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Editorial

Innovative Representation of the Coastal Topo-Bathymetry and Subsurface for Flooding and Erosion Risk Reduction

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Geology is the last bulwark against coastal erosion and flooding. As many coastal cities worldwide transition to a low carbon future, coastal adaptation solutions that work with nature are likely to become more frequent for locations where non-active intervention or management realignment are the preferred coastal management policies. Understanding how the coast might change under these policies over time scales from decades to centuries requires a good representation of the coastal zone structure—defined here as the 3D subsurface structure and the geomorphology of the beach and the enveloping zone (i.e., the nearshore and immediate inland topography). For locations where hold-the-line is the preferred adaptation solution against coastal erosion and coastal flooding, a good representation of the coastal zone structure in front of the defences is key to ensure a minimum level of protection under different climate and socioeconomic scenarios.

This Special Issue titled "Innovative Representation of the Coastal Topo-Bathymetry and Subsurface for Flooding and Erosion Risk Reduction" includes eight contributions [1–7] published during 2020–2022. Overall, the aim of this Special Issue is to collect studies that that have: (i) developed better ways of representing (i.e., 3D subsurface models) [2] and monitoring (i.e., satellite-derived bathymetries, subsidence, etc.) [1,3] the coastal zone structure; (ii) translated current geological understanding into more ready-to-use information for coastal engineering consultants and stakeholders (i.e., shoreline rate of change, sediment yields from an eroding coast and coastal vulnerability assessments) [4,6]; and (iii) contributed to our understanding of the 4D evolution of the coastal zone structure [7]. The scientific collection presented herein will be of importance to scientists, engineers, and coastal stakeholders with an interest in evidence-based decision making to better manage the risk of coastal flooding and erosion. What follows is a brief overview of all the contributions, emphasizing the main investigation topics and the outcomes of the analyses.

Morgan et al. (2022) [1] explored the use of a new survey method, the Passive Seismic Survey (PSS), to assess the beach sediment thickness in different coastal environments on the coast of England, UK. The PSS is an easy-to-deploy and non-invasive technique that measures background seismic noise (both natural < 1 Hz and human-made > 1 Hz) to estimate the thickness of the different layers through different time domains and spectral techniques. The authors used the horizontal-to-vertical spectral ratio (HVSR) spectral technique to infer the depth of the underlying geological interfaces. In this study, the authors verified the results by comparing them to those of other survey techniques, such as ground-penetrating RADAR, the multi-channel analysis of surface waves (MASW), and cone penetration tests. At locations where there was sufficient contrast in physical properties of the beach material compared to the underlying bedrock, the beach thickness (and therefore the volume of erodible material) was successfully determined, showing that the HVSR is a useful tool to use in these settings.

Payo et al. (2022) [2] reported values of bedrock elevations at Perranporth Beach, Southwest England, UK, as proxies for former sea levels using the PSS. The authors reported a three-day survey at Perran Beach, Cornwall. They collected 149 measurements using the PSS, and interpreted the observations supported by auxiliary topographical,

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geological, and independent geophysical observation in the study area. The study site was a contemporaneous beach mostly composed of sand underlain by a wave-cut platform composed of igneous and sedimentary rock; therefore, a high impedance contrast with the sandy beach was anticipated. The elevation of the bedrock relative to the topographical elevation suggested that the bedrock elevation was -15 m $\pm$ 5 m below the present day mean sea level, which is coherent with the observation of relative sea level rise along the region of the Southwest. This study contributes to our current limited understanding of land and sea level movements by providing further subsurface information to the coastal geological archive of Southwest England, a region currently in need of more data to reconstruct land- and sea-level movements.

Paz-Delgado et al. (2022) [3] assessed the application of shorelines extracted from Multi-Spectral Imagery (MSI) and Synthetic Aperture Radar (SAR) from publicly available satellite imagery to map and capture subannual to inter-annual shoreline variability. This was assessed at three macro-tidal study sites along the coastline of England, UK: estuarine, soft cliff environment, and gravel pocket beach. The authors assessed the accuracy of MSI-derived lines against ground truth datum tideline data and found that the satellite-derived lines have the tendency to be lower (seaward) on the Digital Elevation Model than the datum tideline. They compared the metric of change derived from SAR lines differentiating between ascending and descending orbits. The spatial and temporal characteristics extracted from the SAR lines via Principal Component Analysis suggested that beach rotation was captured within the SAR dataset for descending orbits but not for the ascending ones in the study area. This study contributes to our understanding of a poorly known aspect of using coastlines derived from publicly available MSI and SAR satellite missions. It outlines a quantitative approach to assess their mapping accuracy with a new non-foreshore method. This allows for the assessment of variability on the metrics of change using the Open Digital Shoreline Analysis System (ODSAS) [4] method and to extract complex spatial and temporal information using Principal Component Analysis (PCA) that is transferable to coastline evolution assessments worldwide.

Gómez-Pazo et al. (2022) [4] proposed and demonstrated a new baseline and transect method, the open-source digital shoreline analysis system (ODSAS), which is specifically designed to deal with very irregular coastlines. They compared the ODSAS results with those obtained using the digital shoreline analysis system (DSAS). Like the DSAS, their proposed method uses a single baseline parallel to the shoreline and offers the user different smoothing and spacing options to generate the transects. The new method differs from DSAS in the way that the transects' starting points and orientation are delineated by combining raster and vector objects. The ODSAS uses SAGA GIS and R, which are both free open-source software programs. They showed how the ODSAS produces similar values of coastline changes in terms of the most common indicators at the aggregated level (i.e., using all transects), but the values differ when compared at the transect-by-transect level. They argue herein that explicitly requesting the user to define a minimum resolution is important to reduce the subjectivity of the transect and baseline method.

Payo et al. (2020, 2022) [5] proposed and demonstrated the use of a simple geometrical analysis of the backshore topography to assess the likely response of any wave-dominated coastline to a sea-level rise, and they applied it along the entire coastline of Great Britain (GB), which is ca. 17,820 km long. They illustrated how backshore geometry can be linked to the shoreline response (rate of change and net response: erosion or accretion) to a sea-level rise by using a generalized shoreline Exner equation, which includes the effect of the backshore slope and differences in sediment fractions within the nearshore. To apply this to the whole of GB, they developed an automated delineation approach to extract the main geometrical attributes. Their analysis suggests that 71% of the coast of GB is best described as gentle coast, including estuarine coastline or open coasts where back-barrier beaches can form. The remaining 29% is best described as cliff-type coastlines, for which the majority (57%) of the backshore slope values are negative, suggesting that a non-equilibrium trajectory will most likely be followed as a response to a rise in sea level.

For the remaining 43% of the cliffed coast, they further provided regional statistics showing where the potential sinks and sources of sediment are likely to be.

Rey et al. (2020) [6] contributed to the vital discussion around the metrics of vulnerability to coastal flooding for building resilient coastal human-natural cities. They showed how, for a given study area, the same extreme flood event can result in different vulnerability mapping depending on the method used to quantify the vulnerability (CENAPRED, CENAPREDv2, and FRI). For the high-pressure cold front event on 12–14 March 1993 that flooded 25% of the city blocks of the urban coastal municipality of Progreso, Yucatan, they found that the flood risk and flood damage calculations in monetary values differed by more than a factor of three depending on whether only economic asset (household goods) values and flood impacts were included, or whether socioeconomic variables were also included (the CENAPRED method vs. the CNAPREDv2 method). For all three methods, even when calculating flood risk and flood damage without monetary terms (FRI), flood damage was always larger/higher than flood risk because the exceedance probability of the flood was not considered like it was for flood risk in the three methodologies. Economic aspects aside, the FRI method also includes social variables that can help to map the most vulnerable populations in terms of mobility, education, communication access, and others. Therefore, the proposed FRI method is very relevant for disaster risk managers and other stakeholders interested in disaster risk reduction.

Muñoz-López et al. (2020) [7] proposed and demonstrated a new method to measure the relationship between beach levels and cliff recession rates. This is one of the few quantitative studies to show a measurable relationship between the beach thickness (or beach wedge area (BWA) as a proxy for beach thickness) and the annual cliff top recession rate along the undefended coast of North Norfolk and Suffolk in eastern England, UK. Additionally, previous studies have also found that, for profiles with low BWA, the annual cliff top recession rate frequency distribution follows a bimodal distribution. This observation suggests that as BWA increases, the cliff top recession rate not only becomes lower, but also more predictable, which has important implications for coastal stakeholders, and particularly for planning purposes at decadal and longer time scales. In this study, the authors address some of the limitations of the previous analysis, making it more transferable to other study sites and applicable to longer time scales. The authors automatised the extraction of cliff tops, toe locations, and BWA from elevation profiles. Most importantly, they verified the basic assumption of space-for-time substitution in three different ways: (1) extending the number of years analysed in a previous study from 11 to 24 years, (2) extending the number of locations at which cliff top recession rate and BWA are calculated, and (3) exploring the assumption of surface material remaining unchanged over time by using innovative 3D subsurface modelling. This study contributes to our understanding of a poorly known aspect of cliff–beach interaction and outlines a quantitative approach that allows for the simple analysis of widely available topographical elevation profiles, permitting the extraction of measurable indicators of coastal erosion.

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