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Sensitivity of modelled channel network formation to environmental conditions and initial bathymetry

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Estuaries show a variety of distinctive geomorphic features that reflect differences in environmental conditions, such as geological constraints, hydrodynamic forcing (e.g. tidal range, wave climate), sediment loads from the catchment, and the presence and types of both vegetation and benthic organisms. These differences yield varying patterns of sediment erosion/deposition and consequently determine the current shape of the estuary and its future evolution. Understanding how estuarine systems evolve as a function of both natural and anthropogenic drivers is still a main research topic in coastal science. Both the short- and long-term evolution of estuaries are affected by the dynamics related to tidal channel networks. Channel networks often exhibit complex morphological patterns and their initial formation is not entirely understood. Also, the subsequent evolution of channel networks can be accompanied by the development of tidal flats which provide ecologically important habitats. Despite their importance, observations of channel network formation involve large spatial and temporal scales so that detailed studies have rarely been reported. Recently, modelling approaches have been developed to study the long-term evolution of tidal basins and the associated formation of channel patterns.

A model has been developed to simulate the formation of channel networks and tidal flats as a result of the interactions between hydrodynamics, sediment transport, and bed elevation change. Simulations were undertaken using idealised initial bathymetries. Flow velocities are computed using an open source numerical model (ELCOM; Estuary and Lake Computer Model) that solves the unsteady Reynolds-averaged Navier-Stokes equations for incompressible flow using the hydrostatic assumption. The computed flow velocities drive sediment transport, which is calculated using formulas widely adopted in sediment transport studies. Gradients in sediment transport rate yield morphological change which feed back into the hydrodynamic part of the model, thus coupling the different subsystems of the morphodynamic feedback loop. Hydrodynamic conditions are assumed to remain constant unless significant changes in the morphology have occurred. This allows us to reduce numerical effort and facilitates the execution of long-term simulations.

Modelling results indicate that the morphodynamic interactions can cause channel initiation and potentially give rise to channel pattern development. A sensitivity analysis is performed to show that the sediment grain size and tidal range mainly affect the timescale over which channel initiation occurs. We also varied the initial depth of the basin to assess the influence of initial bathymetry on morphological change. Channels start to form rapidly in the case of a shallow basin. When the basin is deeper, the bathymetry evolves differently in a remarkable way. While channels develop in the upper part of the basin, a flood-tidal delta forms simultaneously just landward of the inlet. Eventually, this flood delta channelizes and a complete tidal channel network develops. Additional simulations also indicate that effects related to climate change (i.e. sea level rise) highly affect the overall morphological evolution of tidal environments.