A New Approach for Bathymetric Video-Inversion: Synthetic Case

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1. Introduction and Methods

Scientists and managers of the coastal zone need to know the coastal bathymetry to understand the behaviour of the beaches and be able to predict their evolution. Intensive monitoring programs through campaigns of direct measurements of the bathymetry are excessively expensive, so that in the last decades alternative methodologies have been developed. Many of them are based on video monitoring stations, and among the different existing algorithms, cBathy (Holman et al., 2013) is the algorithm that achieves the best results.

In a first step, cBathy gets the dominant frequencies and their corresponding wave numbers from the Cross Spectral Matrices (CSMs) of a given set of frequency bands. An estimation of the local water depth is then obtained from the dispersion equation. In the second step, the estimated bathymetries obtained for each video are smoothed through a Kalman filter to obtain the final hourly estimates. This algorithm, which has been used in a number of studies (e.g., Bergsma et al., 2016; Rutten et al., 2017) to obtain 2-D bathymetries, presents however some limitations and/or known problems that have been reported in the literature (Rutten et al., 2017).

The work being presented here is an alternative to the first step of cBathy. It consists of performing a Principal Component Analysis (PCA) to the matrix made of pixel intensities from a series of snaps. The result of the PCA is the decomposition of the video into a set of modes associated with the components of the wave field. The spatial part (the Empirical Orthogonal Function, EOF), is associated with the spatial phase of the wave from which a wave number can be derived. The amplitude of the mode (Principal Component, PC) is associated with the frequency of the wave component. To facilitate the decomposition of the videos in modes of travelling waves, a Hilbert transformation in time of the matrix of intensities has been carried out.

The objective of this work is to explore the feasibility of PCA of video images to obtain beach bathymetries. To this end, artificial videos have been generated by assigning pixel intensity to the elevation of the surface free of synthetic waves, both linear and nonlinear (Shi et al., 2012, for FUNWAVE), propagated over known bathymetries.

2. Results

It has been studied the influence on the results of: the discretization in time and space of the videos; the method to derive frequencies and wave numbers from PC and EOF, respectively; the characteristics of waves; and, finally, the complexity of the bathymetry. As a general result, the PCA is able to capture the individual wave components from which bathymetry can be derived, see Figure 1. For nonlinear waves the PCA also encounters the subharmonic components and reflections. For the most common coastal waves (from 5 to 15s), the method allows resolving the spatial structure of the waves with pixels that cover up to 4 m in real world coordinates and recording images with a frequency of 1Hz or greater.

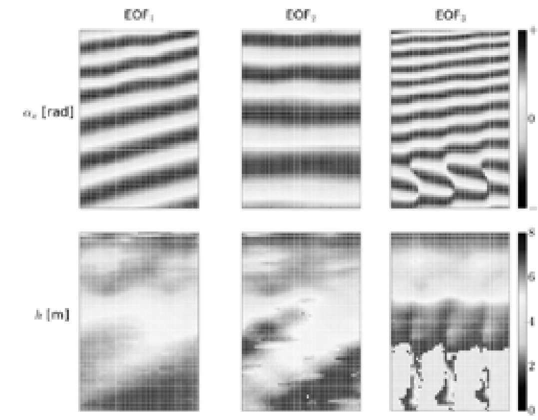

Figure 1. Example of results from PCA. On top the spatial phases, on bottom the recovered bathymetry.

3. Conclusions

PCA of video images allows to isolate the various wave components and determine their frequency and wave numbers, from which the bathymetry can be inferred.

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