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Editorial: Prediction of coastal morphological evolution in the context of climate change adaptation and nature-based engineering

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Editorial on the Research Topic
Prediction of coastal morphological evolution in the context of climate change adaptation and nature-based engineering

Coastal communities worldwide are facing accelerating pressures from rising sea levels, changing storm patterns, and shifting sediment dynamics. These trends demand reliable tools for predicting morphological evolution. Despite advances in this area, existing engineering tools still struggle to predict morphological evolution, especially in settings shaped by interventions such as nature-based solutions aimed at fostering climate-resilient coastal development. Modelling morphological change, which unfolds over much longer timescales than hydrodynamic processes, remains a challenge due to the complexity of sediment transport and related interactions, including flow–vegetation effects and human interventions. These challenges are further heightened by uncertainties in long-term climate projections. Therefore, developing and testing engineering tools capable of delivering reliable predictions is essential for planning effective short- and long-term responses to coastal erosion and flooding.

This Research Topic seeks to advance the existing coastal engineering toolbox, enabling reliable long-term predictions of coastal morphological evolution and flooding in the context of climate change and multi-biophysical phenomena, such as sediment transport and flow-vegetation interactions. Six studies contributed to this Research Topic, spanning riverine sediment supply, estuarine and dyke breach dynamics, vegetated coastal defences, and probabilistic methods for projecting flooding and erosion. These contributions, outlined below in no particular order, illustrate the scientific and methodological advancements that are reshaping our ability to anticipate coastal change and support informed, climate-resilient coastal planning.

Burns et al. studied the behaviour of sediment transport and deposition immediately following a dyke breach at a managed realignment site in Canada's Bay of Fundy, where formerly protected farmland is intentionally flooded to prepare for the growth of salt marsh vegetation. Using a combination of field observations and numerical modelling (using Delft3D-FM), the authors provided quantitative insights into the very early stages of marsh restoration via managed dyke realignment. Provided the right sedimentations and flow conditions are present, sites such as this can accrete vertically at rates comparable to sea-level rise, making them a promising nature-based solution for coastal resilience. Burns et al. also touched on the importance of continuously improving our predictive tools, particularly with regard to modelling cohesive sediments, which necessarily play an important role in the complex interactions between hydrodynamics and sediment transport. The authors also found that morphological pathways, such as ditches and channels, significantly influence hydrodynamics and sediment dynamics in engineering interventions such as this one.

Chen examined how extreme changes in upstream runoff impact the sedimentation regime in the Lingdingyang Estuary in southern China. Using the 2D hydrodynamic-sediment transport model TELEMAC-2D, Chen aimed to understand how runoff variability controls morphological responses by modelling different scenarios, ranging from very low (extreme drought) to very high (catastrophic flooding) flow conditions. This research showcases how upstream hydrological variability (which is expected to increase under climate change) can strongly modulate sedimentation regimes in estuaries, underscoring the need for reliable engineering tools and predictive models that can handle the coupling between hydrology, sediment supply, tidal/estuarine dynamics, and morphological change.

Wang et al. investigated how the turbid plume from the Yellow River estuary into the Bohai Sea responds on an interannual basis, particularly under the influence of the river's managed water–sediment regulation scheme (WSRS), which began in 2002. The WSRS is a short-duration (10–20 days) release of high volumes of water and sediment aimed at flushing the riverbed. Using high-resolution imagery spanning 20 years, the authors set out to gain a comprehensive view of plume variations before and after the WSRS, classify typical plume dispersion patterns, and determine how river discharge, wind, estuary morphology, and coastal currents combine to shape the plume. This work highlights how human water management interventions interact with natural forcing mechanisms to shape coastal sediment dynamics.

Jayson-Quashigah et al. explored the effectiveness of mangroves as a nature-based solution for coastal protection, especially with regard to reducing erosion. The focus was on a data-limited site in Ghana, where nature-based solutions may be more attractive or feasible than conventional solutions, such as seawalls. Using the 1D morphodynamic model XBeach, the authors simulated how different mangrove densities and configurations (on the berm and in the intertidal zone) influence sediment dynamics and erosion under existing and future sea-level rise projections (of ~0.23 m by 2040). This study provides compelling evidence for the use of mangroves as a nature-based solution in regions such as Ghana, suggesting they offer significant protection against coastal erosion under current and future sea-level scenarios.

Finally, in two related articles (Otiñar et al. and Otiñar et al.), Otiñar et al. presented a holistic, probabilistic approach to generating long-term erosion and flooding projections under climate change for the Andalusian coastline in Spain. Together, these two contributions make a significantly integrated contribution to modern coastal risk management in the context of uncertain climate change scenarios. Otinar and co-wokers established a probabilistic, non-stationary modelling framework that captures the intertwined roles of waves, sea-level rise, sediment supply, and human interventions in shaping future flooding and erosion, forming the scientific backbone of this study. Serving as a companion study, Otiñar et al. then transformed these complex outputs into the type of statistically robust, policy-ready indicators that coastal authorities need, such as probability isolines, beach-loss thresholds, and legally actionable classifications of severe regression. These two contributions demonstrate how advanced coastal engineering science can be operationalised into transparent and robust decision-making tools that bridge the gap between process-based modelling and the regulatory realities of shoreline management in a changing climate.

Across these six contributions, a picture emerges of an extremely dynamic field, highlighting recent progress in understanding and modelling sediment dynamics, ecosystem processes, and human- and climate-driven coastal change. They collectively underscore the fact that reliable coastal forecasting must integrate physical, ecological, and human influences, alongside climate uncertainty. By linking process-based research with practical modelling and decision-ready indicators, these contributions demonstrate how coastal science is helping engineers and managers to design and evaluate both traditional and nature-based adaptation strategies in a changing coastal environment.

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