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Current maps and bathymetry from P-band SAR images: preliminary results

René Garello*, Jean-Marc Le Caillec*, H el ene Dupuis†, Vincent Marieu†,
Nathalie Durand‡, Philippe Dreuillet§ and C ecile Titin-Schnaider§

*GET - ENST Bretagne, CNRS FRE 2658 TAMCIC Equipe TIME
Technop ole Brest Iroise, CS 83818, 29238 BREST Cedex, FRANCE

Email: rene.garello@enst-bretagne.fr, Email: jm.lecaillec@enst-bretagne.fr

†DGO - Universit e Bordeaux, CNRS UMR EPOC 5805

1, Av. des Facult es, 33405 Talence Cedex, FRANCE

Email: dupuis@epoc.u-bordeaux.fr, Email: marieu@epoc.u-bordeaux.fr

‡IFREMER - station d'Arcachon

Quai du Commandant Silhouette, 33120 Arcachon, FRANCE

Email: nathalie.durand@ifremer.fr

§ONERA - DEMR Centre de Palaiseau

Chemin de la Huni ere, 91761 Palaiseau Cedex, FRANCE

Email: Philippe.Dreuillet@onera.fr, Email: Cecile.Titin-Schnaider@onera.fr

Abstract—Microwave remote sensing at very long wavelength is already used and validated for coastal zone regions and regions covered by ice (Antarctica) using airborne systems. For many other applications a high potential exists and the PYLA 2001 experiment allowed the acquisition of data for fields still under preliminary tests. The experiment was carried on a Transall aircraft (French army/DGA) and used the SAR sensor RAMSES (multifrequency/multipolarization) from ONERA [1]. For the experiment, the acquisition was performed in P band (435 MHz). The aim was to explore potentials of the low frequency domain for sub-surface moisture detection (Pyla sand dune), biomass evaluation (Nezer forest), mapping of the ocean bathymetry and salinity (Arcachon inlet, estuary of the river Gironde), and archaeology (St Germain d'Esteuil, Dignac, Moulin du F a). A dedicated P-band calibration site was set up in order to fully exploit the polarimetric information.

This part of the study consists of analyzing SAR images from RAMSES (P band) in order to be able to take into account the effect of longer surface waves, winds and currents on the surface roughness in the Arcachon inlet. Tidal currents associated with long oceanic waves dominate the dynamics of the inlet. SAR images were recorded at the mouth of the inlet, including the northern channel and sand banks of the ebb tidal delta. The analysis provides tools allowing the production of current maps, which are in turn compared to in-situ measurements by GPS on surface drifting buoys and to current velocity fields provided by a 2DH numerical model, MARS-2D. The evaluation of the ability of a 1D hydrodynamical model applied to SAR images in order to reproduce currents in the area will be presented.

Multipolarization images can be used in order to separate the information associated with the ocean surface (tilt) modulation, which is different for each polarimetric image, from the hydrodynamic modulation, similar for each image. The tilt modulation is representative of a Real Aperture Radar-like (RAR) image. The data being available quite late we just performed correlations between each set of data by using polarimetric coefficient. We obtain good answers on the information associated with the motion of the scatterers.

I. INTRODUCTION

The Pyla 2001 campaign occurred in the Gironde region (France) with the aim of studying oceanography, continental humidity and archeological sites. The chosen test site - Pyla region in Gironde, France - combined several thematics ranging from archeology to oceanography (see [2] for ocean surface salinity study). Indeed, our part of the project was completely devoted to marine applications. A complete analysis of the data from the airborne platform will be conducted, when they are fully accessible. One subsection of the project consisted of comparing the results from our data and the results obtained using other sensors, primarily spaceborne SAR such as ERS1/2. In order to be able to do so we have selected a set of ERS2 images acquired at the time (within two months) of the airborne experiment.

II. AREA AND DATASET

A. Description of the area

The area of interest ("Inlet of Arcachon") is located in the Bay of Biscay, south of the Gironde river inlet, and at the latitude of the city of Arcachon. Figure 1 shows a large scale view of the area (SPOT satellite visible image), while figure 4 presents the Mars 2D numerical model bathymetry of the Region of Interest (RoI) in zoomed in excerpt. We can see manifestations of bathymetric effects in the latter image. The inlet is delimited at the North by the split of "Cap Ferret". Figure 1 exhibits two channels, the northern and the southern ones. The latest is flattened against the south coast and is shallower than the former. The main sandbank located in between the channels is called "Banc d'Arguin" and part of it remains emerged at high tide. The bathymetric chart displayed on figure 4 shows the same features. The area is submitted to semi-diurnal tides and the current magnitude

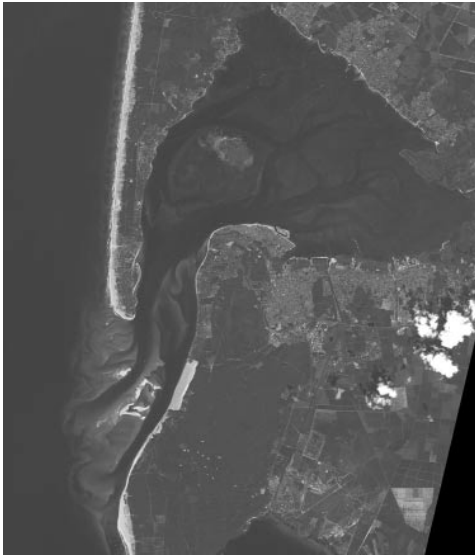


Fig. 1. SPOT image (©SPOTIMAGE, CNES) is displayed with a zoomed-in view of the RoI.

can be greater than 1.5 m/s in the channels. Sediments are therefore transported back and forth modifying the extent of the inlet. As a consequence the mouth of the inlet is subject to short term morphologic evolutions [3] and it is necessary to develop tools able to monitor these evolutions.

B. Description of the dataset

The data is composed of airborne SAR images (04/24/01), one SPOT scene (05/15/01) obtained on the "Inlet of Arcachon". RAMSES is an active sensor working in P-band (0.435 GHz) for a long radar wavelength (66 cm). SAR images were obtained with a spatial-time resolution of 5.9 m in azimuth and range directions. Two transects (P0312 and P0313) of approximately 5x5 km were acquired on April, 24 2001 at 2 pm. A third one (P0302) is available at the South of the RoI. The images were recorded just before the maximum current magnitude was reached and for a tidal coefficient of 93.

The SPOT scene of 05/15/01 is illustrated in figure 1 in XS1 band. The image is not georeferenced and was used to obtain a first guess of the bathymetry using the inversion algorithm provided by [3]. This method based on XS1 allows providing depth up to 6 meters. Figure 4 shows the general orientation of the SAR images relative to the bathymetric chart.

An ERS-1 SAR image is shown for comparison, but was acquired on June, 3 1995. We are currently seeking an ERS2 image at the exact date of the RAMSES acquisition, but the availability of the data is not insured. Figure 2 presents the overall ERS view of the RoI. The ocean conditions (tidal currents, water depth) are of course completely different.

III. METHODS

A. SAR imaging of the bottom topography

It is now well known that surface current gradients in shallow waters can be imaged by SAR [4], [5], [6], [7].

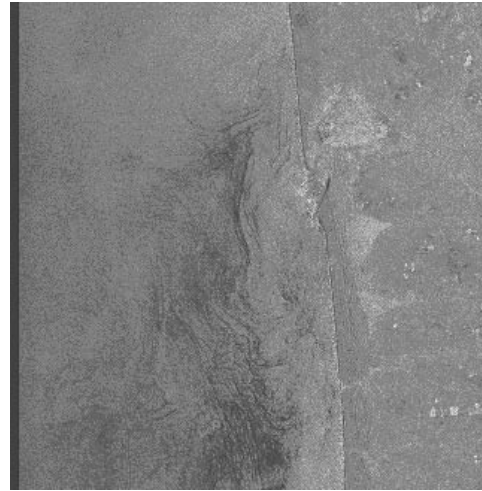


Fig. 2. ERS-1 SAR image of the region of interest (©ESA).

Since the radar is only able to measure surface roughness, the current variations are imaged through energy transfer towards the waves. This imaging mechanism is a two-step process:

- the current modulates the short-wave spatial concentration, thus, the local wave spectrum
- the radar backscatter; is a function of the local wave spectrum.

The energy transferred between the current gradients and the waves is described by the Action Balance Equation (ABE) which gives the relationship between the surface current and the perturbation of the wave spectrum from its equilibrium. Surface current variations can be related to several phenomena such as internal waves or underwater bottom topography. In the latter case, the current is modulated by depth variations. Thus, being able to establish a relationship between, for example, ocean depth and radar image pixel values is of great interest for the oceanographic community. The general formalism that we propose for the inversion of imaging mechanisms is the following:

- obtain a Volterra series expression for the imaging mechanism (from data or physical modelizations);
- invert the Volterra model;
- smooth the observation and use the result as input of the inverse model.

The complete process is described in [7] and [8].

B. MARS-2D simulations and bathymetric map

Ifremer has developed a 2D numerical hydrodynamic model for coastal area called MARS-2D. This model is based on the principle of Newton and the mass conservation, which is reduced to the so-called Saint-Venant equations. For the Arcachon Inlet it is based on a bathymetry obtained mainly from soundings acquired in 1998. The underlying assumptions are that the current is vertically homogeneous, due to the fact that salinity and temperature are relatively homogeneous in the area. Due to the rapid evolution of the morphology, these simulations do not allow to accurately locate the channels

or sandbanks. To evaluate the displacement of the systems, a bathymetry based on a SPOT image was estimated within the same period as the one of the radar image acquisition. Furthermore, the surface currents provided by 2 drifting GPS deployed the 24th of April 2001, during the radar acquisitions, allow validating the outputs of the models. Preliminary analyses show that we have less than 20% errors between vertically average current models and in situ measurements. The RMS is less than 10% and maximum errors are obtained on the sand banks.

C. Polarimetric approach

We started analyzing the polarimetric data. Figure 3 presents two different polarization of the image P0313. A very brief survey shows that the HH-VV correlation is sensitive to the scatterer motions and displays quite well the ship present on the image. The HH-VH correlation is in direct relation with the angle of incidence and displays the tilt effect of the ocean surface.

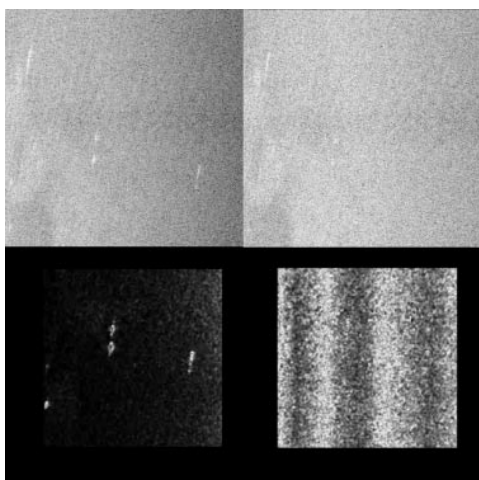


Fig. 3. HH and VV polarization (top left and right images) for the transect P0313. The bottom images show the correlations HHVV (left) with the highlight of the ships and HHVH (right).

IV. CONCLUSION

The P band SAR data were available very late so we haven't yet fully processed them. Nevertheless, we have started to produce the bathymetric charts using the 2D numerical model, MARS-2D. The input is based on in situ measurements (from a 1998 campaign) combined with data points derived from the SPOT image. The idea here is to provide a simulation of the surface current field in the same zone as of the radar acquisition. MARS 2-D simulation models are displayed on figure 4 (top right). Several runs were performed for obtaining the current field maps for the day of SAR data acquisition. Figure 4 (top left) shows the bathymetric charts of the hydrodynamic model of the "Inlet of Arcachon" calculated from the method described in section III-B.

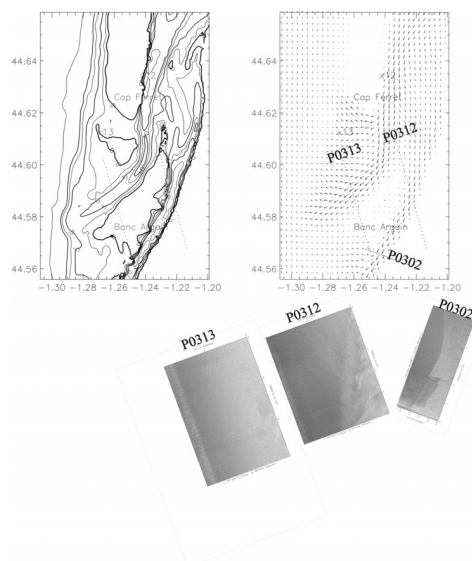


Fig. 4. Current field simulation on the RoI (top right). The bathymetric chart (top left) is recalled. The aircraft transects are shown in dotted lines and the acquired P-band SAR images are shown with the correct orientation.

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