Dynamic Averaging Method to Determine Bathymetry Profile from Radar Images

Andreas P. Wijaya\textsuperscript{1,2} and Ismail A. Jabbar\textsuperscript{1}
\textsuperscript{1}PT. Bahari Berjaya Indonesia, Bandung, West Java, Indonesia
\textsuperscript{2}Department Mathematics, Parahyangan Catholic University, Bandung, West Java, Indonesia

ABSTRACT

Radar images, resulted from the observation of ocean waves by a marine radar, can be analyzed to derive a bathymetry profile. The most common method to invert the depth is 3DFFT that requires large partitions in space and many images (typically 64 or 128 images). This requirement is needed to obtain enough wave data for a reliable 3D spectrum. This paper proposes an approach based on the reconstruction process of a series of images, called Dynamic Averaging and Evolution Scenario (DAES). The estimated depth is obtained by comparing a reconstructed image and the reference image in the physical domain.

KEY WORDS: radar; images; wave; coastal; bathymetry; averaging; shadowing.

INTRODUCTION

X-Band marine radars have been used extensively to observe sea surface elevations. They produce images that show the intensity of the reflected radar signal from the sea surface elevations. Although the intensity map does not represent directly the surface elevation, several sea parameters (e.g. wave spectrum (Hoogeboom and Rosenthal, 1982), significant wave height (Ziemer and Dittmer, 1994; Borge et al., 1999), and sea surface current (Young et al., 1985; Senet et al., 1997)) can be derived from the images. In recent years, attempts to reconstruct and predict phase-resolved waves have been carried out (Dankert and Rosenthal, 2004; Aragh et al., 2008; Alford et al., 2014; Naaijen and Wijaya, 2014; Wijaya et al., 2015). Besides the purpose of the surface information, the analysis of the images can be aimed for the seabed profile. This information is really important for coastal activities. The common way to measure the depth is by using an echo sounding device that is usually attached to a ship or a jet ski. The measurement result using this technique is accurate but expensive and time-consuming. The use of X-band radar can overcome these drawbacks.

Several depth inversion methods from radar images have been reported in the last decades. Based on linear wave theory, the depth inversion was derived from the linear dispersion relation (Bell, 1998; Bell, 1999; Hessner et al., 1999). The objective of the methods was to find two wave parameters, i.e. the wave period and the local wave velocity (or the frequency and the local wavenumber) such that the estimated depth can be calculated. Holman et al. (2013) analyzed images from several cameras and introduced cBathy algorithm that consisted of three steps: frequency-dependent analysis, frequency-independent estimation, and estimation of the depth via a Kalman Filter method. Afterwards, Honegger et al. (2019) applied the cBathy algorithm to X-Band radar images. Zuckerman and Anderson (2018) improved the cBathy algorithm such that the depth estimation from X-Band radar images was carried out without any a priori knowledge of the survey area. The most common method to retrieve frequency-wavenumber pairs from a sequence of radar images is 3DFFT method that involves the calculation of a 3D fast Fourier Transform performed on the images. To estimate the depth the linear dispersion is then fitted to the frequency-wavenumber pairs (e.g. Trzina, 2001; Friedman, 2014). Ludeno et al. (2015) performed the 3D FFT on images to obtain a 3D image spectrum and the depth was estimated by optimizing the so-called Normalized Scalar Product (NSP) between the 3D spectrum and a characteristic function denoting a dispersion shell. The problem with 3DFFT method is that the method is categorized as a global method, hence in order to estimate local depth, the spatial domain of the images should be partitioned into several smaller areas. These are limited by the requirement of 128-256 analysis tiles (or more, depending on the number of wavelength in the tiles). The smaller area will reduce the spectral resolution and will leads to a lower accuracy of the estimated depth (Piotrowski and Dugan, 2002). Senet et al. (2008) introduced a method called Dispersive Surface Classificator (DiSC) that can overcome the spectral resolution limitation occurred in the global 3DFFT method by a spectral decomposition. An approach based on 2DFFT method was proposed by Abileah and Trizna (2010). The depth was estimated by the minimization of the difference between image pairs in the 2D Fourier domain. Since the images are available at different times a propagation kernel was applied on the preceding image.

This paper proposes a different method based on image reconstruction, called Dynamic Averaging and Evolution Scenario (DAES), introduced by Wijaya et al. (2015). The DAES method has been proven to be able to reconstruct poor images that are severely modulated by the shadowing effect. The idea of the depth inversion method is to find the optimal depth that minimizes the difference of an image and a reconstructed image.