SIMP: Slicks as Indicators for Marine Processes

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Abstract – Within the three-years project SIMP scientists from four European countries are working on an improved use of satellite remote sensing data of marine processes in the coastal zone through their imprints on the sea surface, particularly when it is covered by (biogenic or anthropogenic) marine surface films. In this paper, we summarize results from joint field and laboratory experiments conducted in the Japan Sea, Black Sea, and in laboratory wind-wave tank facilities, respectively, and we demonstrate how the interpretation of satellite radar imagery can benefit from a deeper knowledge of the very mechanisms responsible for slick signatures and from auxiliary information provided by sensors working at different electromagnetic frequencies.**

Keywords: Marine Surface Films, Earth Observation Technologies, Satellite Remote Sensing, Oceanography, Environmental Monitoring and Assessment, Coastal Processes.

1. INTRODUCTION

SIMP ("Slicks as Indicators for Marine Processes: Novel Tools for Marine Remote Sensing of the Coastal Zone") is an international project funded by INTAS, that is aimed at improving the information content which can be inferred from multi-sensor satellite imagery of marine coastal areas. Scientific teams from Germany, UK, Portugal, and Russia form the project consortium and focus on the development of novel tools for marine remote sensing of the coastal zone. In particular, the project teams benefit from the fact that marine surface films, that are often present in coastal areas, may enhance the signatures of hydrodynamic processes such as plumes, internal waves, eddies, etc., on microwave, optical, and infrared imagery. SIMP has started in March 2004, and we are presenting first results of our joint studies herein.

The project's objectives are to develop a robust methodology for identifying slick-related phenomena/processes through their surface signatures and thereby, to improve the discrimination capabilities between slicks and other oceanic and atmospheric phenomena by taking into account information gained from satellite imagery quasi-simultaneously recorded at microwave, visible and IR wavelengths. Laboratory and field experiments are being conducted in order to investigate those physical mechanisms which are responsible for variations in slick visibility at different electromagnetic frequencies, and particularly to determine the sensitivity of radar and optical signatures of marine surface films to variations of the wind speed and wave field and to hydrodynamic phenomena such as internal waves, eddies, and currents.

In this paper, we briefly summarize the results of the project year and give examples for the project's web presentation, laboratory and field studies, and of the analyses of various satellite data.

2. SIMP WEBSITE AND DATABASE

Two websites, the SIMP project website and the SIMP database have been created in order to ensure a swift exchange of data and information amongst the project teams, and to allow an easy dissemination of results to interested parties outside the consortium.

2.1 Website

A project website (SIMP, 2005a) has been created to (1) provide an overview of project activities and results to the public, (2) facilitate exchange of documents and information between project partners and (3) keep a transparent record of progress within the project. The website is split into two sections, one of which is open to the public whereas the other part allows access by password only. Figure 1 illustrates the structure of the website schematically.

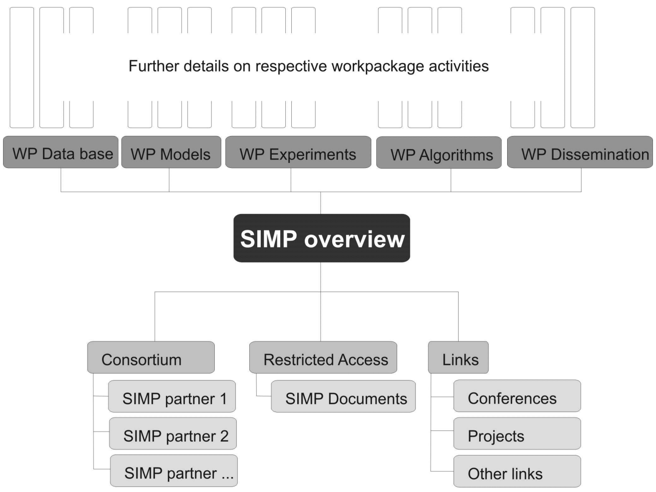

Figure 1: structure of the SIMP website.

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The start page gives an overview of project facts, objectives, links to funding bodies. It then branches out into a more detailed description of project activities sorted by work package (WP). The respective top page of each work package provides a brief description of activities in the field of the project as well as optional further information which will be extended and modified over the duration of the project.
Further links provided in a navigation bar give access to a list of project partners and their contact details, the restricted access section, and a collection of project-relevant links. The latter focuses on other projects involved in similar activities and research as well as conferences which are of interest to the SIMP partners. Website activity is monitored via a counter and access statistics, recording information on residence country, provider, operating system and browser of each site access.

2.2 Database

In order to ensure a swift transfer of data of any type between all project teams a project database (SIMP, 2005b) has been installed on an FTP site accessible to all project participants and to the public. The concept of the presentation of slick images, the file structure, and the presentation layout has been developed in terms of an easy access to the data and to the corresponding information. The database is intended to feature various phenomena and processes visualized by slicks on the sea surface and imaged by different sensors (see Figure 2).

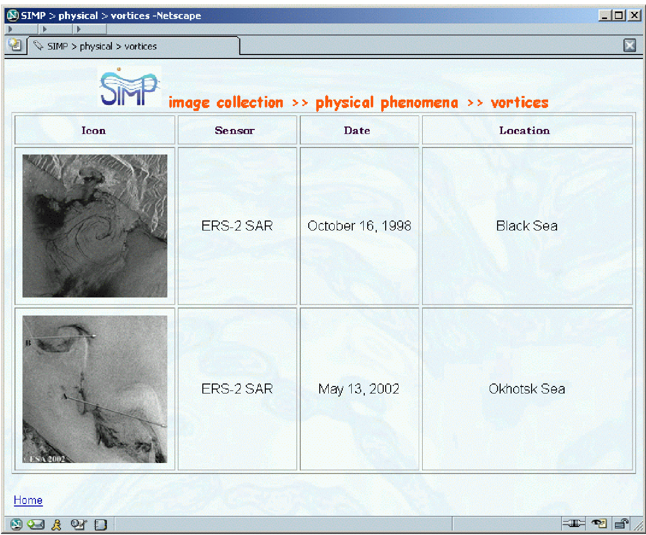

Figure 2: part of the SIMP database containing examples for marine vortices visible on synthetic aperture radar (SAR) imagery.

Images accompanied by a short description, location map and links to auxiliary information are grouped by phenomena. There are two main classes of phenomena: physical such as internal waves, currents, and vortices, and biological such as algal blooms and increased productivity. Images may appear in more than one group and in both classes, depending on the phenomena they feature. Besides the image section, there is a section describing the deployed sensors and also a short introduction to the database.

3. LABORATORY EXPERIMENTS

An important part of SIMP is basic research addressing open questions about hydrodynamic processes that influence the spatial distribution of surface-active material on the water surface. Such basic research has been performed at the wind-wave tanks of the Institute of Applied Physics (IAP-RAS) and of the University of Hamburg (UoH).
Investigations of short wind waves and their variability due to long waves were carried out at IAP-RAS at low wind conditions and short fetches and in the presence of surfacants at different concentrations. Wind waves were measured using an optical spectrum analyser and a coherent Doppler Ka-band radar operating at a wavelength of 0.87 cm. Surface films in the wave tank were formed by oleic acid (OLE) and a polymer (poly)oxyalcylene glycol ("Emkarox"). The modulation of short wind waves was found to be larger than predicted by linear models. It was shown that phase velocities of short wind waves do not obey the linear dispersion relationship and thus bound waves (high order harmonics) give significant contribution in the spectrum of short wind waves. A local balance model was modified and the effect of the generation of bound waves was described by an additional term in the kinetic equation for the spectrum of wind waves, thus allowing to explain the experimental results on short wave modulation.
Another set of laboratory measurements was conducted at UoH. We measured the surface slope and the radar backscattering at 10 GHz (X band), and the three-dimensional sub-surface velocity field at three different depths. The wind was switched on at the beginning of each measurement, and it was switched off after 10 minutes. Each measurement was repeated with oleyl alcohol being deployed while the wind was switched on. Preliminary results (Figure 3) show evidence that the measured sub-surface velocities are due to turbulence generated by the wind-waves.

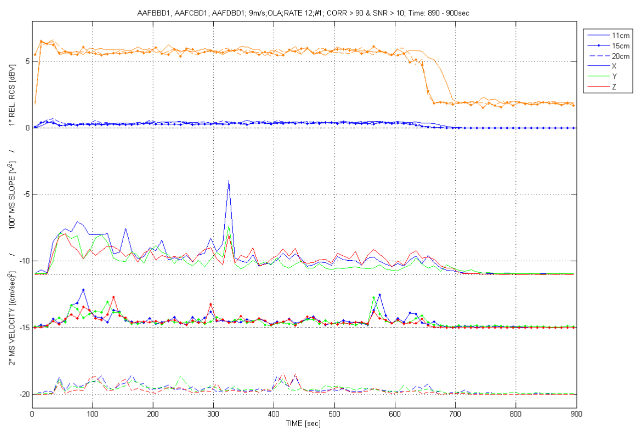

Figure 3: results from the joint UoH/IAP laboratory experiments with an oleyl alcohol slick at 9 m/s wind speed; X band radar backscatter, mean square surface slope, 3-dim. sub-surface velocities at 11 cm, 15 cm, and 20 cm (from top to bottom). Note the variations in sub-surface velocities that were measured after the wind was switched on (left-handed side).

4. FIELD STUDIES

Another important part of SIMP is field experiments that are designed to evaluate results from laboratory studies, to study hydrodynamic processes inside and outside of slick-covered areas, and to provide in-situ data during satellite overpasses. Here we present two examples of field studies performed during the first SIMP year.

4.1 Slicks in shear currents

An experimental campaign was conducted in August, 2004 by the teams of IAP-RAS and the Space Research Institute (IKI-RAS) in the coastal zone of the Black Sea on the base of the South Branch of the Shirshov Institute of Oceanology.

The objectives of these experiments were:

(i) to develop a better understanding of mechanisms of slick formation and of the relation between slick geometry and the structure of surface currents;

(ii) to investigate the physical characteristics of marine films

(iii) to investigate surfactant spreading regimes

A new methodology of measurements of surface currents in a thin surface layer (about 5 mm) was developed at IAP-RAS using special floats which trajectories were traced from a small boat using GPS receivers. Simultaneously, film sampling was carried out from slicks and surrounding non-slick areas. It has been found that surfactants associated with surface currents are located in shear current zones where weak transverse currents also occur, the latter results in surfactant compression. Figure 4 gives an example of trajectories of floats, two of them were placed initially inside a slick band and another two outside the band.

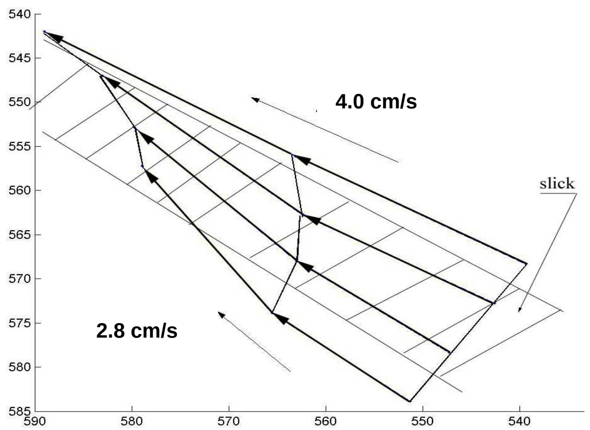

Figure 4: Trajectories of markers inside and outside a natural slick band (see text).

It is clearly seen that a) the current velocities from the sides of the slick band are different and b) there are current components in the cross-slick direction which are responsible for film compression. Envisat SAR imagery of slicks in the area of the experiments were analyzed by IKI-RAS. Eddies were found to appear in the images (SIMP, 2005a) and the studied slicks were considered to be related to the currents in the eddies.

4.2 Biogenic and anthropogenic surface films

In July, September, October 2004 and in February 2005 the team of the Il'ichev Pacific Oceanological Institute (POI-RAS) carried out a series of field experiments at the POI Marine station "Cape Shults" located at the coast of the Peter the Great Bay, Japan Sea. The main aim of the experiments was to conduct sub-satellite optical and hydro-meteorological measurements to improve the interpretation of SAR data and to compare the measured and computed values of the normalized radar cross section (NRCS). In order to estimate effects of temperature and chlorophyll *a* concentration on radar signatures of slicks the field experiments were carried out in different seasons.

Both biogenic and anthropogenic slicks were detected on all SAR images. At wind speeds below 5-6 m/s biogenic slicks visualized the oceanic dynamic phenomena. Coastal mountains, a complicated coast line, and small islands in combination with bottom topography and surface currents were found to be responsible for the generation of eddies, internal waves, and costal fronts (see Figure 5).

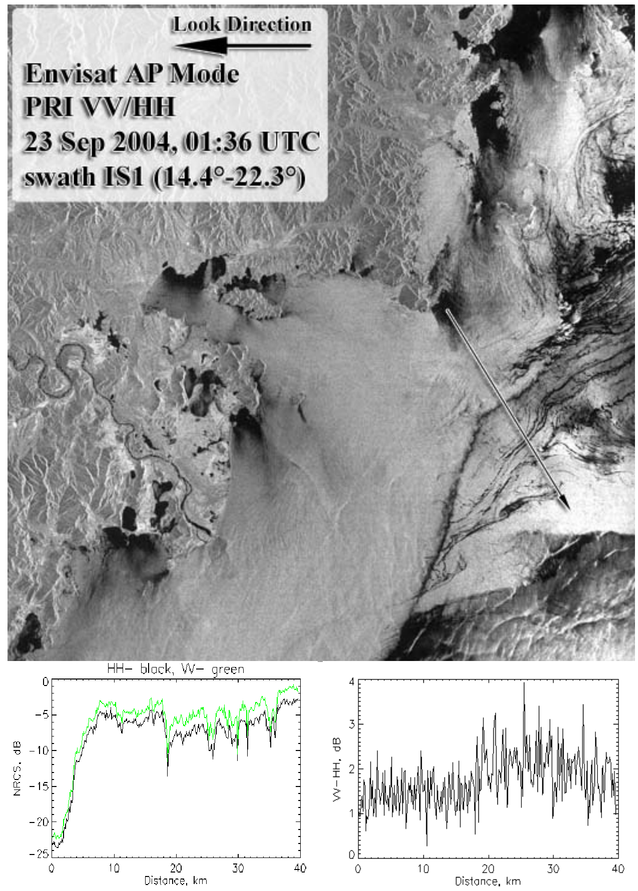

Figure 5: top: ENVISAT ASAR image of the Peter the Great Bay, Japan Sea, showing various marine and atmospheric processes and marine surface films; bottom: transects along the arrow in the DSAR image, showing the dual-polarization NRCS (left) and the polarization ratio (right). Note the different polarization ratios on either sides of the front.

5. ANALYSES OF SATELLITE DATA

5.1 SAR signatures of internal waves

Oceanic internal waves are often associated with a spatially varying distribution of organic surface films. Several ERS SAR and ENVISAT ASAR images covering the West and South off the Iberian Peninsula were processed at the University of Lisbon (UoL) are were analyzed with respect to various oceanographic features, including internal waves, upwelling, natural slicks and oil spills. The spatial coverage of the data set was chosen to map internal waves on the western and southern continental margin of the Iberian Peninsula. The precise regions to be imaged were based on maps of barotropic tidal forcing (Baines, 1982) indicating hot-spots of internal wave generation, and propagation directions of internal solitary waves. One of the regions where the tidal forcing was found to reach maximum values was near the submarine canyon of Nazare (off Portugal) and to the West of Lisbon Canyon (see Figure 6).

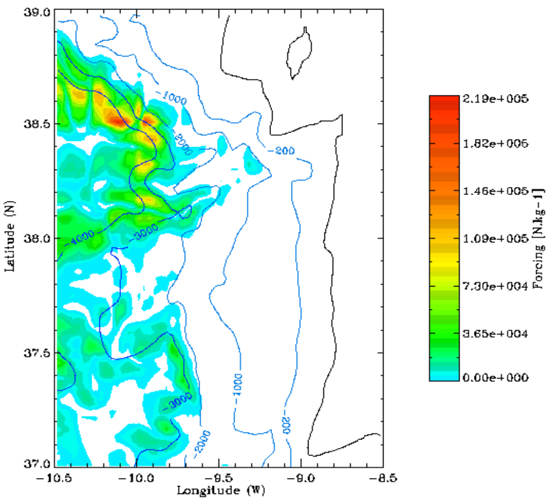

Figure 6: model simulations of barotropic tidal forcing on 15.09.03 (a date of an ENVISAT overpass) in the southwest region of the Portuguese continental margin. Internal solitary wave signatures observed in SAR images match the model predictions quite well.

5.2 Slick damping measured by radar altimeter

It is well known that marine surface films show up on SAR imagery as dark patches. Moreover, because of their strong damping capability (so-called Marangoni damping (Alpers and Hühnerfuss, 1989)), marine slicks may also influence the signal measured by space-borne radar altimeters. In Figure 7, we plot "differential slope" (the mean square slope of waves of 6-16cm) against "C Band Slope" (the mean square slope of longer waves) for two years of TOPEX data from the Irish Sea that were analyzed at the National Oceanography Centre (NOC). Most data fall close to the black curve (a polynomial fit to all data), but there is some data above the curve and may more data far below the curve. Data for which the significant wave height implies unusually high sea state (for a given wind speed) are identified by maroon symbols and the maroon curve is a fit to this data. Sea state appears unrelated to deviations from the curve at low wind speeds (or slope) but high sea state does correlate to "negative residuals" (i.e. data below the curve) for differential slopes > 0.015 rad^2. Thus, large residuals are most unlikely to be related to sea state development, at least for low differential slopes. The data above the curve are most likely instances of rain, and the many large negative residuals are "candidate" areas of Marangoni suppression, which would account for the anomalously low amplitude of 6-16cm waves.

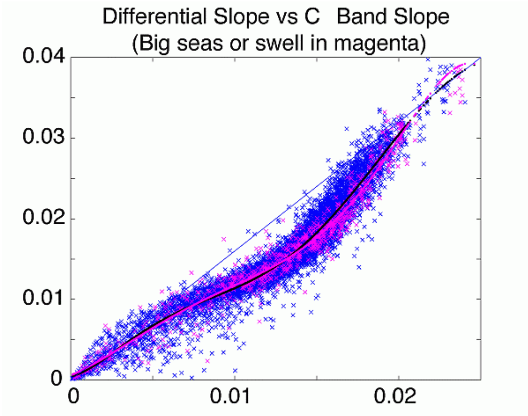

Figure 7: differential slope vs. C band slope (see text) for two years of TOPEX data from the Irish Sea.

6. CONCLUSIONS

During its first year, SIMP has already proven to bring out a wealth of new results on the influence marine surface films (slicks) may have on data from satellite-borne sensors. During the remaining project duration, the consortium will continue focusing on various marine processes whose imprints on satellite imagery are enhanced by marine surface films of biogenic and anthropogenic origin.

7. ACKNOWLEDGMENTS

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8. REFERENCES

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