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14. ABSTRACT

The swash zone is the area of the nearshore that is intermittently covered and uncovered by wave run-up. Since swash hydrodynamics control the evolution of beach morphology, understanding these motions is of paramount importance. Typical studies of swash zone hydrodynamics involve the deployment of several instruments (current meters, e.g. Puleo et al., 2000; Doppler devices, e.g. Petti and Longo, 2001; among other methods) to measure the swash zone fluid velocity. While the Doppler devices have the ability to readily distinguish vertical flow structure, instrument deployment is necessarily sparse due to cost and logistics. Recently a video-based remote sensing technique has also been developed that is capable of quantifying surface swash velocities over a fairly large spatial domain, but yields no information regarding subsurface flows (Holland et al., 2001).

Another possibility for understanding swash hydrodynamics is through numerical simulations. A two dimensional (2D) numerical

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NUMERICAL MODELLING OF SWASH ZONE HYDRODYNAMICS

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1. INTRODUCTION

The swash zone is the area of the nearshore that is intermittently covered and uncovered by wave run-up. Since swash hydrodynamics control the evolution of beach morphology, understanding these motions is of paramount importance. Typical studies of swash zone hydrodynamics involve the deployment of several instruments (current meters, e.g. Puleo *et al.*, 2000; Doppler devices, e.g. Petti and Longo, 2001; among other methods) to measure the swash zone fluid velocity. While the Doppler devices have the ability to readily distinguish vertical flow structure, instrument deployment is necessarily sparse due to cost and logistics. Recently a video-based remote sensing technique has also been developed that is capable of quantifying surface swash velocities over a fairly large spatial domain, but yields no information regarding subsurface flows (Holland *et al.*, 2001).

Another possibility for understanding swash hydrodynamics is through numerical simulations. A two dimensional (2D) numerical model, RBREAK (Wurjanto and Kobayashi, 1991), based on the viscid non-linear depth-averaged shallow water equations accurately models observations (Raubenheimer *et al.*, 1995; van der Meer and Breteler, 1990). But, the depth-averaged nature limits the information (no quantification of shear stresses, vorticity etc.) gleaned from the model. However, Slinn *et al.* (2000), have utilized an existing 2D depth-dependent model, RIPPLE (Kothe *et al.*, 1991), for simulating swash zone hydrodynamics. The RIPPLE model will be investigated here, specifically in comparison to laboratory observations.

2. RIPPLE MODEL AND SIMULATIONS

The RIPPLE model is based on the 2D Navier-Stokes equations and is capable of simulating the non-linear time dependent flow in the swash zone. The model domain is discretized into individual control volumes, which may be empty, full or partially filled with water. This volume of fluid (VOF) approach enables the capture of breaking waves and other swash hydrodynamics by calculating the appropriate force balances in each control volume and the flux of water across each of the control volume surfaces. Presently, model domains are typically only a few meters in the cross-shore with very small control volumes (sub-millimeter near the bed to millimeter near the surface) and time steps of generally 1/100 of a second such that the detailed structure of the boundary layer, shear stresses and breaking processes can be calculated.

Figures 1 and 2 shows 3 snapshots of a low viscosity model run on a 20 degree slope. The model was forced in the seaward region (roughly -25 to 0 cm) with monochromatic waves having a period of 1 second and a wave height of 2 cm. The domain consisted of 126 (vertical) by 700 (horizontal) control volumes. Figure 1 shows the fluid portion of the domain and Figure 2 shows the corresponding velocity vectors (for clarity, only every 10th vector is shown). In the first set of panels at t ~ 1.7 s, the backwash is moving down slope and a small wave is curling over and preparing to break. The corresponding velocity vectors (~ 55 cm/s) are headed downslope in the very thin backwash with upward pointing vectors in the vicinity of the wave face and shoreward directed vectors (~75 cm/s) at the lip of the wave. By t~1.9 s, the wave has broken on the beach face and the uprush process has begun. Here velocity vectors are headed onshore and downward toward the bed. The uprush has extended further up the beach by t~2.2 s and has thinned considerably. At this point, velocities have decreased to about 25 cm /s. The vector field shows that in the lower swash the flow has already begun its seaward return while the flow on the upper beach is still in the landward direction.

In June 2001, laboratory studies were carried out in the Large-scale Sediment Transport Facility (LSTF) at the Coastal Hydraulics Laboratory of the Army Corps of Engineers in Vicksburg, MS (Hamilton and Ebersole, 2001). The LSTF is 30 m cross-shore by 50 m alongshore by 1.4 m deep with a nominal beach slope of 1:30. Both monochromatic and random waves of prototype scale will be used as the offshore boundary condition. Swash velocities and surface profiles will be recorded with numerous acoustic Doppler instruments, video cameras, and wave gages. The free surface profile and vertical velocity structure in the swash zone will be compared to the RIPPLE model output using the same boundary conditions.

3. SUMMARY

Numerical simulations of swash hydrodynamics were performed for prototype laboratory waves on beaches to investigate the validity of the RIPPLE model and the detailed structure of the boundary layer, shear stresses and other important characteristics of swash flows. The use of these types of simulations can overcome the drawbacks from previously used numerical models and *in situ* instrumentation. The true ability of this type of modeling will manifest in future work when the hydrodynamics are coupled with appropriate sediment transport formulations.

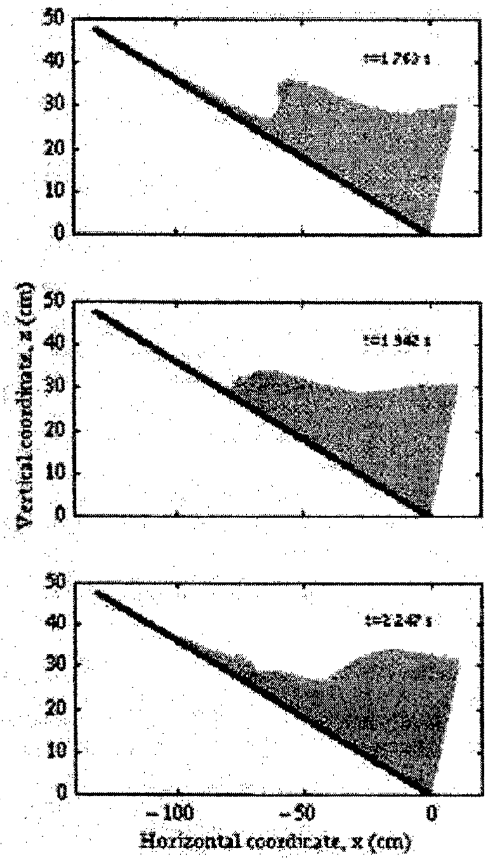

Figure 1: Time history of swash fluid motion.

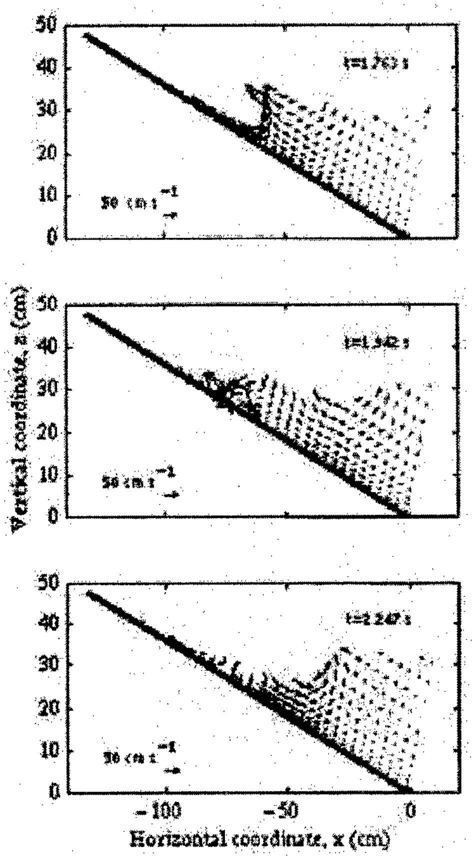

Figure 2: Time history of swash velocities.

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