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Remotely sensing in detecting the water depths and bed load of shallow waters and their changes

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Abstract

Bed load is a type of sand drift and accumulation on the sea-bed. Sand drift is a very important index to survey the erosion or deposition of coastal zone. The change of water depths indicates the change of bed load in shallow waters. The conventional method for measuring water depth uses the shipboard echo sounder, which is accurate for point-measurement, but is a time-consuming and labor-intensive task. For periodic survey of bathymetry as synoptic scale, the remote sensing method may be a viable alternative. Wave spectrum bathymetric (WSB) method takes advantages of remote sensing to obtain the bathymetry of shallow waters safely, economically and quickly. The WSB method is feasible to detect the change of water depths over coastal zones where water depths are less than about 12 m. This remote sensing method is worthy to be well developed and efficiently applied to change detection of water depths and bed load in shallow waters.

Keywords: Wave spectrum; Water depth; Bed load; Sand drift; Bathymetry; Change detection

1. Introduction

The bathymetry of coastal waters is of vital importance to coastal ocean engineering projects as well as the shipping safety. The conventional method for measuring water depths uses the shipboard echo sounder, which is accurate for point-measurement, but is a time-consuming and labor-intensive task. For periodic survey of bathymetry at synoptic scale,

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the remote sensing method may be a viable alternative. There are several indirect methods for remotely sensing water depths. One is the optical bathymetry method, which is based on the principles that the total reflected energy of electromagnetic waves from a water column (including the water surface, the water body and the sea bottom) varies with the water depth. Actually, the reflectivity of visible light depends on the quality of the water column and the type of sea floor; the depth of highly turbid water is difficult to be determined by the optical bathymetry method (Hengel and Spitzer, 1991; Tripathi and Rao, 2002). Other methods use radar, such as Synthetic Aperture Radar (SAR), or Side Looking Airborne Radar (SLAR) images to derive the bathymetry of near shore with fairly good results (Kasischke et al., 1983; Alpers and Hennings, 1984; Vogelzang, 1992). Variation in bathymetry or texture of the sea floor under a strong tidal current induces spatial variation of the sea surface roughness. Therefore, studying the backscattered radar intensity along with simultaneous data of wind speed and surface water velocity allows us to determine the sea bottom features under all weather conditions. Generally, the field observation part of this method is relatively difficult to carry out. In this study, an indirect method of remote sensing is applied to determine the water depths and to overcome problems described above. As waves propagate onshore, their wavelengths decrease with water depths in the coastal zone. Therefore, the two-dimensional wavenumber spectrum may be used to derive the water depth. A method has been developed to obtain the bathymetry of shallow waters from wave spectra (Leu, 1998; Kuo et al., 1999). This method is called the Wave Spectrum Bathymetric (WSB) method. The goal of this study is to adopt the WSB method mapping bathymetry of shallow waters and detecting the change of water depths and bed load in coast zone.

In order to use the WSB method to derive the bathymetry of the coastal zone, one has to start by analyzing the wave field. Remote sensing techniques used to observe the water surface waves rely on spatial measurement. In the early development of this method, photography was used to detect the water waves (Cox and Munk, 1954). Since US launched the satellite SEASAT in 1978, SAR images were used to observe sea surface waves (Beal, 1980). The French satellite, Systeme Pour l'observation de la Terre (SPOT) has a visible sensor that provides high-resolution images of surface waves. Unlike the optical bathymetry method where the sensitively is affected by the water quality and the bottom reflectivity, the WSB method is especially suitable for estimating water depths in the west of Taiwan where water quality varies in a short distance. In this paper, two SPOT images over Taichung Harbor (Fig. 1) are analyzed for the spatial distribution of their wavenumber spectra. Assuming that the frequency of wave does not change, and the general dispersion relation between the water depth and the wavelength holds during the wave propagation, we may determine the coastal water depths from the spatial variation of the wave spectra. This WSB method has feasible application because it does not depend on other environmental data, like the water quality and bottom reflectivity for the optical method, and the simultaneously observed wind speed and surface current velocity for analyzing radar images. Vesecky and Stewart (1982) suggest that waves will not be imaged by SAR if the significant waveheight is less than 1.4 m. Generally, the good result of WSB method can be derived from the visible imageries with high spatial resolution and clear wave pattern. Further, by analyzing multi-temporal images, this WSB method could be applied to detect the water depths and bed load accumulated in coastal zone and their changes.