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Sediment transport over moving bed

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The scope of the present work was to study in detail the sediment dynamics that occur under oscillatory flow conditions over moving sandy beds. Large-eddy simulations (LES) were performed, with emphasis on the development of a morphological module in order to analyze the creation and evolution of ripples. The simulations were based on the numerical solution of the Navier-Stokes equations for incompressible flow and the advection-diffusion equation for the suspended load, while empirical formulas were used for the bed load. The evolution of the bed form was obtained by the numerical solution of the equation of sediment continuity, also known as the Exner equation. A fractional time-step scheme was used for the temporal discretization, while finite differences were used for the spatial discretization on a Cartesian grid. The Immersed Boundary method was implemented for the imposition of fluid and sediment boundary conditions on the moving bed surface. The numerical model was effectively validated against numerical studies and laboratory measurements involving oscillatory wave motion and sediment transport. Results were obtained for ripple creation and propagation from a quasi-flat bed, as well as results of ripples adapting to water conditions. The numerical model was able to capture phenomena of ripple creation and propagation, resulting in ripple dimensions in agreement with those predicted by empirical equations and experimental studies. It was found that under the same hydrodynamic forcing, the bed tends to reach the same equilibrium state, regardless of the initial bed form. The relative contribution of bed load versus suspended load on the total sediment load was found to depend on the mobility parameter, ψ, and the ratio ao/Dg, where ao is the orbital amplitude and Dg is the sand grain diameter. The computed sediment fluxes were found to be smaller in comparison to cases of fixed two-dimensional ripples, therefore, it was concluded that the three-dimensionality of the sandy bed strongly influences the sediment transport processes. Finally, the re-orientation of bed ripples was examined, showing that under oblique oscillatory flow conditions, ripples are re-oriented and formed perpendicular to the flow direction.

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