ID15- BATHYMETRIC SURVEYS FROM SAR SATELLITE IMAGES USING WAVELETS

DIOGO SANTOS[1], TIAGO ABREU[2], PAULO A. SILVA[3], PAULO BAPTISTA[4]

1Departamento de Geociências, Universidade de Aveiro, Campus de Santiago, 3810-193, Aveiro, Portugal. E-mail: dmps@ua.pt
2CESAM & Departamento de Engenharia Civil, Instituto Superior de Engenharia do Porto (ISEP-IPP),
Rua Dr. António Bernardino de Almeida, 431, 4249-015, Porto, Portugal. E-mail taa@isep.ipp.pt
3CESAM e Departamento de Física, Universidade de Aveiro, Campus de Santiago, 3810-193, Aveiro, Portugal. E-mail: psilva@ua.pt
4CESAM & Departamento de Geociências, Universidade de Aveiro, Campus de Santiago, 3810-193, Aveiro, Portugal. E-mail: renato.baganha@ua.pt

Abstract

When waves propagate in coastal areas they suffer changes in the wavelength and wave direction resulting from the interaction with the sea bottom. In SAR images, the waves can be identify through variations in the gray tones of the image, making it possible to infer the bathymetry from the variations in the wavelength. Commonly, the fast Fourier transform (FFT) is used to estimate the wavelength in domains close to the coast, recognizing, however, that this method has some limitations, mainly for small depths. To overcome the limitations of FFT, this work uses wavelet spectral analysis to estimate bathymetric data. The new image processing methodology shows positive and promising results for mapping shallow marine environments.

Keywords

Satellite imagery, Bathymetry, Wavelength, Wavelet Transform

INTRODUCTION

The study of the seabed provides information that can be applied in several scientific areas such as marine geology, physical oceanography or civil engineering. The seabed, especially closer to coastal areas, is an extremely dynamic system, with variations in its morphology over short periods of time. Due to these rapid variations, constantly monitoring the morphology of the seabed, especially in coastal areas and harbour areas, is of particular relevance both for navigation safety and in terms of coastal erosion. Currently, the most used methods for monitoring the seabed are based on acoustic systems. These methods, although presenting a very high precision, are relative expensive, difficult to operate in shallow waters and their use depends on weather and wave conditions [1], so monitoring is not done regularly. In areas closer to the coast, the disadvantages mentioned above can be overcome with the use of SAR images obtained by remote sensing. The use of SAR images is possible for two reasons: (i) the waves, as they propagate towards the coast, suffer variations in their wavelength, from the moment the depth is smaller than half the wavelength, and (ii) SAR sensors can capture variations in the roughness of the ocean surface associated with the wavelength. The changes in the wavelength can be estimated using spectral analysis and the dispersion relation can be solved inferring the bathymetry. The most used spectral analysis methodology to estimate the wavelength is the Fast Fourier Transform (FFT). However, previous studies [2] show that this technique presents some limitations to calculate the bathymetry, particularly, for small depths. The NAVESAFETY project "Emerging remote sensing technologies to support real-time safety in navigation in harbour areas" seeks to develop an algorithm that allows estimating the wavelength and associated bathymetry when applied to SAR satellite images.

METHODOLOGY

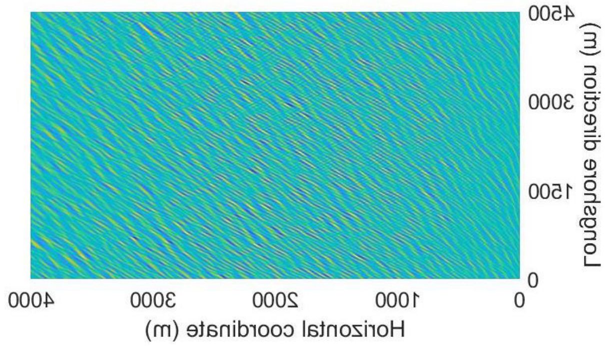
The wavelet transform (WT) is a technique that decomposes a signal into several parts and then analyse the parts separately, enabling to represent a signal in the time and frequency domain at the same time, providing information about the 'when' and 'where' different frequency components occur. Satellite images allow coverage of a wide area, so it is difficult to validate with real data due to their scarcity. In this way, the application of WT to estimate the wavelength was tested with images generated from synthetic data. The advantage of synthetic data is that it is known exactly which bathymetry should result from the application of the WT. The produced synthetic images of the sea surface, that mimic real satellite images (e.g., SAR), were obtained using a wave propagation model that describes properly the temporal and spatial variations in the wave height and wave direction over different known bottoms. The wave propagation model FUNWAVE-TVD that solves the Boussinesq's equations was selected for that purpose.

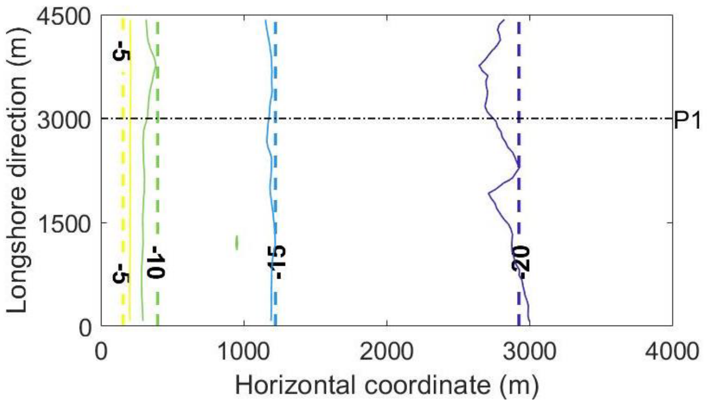
RESULTS

When considering the propagation of irregular waves, with changing wavelength and height patterns, the direct application of the wavelet transform does not work with the accuracy that it does for regular waves. The evaluation of the properties of random waves on a wave-by-wave basis would provide very different wavelength estimates in the analysed spatial domain. Therefore, some solutions were explored to help solving this problem. It was found that performing simultaneously an analysis by subdomains and filters, the results of the methodology were optimized. However, at some points in the spatial domain, some estimated wavelength values revealed sudden unreal changes, differing significantly from other estimates. The solution found to remove these outliers was to use the median in the analysis process. Fig 1 shows the results of applying the WT for a case study with a sand bar in which the propagation of irregular waves was simulated according to a JONSWAP spectrum ($\gamma=3.3$) with a significant wave height of 2m and a peak period of 10s. The results show that the calculated isobaths are roughly disposed parallel to the coast and the sandbar is also reproduced. The errors are small and mostly below 10%, representing absolute errors always below 2 m.

The determination of the seafloor bathymetry from remote sensing imagery presents a rather easier process to explore potentially widespread areas. The direct application of the wavelet transform for irregular waves does not work with accuracy as for regular waves. However, the results of the applied spectral analysis can be optimized by performing simultaneously subdomains analysis and by adopting filters. By doing so, the methodology indicates that the WT is a powerful tool, providing fairly accurate bathymetries. The observed capabilities of this new methodology justify additional work to map shallow marine environments from satellite images that enable retrieving the wave field (e.g., Sentinel-1).

CONCLUSIONS





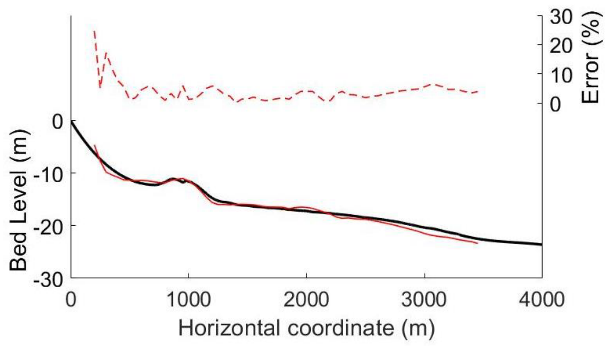


Fig 1. Irregular waves propagating over a sandbar at oblique incidence: (a) generated image representing the two-dimensional wave propagation at the surface; (b) isobaths of the calculated bathymetry over the real bathymetry; (c) cross-shore profile P1 (real - black line; estimation using wavelets - red line) and respective relative errors.

REFERENCES

[1] Jawak, S.D.; Vadlamani, S.S.; Luis, A.J. (2015) A Synoptic Review on Deriving Bathymetry Information Using Remote Sensing Technologies: Models, Methods and Comparisons. Advances in Remote Sensing, 4, 147-162

[2] Pereira, P.; Baptista, P.; Cunha, T.; Silva, P.A.; Romão, S.; Lafon, V. (2019). Estimation of the nearshore bathymetry from high temporal resolution Sentinel-1AC-band SAR data-A case study. Remote Sensing of Environment, 223, 166-178