Simulating a Typhoon Storm Surge in the Bohai Sea Using a Coupled Model

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ABSTRACT

A coupled numerical model with a 1'×1' resolution grid has been developed and used to simulate two typical typhoon storm surges in the Bohai Sea of China. Three main driving forces have been considered in this coupled model: wave radiation stress, combined wave–current bottom shear stress and wave-state-dependent surface wind stress. This model has then been compared with in situ measurements of the storm set-up. The effect of different driving force components on the total storm surge has also been investigated. This study has found that the coupled model with high resolution is capable of simulating the two typical typhoons better than the uncoupled models, and that the wave-dependent surface wind stress plays an important role in typhoon storm surge–wave coupling in this area. The study has shown that the general coupling effects could increase storm set-up by 2–8%. Thus, it is suggested that to predict typhoon storm surges in the Bohai Sea of China, a storm surge–wave coupled model should be adopted.

KEY WORDS: wave; surge; tide; coupled model; typhoon storm; wave effects; set-up.

INTRODUCTION

The generation of waves and storm surges is closely related, as they are both generated by the wind. There exist strong nonlinear interactions between waves, tides and storm surges in shallow water. The study showed that the coupling of waves and tide–surge motion is driven by several mechanisms in which waves and the mean flow, or the water level associated with the tide and surge, interact with every component in the total motion, thus affecting all other motion. These mechanisms include mainly the wave-state-dependent surface wind stress, the wave–current interaction bottom stress, and the radiation stress. In the past 20 years, various studies including of: Mastenbroek et al.(1993)coupled a third-generation ocean wave model with a two-dimensional storm surge model in which only the wave has effects on currents and not vice versa.;Davies et al.(1994),used a three-dimensional hydrodynamic model involving a flow-dependent eddy viscosity and including enhancements of bottom friction due to wave-current interaction in shallow water, but not consider the interaction between air and sea. Zhang and Li et al.(1996,1997)synchronously coupled a third-generation ocean wave model with two-dimensional storm surge model taking into account the mutual influence of waves and currents, and their results show that the wave-dependent surface stress incorporated in the three-dimensional hydrodynamic model has significant impact on water surface velocities and surface elevations. Jin et al.(1997),coupled a third-generation model with a two-dimensional storm surge model taking into account the bottom stress to allow for wind. Mombaliu et al.(1998), discussed the sensitivity of wind wave simulation to coupling with a tide surge model with application to the southern north sea. Ozer et al.(2000) used a wave model and a hydrodynamic model, which were incorporated into a coupling framework, and and applied to the North Sea, the results shows that the sensitivity of waves to coupling increases from deep to shallow water. The sensitivity of surges is more uniformly distributed. Xie et al.(1996,2001) used two eddy-permitting models of the South Atlantic (S-coordinate Primitive Equation Model (SPEM) and Ocean Parallel (OPA) model) to simulate the near-surface mean and eddy flows and compare the results; the conclusions are the topographic constraint (trapping of boundary currents and interaction of mean and eddy flows with bathymetry) is stronger in SPEM than in OPA.. Choi et al.(2003) used the coupled model based on the synchronous dynamic coupling of a third-generation wave model, WAM-Cycle 4, and the two-dimensional tide–surge model to investigate the effect of tides, storm surges, and wind waves interactions during a winter monsoon on November 1983 in the Yellow Sea and the model simulations showed that bottom velocity and effective bottom drag coefficient induced by combination of wave and current were increased in shallow waters of up to 50 m in the Yellow Sea during the wintertime strong storm conditions. Among others, Lin et al. (2003) discussed the effects of radiation stress on wave heights and sea level in the interaction of coupled wave-tide–surge in the coastal area. Yin et al.(2003,2004), considered wave–currents or waves and tide–surge interaction mechanisms in researching wave–currents and wave-storm

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