

Editorial

# Editorial on Special Issue “Applications of Remote Sensing in Coastal Areas”

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Coastal areas are remarkable regions with high spatiotemporal variability. Many domains are affected by their physical and biological processes, from tourism to biodiversity and productivity. Coastal ecosystems perform several critical ecosystem services and functions such as water oxygenation and nutrient provision, seafloor and beach stabilization (as sediment is controlled and trapped within the rhizomes of the seagrass meadows), carbon burial, and areas for nursery and refuge of several commercial and endemic species. Knowledge of the spatial distribution of marine habitats is prerequisite information for the conservation and sustainable use of marine resources. This Special Issue contains 14 papers in several fields of coastal remote sensing and reveals the potential of remote sensing in integrated coastal management.

Cliff coasts are dynamic environments that can retreat very quickly. However, short-term changes and factors contributing to cliff coast erosion have not received as much attention as dune coasts. Terefenko et al. [1] conducted work at three soft-cliff systems in the southern Baltic Sea; these have been monitored with the use of terrestrial laser scanner technology over a period of almost two years to generate a time series of 13 topographic surveys. Digital elevation models constructed for those surveys allowed the extraction of several geomorphological indicators describing coastal dynamics. Combined with observational and modeled datasets on hydrological and meteorological conditions, descriptive and statistical analyses were performed to evaluate cliff coast erosion. A new statistical model of short-term cliff erosion was developed by using a non-parametric Bayesian network approach. The results revealed the complexity and diversity of the physical processes influencing both beach and cliff erosion. Wind, waves, sea levels, and precipitation were shown to have different impacts on each part of the coastal profile. At each level, different indicators were useful for describing the conditional dependency between storm conditions and erosion. These results are an important step toward a predictive model of cliff erosion.

Poursanidis et al. [2], for first time, exploit the capabilities of PlanetScope Cubesats for the calculation of coastal bathymetry. High spatial and temporal resolution satellite remote sensing estimates are the silver bullet for monitoring of coastal marine areas globally. From 2000, when the first commercial satellite platforms appeared offering high spatial resolution data, mapping of coastal habitats and extraction of bathymetric information have been possible at local scales. Since then, several platforms have offered such data, although not at high temporal resolution, making the selection of suitable images challenging, especially in areas with high cloud coverage. PlanetScope

CubeSats appear to cover this gap by providing their relevant imagery. The current study is the first that examines the suitability of them for calculating satellite-derived bathymetry. The availability of daily data allows the selection of the most qualitatively suitable images within the desired timeframe. The application of an empirical method of spaceborne bathymetry estimation provides promising results, with depth errors that fit to the requirements of the International Hydrographic Organization at the Category Zone of Confidence for the inclusion of these data in navigation maps. While this is a pilot study in a small area, more studies in areas with diverse water types are required for solid conclusions on the requirements and limitations of such approaches in coastal bathymetry estimations.

Coastal dunes provide the hinterland with natural protection from marine dynamics. The specialized plant species that constitute dune vegetation communities are descriptive of the dune evolution status, which in turn reveals the ongoing coastal dynamics. De Giglio et al. [3] work towards demonstrating the applicability of a low-cost unmanned aerial system for the classification of dune vegetation, in order to determine the level of detail achievable for the identification of vegetation communities and define the best-performing classification method for the dune environment according to pixel-based and object-based approaches. These goals were pursued by studying the North Adriatic coastal dunes of Casal Borsetti (Ravenna, Italy). Four classification algorithms were applied to three-band orthoimages (red, green, and near-infrared). All classification maps were validated through ground truthing, and comparisons were performed for the three statistical methods, based on the  $k$  coefficient and on correctly or incorrectly classified pixel proportions of two maps. All classifications recognized the five vegetation classes considered, and high spatial resolution maps were produced (0.15 m). For both pixel-based and object-based methods, the support vector machine algorithm demonstrated a better accuracy for class recognition. The comparison revealed that an object approach is the better technique, although the required level of detail determines the final decision.

Coastal areas harbor the most threatened ecosystems on Earth, and cost-effective ways to monitor and protect them are urgently needed, but they represent a challenge for habitat mapping and multitemporal observations. The availability of open access remotely sensed data with increasing spatial and spectral resolution is promising in this context. Thus, in a sector of the Mediterranean coast (Lazio region, Italy), Marzialesi et al. [4] tested the strength of a phenology-based vegetation mapping approach and statistically compared results with previous studies, making use of open source products across all the processing chain. We identified five accurate land cover classes in three hierarchical levels, with good values of agreement with previous studies for the first and the second hierarchical levels. The implemented procedure resulted as being effective for mapping a highly fragmented coastal dune system. This is encouraging to take advantage of Earth observations through remote sensing technology in an open source perspective, even at the fine scale of highly fragmented sand dunes landscapes.

One of the most important linear features on the Earth's surface is coastline; thus, the detection and monitoring of dynamic coastlines through time and space is critical for tracking changes in vulnerable coastal zones and managing increasingly threatened water resources. In their study, Bishop-Taylor et al. [5] evaluated a method for mapping waterlines at subpixel accuracy from satellite remote sensing data, combining a synthetic landscape approach with high-resolution WorldView-2 satellite imagery. Their method reproduced, with confidence, both absolute waterline positions and relative shape at a resolution that exceeds that of whole-pixel thresholding methods in environments without extreme contrast between water and land. Their subpixel waterline extraction method is available as an open source tool and has low computational overhead; thus, it is suitable for continental-scale or full time-depth analyses aimed at accurately mapping and monitoring dynamic waterlines.

Sha et al. [6] revealed asymmetric oceanic thermal responses corresponding to an island wind wake and proposed associated mechanisms with ocean heat advection terms. Using multisensor remote sensing observations including advanced synthetic aperture radar (ASAR), the work investigated the sub-mesoscale features of the local wind wake. Then, by combining the satellite observations and

model results, the ocean heat advection terms were reconstructed and compared with the air–sea heat flux. The results highlighted the contribution of the wind-driven heat advection in the regional ocean thermal dynamic process.

Unmanned aerial systems (UAS) are used in an increasing number of applications, especially for data acquisition, to map spatiotemporal changes. Papakonstantinou et al. [7] used UAS true-color RGB (tc-RGB) and multispectral high-resolution orthomosaics by applying object-based image analysis (OBIA) to map marine habitats. Furthermore, they examined the usefulness of bathymetry and the roughness of information derived from the echo sounder as training data to the UAS-OBIA methodology, applying three different scenarios using k-nearest neighbor (k-NN), fuzzy rules, and their combination as classifiers. High-resolution classification maps produced from the methodology followed, providing valuable information regarding the current state of the habitat species and enabling in-depth analysis of change detections caused by anthropogenic interventions and other factors.

Sea-level rise, storm surges, and many other ocean dynamics affect coast vulnerability and lead to hazards such as beach erosion, sedimentation, or inundation. By using 40 years of satellite observations from multisensors, Waqas et al. [8] analyzed spatial and temporal variations of barrier islands (BIs) along the Indus Delta region of the Pakistan coast. They concluded that approximately 75% of these BIs are vulnerable to the ocean controlling factors. Therefore, coastal protection and management along the Indus Delta should be adopted to defend against the erosive action of the ocean.

On the other hand, reclaimed lands or islands may also suffer the problem of ground subsidence in addition to the erosion by the ocean. Liu et al. [9] showed that the maximum annual subsidence rate of the new airport constructed on the reclaimed land of the Xiamen City reached  $-130$  mm/year between 2015 and 2016, based on the interferometry of Sentinel-1 SAR data.

To map fine variations of the coastal zone, Almeida et al. [10] proposed a method of deriving high-resolution (2.0 m) DEM from the Pleiades satellite data with a pixel size of 0.7 m, which showed a good agreement with ground truth measurements by GPS.

Besides spaceborne optical and radar sensors, which are widely used for coastal monitoring, other instruments exhibit their advantages for some applications. Ma et al. [11] proposed a method of detecting photon signals of Lidar, by which they estimated surface profiles of different surface types in coastal zones.

Song et al. [12] proposed a semi-global subpixel shoreline localization method based on Landsat 8 Operational Land Imager (OLI) data. Authors selected the port of Caofeidian and the Xiamen coastal area as the study areas and utilized higher-resolution shoreline extracted from GF-2, which is capable of acquiring optical images with a spatial resolution better than 1 m. The proposed methodology utilizes global spectral information and shoreline morphological features coupled with local water index homogeneity features to determine the artificial shoreline with an RMSE of less than 5 m.

Cao et al. [13] analyzed 40 features extracted via polarimetric decomposition in the full-polarimetric (FP), simulated compact-polarimetric (CP), and dual-polarimetric (DP) SAR modes for ship detection using the Euclidean distance and mutual information. Authors found that the features in CP SAR were better than those of FP or DP SAR in general. The study also proposed a CP SAR based feature, named 'phase factor'. In the framework of the study, the authors concluded the 'phase factor' based detector performed better than other traditional ship detection techniques in low, medium, and high sea states.

Su et al. [14] proposed sea ice information indexes using medium resolution Sentinel-3 Ocean and Land Color Instrument (OLCI) images and validated the index performance using Sentinel-2 MultiSpectral Instrument (MSI) images with higher spatial resolution. The study evaluated the proposed Enhanced Normalized Difference Sea Ice Information Index based on 4 OLCI bands (B12, B16, B20, and B21). Authors demonstrated that the proposed index effectively detected sea ice information in the Bohai Sea and suppressed most background information compared to other established methods.

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