Coastal Bathymetry Mapping Using High-Resolution Optical imagery

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Abstract

Accurate maps of the submarine topography are required to navigate in shallow water areas. Although field measurements are in many cases necessary for channel beaconing, remote sensing offers alternative cost-effective and efficient means for mapping bathymetry over broad areas. In addition, in the areas characterized by high morphologic variability, field-based empirical calibrations of the images can be performed to map the bathymetry map of the inlet partially achieved by local management authorities based on field data (Froidefond and Lafon, 2012). The resulting accuracy of the map produced by this approach depends on the water turbidity condition and the composition changes that are expected to occur inside the study area. Also, it is constrained by the spatial coverage of the field data. However, the root mean square error achieved on the computed depth is about 50 cm. With the aim to develop an operational and less constrained approach for mapping broad areas with heterogeneous optical properties, semi-analytical methodologies are applied both to the inlet of Arcachon (Lafon et al., 2002; Capo, 2012) and to shallow coastal areas (Capo et al., 2012). This methodology requires the acquisition of optical measurements to invert the space-based reflectance into depth. Based on this methodology which was applied to SPOT imagery, the accuracy of the derived maps ranges from 40 cm to 1 m on average. The retrieved depth accuracy appears to be limited by the spatial resolution of the sensors. Thus, the super-resolution high resolution Sentinel-2 mission is expected to substantially improve the inversion of physics-based radiative transfer models.

Over deeper places where reflectance-based algorithms are not applicable any long, the estimation of nearshore bathymetry is obtained by inverting the linear wave dispersion relationship from either remotely sensed optical or SAR images (Splinter and Holman, 1999). Along the Arcachon coast, this method is exploitable down to about 40 m depth (Guérin, 2010). In order to fulfill manager demand regarding the achievement of electronic morphological analysis based on space-based imagery, a service demonstrator integrating optical- and wave-inverted depth is currently developed in the framework of the INFOLITTORAL-1 program based on SPOT and Formosat-2 imagery. This demonstrator will be further promoted in the GMES-like APSAT-BR project downstream service funded by INTERREG. In the perspective of INFOLITTORAL and BALIST demonstrators, Sentinel-2 is expected to ensure the development and sustainability of coastal observation services worldwide.

In shallow waters, empirical fitting is time-efficient, but requires simultaneous high-density soundings in order to provide accurate results whatever the variations of turbidity. Thus, this method is excessively and only adapted to already surveyed coastal regions. Conversely, the semi-analytical approach can be implemented in any place without any ground truth data needed. The model needs in situ and/or remotely-sensed inherent optical properties values. It also requires accurate top-ocean imagery to invert reflectances in realistic water depths. As this is still a hard task to deal with in coastal areas, bathymetric applications are still a challenging task. The main formulation and adjustments of the QAA model to fit the HR systems requirements have demonstrated a reliable algorithmic inversion but insufficient accuracy for now. However, the higher number of Sentinel-2 spectral bands compared to SPOT offers potential for improving the inversion of physics-based radiative transfer models.

In deeper waters, the Inversion of wave imagery reveals a great potential but needs further work. The INTERREG APSAT-BALIST R&D project (2012-2014) aims at developing operational GMES services for such bathymetry and coastal monitoring applications.

References


NEARSHORE MORPHOLOGY RECONSTRUCTION

Fig. F : Empirical approach. The accuracy is satisfying (0.5 m) and not depth-dependent.

Fig. G : Semi-analytical model. The accuracy is depth-dependent getting worse with larger water depths. The computed depths are under-estimated when water depth exceeds 2.5 m.

Fig. H : Interpolation of multi-spectral bathymetric data. A special method for bathymetric data interpolation was also developed, incorporating the local anisotropy of the study area due to curvilinear structures like channels.

Fig. I : Study of the morphodynamic processes in a mesotidal inlet

APPLICATION:

MONITORING OF COASTAL MORPHODYNAMICS

Fig. J : Beach management and nourishment monitoring (interannual loss surfaces are in red)

Conclusions

In shallow waters, empirical fitting is time-efficient, but requires simultaneous high-density soundings in order to provide accurate results whatever the variations of turbidity. Thus, this method is excessively and only adapted to already surveyed coastal regions. Conversely, the semi-analytical approach can be implemented in any place without any ground truth data needed. The model needs in situ and/or remotely-sensed inherent optical properties values. It also requires accurate top-ocean imagery to invert reflectances in realistic water depths. As this is still a hard task to deal with in coastal areas, bathymetric applications are still a challenging task. The main formulation and adjustments of the QAA model to fit the HR systems requirements have demonstrated a reliable algorithmic inversion but insufficient accuracy for now. However, the higher number of Sentinel-2 spectral bands compared to SPOT offers potential for improving the inversion of physics-based radiative transfer models.

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Acknowledgements

Satellite data analysis is funded by INFOLITTORAL-1 program, the Biscarrosse City Council and the SIBA (Syndicat Intercommunal de Bassin d’Arcachon).