Modelling the morphodynamics of tidal channels

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Abstract

The present study deals with the morphodynamics of rivers and estuaries. The morphodynamic behaviour of natural systems has been investigated using numerical tools. As a first step the hydrodynamics and morphodynamics of both convergent and non-convergent tidal channels have been studied. The analysis has been made using a second order numerical scheme, solving the 1D flow equations and the continuity equation for the bed evolution in order to point out the main characteristics of the phenomenon. Numerical results show that the behaviour is non-linear also for relatively small values of the ratio between tidal amplitude and mean flow depth.

The morphodynamic behaviour of tidal dominated estuaries is characterised by the formation of a rising landward bed profile. This trend is due to the flood dominated character of the convergent estuaries with horizontal bed profile, which induces a landward net sediment flux. Due to this sediment flux the channel is filled in with sediment and a beach can form, whose position depends on the geometrical characteristics (channel length, flow depth, convergence degree) and on the hydrodynamic characteristic (tidal amplitude, friction factor). The equilibrium conditions are characterised by symmetrical flood and ebb phases. The second step is the developments of a three-dimensional numerical model for the comprehension of the altimetric behaviour of almost straight channels. Bed forms can form spontaneously starting from a configuration with a plane bed profile. The research activity concerns in particular the geometrical characterisation of the bed forms: wavelength, Fourier composition, mean celerity, maximum scour and deposition and the time scale of the formation phenomenon. The investigation is oriented to the characterisation of the equilibrium geometry, to the description of the dynamical behaviour, of the flow field and of the concentration field. This goal has been obtained using a fully non-linear 3D numerical model, which takes into account sediment transported as bed load and the suspended load. The numerical scheme is that proposed by Casulli & Cattani (1994) suitably modified for this particular problem; the advection-diffusion equation for the sediments transported into suspension , is solved using an original semi-analytical conservative scheme.

Results are in agreement with those obtained through analytical linearized theories (see Tubino et al., 1999 for a review). Numerical results suggest that in fine sediment channels, when the suspended load is dominant over the bed load, the instability process is different with respect to the gravel bed case. When suspended load is dominant the model predicts the tendency of free bars to emerge from the free surface, forming islands. A similar behaviour is observed also in gravel bed rivers at relatively high value of the width to depth ratio, while under suspended load dominated conditions the maximum deposits are relatively large also for values of the aspect ratio close to the threshold for bar formation. Finally the analysis and the results for the formation of alternate bars in uniform flow have been extended to the tidal context, adopting a suitable basic flow. In the tidal case the bed forms show vanishing celerity, therefore the altimetric and the planimetric morphological responses might interact. Numerical simulation under tidal conditions are very long until a month of computational time, because the time step for the computation must be mush shorter respect to the tidal period. Therefore we have looked for a suitable 2D approximate formulation for the suspended flux, in order to reduce the number of computational nodes and so also the computational time. In the literature there are many approaches for the evaluation the suspended load through analytical perturbative methods. Here a comparison has been made between the numerical solution and an analytical solution, showing that the latter can be applied for a range of the parameters relatively small.