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Editorial: Advances and modelling of climate change effects on coastal and estuarine hydro-morphodynamics

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Editorial on the Research Topic
Advances and modelling of climate change effects on coastal and estuarine hydro-morphodynamics

Sea levels and extreme wave events continue to rise at an accelerated rate due to climate change threatening coastal areas all over the world. Coastal erosion, shoreline retreat and changes in beach morphology are a result of more frequent and severe extreme coastal water levels caused by relative sea level changes, storm surges and storm waves as pervasive mechanisms. Therefore, the main objective of this Research Topic is to provide new insights into the understanding, assessment, and modelling of climate change impacts on coastal morphology and estuarine dynamics. The topic consists of 5 articles, highlighting the complexity of the subject and the many variables, physical processes and interactions that need to be considered.

The science of climate change is constantly evolving. The development of global, regional climate and Earth system models is providing new and updated information on relative sea level changes, climate extremes and common adaptation pathways. In this context, the work by Toomey et al. investigates the spatial and temporal variability of extreme coastal sea levels in the Mediterranean basin using a new ocean hindcast generated with a coupled hydrodynamic-wave model that simulates storm surges and wind waves. The numerical simulation covers the period 1950-2021 with high temporal sampling and unprecedented spatial resolution for a basin-scale analysis. Coastal storm surges and wave heights are validated with available observations. The results confirm that extreme coastal sea levels are more likely to occur in regions with broad continental shelves, which favor the wind contribution to storm surges, and shallow waters, which favor wave setup induced by depth breaking. The contribution of waves to extreme coastal sea levels is quantified using the hindcast in combination with an uncoupled simulation and is shown to be significant. The spatial footprint of wave setup is assessed on a regional scale, and observed maximum sea levels are increased by up to 120% in the presence of waves.

The effects of climate change described above by Toomey et al. are crucial factors in nearshore physical processes such as longshore sediment transport which will have important implications for the dynamics and evolution of the coastline. The paper by Zarifsanayei et al. carried out a series of experiments to investigate the uncertainty in future projections of longshore sediment transport, considering both changing wave patterns and sea-level rise. They found that climate variability acting on 20-30 year time scales affects sediment transport rates. The results of this interesting work highlight the role of the different wave parameterisation schemes used in the final results. This, in addition to the uncertainty inherent in the projections, is undoubtedly a research challenge that that needs to be addressed by the scientific community. In particular, as the authors address in their conclusions, the following sources of uncertainty should be considered: (1) wave forcing conditions, (2) wave transformation methods, and (3) sediment transport models.

It is well known that estuaries, due to their morphological characteristics and their social, economic and ecological wealth, will be among the environments that will be more difficult to manage in the coming decades due to the effects of climate change. The effects of waves on the hydrodynamics, stratification process and dynamics of the salt wedge in the Magdalena River estuary, a microtidal case study, are analyzed in the work of Higgins Álvarez et al. The results of this work, in conjunction with the previous work of Zarifsanayei et al. have shown that the inclusion of wave effects in the numerical simulations reproduces more realistic conditions in the circulation patterns and salinity distribution in the outer estuary. These variations in hydrodynamics and stratification may be associated with increased wave-induced bottom shear stress, variations in barotropic and baroclinic acceleration, and increased vertical mixing. This work strengthens the line of research dedicated to understanding how waves affect the coastal environment and how it will be modified by climate change.

The two previous papers have highlighted relevant impacts on physical processes derived from climate change, although socially it is very important to know the expected impacts on populations and infrastructures and, if necessary, to establish early warning systems. Kirezci et al. undertook a comprehensive analysis considering both existing levels of coastal defence and two scenarios for future changes in defence levels. A range of plausible future climate change scenarios are considered along with narratives of socio-economic change. The main overall conclusion is that the impact of such floods will have a disproportionate impact on developing countries, which will be the most severely affected regions. However, it is interesting to note that global scale models have many limitations, mainly due to the use of many simplifications. Therefore, local scale results should always be analyzed with caution. Improving such modelling capabilities is certainly a challenge for the coming years.

Authorities and experts have identified early warning systems as an important tool to improve preparedness and response to coastal flooding and thereby reduce risks. Thus, considering the impacts described in the previous papers of this Research Topic, the work of Apecechea et al. developed a proof-of-concept for a European Coastal Flood Awareness System. The manuscript evaluates, for the first time, the ability of the current operational ocean models of Copernicus Marine to predict extreme coastal water levels and thus to feed applications for coastal flood awareness on a European scale. We would like to highlight the limitations encountered and the recommendations made, rather than the specific and detailed conclusions of the work. As pointed out by the authors, in the future, when homogeneous multi-decadal model records are available, robust extreme value analyses could be performed and a better characterization of the impact of forecast lead time could be achieved if past forecasts were routinely stored. In addition, models such as the Copernicus Marine Service provide valuable marine hazard information for large-scale coastal flood awareness applications, where the aim is to provide sufficiently localized coastal flood warning information. Higher resolution local systems could be nested as downstream components of the parent pan-European system to target coastal areas characterized by fine-scale water level and wave dynamics.

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