Estimating coastal water depth from space via satellite-derived bathymetry

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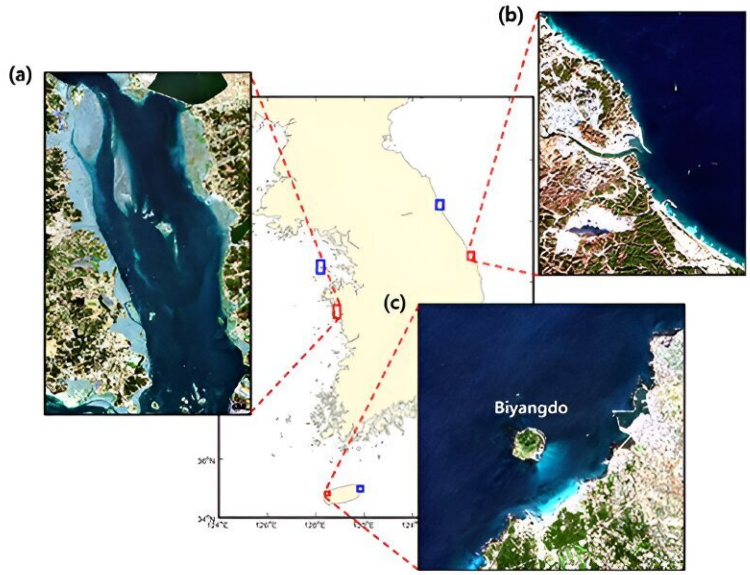

The proposed satellite data-based model provided coastal depth estimations for three Korean coastal areas with unique characteristics: Cheonsuman (a), Hallim (b), and Samcheok (c). Credit: *Journal of Applied Remote Sensing* (2024). DOI: 10.1117/1.JRS.18.014522

Since ancient times, knowing the depth of coastal waters has been key to safe and successful navigation and to exploit the sea's resources. Today, bathymetry—the measurement of sea depth—is even more important, playing essential roles in our understanding of marine environments and the development of large marine structures.

With the development of shipborne echo sounders in the early 20th century, bathymetric surveys saw massive leaps in both accuracy and convenience. However, even with modern echo sounders, there are still many hardships to overcome when conducting bathymetric surveys. These include high cost, unpredictable weather, high ship traffic, and potential geographic or diplomatic issues, to name a few.

To address these issues, scientists around the world have been developing satellite-derived bathymetry (SDB) techniques, which estimate water depth from multispectral satellite images. These methods can sometimes produce accurate results, especially for depths up to 20 meters.

Unfortunately, most SDB models were developed using data from coastal regions with clear waters and a uniform distribution of seabed sediment. Since light reflects differently depending on water turbidity and the composition of the seabed, developing SBD models with consistent performance throughout different coastal environments has proven challenging.

Against this backdrop, a research team from Korea has been developing a new SDB model that leverages machine learning to shed light onto the various factors that can compromise accuracy, thus paving the way to potential solutions. Their latest study, which included Dr. Tae-ho Kim from Underwater Survey Technology 21 (UST21), is published in the *Journal of Applied Remote Sensing*.

One of the main goals of this study was to analyze how the model trained on different coastal regions would be affected by each region's unique characteristics. To this end, they selected three areas around the Korean Peninsula: Samcheok, characterized by its clear waters; Cheonsuman, known for its turbid waters; and Hallim, where the seabed contains various types of sediments.

The team obtained multispectral satellite data of these regions from the Sentinel-2A/B missions, openly provided by the European Space Agency, and selected multiple images of these areas at different time points with clear skies. To train the SDB model on these data, they also acquired echo sounder-derived nautical charts from the Korea Hydrographic and Oceanographic Agency (KHOA); these charts were used as ground truth.

The SDB model itself was based on a well-established theoretical framework that links how light coming from the sun is reflected by the atmosphere, the sea, and the seabed before reaching a satellite. As for the machine learning part of the model, the team employed a random forest algorithm because of its ability to adjust to multiple variables and parameters while handling large amounts of data.

Upon training and testing region-specific instances of the SDB model, the researchers found that accuracy was generally acceptable for Samcheok, with a root-mean-squared error of about 2.6 meters. In contrast, accuracy was markedly lower for both Cheonsuman and Hallim, with satellite-based depth predictions deviating significantly from KHOA measurements.

To understand these discrepancies better, the researchers first tried correcting the predictions by including a turbidity index in the calculations. This improved results mainly for Cheonsuman. Then, to further investigate the sources of error, the team acquired high-resolution satellite images from the WorldView-3 mission, as well as on-site photos. Analyses revealed the reflectance characteristics of the seabed sediments had a large impact on depth estimations, with dark-colored basalt leading to a consistent overestimation.

"If we incorporate additional seabed spatial data into the training dataset in the future, we anticipate enhancements in model performance," said

Dr. Kim. "A sediment distribution map, created from airborne hyperspectral imaging, is scheduled to be provided by R&D project."

Finally, the researchers then tested the generalization capability of their approach by applying region-specific SDB models on other coastal areas with similar characteristics.

"Unlike previous studies that presented SDB model results for waters with high transparency only, we developed individual SDB models that can be applied to waters with various characteristics, and suggested methods for obtaining improved results," Dr. Kim said.

With any luck, these efforts will lead to improvements in SDB technology and pave the way for more convenient coastal depth mapping.

Satisfied with the results, Dr. Kim concludes, "Ultimately, SDB results will be applied as depth monitoring data to facilitate safe ship passage in coastal areas, as well as input data for numerical ocean models, contributing to various scientific fields."

More information: Jae-yeop Kwon et al, Estimation of shallow bathymetry using Sentinel-2 satellite data and random forest machine learning: a case study for Cheonsuman, Hallim, and Samcheok Coastal Seas, *Journal of Applied Remote Sensing* (2024). DOI: 10.1117/1.JRS.18.014522

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