Global Shallow-Water Bathymetry From Ocean Color Satellites

Knowledge of ocean bathymetry is important, not only for navigation but also for scientific studies of the ocean's volume, ecology, and circulation, all of which are related to Earth's climate. In coastal regions, moreover, detailed bathymetric maps are critical for storm surge modeling, marine power plant planning, understanding of ecosystems connectivity, coastal management, and change analyses. Because ocean areas are enormously large and ship surveys have limited coverage, adequate bathymetric data are still lacking throughout the global ocean.

Satellite altimetry can produce reasonable estimates of bathymetry for the deep ocean [Sandwell et al., 2003, 2006], but the resolution is very coarse (4–5-kilometer) and can be highly inaccurate in shallow waters, where gravitational effects are small. For example, depths retrieved from the widely used ETOP02 bathymetry database (the National Geophysical Data Center's 2-minute global relief data; http://www.ngdc.noaa.gov/mgg/liffs/htimag04.html) for the Great Bahama Bank (Figure 1a) are seriously in error when compared with ship surveys [Dierssen et al., 2010] (see Figure 1b). No statistical correlation was found between the two bathymetry measurements, and the root-mean-square error of ETOP02 bathymetry was as high as 208 meters. Yet determining a higher-resolution (e.g., 300-meter) bathymetry of this region with ship surveys would require about 4 years of nonstop effort.

Clearly, alternative methods are needed for estimating bathymetry in shallow coastal regions. A rapid and relatively robust method may be found through a new way of looking at satellite measurements of ocean color. This takes advantage of the fact that photons hitting the shallow ocean bottom and reflecting back to the surface modify the appearance of ocean color.

Retrieving Depth From Analyzing Spectral Data

It is well known that measurements of water color could help define bathymetry in shallow regions [Czerny, 1985; Pykaret al., 1970]. Earlier methods to estimate bathymetry from ocean color, however, were limited to approaches [Czerny, 1981; Polcyn et al., 2003; Klonowski et al., 1994; Doerffer and Fischer, 1991] that could not transferable to other images or areas. Further, the approach is not applicable for regions difficult to reach, due to lack of in situ calibration data.

To overcome such a limitation, a physics-based approach, called hyperspectral optimization process exemplar (HOPE), has been developed [Lee et al., 1999]. Basically, the spectral reflectance (Rs) of water-leaving radiance to downwelling irradiance hitting the sea surface is modeled as a function of five independent variables that include water depth. In a fashion similar to other spectral optimization schemes [e.g., Doerffer and Fischer, 1994; Klonowski et al., 2007; Brando et al., 2009], HOPE derives bottom depth by iteratively varying the values of the five unknowns until the modeled Rs best matches the measured Rs.

Unlike the empirical approaches used for retrieving depth from water color [Czerny, 1981; Polcyn et al., 2003], the only required inputs for HOPE are the spectral reflectance data obtained from a remote sensor, thus eliminating the need for image-specific or region-specific algorithm tuning.
New Approach

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also of having reduced logistics costs, higher production rates, and less impact on the environment than explosives. Further investiga-
tions should address appropriate selec-
tion of vibrator size (commercially avail-
able vibrators range from 50 kilograms to more than 10 tons) for a trade-off between resolution and penetration depth de-
pending on target objectives and the applicabil-
ity of vibrator types (inducing shear or pres-
sure waves) for sophisticated analyses meth-
ods such as amplitude variation with offset.

Logistical limitations require improved implementa-
tion such as mounting a vibrator

... directly on a sled (instead of on a

truck as done at George VI Ice Shelf).

The key points of the study, which could be

extended to other ice shelves, are as follows:

1) Vibroseismic measurements should be

performed using smaller airplanes.

2) Use of around 3 meters cautions against

the use of small-scale techniques.

3) The measurement of water depth by remote sensing is robust and repeatable. Although the error

on the order of 10 cm is large, it is

small enough for large-scale applications

... but also high-resolution shallow-bottom

measurements are coupled with high-sensitivity

sea-level wave center for the transport on

ices around the world.

Fig. 1. Comparison of shot files sampled at 1-millisecond intervals.

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