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Three-dimensional finite element modeling of the flow around a shallow-water island: impact of the turbulence closure scheme on vertical transport

S. Blaise (1), L. White (2,3), R. Comblen (2), V. Legat (2), E. Deleersnijder (3,2)

(1) Université catholique de Louvain, Département de Génie Civil et Environnemental, Belgium, (2) Université catholique de Louvain, Centre for Systems Engineering and Applied Mechanics, Belgium, (3) Université catholique de Louvain, G. Lemaitre Institute of Astronomy and Geophysics, Belgium (blaise@gce.ucl.ac.be)

A three-dimensional finite-element model is used to investigate the tidal flow around Rattray Island, Great Barrier Reef, Australia. Field measurements and visual observations show both stable eddies developing at rising and falling tide in the wake of the island. The water turbidity suggests intense upwelling able to carry bed sediments upwards. Based on previous numerical studies, it remains unclear at this point whether the most intense upwelling occurs near the centre of the eddies or off the island's tips, closer to the island. All these studies resorted to a very simple turbulence closure, with a zero-equation model whereby the coefficient of vertical viscosity is computed via an algebraic expression. In this work, we aim at studying the influence of the turbulence closure on model results, with emphasis on the prediction of vertical motions. The Mellor and Yamada level 2.5 is used and an increase in the intensity of vertical transport is observed. This increase is partly explained by the fact that the Mellor and Yamada closure takes into account the hysteresis effect in the time variation of turbulence variables. The influence of the advection of turbulence variables is estimated to be negligible. By a better representation of transient coastal phenomena, the Mellor and Yamada level 2.5 turbulence closure improves the model to a significant degree.