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Analytical solutions for salt-marsh equilibrium states and transient dynamics

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Salt marshes are coastal ecosystems of great relevance characterized by extremely high biodiversity and primary productivity, their ecosystem services being acknowledged as fundamental. The overall dynamics of such systems, which are agreed to be important indicators of environmental change, are governed by complex two-way interactions between ecological and geomorphological processes, their evolution and possible survival depending on complex feedbacks between biotic and abiotic processes.

Historical acceleration in the rate of global sea level rise and recent observations of marsh degradation worldwide highlight the importance of improving our understanding of the chief landforming processes which control the response of salt-marsh ecosystems to current natural climate changes and to the effects of changes in sediment supply, usually associated with human interference. To address this important issue we have developed the first analytical model describing the morphodynamic evolution of salt-marsh ecosystems in the vertical plane. The model allows us to study salt-marsh equilibria and dynamics in response to changes in sediment load, organic soil production, and rates of relative sea level rise. Our results show that in the case of a step change in the rate of relative sea level rise or in the availability of sediment, the time required by the marsh platform to reach new equilibrium conditions depends on the initial and final sediment availability, on vegetation productivity, on the tidal range, and on the initial and newly imposed rate of sea level rise. Marshes are more resilient to a decrease rather than to an increase in the rate of relative sea level rise, whereas they are more resilient to a decrease rather than to an increase in sediment availability. Despite the model is based on a few simplifying assumptions it provides a coupled description of the key biogeomorphic processes governing the vertical evolution of salt-marsh ecosystems and allows an instant assessment of key dynamical behaviour of salt-marsh surfaces. Model results are consistent with field observations and with he results of previous numerical models, and furthermore provide means to improve our understanding of salt-marsh biomorphodynamics.