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URANS simulation of resonant flows in river bank embayments: high order resolution of the SWE with turbulent diffusion

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Turbulent shallow flows are commonly studied in the framework of environmental and civil engineering. Such flows are mainly characterized by the presence of horizontal large-scale vortices, which are caused due to local variations of the velocity field. These macro vortical structures play a significant role in several aspects: the conveyance of fine sediments in suspension, the transport of pollutants or the mass exchange of nutrients between the flow and the aquatic biota. Apart from these 2D macro horizontal vortices, small scale 3D turbulence, mainly produced by the friction with the bottom, is also present in turbulent shallow flows and it is responsible of the vertical mass and momentum transfer. To adequately represent both turbulent scales, 2D large-scales and 3D small-scales, with an affordable computational time and at the same time with sufficient precision, depth-averaged models based on the unsteady RANS (URANS) approach are used. URANS models are constructed departing from the Shallow Water Equations (SWE) and they compute turbulent diffusion terms. The 3D small-scale vortices are modelled by means of the diffusion terms, whereas the 2D large-scales are resolved. In this work, we assess the performance of a high order WENO-ADER scheme in a URANS model. The numerical scheme is validated by means of complex flume experiments that involve the presence of resonant phenomena. These resonant flows are typical of enclosed water bodies, such as those found in the lateral cavities built in the banks of rivers to create harbors or to promote areas with hydraulic and morphologic diversity, are herein studied. These flow configurations include the coupling between the vortex shedding created in the edges of the cavities and the transversal standing wave (seiche) caused by the enclosed fluid domain. We show that our high order WENO-ADER scheme in combination with the computation of the turbulent diffusion allows to obtain a powerful URANS simulation tool. Numerical results successfully reproduce the coupling between standing gravity waves and the shedding of large-scale eddies. The frequency and amplitude of both pressure and velocity oscillations are accurately captured.