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Numerical analysis of rip currents at RK Beach, Visakhapatnam, India using XBeach model

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Abstract

Rip currents are powerful, narrow currents that flow from the shore out to sea, originating within the surf zone due to the intricate interplay of waves, tides, currents, and the nearshore bathymetry. These currents pose significant danger, swiftly transporting swimmers and surfers offshore, resulting in numerous drownings globally. RK Beach in Visakhapatnam has reported a high number of rip current related drowning incidents. This study uses the 2D hydrostatic, phase-averaged, surf beat non-stationary mode of the XBeach model to simulate rip currents under diverse wave and tidal conditions. The primary inputs for the model consist of surveyed beach profile, nearshore bathymetry, wave fields from a nearby offshore wave rider buoy, and water levels from a tide gauge. Under nearly shore-normal wave incidence, particularly during the pre- and post-monsoon periods, intense velocities ranging from 0.5 to ~1.2 m/s were observed in the rip neck region, gradually decreasing toward the rip head. The model simulated rip current locations closely match the channels depicted in nearshore bathymetry, a pattern also observed in high-resolution satellite

images, suggesting bathymetrically controlled rip currents. Model simulations conducted under diverse seasonal hydrodynamic conditions showed close agreement with field observations, indicating high model reliability in simulating rip current dynamics, with RMSE values of 0.1 m for significant wave height, 0.03 m for water level, 5–10° for peak wave direction, and 0.15 m/s for current velocity. This is further supported by the strong agreement between the modelled patterns and the observed drifter velocities, Rhodamine-B dye dispersion, dimensionless fall velocity parameter (Ω) and satellite imagery. This study provides a basis for future simulations with variable nearshore bathymetry derived from satellite or video sources and accurately predicted hydrodynamics from suitable nearshore models toward developing an operational rip current forecasting framework. © 2025 Elsevier B.V.

Author keywords

And satellite images; Drifters; Numerical modelling; Rip currents; RK beach; XBeach

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