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Evaluation of Spectral Wave Breaking Formulations in Wave and Current Coexisting Field

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ABSTRACT

Five kinds of energy dissipation formulations due to wave breaking are incorporated into a spectral wave model through parameterizations by two methods. The spectral wave model is based on the wave action balance equation with diffraction effects. The laboratory data from an experimental study of random waves shoaling and breaking on steady ebb currents at an idealized inlet are used to evaluate the performance of spectral wave breaking formulations in the wave and current coexisting field. Model to data comparisons show the bore-based formulation of Battjes and Janssen with a breaker height of 0.73 times the water depth produces the best fit in the applications studied herein.

KEY WORDS: Wave-current interactions; phase averaging wave model; random wave; wave breaking.

INTRODUCTION

In most coastal inlets and estuaries, where a great deal of human activity takes place, strong tidal currents may have a dramatic effect on wave transformation. Waves shortened and steepened by ebb currents lead to considerable breaking in both areas outside and inside the navigation channels. With strong currents, wave blocking becomes a serious navigation hazard. Therefore, reliable numerical predictions of waves are crucial in coastal engineering studies such as shore protection, harbor construction, nearshore morphological evolution, navigation channel maintenance and maritime disaster reduction.

One of the most important factors in the reliable modeling of nearshore waves is the characterization of wave breaking, since turbulent dissipation of the wave energy becomes the dominant dissipative mechanism and breaking processes play a quite important role in the wave transformation once waves are broken. In the absence of ambient currents, Zhao et al. (2001) examined five types of parameterizations for wave breaking in a two-dimensional elliptic wave model. They found that the formulations of Battjes and Janssen (1978) and Dally et al. (1985) performed better consistently and were robust to be used in their mild-slope wave equation model. Smith (2001) also evaluated alternative forms of breaking parameterizations for a spectral wave model using the Duck94 field data, and concluded that the Battjes and Janssen (1978) parameterization yielded the smallest errors when applied with the full Rayleigh distribution to estimate percentage of wave breaking. Subsequently, Zubier et al. (2003) reported that the formulation of Battjes and Janssen (1978) provided a better fit to field data than that of Dally et al. (1985).

In the presence of ambient currents, however, no comprehensive evaluation of different wave breaking formulations has been conducted, although there are a number of formulas available in the literature for considering the effect of currents on spectral wave breaking (e.g. Hedges et al., 1985; Sakai et al., 1989; Li and Dong, 1993; Smith et al., 1998; Chawla and Kirby, 2002). In fact, recent studies have revealed how important is the wave breaking and dissipation implemented in a two-dimensional wave model. Lin and Demirbilek (2005) used a set of wave data collected around an ideal tidal inlet in the laboratory (Seabergh et al., 2002) as a benchmark to examine the performance of two spectral wave models, STWAVE and GHOST, for random wave prediction around four different type of jettied-inlet geometries. They found that both models significantly underestimated the wave height inside and seaward of inlets, suggesting that further enhancement of wave breaking and wave-current interaction near inlets would be necessary to improve the reliability of spectral wave model predictions in inlet applications. Mase et al. (2005) also used two different spectral wave models, WABED and SWAN, to simulate the wave transformation over a sloping beach to simulate rip currents. They concluded that the high order differentiation scheme used in SWAN ver.40.41 produced questionable results and the differences between WABED and SWAN predictions were mainly due to different formulations used in both models for the treatment of wave breaking and wave diffraction.

The purpose of this study is to explore the behavior of different coupled current and depth limited wave breaking formulations in conjunction with a phase averaging spectral wave model. This objective is accomplished by model to data comparison of random wave shoaling and breaking on steady ebb currents at an idealized inlet (Smith et al., 1998), which covered a good range of wave and current parameters and can be used in evaluation of wave dissipation formulations that represent current and depth induced wave breaking.