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Long-term morphological response of tide-dominated estuaries

Abstract of the doctoral thesis

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Most estuaries of the world are influenced by tides. The tidal action is a fundamental mechanism for mixing river and estuarine waters, resuspending and transporting sediments and creating bedforms. The planform of tide-dominated estuaries is characterized by a funnel-shaped geometry with a high width-to-depth ratio. The width of the estuarine section tends to decrease rapidly upstream, following an exponential law and the bottom slopes are generally non-significant.

In this thesis the long-term morphological evolution of tide-dominated estuaries is investigated through a relatively simple one-dimensional numerical model. When a reflective barrier condition is assigned at the landward boundary, the morphological evolution of an initially horizontal tidal channel is characterized by the formation of a sediment wave that migrates slowly landward until it leads to the emergence of a beach. The bottom profile reaches a dynamical equilibrium configuration which has been defined as the condition in which the tidally averaged sediment flux vanishes or, alternatively, the bottom elevation attains a constant value. For relatively short and weakly convergent estuaries, the beach is formed at the landward end of the channel, due to the reflective barrier chosen as boundary condition, and the equilibrium length coincides with the distance of such boundary from the mouth. When the above distance exceeds a threshold value, which decreases for increasing values of the degree of convergence of the channel, the beach forms within an internal section of the estuary and the final equilibrium length is much shorter and mainly governed by the convergence length. The final equilibrium length of the channel is found to depend mainly on two parameters, namely the physical length of the channel and the degree of convergence. Moreover, if a condition of vanishing sediment flux from the outer sea during the flood phase is imposed, a larger scour in the seaward part of the estuary is observed, though the overall longitudinal bottom profile does not differ much from that corresponding to a sediment influx equal to the equilibrium transport capacity at the mouth.

This fixed banks model is not able to explain this typical funnel shape; furthermore, the bottom slopes obtained with this models are quite large if compared with the mild slopes of real tide-dominated estuaries. For these reasons, the problem has been analysed to understand the reason why tidal channels are convergent and to define the conditions under which the exponential law

for width variation, which is so often observed in nature, is reproduced. The long-term evolution of the channel cross-section is investigated allowing the width to vary with time. The one-dimensional model is expanded by considering a simple way to take the banks erosion into account. A strongly simplified approach is adopted, whereby only the effects related to flow and sediment transport processes within the tidal channel are retained and further ingredients, like the control exerted by tidal flats or the direct effect of sea currents in the outer part of the estuary, are discarded. The lateral erosion is taken into account and computed as a function of bed shear stress, provided it exceeds a threshold value within the cross section. The effect of different initial and boundary conditions on the widening process of the channel is tested, along with the role of the incoming river discharge.

Another problem, which is somehow analogous to that of the cross-section evolution, is tackled: a part of a tidal flat dissected by a series of parallel channels is considered and the response of the system induced by a modification of the depth of the channels is studied. In particular, the aim is to assess whether the increase of the depth of one channel, starting from an equilibrium configuration, causes deposition in the others inducing their closure. The evaluation of the morphological effect of a depth variation in one of channel upon the other channels is quite a relevant task, because the stability of salt marshes and lagoons is intrinsically related to the stability of the hydrodynamic functionality of the channels. A result of this analysis is the determination of a characteristic distance between the channels to have mutual influence. It is found that this distance scales with the root of the longitudinal length of the flat; thus, a scale-dependent spacing is expected in tidal networks.