A Hybrid LS and VOF Method for 3-D Simulation of Wave Breaking and Overtopping

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INTRODUCTION

The determination of wave overtopping is crucial for analyzing the performance of sea defenses and estimating coastal flood risk during extreme events. Due to the violent nature of wave breaking and overtopping, the mechanism of this phenomenon is far from being well captured in numerical simulation.

Previous investigations on the wave overtopping mainly focused on the empirical formula derived from the laboratory experiments or field observations (Saville, 1995; Owen, 1980; Owen and Steele, 1993; Franco and Franco, 1999). A lot of analytical work has also been done in this regard. However, there are strong limitations in putting these results into practice, since they rely heavily on a particular site and configuration. There is then a great interest in developing techniques which can predict wave overtopping accurately and remain applicable over a whole range of structure geometries, water levels and wave conditions. Numerical models that solve the equations of fluid flow appear to provide just such an approach.

For decades, two-dimensional (2-D) hydrodynamic models, based on structured grids, have gained prominence and been used for widespread applications in surf zone studies (Kobayashi and Wurjanto, 1989; Titov and Synolakis, 1995; Dodd, 1998; Li et al., 2004; Wang, ZY, et al., 2009; Zhang, YL, et al., 2009). Reasons for this include their relative simplicity to implement and low CPU time demand. However, the accuracy of predictions made by a 2-D model may suffer from the neglect of the additional space direction. In addition, due to the difficulties posed by structured mesh schemes, surf zone geometries must be simplified before being transformed into the modeling domain, and many irregularly shaped structures have to be removed. Nowadays, the availability of greater computing power has driven the development of hydrodynamic models using 3-D unstructured meshes. Compared with its structured counterpart, the unstructured model has several attractive advantages such as: flexible modeling of complex geometries, convenient adaptive meshing capabilities and homogenous data structures well suited for massively parallel computer architectures (Navrtil, Pelaez and Kandill, 2001; Venkatakrishnan, 1995). This study presents a novel, coupled VOF (VOF) / LS (LS) interface capturing scheme for the prediction of violent free-surface flows. This method will be integrated into a well validated 3-D unstructured finite volume (FV) based solver (Zhao et al., 2001, 2002) to investigate wave breaking and overtopping over a structure. Further, large-eddy simulation (LES) is employed to predict the turbulence.