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*Editorial*

# Advances in Remote Sensing of the Inland and Coastal Water Zones

**Jacek Lubczonek [1,*], Paweł Terefenko [2], Katarzyna Bradtke [3] and Marta Wlodarczyk-Sielicka [1]**

[1] Chair of Geoinformatics and Hydrography, Maritime University of Szczecin, 70-500 Szczecin, Poland
[2] Institute of Marine and Environmental Sciences, University of Szczecin, 70-453 Szczecin, Poland
[3] Institute of Oceanography, University of Gdańsk, 80-309 Gdańsk, Poland
* Correspondence: j.lubczonek@pm.szczecin.pl

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Coastal zone areas are important parts of the environment, very often subject to constant change. This applies to both marine and inland coastal zones. Factors for these changes can include the natural impact of marine and inland waters on land, anthropogenic activities, environmental changes affecting the ecosystem, or climate change. Given that coastal zone areas cover diverse types of regions, including urbanised as well as non-urbanised regions, they often have an impact on the functioning of ports, natural or recreational areas, or on human activities. Therefore, these two environments require constant monitoring. Increasingly detailed and diverse remote sensing data of the aquatic environment and adjacent areas enable comprehensive studies, often related to the increasing resolution, completeness, availability, or the development of the survey instruments themselves. This Special Issue presents scientific papers related to studies of the coastal zone environment and inland waters, addressing complex and current trends in solving scientific problems. The research presented in the publications deals with the application of geospatial techniques such as the classification of submerged vegetation and wetlands, the geomodelling of remote sensing data to create combined bathymetric and topographic models, atmospheric corrections of airborne hyperspectral images, the creation of bathymetric surfaces from unmanned aerial vehicle (UAV) and unmanned surface vehicle (USV) data, image processing for monitoring underwater objects, the determination of sound velocities in shallow-water areas, analyses of multi-temporal shoreline changes in the Baltic Sea using aerial imagery, supporting navigation processes using modern geospatial environments in the form of augmented and virtual reality, assessments of adjacency correction using Sentinel-2 MSI images, applications of optical and synthetic aperture radar images and data analysis techniques to quantify vertical ground displacements, and applications of the Google Earth Engine for monitoring sand split variability. Twelve publications providing new insights into the subject of remote sensing of inland and coastal water zones are presented, detailed below.

The research in the first publication [1] addresses the issue of estuary degradation, which is rapidly increasing due to anthropogenic pressure. The twin Sentinel-2 A/B satellites of the Copernicus program were used to study the Guadiaro River estuary (Spain) over a 4-year period (2017–2020). Mapping of marine sites was performed using the Normalised Differential Water Index (NDWI) in the Google Earth Engine (GEE) platform, selecting Sentinel-2 Level 2A imagery. In this study, an optimised data processing method was developed. Through research using the optimised data processing method, the considerable potential of Sentinel-2 as well as GEE images for estuarine monitoring was found. In addition, the practical aspect of the developed image processing method was shown, related to possible continuous and detailed monitoring of the estuary.

Observations from the C-band Envisat/ASAR and Sentinel-1A sensors (2004–2010 and 2014–2016) enabled the study of vertical ground displacements and assessment of their contribution to coastline erosion along the Karachi Coastline (Pakistan) [2]. The results suggest that some coastline parts are subsiding at comparable rates to, or even much higher than, the relative sea-level rise. Landsat images from 1989 to 2018 (10-year temporal resolution) were further used to examine the state of coastline erosion using different statistical approaches. The results indicate that rapid urbanization, construction on reclaimed land, coastline erosion favouring seawater intrusion, failed drainage/sewerage networks, and soil liquefaction are contributing to the site-specific variations in land displacement in Karachi.

Quantifying water quality using medium-resolution optical satellite sensors for small inland lakes is challenging due to distortions of the water signal by radiation reflected from the surrounding land surface and scattered in the atmosphere towards the radiometer. In [3], the authors used Sentinel-2/MSI images and in situ optical measurements to assess the uncertainty of reflectance derived from satellite data due to adjacency effects for lakes surrounded by both natural and urbanized environments and characterized by different optical characteristics of water. They assessed the importance of factors such as aerosol load, water body shape and size, differences in the reflectance of water and land cover on the strength of this effect, and the accuracy of its correction. Using a physical approach based on the Atmospheric Point Spread Function (APSF) to correct the influence of the surrounding land on the reflectance determined from the satellite data, the authors achieved good agreement with in situ observations, especially in the visible part of the spectrum (MAPE close to 50%), while pointing out that proper determination of the horizontal range of the adjacency effect is crucial for the correction.

A remarkably interesting solution is the use of augmented and virtual reality to support the safe navigation of sailors in inland shallow waters proposed in [4]. The authors identified a new solution used during bottom modelling. Nowadays, these models are mainly represented by visualizations on standard displays. The proposed solution, augmented reality (AR) technology, is a new and interesting approach for their presentation. The authors proposed the use of AR on inland and coastal waterways to enhance the safety of boating and other water-sports-related tourist activities. They showed the detailed architecture and prototype of an augmented reality mobile application (MAR). Notably, the authors also demonstrated that the real-time AR capabilities enabled the observation of other users on the water in conditions of limited visibility and at night. Their study shows that the performance of the prototype has been verified during tests on the waters of the lakes of Warmia and Mazury in Poland. The tests clearly indicated that the proposed solution can be used in practice.

One example of the analysis of coastal changes on a protected section of the southern Baltic coast, free from anthropogenic impacts, is presented in [5], based on historical and contemporary aerial photographs and orthophotomaps. The authors determined the size and intensity of morphodynamic changes in 1951–2016 (a period of 65 years) and indicated the intensification of erosion and accumulation processes as a result of the occurrence of severe storms. The obtained results confirm that despite the periodical changes in the regime from accumulative to erosive, and vice versa, the coastal processes on such naturally formed sections of the shoreline remain in balance.

Unmanned surface vessels are very often equipped with single-beam echo sounders (SBES) and multi-beam echo sounders (MBES), which measure depths in bodies of water. These devices need information about the speed of sound in the water. Makar, in [6], proposed a simplified method for determining the speed of sound in water based on temperature measurements and salinity prediction for shallow-water bathymetry. His main objective was to develop a method to determine the speed of sound based on temperature measurements made using an ordinary laboratory, low-cost thermometer with a probe fitted with a long cable. This is an interesting approach to the problem under study. Makar assumed that a change in the salinity of the water relative to its depth has no significant effect on the distribution of the speed of sound determined from changes in temperature. The study only assessed shallow water. The speed of sound in the water was determined from commonly accepted formulae, and the salinity was obtained via a web service from the nearest measuring station. The author compared the results with those obtained from measurements made with the Conductivity/Salinity Temperature Depth (CTD/STD) probe. The impact of the inaccuracy of the sound velocity determination in relation to the SBES immersion depth was calculated. Measurements were taken in the low-salinity Baltic Sea and then verified with measurements in the Mediterranean Sea, representing a high-salinity environment. The author indicated that the proposed method could be an alternative to the bar check calibration of SBES.

Performing frequent monitoring activities, especially when applying new nature-friendly coastal defence methods, is a major challenge. In their manuscript [7], Śledziowski et al. propose a pipeline for performing low-cost monitoring using RGB images, accessed by an UAV and a four-level analysis architecture of an underwater object detection methodology. First, several colour-based pre-processing activities were applied. Second, contrast-limited adaptive histogram equalization and the Hough transform methodology were used to automatically detect the underwater, circle-shaped elements of a hybrid coastal defence construction. An alternative pipeline was used to detect holes in the circle-shaped elements with an adaptive thresholding method; this pipeline was subsequently applied to the normalized images. Finally, concatenation of the results from both the methods and the validation processes was performed. The results indicate that automated monitoring tools work for RGB images captured by a low-cost consumer UAV.

Despite being recognized as a key component of shallow-water ecosystems, submerged aquatic vegetation (SAV) remains difficult to monitor over large spatial scales. In their paper [8], authors propose an example of an adaptable open-source object-based image analysis (OBIA) workflow to generate SAV cover maps. They applied radiometric calibration, atmospheric correction, a de-striping correction, and hierarchical iterative OBIA random forest classification to generate SAV cover maps. The workflow was applied to images taken over two spatially complex fluvial lakes in Quebec, Canada, using Quickbird-02 and Worldview-03 satellites. Classification performance based on training sets revealed conservative SAV cover estimates with less than 10% error across all classes except for lower SAV growth forms in the most turbid waters. The results indicated that it is possible to monitor SAV distribution using high-resolution remote sensing within an open-source environment with a flexible and functional workflow.

Today, more and more data are being acquired using unmanned platforms. One interesting case is the combination of bathymetric data acquired with hydroacoustic and photogrammetric sensors. Research in this area was carried out in [9]. This study presents a method for integrating data acquired by unmanned surface vehicles and unmanned aerial vehicles, based on data geoprocessing using a bathymetric reference surface. The aim was to create a uniform bathymetric surface extending to the shoreline in shallow and ultra-shallow areas. Numerical bathymetric models created by interpolation methods confirmed the usefulness of the proposed method.

Aerial hyperspectral sensors, such as CASI-1500, are used in bio-optical research in inland waters due to their high and adjustable spatial and spectral resolutions. The use of data for quantitative assessments requires, as in the case of satellite data, correction of the influence of the atmosphere. Yang et al., in their study [10], compared the results of three commonly used atmospheric correction approaches, i.e., Polymer, 6S, and FLAASH, for CASI-1500 data recorded over the shallow waters of the Uljin coast in Korea, where primary production is dominated by seaweed, and adverse environmental changes affect coral bleaching. The results showed that only the Polymer algorithm (POLYnomial algorithm based on MERIS), originally developed for the MERIS satellite sensor, yielded reliable reflectance ($R_{rs}$) spectra, which was further confirmed by comparison with satellite data recorded with the Moderate Resolution Imaging Spectroradiometer sensor (MODIS). The other two algorithms calculated negative reflectance values in the blue spectral range. However, the authors noted the differences in $R_{rs}$ derived from CASI-1500 and MODIS data. The recordings from both sensors were separated by 1 day; therefore, the authors identified the need for further validation based on in situ measurements and the possible modification of the Polymer algorithm in order to improve its results.

To develop the final product, remotely sensed elevation data often require processing to create a digital geographic surface. In [11], research related to the use of interpolation and data reduction techniques was carried out. A novel approach in the field of research is the interpolation method based on processing datasets with different degrees of spatial data reduction. Surface modelling was carried out using data acquired by modern remote sensing sensors, such as a single-beam echo sounder and an RGB camera mounted on an unmanned aerial platform. The developed method of data processing and surface modelling allows for minimizing the error of the surface approximation of combined bathymetric and topographic models.

Natural wetlands can be categorized as coastal zone areas. They have an impact on the environment and the ecosystems that exist there due to the strong variations in hydrological and biogeochemical processes. They are heterogeneous and consist of a mosaic of ecosystem patches with different vegetation types. Ju and Bohrer [12] proposed a method for the classification of wetland vegetation based on NDVI time series from the HLS Dataset. The authors used very-high-resolution multispectral imagery to classify wetland vegetation. They used NDVI time series, generated from NASA's HLS dataset, to classify vegetation patches. The authors conducted their study on the coastal estuarine, mineral soil marsh of Lake Erie. It should be mentioned that a sudden rise in water levels was observed in the study area. The article presents the classification process, which consists of several steps. The authors obtained results with a classification accuracy rate of more than 73% for all patch types, except water lily. It was shown that the accuracy of the proposed classification was higher in pixels with a more uniform composition.

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