Boussinesq Modelling of Wave-Induced Nearshore Circulation

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Modelling surf zone hydrodynamics, including transformation of surface waves, cross-shore and longshore currents, and low frequency motions, is of great interest for many reasons. Recently, advances have been made in extending the Boussinesq equations from a set of equations valid only for surface waves with very small wave numbers to numerical models that are now capable of modelling wave propagation from deep water to shallow water, including wave breaking. Computational advances now permit the use of these equations for large nearshore regions and to allow the averaging of model results to predict mean flows at a shoreline, including longshore and rip currents. The wave blockage by strong opposing currents is also simulated by Chen et al. (1998) using a Boussinesq model for the fully coupled wave and current motion.

In this study, we employ a time-domain numerical model based on the fully nonlinear Boussinesq equations (Wei et al., 1995) to investigate the fully coupled interaction of surface waves with rip currents, and the nearshore circulation generated by wave breaking on a barred beach with a rip channel. The energy dissipation due to wave breaking is modelled by introducing an eddy viscosity term into the momentum equations, with the viscosity strongly localized on the front face of the breaking waves. Wave runup on the beach is simulated using a moving shoreline technique. Figure 1a illustrates the computed wave field over the barred beach with a rip channel in the middle. The numerical wave basin is 20 m long and 9.1 m wide. A 1.8 m wide rip channel breaks a submerged bar on a beach with a 1:30 slope. The water depth on the crest and at the offshore toe of the bar is 0.1 m and 0.048 m, respectively. We use a normally-incident, monochromatic wave train with a period of 1.0 second and 4.8 cm in wave height as an input to the model. Wave breaking occurs near the crest of the submerged bar and near the shore line. The free surface becomes irregular behind the bar because of the current effects and the release of higher harmonics. Several interesting phenomena are observed from Fig 1a. First, a longshore oscillation along the wave crests offshore of the submerged bar is caused by the diffraction effect of the underlying rip current field as shown in Fig. 1b. We obtain the mean current field by averaging the modelled fluid particle velocity over one wave period. The vortex pairs associated with the rip diffract the wave field and the rip current increases the wave height significantly in front of the rip channel. The diffracted waves will cause non-uniformity of the radiation stresses in the longshore direction and may contribute to the complexity of the circulation pattern behind the submerged bar.

A laboratory experiment on the rip current generation with a similar topography was conducted by Haller et al. (1997). Comparisons of the velocity, set-up of the mean free surface, and the root mean square of the wave height along several transects give satisfactory agreement between the numerical results and measurements. It is worth mentioning that the perturbation due to the bathymetry and wave generation in the physical experiment results in an unstable rip current meandering away from the central line of rip channel. The phenomenon of rip migration is observed in the numerical simulation if the experimental bathymetry is employed in the numerical model.

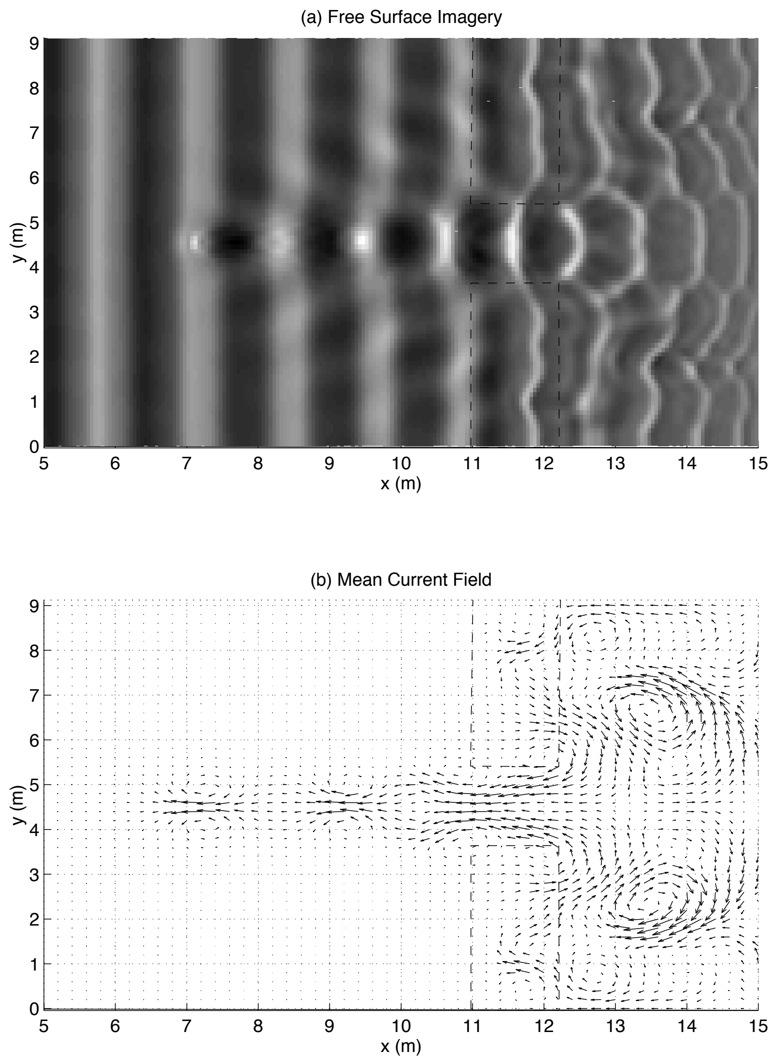

Figure 1: A snapshot of the computed wave field and the underlying mean current field. The waves propagate from the left to the right. The dash lines in the top panel denote the bar foot-print.

References

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