ASSESSING UNCERTAINTY IN THE MODELING OF RUNUP AND SWASH MORPHODYNAMICS USING XBEACH

Jantien Rutten, Universidad Nacional Autónoma de México, JRutten@iingen.unam.mx
Alec Torres-Freyermuth, Universidad Nacional Autónoma de México, ATorresF@iingen.unam.mx
Jack A. Puleo, University of Delaware, jpuleo@udel.edu

INTRODUCTION

Phase-resolving numerical models are frequently used tools to investigate short and long wave transformation, nonlinear wave interactions, and wave runup. Moreover, nearshore morphodynamics can be explored with the recent advancement of the models and computational resources. Sea surface elevation time series that force phase-resolving models at the offshore boundary are often unavailable. Therefore, time series are usually recreated from wave energy-frequency spectra through the superposition of harmonics. The wave phases of the harmonics are unknown and therefore assumed to be randomly distributed. This implies that an infinite number of time series with different sequencing of waves can be recreated from a single wave-energy spectrum and, for that reason, recreated time series are a source of uncertainty in model predictions. This intrinsic uncertainty has been found to cause variability in wave overtopping of structures (e.g., Pearson et al, 2002; Williams et al., 2014; Romano et al., 2015) and in setup and runup at beaches (McCabe et al., 2011; Torres-Freyermuth et al., 2019). Torres-Freyermuth et al. (2019) investigated the effect of intrinsic uncertainty on runup at planar beaches for different wave conditions and beach slopes and suggested that uncertainty is especially important under dissipative conditions. Yet unknown is the effect of intrinsic uncertainty on bed evolution. Here we assess the effect of intrinsic uncertainty on inner surf and swash zone evolution at three beaches with different beach morphology.

METHODS

Wave transformation, runup, sediment transport and bed evolution were simulated with the phase-resolving numerical model XBeach Nonhydostatic (Roelvink et al., 2009; Smit et al., 2010). Sediment transport was computed through the depth-averaged advection diffusion equation with a source-sink term based on the instantaneous and equilibrium sediment concentration. The Van Thiel-Van Rijn formation was used to compute the equilibrium sediment concentration. Note that the sediment transport formulation was developed and validated for phase-averaged models (e.g. XBeach Surfbeat). Here, simulated bed level changes should be interpreted carefully as the transport formulation was used with a phase-resolving model.

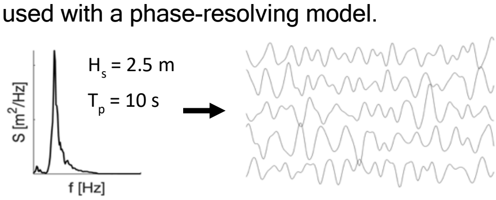

Figure 1. Example of energy-frequency spectra (left) and 5 corresponding time series with different wave phases (right).

The model was implemented for three different beach profiles, characterized by a steep foreshore and beach face (DE), a mild shoreface, steep beach face and low-tide terrace (DU), and a gentle shore- and beach face and sub- and intertidal bars (TS; Fig. 2c). Intrinsic uncertainty was evaluated by forcing the model with 100 different time series of sea surface elevation at each site, resulting in a total of 300 simulations. All the time series corresponded to the same wave spectrum (H_s = 2.5 m, T_p = 10 s) but differed in the sequencing of the waves due to random wave phases (Fig. 1). Simulations were run for 7 hr with an evolving bed, after a 75 min (85 min for TS) spin-up time with a fixed bed.

FINDINGS

Fig. 2 shows that intrinsic uncertainty affects bed evolution at all sites but that the importance of the uncertainty differs between the sites. At DE and DU, the upper beach face erodes and sediment deposits at the lower beach face in all 200 simulations. The terrace edge at DU erodes.

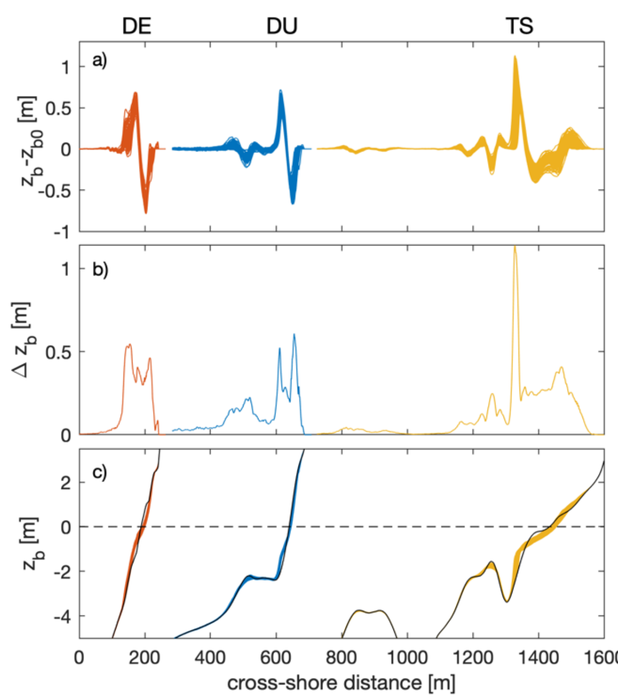

Figure 2. Simulated bed evolution after a 7 hr storm (H_s= 2.5 m and T_p=10 s) at DE (left), DU (middle) and TS (right) for 100 simulations that differ in the offshore wave forcing with (a) bed elevation change, (b) maximum difference in bed elevation, and (c) bed elevation. Positive (negative) values in (a) indicate deposition (erosion). The colored lines in (a) and (c) correspond to the 100 different simulations, whereas the black lines in (c) indicate the initial bed elevation.

Although all simulations at DE and DU show a similar erosion-deposition pattern, after 7 hr bed elevation can differ by 0.6 m between simulations due to the different sequencing of the waves in the offshore forcing (Fig. 2b). At TS, the swash zone can either erode or accrete, depending on the sequencing of the waves in the offshore forcing. The highest variability among the sites due to intrinsic uncertainty is found at TS, where bed elevation can differ by 1.1 m after 7 hr (Fig 2b). Intrinsic uncertainty has the largest effect under the most dissipative conditions (TS; Fig. 2b), in line with the findings on runup at planar beaches by Torres-Freyermuth et al. (2019). At the conference, intra-site differences in the cross-shore propagation of intrinsic uncertainty in wave transformation and swash dynamics will be discussed.

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