Well-balanced shock-capturing hybrid finite volume - finite difference schemes for Boussinesq-type models

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A numerical scheme for numerical solving a class of extended Boussinesq equations is presented. Both the extended Boussinesq formulations of Nwogou (1993) and Madsen and Sörensen (1992) are considered. The governing equations include the conservative form of the nonlineal shallow water equations for shock capturing. The numerical scheme combines a Godunov-type finite volume technique, based on an approximate Riemann solver, for the inter-cell advective fluxes and bathymerty source terms, with the finite difference method, used to discretize the dispersive terms. Time integration is performed using a fourth order Adams-Basforth-Moulton predictor scheme while a fourth-order MUSCL-type reconstruction technique is implemented to compute the values at cell interfaces for use in the local Riemann problems. The bathymerty source term is discretised as to provide a well-balanced scheme, also in the presence of wet/dry fronts which are properly handled in the numerical model.

Two different option in order to handle wave breaking are presented and tested. The first one relays on the shock-capturing features of the finite volume method that allows an intrinsic representation of wave breaking, while the second option handles breaking through momentum conservation with energy dissipation based on an eddy viscosity concept. To assess the performance and expose the merits and differences of the two Boussinesq formulations and wave breaking options, the numerical model has been applied to a number of standard test cases, for solitary wave propagation and interaction, as well to reproduce laboratory data for wave propagation, wave breaking and runup on plane beaches, and wave transformation over fringing reefs.