR data