Wave-current interaction in formation of rip channel system

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Abstract:

Current effects on waves (CEW) have been recognized to play an essential role in attenuating offshore extent of rip currents (e.g., Yu and Slinn, 2003, JGR). The present study analyzes its mechanism and associated evolution of rip channel system through deformation of a longshore bar with a phase-averaged barotropic numerical model. The model relies mainly on a novel mathematical framework by Uchiyama et al. (2009, JGR; 2010, Ocean Modell.) based on an Eulerian-averaged vortex force formalism (McWilliams et al., 2004, JFM), accounting for two-way mutual interaction between waves and currents around the surf zone. Differing from the traditional radiation stress formalism, it cleanly separates conservative (vortex force, wave set-down, Stokes-Coriolis force if necessary) and non-conservative (wave breaking, bottom drag, boundary streaming, enhanced mixing) wave effects. An empirical total sediment load model of Soulsby and Van Rijn (1997) with a diffusive downslope transport effect (e.g., Garnier et al., 2008, JGR) is utilized for evaluating sediment transport and associated morphological evolution.

The model successfully reproduces the rip current reduction by CEW on an immobile barred-beach topography with equally-spaced rip channels. Among the other CEW such as Doppler shift and wave set-down/up, wave refraction on currents is found to be most substantial to modify the wavenumber field and breaker dissipation, leading to a systematic change in the diagnostic momentum balance. An alongshore-uniform barred topography evolves into a rhythmic rip channel system through intrinsic instability triggered by a small disturbance. We demonstrate that CEW is responsible for widening the rip channel spacing, shoaling the rip channel in the surfzone, and shrinking submerged crescent bumps in the offshore beneath rip heads.

Key words: wave-current interaction, sediment transport, rip current

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