Numerical Simulations of Onshore Sandbar Development

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ABSTRACT

Prediction of the dynamic behavior of onshore and offshore sandbar systems could be of great importance. A quasi-three-dimensional (Q-3D) morphological numerical model for sandbar forming and migrating shoreward has been developed. The model combines a Boussinesq wave model, a two-dimensional depth integrated wave-driven currents model with a one-dimensional vertical currents model for maximum undertow and onshore acceleration skewness of wave orbital velocities near sandbar crest. The combined model makes a simultaneous simulation of the sandbar-forming and shoreward moving processes associated with the onshore acceleration skewness of wave orbital velocities and the horizontal wave-driven circulation currents. The numerical results of sandbar formation are verified by the DHI LIP11D test1b with good agreement in wave heights, vertical velocities, and sandbar migration. Therefore, the present model is suitable for prediction of sandbar formations and migrations. The sandbar forming and migrating shoreward is also discussed.

KEY WORDS: Onshore sandbar; Wave-driven currents; Boussinesq wave model; Sediment transport; Quasi-three-dimensional model.

INTRODUCTION

Nearshore sandbars are the important feature of natural beaches morphodynamics. The cross-shore location of sandbars changes by the interactions between the sandbar and the sediment transport fluxes from waves and wave-driven-currents. Hoeefel and Elgar (2003) indicated the mechanics of wave-induced sediment transport and sandbar migration: large waves breaking on the sandbars caused offshore mean currents, which maximum near the sandbar crest, will lead sandbars moved offshore; small waves pitching forward on the sandbars made the onshore acceleration skewness of wave orbital velocities, which maximum near the sandbar crest, will lead the sandbar moved onshore. The nearshore sandbars could protect shorelines from wave attack by dissipating wave energy offshore through sandbar-crest-induced wave breaking. In general coasts, the dynamic behavior of nearshore sandbars are similar to quasi-cycle for storm and seasons waves alternated. However, the formation and evolution of sandbars are very important to coastal planners and engineers. Prediction of the dynamic behaviour of nearshore sandbar systems could be of great importance, there are many studies about the evolutions and migrations of nearshore sandbars by numerical simulations in last decade (Hsu et al., 2006; Long et al., 2006; Ruessink et al., 2007; Dronen and Deigaard, 2007; Ruessink and Kuriyama, 2008; Houser and Greenwood, 2009; Ruessink et al., 2009; Pape et al., 2010; Almar et al., 2010).

According to Hoeofel and Elgar (2003), two mechanisms are commonly used in the explanation of morphodynamics of sandbars migration. The first mechanism type is the migration of offshore sandbars. The offshore sandbars migrated seaward observed during storms were driven primarily by a maximum in the offshore mean current (Under highly energetic storm conditions, breaking waves cause near bottom seaward flows, also called “undertow”) near the sandbar crest. Offshore sandbar migration during storms results from feedback and interaction between breaking waves driven the “undertow” and bathymetric evolution (Elgar et al., 2001).

The second mechanism associates the migration of onshore sandbars. There are many studies have suggested mechanisms that could drive sandbars migration shoreward. Trowbridge and Young (1989) and Trowbridge and Madsen (1984) demonstrated that nonlinear wave boundary layer processes might play a role. Onshore sandbars migration might also be derived by the systematic changes in wave kinematics when passing over nearshore sandbars. As waves shoaling, their shapes are often described as “skewed” and “asymmetric” (Elgar, 1987), the mean water elevation depressed (the “Wave set-down”) leads mean currents been weak. The non-breaking wave caused sediment transport over sandbars is driven predominately by wave asymmetric orbital velocities. Under the steep skewed and asymmetric waves, the water particle velocity is accelerated strongly as the asymmetric orbital velocity rapidly changes from maximum offshore to maximum onshore (e.g., Elgar et al., 1988).

In order to describe morphodynamics sandbars well, a key parameter for cross-shore sediment transport under breaking and near-breaking waves is well performed the near-bed skewed and asymmetric wave orbital velocity. Therefore, the three dimensionality of the hydrodynamic system should be considerable and must be taken into account. Most sediment transport models are based on phase-averaged wave models, depth-integrated hydraulic models (currents and wave...