SWIMSAT : a mission proposed to measure spectral properties of ocean waves

Danièle HAUSER, CETP/CNRS

SWIMSAT has been proposed to ESA, is response to the Call for Opportuniy Missions of the Earth Explorer Program

Content of the presentation

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- Main characteristics of the instrument and mission

- Expected performances (from simulation)

- Assimilation tests

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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).

Present status

Proposed (January 2002) in response to the new Announcement of Opportunity (opportunity missions for the Earth Explorer Program)

2 PI (D. Hauser and S. Lehner) and 26 CoI from 19 research groups, mainly in Europe

Feasibility of the concept studied since 1994

Improvements in the concept proposed in 2002 with respect to the former VAGSAT proposal

First results of an assimilation study

Result of evaluation should be known in May 2002

Main characteristics of the instrument and mission

Instrument:

Ku-Band (13.6 GHz)
Multi-beam (incidence 0 to 10°) scanning in azimuth
Beam aperture (2x 2°), range resolution 0.5 to 0.75 m

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

Orbit:

450 to 500 km
Near-polar to ensure a coverage from 83 S to 83 N
Sun-Synchronous is possible but not mandatory
Proposed Cycle 8 days (tentative)

Payload:

Radar:

Nadir looking antenna + 5 beam Antenna (2, 4, 6, 8, 10°)

Conical scans: only the transmitting horns are in rotation

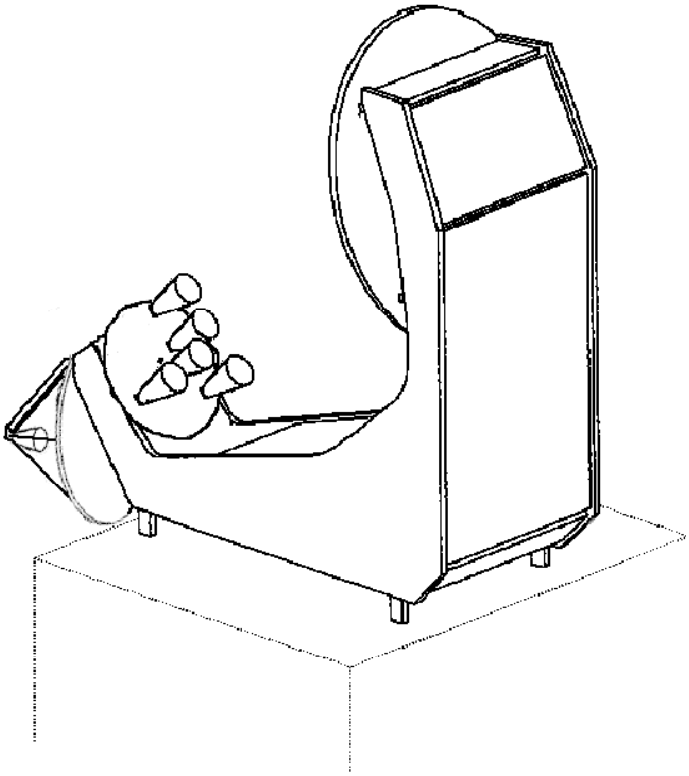
Microwave part, processing part, …

Power required: 190 W Weight: 75 kg

Platform:

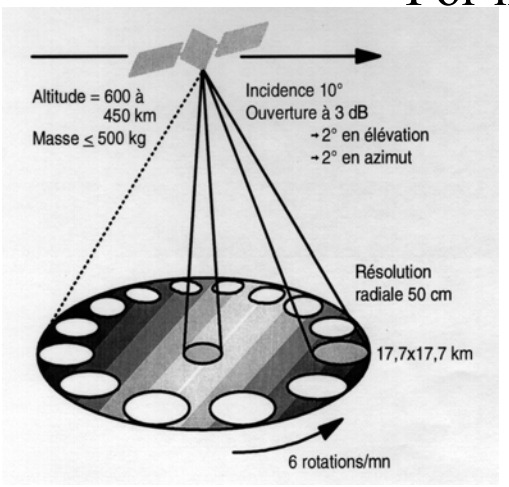
Compatibility with PROTEUS (CNES), but other choices are possible

Antenna design (Alcatel)

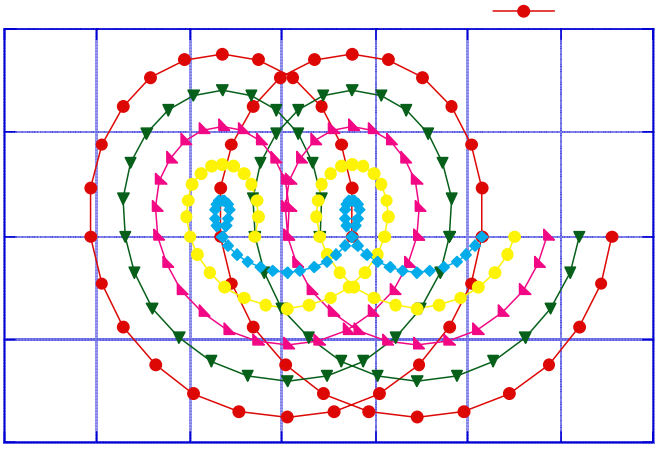


Geometry of observation

For incidence 0 and 10°

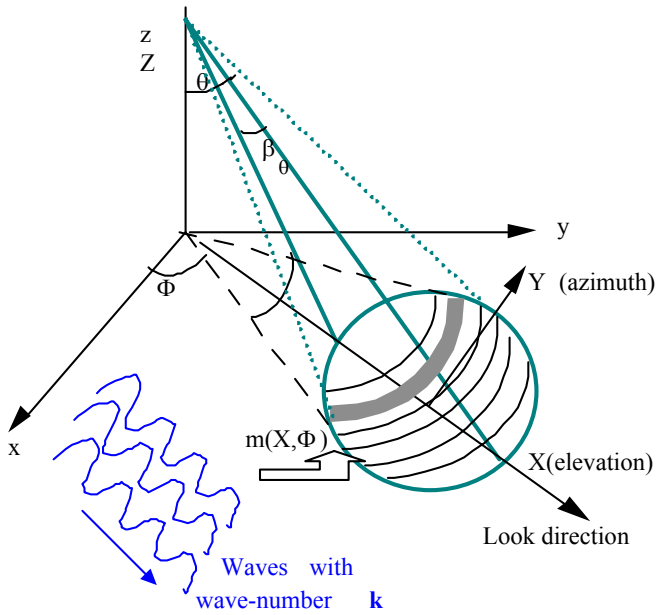


For incidence 2 to 10°



Principle of wave spectra retrieval:

(Jackson et al, 1985, Hauser et al, 1992)



In each azimuth direction, the backscattered signal is modulated by the tilt of the long waves (wavelength > 50 m)=> Measurement of these modulations m(x,ϕ) , calculation of their spectrum $P_m(k,\phi)$

Linear relationship between modulation spectrum and wave slope spectrum

$$P_m(k,\phi) = \frac{\sqrt{2\pi}}{L_y}\alpha^2 k^2 F(k,\phi)$$

Complete directional information using the 360° scans

Normalization of the wave height spectrum using the nadir beam (providing the significant wave height) and/or the profile of σ_0 with incidence (SWIMSAT option)

Expected geophysical products

$\Rightarrow$ 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)

=> Probablity density function of wave slopes (through the analysis of $\partial\sigma_0/d\theta$)

=> Wind speed and significant wave height from nadir looking

$\Rightarrow$tentativeley: wind speed and direction from combined measurements at different incidence angles

=> Sea surface height but with « rough » accuracy (no radiometer, no Doris instrument planned at the moment)

Expected performances (From simulation studies, taking into account noise sources)

=> 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: method and preliminary results (Coll. Météo-France)

- 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) :
  Partitioning concept (wave train decomposition)
  Optimal interpolation

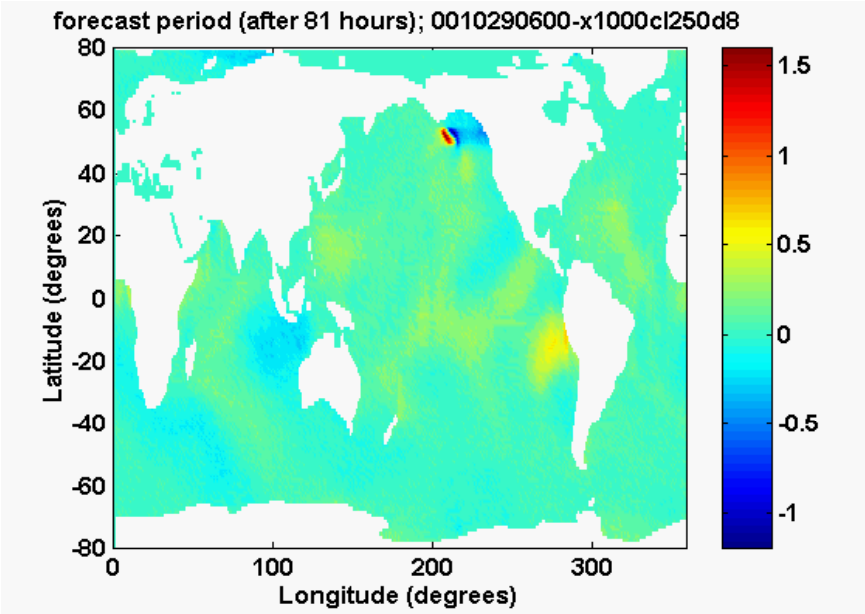
- Synthetic SWIMSAT data :
  Run without assimilation (analysed wind field)
  observation locations along SWIMSAT orbits with repeat cycle of 7 days

- Disturbance of the wind field :
  Forecasted wind field 4 days before
  New wave field is generated

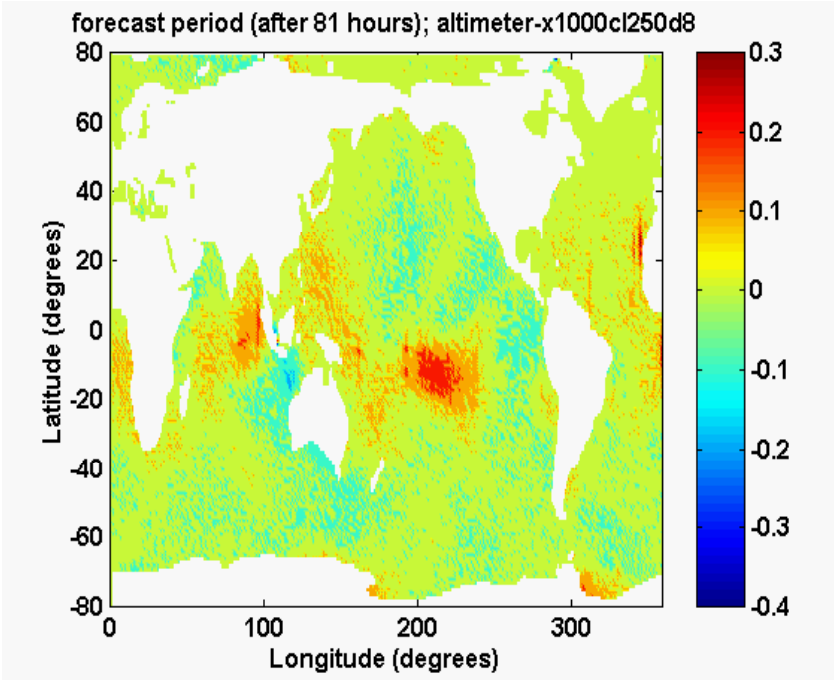
- Run with assimilation of the synthetic directional spectra

  Area of impact=1000km;
  correlation length=500 and 200km
  Assimilation time step 6 hours

Difference (in meters) of the significant wave height between the run with and without assomilation, 3 days after the end of the simulation period



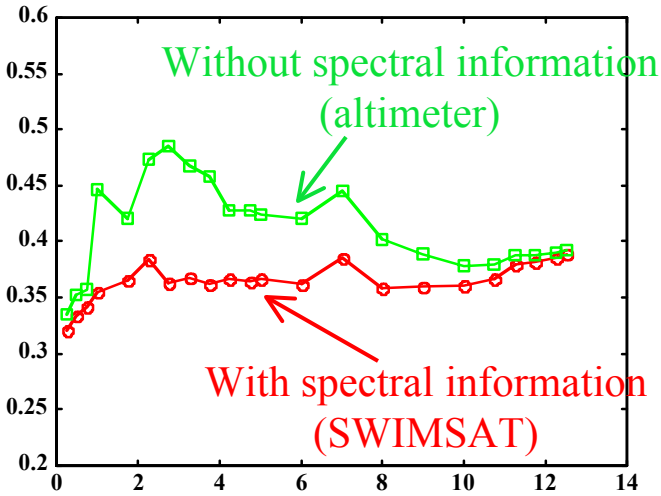
With spectral information (SWIMSAT)



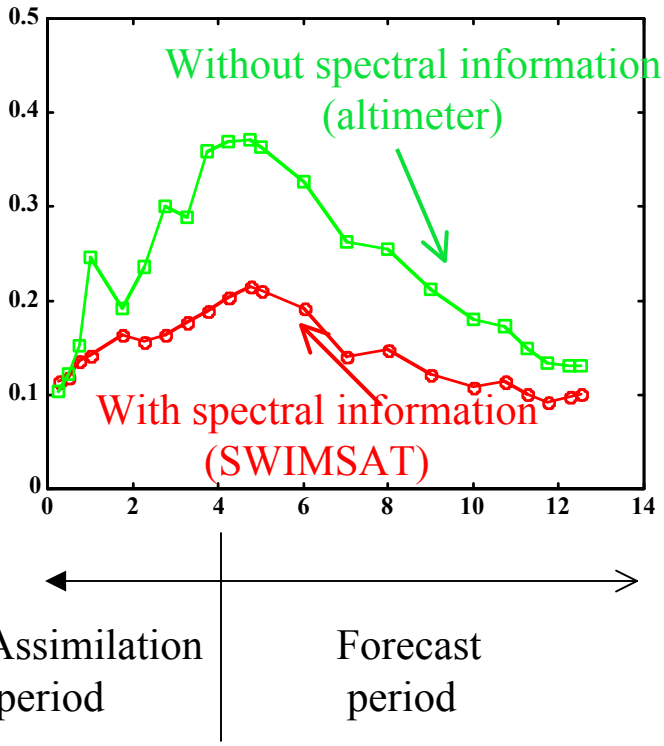
Without spectral information (altimeter case)

Impact on wave height: difference between model with assimilation and observations (synthetic data)

For all points where the impact is less than 1.5 m



Standard deviation (m)



Mean error (m)

SWIMSAT within GAMBLE

Involved in themes 1,2,4, 5, 6

Theme 1: Asses the interest of SWIMSAT as an altimeter for ocean topography but with rough accuracy for topography

Theme 2: wave spectral information that can be obtained by SWIMSAT (in coordination with an altimeter constellation); assimilation into models for sea-state analysis and forecast

Theme 4: taking into account requirements from matine operators regarding surface wave spectra and wind speed

Theme 5: definitition of wave, and wind products for climate studies and marine operations. In addition: assess the interest of additional information provided by SWIMSAT for the altimeter applications: improve sea-state bias estimate, using spectral and statistical information on waves)

Theme 6: optimize constellation of several missions