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Morphodynamic equilibrium of alluvial estuaries

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The evolution of the longitudinal bed profile of an estuary, with given plan-form configuration, subject to given tidal forcing at the mouth and prescribed values of water and sediment supply from the river is investigated numerically. Our main goal is to ascertain whether, starting from some initial condition, the bed evolution tends to reach a unique equilibrium configuration asymptotically in time. Also, we investigate the morphological response of an alluvial estuary to changes in the tidal range and hydrologic forcing (flow and sediment supply). Finally, the solution helps characterizing the transition between the fluvially dominated region and the tidally dominated region of the estuary.

All these issues play an important role also in interpreting how the facies changes along the estuary, thus helping to make correct paleo-environmental and sequence-stratigraphic interpretations of sedimentary successions (Dalrymple and Choi, 2007). Results show that the model is able to describe a wide class of settings ranging from tidally dominated estuaries to fluvially dominated estuaries. In the latter case, the solution is found to compare satisfactory with the analytical asymptotic solution recently derived by Seminara et al. (2012), under the hypothesis of fairly 'small' tidal oscillations. Simulations indicate that the system always moves toward an equilibrium configuration in which the net sediment flux in a tidal cycle is constant throughout the estuary and equal to the constant sediment flux discharged from the river.

For constant width, the bed equilibrium profile of the estuarine channel is characterized by two distinct regions: a steeper reach seaward, dominated by the tide, and a less steep upstream reach, dominated by the river and characterized by the undisturbed bed slope. Although the latter reach, at equilibrium, is not directly affected by the tidal wave, however starting from an initial uniform stream with the constant 'fluvial' slope, the final equilibrium state is reached through an erosional wave, which leads to bed degradation of the upstream 'fluvial reach'. For a given river discharge, the length of the tidal reach increases quite rapidly with tidal amplitude, up to some threshold value of the tidal amplitude above which the length of the estuary becomes comparable with the length of the tidal wave.

When the channel plan-form is convergent, deposition of sediments of fluvial origin in the funnel-shaped region drastically changes the equilibrium configuration. The effect of an increasing channel convergence is thus to induce bed aggradation close to the inlet. Nevertheless, tidal forcing only slightly changes the non-tidal profile. The effect of increasing tidal oscillations again leads to an increase of the bed slope at the inlet and to a general bed degradation upstream. The effects of varying sediment supply, flow discharge and river width in the upstream reach have also been investigated and play an important role.

Further geomorphological implications of these results will be discussed at the meeting.

References

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