NONHYDROSTATIC AND MESH-FREE COMPUTATIONAL FLUID DYNAMICS MODEL COMPARISONS OF SURF ZONE HYDRODYNAMICS BY PLUNGING IRREGULAR WAVES

Ryan J Lowe, The University of Western Australia, Ryan.Lowe@uwa.edu.au
Corrado Altomare, Universitat Politecnica de Catalunya – BarcelonaTech, corrado.altomare@upc.edu
Mark L. Buckley, U.S. Geological Survey, mbuckley@usgs.gov
Renan Fonseca da Silva, The University of Western Australia, renan.silva@research.uwa.edu.au
Jeff E. Hansen, The University of Western Australia, Jeff.Hansen@uwa.edu.au
Dirk P. Rijnsdorp, Delft University of Technology, d.p.rijnsdorp@tudelft.nl
Jose M. Domínguez, Universidade de Vigo, jmdominguez@uvigo.es
Alejandro J. C. Crespo, Universidade de Vigo, alexbexe@uvigo.es

INTRODUCTION

Wave breaking over steep bathymetry often generates plunging waves where the free surface overturns and violent water motion is triggered. Simulating these complex surf zone processes poses significant challenges for conventional mesh-based hydrodynamic models, due to the rapidly-deforming nature of the free surface and underlying turbulent flows. Yet accurate prediction of these hydrodynamics is essential to characterize the wide range of nearshore processes driven by wave breaking.

In this study we rigorously compare the ability of two different classes of phase-resolving wave-flow models to predict a wide range of hydrodynamic processes driven by irregular wave breaking over a fringing reef using data from Buckley et al. (2015). These two models were: 1) the mesh-based nonhydrostatic wave-flow model SWASH, having vertical resolution but only providing a single-value representation of the free-surface; and 2) the mesh-free, Lagrangian particle-based approach Smoothed Particle Hydrodynamics (SPH) using DualSPHysics (DSPH), which directly resolves the overturning free surface. Both models were applied in 2DV mode.

METHODS

The Buckley et al. (2015) experiments used a 1:36 scaled model of a fringing reef subject to a range of wave and water level conditions, with detailed measurements of waves, water levels, velocities, and runup. The SWASH model was run in multi-layered mode (up to 20 vertical layers) with offshore boundary conditions specified by Fourier coefficients derived from the incoming wave timeseries. The DSPH model used the same configuration described in Lowe et al. (2022), that used an inter-particle spacing of 3 mm. To compare the DSPH results under identical forcing conditions, the DSPH model was coupled to SWASH using inlet outlet boundary conditions. Both models were compared for ~500 peak periods with model output processed identically.

RESULTS AND SUMMARY

An example of the same breaking wave simulated by both SWASH and DSPH is shown in Figure 1, revealing substantial differences in the breaking processes, with DSPH resolving the overturning plunging wave. Despite these differences, both models reproduced bulk wave parameter with comparable accuracy (including sea-swell and infragravity wave heights, skewness/asymmetry, and runup). Wave setup predictions also agreed comparably well to the observations; however, there were some notable differences in the 2DV mean current profiles.

The agreement between models in the prediction of many common bulk wave parameters and wave setup is rather surprising given the striking differences in how each model resolves breaking. To explain the consistency between models, we describe results from a detailed analysis of the individual terms in the mean (wave-averaged) wave energy fluxes and momentum balances.

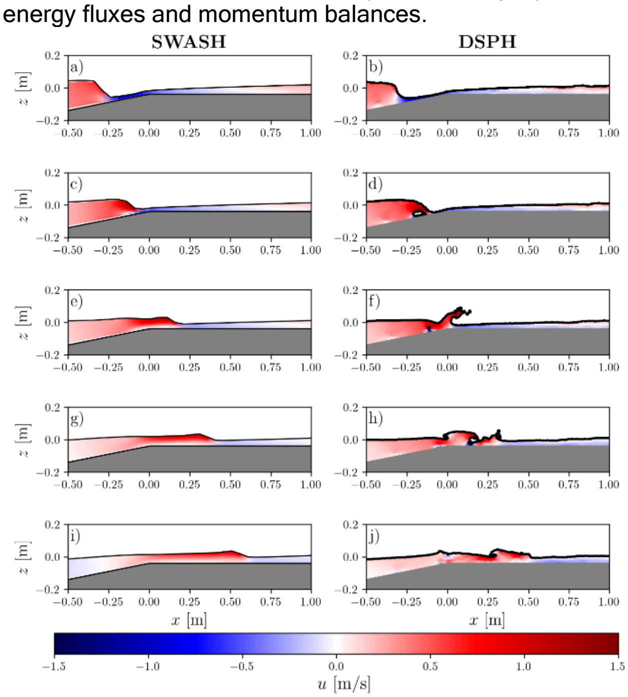

Figure 1 – Example of a breaking wave near the reef crest at with colours denoting the horizontal (u) velocity component. (a) SWASH predictions, (b) DSPH predictions.

REFERENCES

Buckley, Lowe, Hansen, Van Dongeren (2015): Dynamics of wave setup over a steeply sloping fringing reef. Journal of Physical Oceanography, 45, 3005-3023.

Lowe, Altomare, Buckley, da Silva, Hansen, Rijnsdorp, Domínguez, Crespo (2022): Smoothed Particle Hydrodynamics simulations of reef surf zone processes driven by plunging irregular waves, Ocean Modelling 171, 101945