

Modelling wetland vulnerability to sea-level rise

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Abstract: Coastal wetlands—such as tidal marshes and mangrove forests—are highly valued for the wide range of ecosystem services they provide, including shoreline protection, attenuation of storm surges and floods, water quality improvement, wildlife habitat and biodiversity conservation. Notably, these ecosystems have been observed to sequester atmospheric carbon dioxide at rates significantly higher than many other ecosystems, positioning them as promising nature-based solutions for climate change mitigation. However, projections of coastal wetland conditions under sea-level rise (SLR) remain highly variable, owing to uncertainties in environmental factors as well as the necessary simplifications embedded within the wetland evolution modelling frameworks. Assessing wetland resilience to rising sea levels is inherently complex, given the uncertain nature of key processes and external influences. To enable long-term simulations that span extensive temporal and spatial scales, models must rely on a range of assumptions and simplifications—some of which may significantly affect the interpretation of wetland resilience.

Here we present a novel eco-hydro-geomorphological modelling framework to predict wetland evolution under SLR. We explore how accretion and lateral migration processes influence the response of coastal wetlands to SLR, using a computational framework that integrates detailed hydrodynamic and sediment transport processes. This framework captures the interactions between physical processes, vegetation, and landscape dynamics, while remaining computationally efficient enough to support simulations over extended timeframes. We examine several common simplifications employed in models of coastal wetland evolution and attempt to quantify their influence on model outputs. We focus on simplifications related to hydrodynamics, sediment transport, and vegetation dynamics, particularly in terms of process representation, interactions between processes, and spatial and temporal discretisation. Special attention is given to identifying modelling approaches that strike a balance between computational efficiency and acceptable levels of accuracy. The model is then used to assess the resilience to SLR of several coastal wetland sites around the world.

Keywords: Coastal wetlands, eco-geomorphological modelling, sea-level rise