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Equilibrium states and transient dynamics in tidal bio-geomorphic systems subject to climate change

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We describe and apply a point model of the joint evolution of tidal landforms and biota to explore the equilibrium states and the transient behaviour of such systems under varying rates of sea-level change and of sediment supply. The model incorporates the dynamics of intertidal vegetation, benthic microbial assemblages, erosional, depositional, and sediment exchange processes, wind-wave dynamics. Alternative stable states and punctuated equilibria emerge, characterized by possible sudden transitions of the system state, governed by vegetation type, disturbances of the benthic biofilm, sediment availability and marine transgressions or regressions. Multiple stable states are suggested to result from the interplay of erosion, deposition and biostabilization, providing a simple explanation for the ubiquitous presence of the typical landforms observed in tidal environments worldwide. The explicit and dynamically-coupled description of biotic and abiotic processes thus emerges as a key requirement for realistic and predictive models of the evolution of a tidal system as a whole. The analysis of such coupled processes indicates that hysteretic switches between stable states arise because of differences in the threshold values of relative sea level rise inducing transitions from vegetated to unvegetated equilibria and viceversa, with implications for the preservation of tidal environments under a climate change. Finally, we explore the transient behaviour of the system forced by synthetic and observed sea-level rise forcings and identify the effects of the characteristic response time of vegetation to environmental changes on the overall system dynamics.