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Landscape evolution in tidal embayments: modelling the interplay of erosion, sedimentation, and vegetation dynamics

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The long-term landscape evolution of tidal embayments need be described in terms of a holistic eco-geomorphological approach, through the description of the delicate balance and strong feedbacks characterizing hydrodynamic and sediment transport processes on the one hand, and ecological dynamics on the other hand. In order to address issues of conservation of these delicate systems and predict their future fate we have set up a process-based eco-morphodynamic model which conceptualizes the chief landforming processes operating on the intertwined, long-term evolution of marsh platforms and tidal networks cutting through them. Such a model is aimed at improving our understanding of the main processes shaping the geomorphological and biological characters of the tidal landscape. Based on observational evidence indicating the existence of different time scales governing the various landscape-forming processes, the model decouples the initial rapid network incision from its subsequent slower elaboration and from the eco-morphological evolution of intertidal areas, governed by sediment erosion and deposition and crucially affected by the presence of vegetation. This allows us to investigate the response of tidal morphologies to different scenarios of sediment supply, colonization by halophytes and changing sea level. Different morphological evolutionary regimes are shown to depend on marsh ecology. Marsh accretion rates, enhanced by vegetation growth, and the related platform elevations are found to decrease with distance from the creek, measured along suitably defined flow paths. The negative feedback between surface elevation and its inorganic accretion rate is reinforced by the relation between plant productivity and soil elevation in Spartina-dominated marshes whereas counteracted by positive feedbacks in marshes populated by a variety of vegetation species. When evolving under constant sea level, unvegetated and Spartina-dominated marshes asymptotically tend to mean high water level, differently from multiple-vegetation species marshes, which can make the evolutionary transition to upland. Equilibrium configurations below mean high water level can be reached under constant rates of sea level rise, depending on sediment supply and vegetation productivity. Marine regressions, leading to network shrinking and retreat, or transgressions, leading to channel expansion and incision, in response to sea level variations are also studied, identifying the signatures of supply- or transport-limited regimes. Complex modeled network structures and sedimentation patterns meeting distinctive characteristics of geomorphic relevance typical of observed morphologies are reproduced by the model.