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Editorial

Relative Sea-Level Changes and Their Impact on Coastal Zones: Past and Future Scenarios from Cases Studies around the World

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In recent decades, the study of sea-level changes as recorded along entire coastlines around the world has been a primary scientific focus in climate change studies; it allows the exploration of past landscape evolution, geomorphological processes, human impact, and system response to develop future perspectives.

The relative local sea level is the sum of global, regional, and local processes, i.e., subsidence, isostasy, tectonics, and human activities; all these processes are spatially and temporally variable and cause complex sea-level changes at both regional and local scales, at long-/short-term scale or during a proximal time such as tsunami and storm surge. A multidisciplinary approach addressing paleo-sea level reconstructions at different scales is essential to understand the role of the underlying natural and anthropogenic forces in landscape evolution, as well as to discover past human adaptions to natural modifications of the landscape to develop future ones.

The classical approach to this type of study has thus far been based on the geological–geomorphological study of a coastal area aimed at the detection and measuring of erosive/depositional sea-level markers, interpreted as imprints of past sea levels. Furthermore, in recent decades, traditional surveys and analysis were progressively integrated by (1) digital high-resolution field survey methods, (2) new methods of post-processing analysis, and (3) improvement in geochemical and geoarchaeological methods of age attribution. Geoacoustic and remote sensing methods—including UAV- and UTV-mounted systems—can provide the high-resolution mapping of wide coastal areas and seabed morphologies. On the other hand, AMS dating techniques are increasingly precise owing to the need for small samples, together with daily advanced sedimentological, palynological, and paleontological analysis techniques, allowing the interface of their results with typical archaeological findings to highlight every change in coastal environments in the relation to sea-level history. Moreover, these methods are more precise techniques to evaluate the local vertical ground movement (VGM) that are a primary force in sea-level oscillations in the medium/short term. To be sure, multidisciplinary studies can be considered the most appropriate modern approach to paleo-landscape and paleo-sea level reconstructions.

These advances reinforce the increasingly accurate techniques for the survey of coastal sectors by acquiring a large volume of four-dimensional—i.e., 3D points and time—data that, in the specific case of geoarchaeological sites, have also a documental value in terms of cultural and natural heritage.

Detailed multidisciplinary survey and consequent analysis provide multiscale/temporal datasets about landscape reconstruction, its evolution, and dynamics over the last millennia. At the same time, investigating these regional and local patterns is urgently needed to reconstruct possible scenarios of the relative impact of a rise in sea levels and to prepare the adaptation of coastal communities threatened by future implications of climate change, defining hazard and vulnerability as components of the risk of coastal inundation and submersion.

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This Special Issue aims to collect contributions addressed to discuss methodological and multidisciplinary approaches to studying relative changes in sea level and the related coastal modification, aiming to reconstruct possible future trends and evaluate the impact of such changes on coastal zones and their amount [1–12].

This collection deals with a broad range of contributions, in which different methodologies were applied to deepen this knowledge. Even if the Special Issue includes study cases from extra-Mediterranean sectors, such as North America, Baltic, and Iberian Atlantic coast, special consideration was given to the Mediterranean area, with cases from Croatian, Italian, and Iberian coasts, considering that this semi-enclosed basin is relevant in the framework of the ongoing climate change studies. In fact, it represents a transitional zone between mid-latitude and subtropical climate zones and, consequently, is affected by present and future global warming trends. Additionally, according to recent IPCC reports, changes in land use, increasing pollution, and declining biodiversity are exacerbating this warming process, making this area a climate hotspot.

The manuscripts amassed in this Issue focused on the main effects related to past and future trends related to climate change, both in terms of coastal changes and environmental risks.

They cover three fundamental topics, highlighting different aspects through an original angle of investigation: (1) late quaternary coastal changes in coastal plain and rocky sectors due to RSL variations, often exacerbated by vertical ground movements of tectonic and volcano-tectonic origin; (2) recent coastal changes due to short-term variations in sea levels, also related to extreme events, and their effects in terms of human adaptations; (3) future coastal changes and flooding scenarios due to ongoing climate change and subsequent accelerated trends in a rise in sea levels.

The first group of manuscripts is focused on four significant Italian case studies of paleo-landscape and morpho-evolutive reconstructions of coastal plains located in different morpho-dynamic contexts by using direct and indirect methods. In particular, Corrado et al. [1] analyzed a robust dataset of stratigraphic records to evaluate the tectonic subsidence rate and the morpho-evolutionary path of the Volturno plain before and after the Campania Ignimbrite super-eruption, reconstructing the interactions among eustatic changes, tectonics, and sedimentary input variations. In comparison, D'Orefice et al. [2] applied the same methodology to the study of the environmental and morphological evolution of the Burano paleo-lagoon during the last 8000 years to reconstruct a site-specific sea-level curve.

As regards the indirect methods applied to long-term paleoenvironmental reconstructions, De Santis et al. [3] analyzed a high-precision seismic dataset inferred from submerged boreholes to evaluate the Holocene morpho-evolution of the coastal barrier systems of Ofanto and Carapelle-Cervaro Valleys concerning the post-glacial sea-level rise and paleoclimatic effects. Finally, a multidisciplinary approach comprising photogrammetric and direct surveys was applied by Aucelli et al. [4] to outline the main coastal changes due to ground movements of volcano-tectonic origin and consequent human interventions during the Roman period of a well-known military and commercial hub (Portus Julius) built along the Gulf of Pozzuoli coasts, located in Campi Flegrei Caldera.

Moving from past to recent coastal changes, the second set of articles document advances in the measurement of coastal effects due to storm or atmospheric extreme events. In particular, Ferrando et al. [5] integrated several remote sensing techniques, such as photogrammetry from unmanned aerial vehicles (UAV), mobile laser scanners (MLS), and multibeam echo-sounders (MBES), to evaluate the strong coastal effects at Portosole Marina (Sanremo, Western Liguria) consequent to the storm Vaia that occurred in October 2018, well-known for catastrophically hitting the Tyrrhenian coasts. Scicchitano et al. [6] used the same terrestrial methods to reconstruct immersive virtual scenarios to geometrically analyze boulder displacements recorded in the first video account of coastal boulder displacements recorded during the impact of Medicane Zorbas on southeastern Sicily. Buonocore et al. [7] considered the combined effects of the global increase in sea levels and regional atmospheric perturbations that tripled the sea-level variations in the

Gulf of Naples over the last 20 years, by analyzing a tide-gauge dataset collected on the Island of Ischia. Special focus was placed on the Aqua Alta episodes whose frequency has increased in recent decades, with dramatic effect on coastal areas where intense social and economic activity occurs.

The third group of articles—contributions by Antonioli et al. [8], Scardino et al. [9], Abadie et al. [10], White et al. [11], and Vecchio et al. [12]—mainly addressed future coastal scenarios related to the present acceleration in sea-level rise in different morphological contexts around the world. This topical issue was faced at the Mediterranean scale by analyzing LiDAR and Copernicus Earth Observation data to provide estimates of potential marine submersion in 2100 for 16 small-sized coastal plains located in the Italian Peninsula and four Mediterranean countries (i.e., France, Spain, Tunisia, and, Cyprus), all characterized by different geological, tectonic and morphological features, as revealed by Antonioli et al. [8]. However, a high-precision multitemporal mathematical model of coastal submersion was implemented by Scardino et al. [9], to evaluate the sea-level rise and changes in shorelines at a larger scale in the Gulf of Taranto.

Finally, scenarios regarding sea-level variability were reconstructed in the Mediterranean scale by Vecchio et al. [12], and extra-Mediterranean scale, i.e., in the North American context presented by White et al. [11], taking into account the IPCC predictions and regional tectonic behaviors. Peculiar is the case study presented by Abadie et al. [10], in which the potential economic damage in 62 Iberian coastal cities from 2020 to 2100 was estimated using relative regional data on sea-level rises under three representative concentration pathways (RCP 8.5, RCP 4.5, and RCP 2.6).

The papers collected in this Special Issue underline, from different angles, the need for direct and indirect measurements of past and recent relative sea-level oscillations to also enhance our knowledge about their effects on future coasts. These different contributions perfectly fit into the international scenario of sea-level studies (cited in the Introduction), demonstrating the importance of collecting historical records of coastal evolution as key to predicting future modifications of littoral areas in a context of global climate change, rise in sea levels, and an increasing number of extreme events.

On the other hand, they emphasized the significance of high-resolution reconstruction, at both regional and local scales. Special emphasis was placed on Holocene coastal modifications, demonstrating the major influence of climatic modifications on changes in coastal landscapes, both in terms of varied rates of sea-level rise and increased intensity of extreme events during this period.

Anthropogenic adaptations to such climatic variability have also been a central focus of this Special Issue, both in terms of the risk of flooding in coastal areas and the costs that such flooding may produce for coastal communities.

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References

1. Corrado, G.; Amodio, S.; Aucelli, P.P.; Pappone, G.; Schiattarella, M. The subsurface geology and landscape evolution of the Volturno coastal plain, Italy: Interplay between tectonics and sea-level changes during the Quaternary. *Water* **2020**, *12*, 3386. [CrossRef]
2. D'Orefice, M.; Bellotti, P.; Bertini, A.; Calderoni, G.; Censi Neri, P.; Di Bella, L.; Fiorenza, D.; Foresi, L.M.; Louvari, M.A.; Rainone, L.; et al. Holocene Evolution of the Burano Paleo-Lagoon (Southern Tuscany, Italy). *Water* **2020**, *12*, 1007. [CrossRef]
3. De Santis, V.; Caldara, M.; Pennetta, L. "Continuous" Backstepping of Holocene Coastal Barrier Systems into Incised Valleys: Insights from the Ofanto and Carapelle-Cervaro Valleys. *Water* **2020**, *12*, 1799. [CrossRef]
4. Aucelli, P.P.C.; Mattei, G.; Caporizzo, C.; Cinque, A.; Troisi, S.; Peluso, F.; Stefanile, M.; Pappone, G. Ancient coastal changes due to ground movements and human interventions in the Roman Portus Julius (Pozzuoli Gulf, Italy): Results from photogrammetric and direct surveys. *Water* **2020**, *12*, 658. [CrossRef]
5. Ferrando, I.; Brandolini, P.; Federici, B.; Lucarelli, A.; Sguerso, D.; Morelli, D.; Corradi, N. Coastal Modification in Relation to Sea Storm Effects: Application of 3D Remote Sensing Survey in Sanremo Marina (Liguria, NW Italy). *Water* **2021**, *13*, 1040. [CrossRef]
6. Scicchitano, G.; Scardino, G.; Tarascio, S.; Monaco, C.; Barracane, G.; Locuratolo, G.; Milella, M.; Piscitelli, A.; Mazza, G.; Mastronuzzi, G. The First Video Witness of Coastal Boulder Displacements Recorded during the Impact of Medicane "Zorbas" on Southeastern Sicily. *Water* **2020**, *12*, 1497. [CrossRef]
7. Buonocore, B.; Cotroneo, Y.; Capozzi, V.; Aulicino, G.; Zambardino, G.; Budillon, G. Sea-Level Variability in the Gulf of Naples and the "Acqua Alta" Episodes in Ischia from Tide-Gauge Observations in the Period 2002–2019. *Water* **2020**, *12*, 2466. [CrossRef]
8. Antonioli, F.; De Falco, G.; Lo Presti, V.; Moretti, L.; Scardino, G.; Anzidei, M.; Bonaldo, D.; Carniel, S.; Leoni, G.; Furlani, S.; et al. Relative Sea-Level Rise and Potential Submersion Risk for 2100 on 16 Coastal Plains of the Mediterranean Sea. *Water* **2020**, *12*, 2173. [CrossRef]
9. Scardino, G.; Sabatier, F.; Scicchitano, G.; Piscitelli, A.; Milella, M.; Vecchio, A.; Anzidei, M.; Mastronuzzi, G. Sea-level rise and shoreline changes along an open sandy coast: Case study of gulf of taranto, Italy. *Water* **2020**, *12*, 1414. [CrossRef]
10. Abadie, L.M.; Sainz de Murieta, E.; Galarraga, I. The Costs of Sea-Level Rise: Coastal Adaptation Investments vs. Inaction in Iberian Coastal Cities. *Water* **2020**, *12*, 1220. [CrossRef]
11. White, E.D.; Meselhe, E.; Reed, D.; Renfro, A.; Snider, N.P.; Wang, Y. Mitigating the effects of sea-level rise on estuaries of the Mississippi Delta Plain using river diversions. *Water* **2019**, *11*, 2028. [CrossRef]
12. Vecchio, A.; Anzidei, M.; Serpelloni, E.; Florindo, F. Natural Variability and Vertical Land Motion Contributions in the Mediterranean Sea-Level Records over the Last Two Centuries and Projections for 2100. *Water* **2019**, *11*, 1480. [CrossRef]