VERTICALLY-AVERAGED COASTAL FLOW MODELLING USING MOMENT EQUATIONS

Francisco N. Cantero-Chinchilla[1*], Rafael J. Bergillos[2], Oscar Castro Orgaz[2]

1IAS-CSIC, Spanish National Research Council, Córdoba, Spain; 2University of Córdoba, Córdoba, Spain

*Correspondence: fncantero@ias.csic.es

Abstract This work presents the evaluation of a Vertically-Averaged and Moment (VAM) model for simulating complex one-dimensional coastal flows. A challenging test comprising non-linear wave propagation, wave breaking, bore propagation and reflection is selected. The accuracy of the results as compared to the experimental data highlights the utility of VAM models as alternative tools to Boussinesq-type models in coastal flow modelling.

Keywords: Depth-integrated modelling, weighted residual method, coastal flow, wave breaking, reflection.

Introduction

Depending on the environmental conditions, coastal flows involve non-hydrostatic and non-linearity during wave propagation, thereby requiring suitable mathematical modelling. To reduce the computational cost as compared to the full 3D numerical setting, vertically-integrated non-hydrostatic models are used in practice. In maritime hydraulics these models can be sorted in three related families: (i) Boussinesq-type models, (ii) multilayer extension of the shallow water equations, and (iii) VAM models. However, VAM models have been rarely explored to simulate nearshore flows.

The objective of this work is to investigate the potential of the VAM model to simulate coastal flows in surf and swash zones comprising non-linear wave propagation, wave breaking, bore propagation and wave reflection.

Physics of the VAM model

First, in the mathematical development, predictors involving a set of perturbation parameters of both the velocity and pressure fields are prescribed into the vertically-averaged RANS equations. Then, the weighted residual method is used to produce additional vertically-averaged equations and resolve the extra degrees of freedom introduced by the perturbation parameters. In Cantero-Chinchilla et al. (2020) the system of equations is described in detail.

The VAM model is a system of 6 time-dependent PDE equations with 6 independent variables, involving the water depth, discharge and perturbation parameters of the velocity and pressure fields. The details of the numerical method can be consulted in Cantero-Chinchilla et al. (2020).

Application of the VAM model to coastal flows

Fig. 1 shows the results of the VAM model compared with those obtained by a Boussinesq-type model (Castro-Orgaz and Hager, 2017) for the complex coastal experimental test of Roeber (2010). The results show the ability of the VAM model to tackle wave breaking without any ad-hoc complementary model to mimic the breaker (Fig. 1a). Further applications to challenging coastal flows can be found in Cantero-Chinchilla et al. (2020).

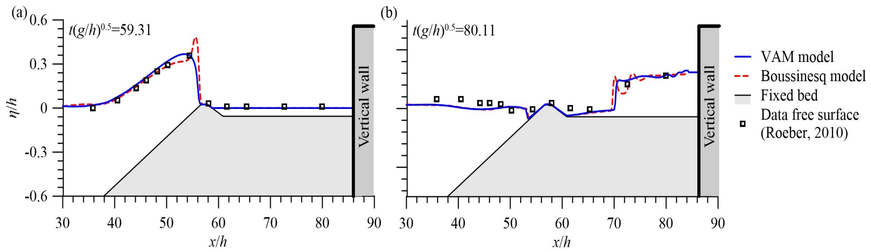

Figure 1. VAM model results as compared to a Boussinesq-type model using the data by Roeber (2010) at (a) $t(g/h)^{0.5}$ = 59.31 and (b) $t(g/h)^{0.5}$ = 80.11, where h = 2.5 m is the still water depth, η is the water elevation over the still water depth, g is the gravitational acceleration, x is the longitudinal distance and t is time.

Conclusions

A high-resolution, depth-averaged non-hydrostatic VAM model accurately tackle complex coastal flows involving wave breaking thanks to the modeled velocity profile. These results highlight the potential of the VAM model as a suitable alternative to Boussinesq-type models for maritime and coastal engineering applications.

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Bibliography

Cantero-Chinchilla, F. N., Bergillos, R. J., and Castro-Orgaz, O. (2020). Nearshore coastal flow processes using weighted-averaged equations. Ocean Engineering, 211, 107480.

Castro-Orgaz, O. and Hager, W.H. (2017). Non-hydrostatic free surface flows. Springer, 696 pp.

Roeber, V. (2010). Boussinesq-type model for nearshore wave processes in fringing reef environment. Ph.D. dissertation, University of Hawaii at Manoa, Honolulu.