

SEAFLOOR TOPOGRAPHY MODELLING IN NORTHERN ADRIATIC SEA USING SYNTHETIC APERTURE RADAR

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ABSTRACT

Underwater bottom topography may be visible on Synthetic Aperture Radar (SAR) images through the radar signature of ocean surface currents. Using SAR images and a limited number of echo soundings it is possible to construct accurate depth maps, greatly reducing the costs of bathymetric surveying. Based on shallow water bathymetry synthetic aperture radar (SAR) imaging mechanism and the microwave scattering imaging model for oceanic surface features, we are working to develop a new method for shallow water depth retrieval from space-borne SAR images. Shallow waters in the northern part of Adriatic sea may represent favorable depth condition for underwater bottom topography estimation testing over large area, using SAR imagery, although such area does not show strong tidal currents. Strategy for northern Adriatic Sea seafloor modeling is presented, using the Bathymetry Assessment System (BAS). Evaluation is conducted using SAR imagery from different satellite platforms and in multitemporal framework, in cooperation with echo soundings from bathymetric surveying. Two monitoring sites supply in situ data, such as water level, current flow, wind velocity and direction. Physical conditions evaluation in the study site supports selection of the best SAR images for depth estimation. Multisensor approach will give the possibility to evaluate differences in bottom topography estimation from sensor with different characteristics.

1. INTRODUCTION

Underwater bottom topography may be visible on Synthetic Aperture Radar (SAR) images through the radar signature of ocean surface currents. In 1984 Alpers and Hennings [1] proposed a simple theoretical model of the imaging mechanism underwater of bottom topography by real and by synthetic aperture radar (SAR). The imaging mechanism, which reflects under water topography in a given SAR image is a generally accepted model, it includes three steps:

- interaction between bottom topography and (tidal)

current causes modulations in the surface current velocity;

- modulations in the surface current velocity cause variations in the spectrum of short wind-generated waves that determine the sea surface roughness;

- variations in sea surface roughness show up in radar images as intensity modulations.

The first step is described by a flow model, the second step by a wave model solving the action balance equation, and the third step by a radar backscatter model.

Underwater topography SAR imaging aims to retrieve seafloor for ocean bottom topographic mapping, many experimental studies were investigated after the theoretical model was proposed in 1984 [2,3,4,5,6,7,8].

In 2001 Wensink et al. [9], collecting the theoretical models developed in the previous 20 years, presented to the open literature the Bathymetry Assessment System (BAS): an efficient system to construct accurate depth maps from radar images and a limited number of echo soundings.

The system needs a first guess depth map that may be derived from echo soundings or an old map of the area.

The forward model calculates a simulated radar image.

This is compared with the actual radar image by evaluating a penalty function. The penalty function also contains a term that compares model depths with measured depths and a term that contains a smoothness criterion, prohibiting speckle noise to be interpreted as depth variations. The inversion part of the system consists of optimization of the penalty function. This leads to an iterative procedure in which some model parameters are also estimated. When converged, the model depth is an estimate for the real depth. This model depth matches radar images and echo soundings as closely as possible [10].

Data required for BAS are: sonar sounding data along calibration tracks to allow tuning, tidal data relating to the acquisition time of the SAR image, wind speed and direction relating to the acquisition time of the SAR image, and the SAR image with radar parameters such as the radar wavelength, incidence angle and radar look direction [11].

2. STUDY AREA

Study area is located in the northern part of the Adriatic Sea, it is characterized by shallow turbid waters and bottom is a mixture of sand and mud. The average water depth in the test site is about 20 meters, and the seafloor is deepening gently towards the southeast.



Figure 1. Study area, located in the northern Adriatic Sea

“Acqua Alta” oceanographic platform is located in the study area 17 km from the coast and is equipped with a tide gauge and various meteorological instruments to provide measurement of the sea level and met-ocean conditions. Buoys in the study area will provide additional in-situ data over sea physical parameters. Site characteristics and in-situ data availability gives capabilities for seafloor retrieval.

3. MATERIALS AND METHODS

The bathymetric surveys in deep-water environments are now conducted almost exclusively with multibeam instruments. This instrumentation allows measuring the depth very tightly around the field of investigation by reducing or eliminating the need to estimate the depth at points not sampled. In environments of shallow water,

however, the productivity of such tools is considerably reduced and below a certain head of water they cannot operate. If the investigated areas are the lagoons like the Venezia one, then the complexity must be added the difficulty of navigation, the extreme heterogeneity of the seabed and the changeability of the environment. The approach is to investigate the possibility of using SAR satellite images to integrate a reduced number of measurements, performed with instrumentation multibeam, for the estimation of bathymetry in environments of low water and lagoon. The available data will allow us as a first step to make variographic correlations and analysis of various SAR data sets using multivariate statistical techniques [12].

In-situ data about wind speed and sea level will be used to select available SAR scenes for seafloor detection. The best ERS and ENVISAT C-band images available will be selected for the study case, scene selection will be based on detection model suitable conditions, specifically wind speed between 3 and 10 m/s and strong tidal current. The use of some ALOS-PALSAR L-band SAR will overcome restrictions in complex topography retrieval, as it is more suited for bathymetry applications [7].

Multibeam echo sounders acquisitions will be used to derive the depth map. BAS will be performed using the collected data, preprocessed for the purpose.

It is known from the underwater topography SAR imaging mechanism that the SAR image of the same underwater topography acquired at different time are different because of different tidal current, thus the information of the underwater topography is different and the detection result of one single SAR image can only reflect partially the real topography. We will use a detection model of the underwater topography with a series of SAR images acquired at different time, since it give better results than using a single SAR scene, as described by Yang [13]. One SAR image will be used as the reference image.

The relation between the backscattering cross section of SAR images acquired at different time can be established through tidal current numerical simulation. Different combination of input data, related to SAR imageries and sounding data, will be checked to detect seafloor. A different number of scenes will be used to designate the SAR image series, and scene combinations will count also the use of one L-band SAR. The depth map, derived from echo sounder acquisitions, will be interpolated using a different number of points, in order to define the best compromise between accuracy and data capture costs.

4. RESULTS

This preliminary study could show that under conditions of low density sampling the introduction of SAR information can increase the accuracy of the estimate of bathymetry. The use of this technique can then be integrated advantageously in all those environments with shallow water bathymetric and morphological characteristics where the use of multibeam could be expensive. In particular, the methodology could demonstrate that this method is surprisingly accurate, given the small amount of data that are used to generate the bathymetry. Detection model performance for each input data combination will be evaluated, in order to define the most suitable input data combination for bathymetry retrieval using SAR images.

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6. REFERENCES

1. Alpers W., Hennings I. (1984). A Theory of the Imaging Mechanism of underwater Bottom Topography by Real and Synthetic Aperture Radar. *Journal of Geophysical Research* **89**(6), 10,529-10,54.
2. Vogelzang J., Wensink G.J., De Loor G.P., Peters H.C., Pouwels H. (1992). Sea bottom topography with X-band SLAR: the relation between radar imagery and bathymetry. *International Journal of Remote Sensing* **13** (10), 1943-1958.
3. Vogelzang J. (1997). Mapping submarine sand waves with multiband imaging radar, 1. Model development and sensitivity analysis. *Journal of Geophysical Research* **102**, 1163–1181.
4. Vogelzang J., Wensink G.J., Calkoen C.J., van der Kooij M.W.A. (1997). Mapping submarine sand waves with multiband imaging radar, 2. Experimental results and model comparison. *Journal of Geophysical Research* **102**, 1183–1192.
5. Romeiser R., Alpers W. (1997). An improved composite surface model for the radar backscattering cross section of the ocean surface, 1. Theory of the model and optimization/validation by scatterometer data. *Journal of Geophysical Research* **102**(C11), 25,237-25,250.
6. Romeiser R., Alpers W. (1997). An improved composite surface model for the radar backscattering crosssection of the ocean surface, 2. Model response to surface roughness variations and the radar imaging of underwater bottom topography. *Journal of Geophysical Research* **102**(C11), 25,251-25,267.
7. Greidanus H., Calkoen C., Hennings I., Romeiser R., Vogelzang J., Wensink G.J. (1997). Intercomparison and Validation of Bathymetry Radar Imaging Models. *International Geoscience and Remote Sensing Symposium* **3**, 1320-1322.
8. Hennings I., Lurin B., Didden N. (2001). Radar Imaging Mechanism of the Seabed: Results of the C-STAR Experiment in 1996 with Special Emphasis on the Relaxation Rate of Short Waves due to Current Variations. *Journal of Physical Oceanography* **31**, 1807-1827.
9. Wensink G.J., Hesselmanns G.H.F.M., Calkoen C. J., Vogelzang J. (1997). The bathymetry assessment system. *Elsevier Oceanography Series* **62**, 214–223.
10. Calkoen C. J., Hesselmanns G. H. F. M., Wensink G. J., Vogelzang J. (2001). The Bathymetry Assessment System: Efficient depth mapping in shallow seas using radar images. *International Journal of Remote Sensing* **22**(15), 2973-2998.
11. Alpers W., Campbell G., Wensink H., Zhang Q. (2004). Synthetic Aperture Radar Marine User’s Manual. U.S. Department of Commerce, Ch. 10, pp 245-262.
12. Raspa G., Innocenti C., Taramelli A. (2008). Integrazione geostatistica tra dati di campo ed immagini satellitari multi spettrali per il rilievo batimetrico in ambienti di acque basse. Atti 12a conferenza nazionale ASITA - L’aquila 21-24 ottobre 2008 (proceedings), pp 1717-172.
13. Yang J., Zhang J., Meng J. 2010. A detection model of underwater topography with a series of SAR images acquired at different time. *Acta Oceanologica Sinica* **29**(4), 28-37.