INDIVIDUAL WAVE EFFECTS ON COASTAL STRUCTURE DAMAGE DURING WINDSTORMS

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INTRODUCTION

In hazard assessment studies that evaluate the damage caused to coastal structures by windstorm-generated surge and waves, the standard approach has been to estimate structural loading by applying phase-averaged wave propagation models (e.g., SWAN, STWAVE) and storm surge models (e.g., ADCIRC), coupled or not with each other. Bare-earth "Digital Elevation Models" (DEMs) have typically been used as a basis for model grid development, with sometimes empirical adjustments being made to beach profiles or dune crest levels to account for storm-induced erosion. In recent work, the latter approach has been improved by including real time morphodynamic changes in simulations, using models such as XBeach (e.g., Schambach 2017; Schambach et al., 2017), which are still based on the wave action conservation equation, including semi-empirical parameterizations of wave breaking and many formulations based on linear wave theory (e.g., phase/group velocity, radiation stresses,…), as well as low-order wave-wave interaction terms. Finally, structural damage has typically been estimated based on empirical damage curves, developed based on field surveys, that use flow depth and controlling wave crest height as inputs (e.g., Grilli et al., 2017). Neglected in this modeling approach, however, are dynamic set-up and runup effects, as well as strongly nonlinear wave interactions that occur near and in the surf and swash zones.

WORK AND RESULTS

We assess the importance of such dynamic wave effects in coastal damage estimates, by using the wave-resolving Boussinesq model FUNWAVE-TVD (Shi et al., 2012) (FTVD) to simulate the impact of a 100-year storm in Southern RI (Fig. 1a). As in the above studies, time series of storm surge and wave spectra are extracted from the USACE "North Atlantic Coast Comprehensive Study" (NACCS) database. Wave spectra are specified in the model using an internal wavemaker. In Fig. 1, storm surge is simply set as a static level, but this will later be dynamically adjusted, together with depth-averaged mesoscale current time series specified along the model boundary. Fig. 1b shows that, compared to modeling the same storm with STWAVE, maximum crest elevations (0.7x1.66 =1.2 H_s in STWAVE and 1% maximum crest in FTVD) are larger in FTVD in the swash zone. Fig. 1c shows maximum structural damage (%) from NACCS curves, based on these crests and flow depth. Despite the large storm surge (3.7 m) that dominates damage, FTVD predicts larger damage than STWAVE (not shown) for many structures located in the swash zone.

We use XBeach to simulate the beach and coastal barrier erosion and built-up DEM to assess the wave impact on structures.

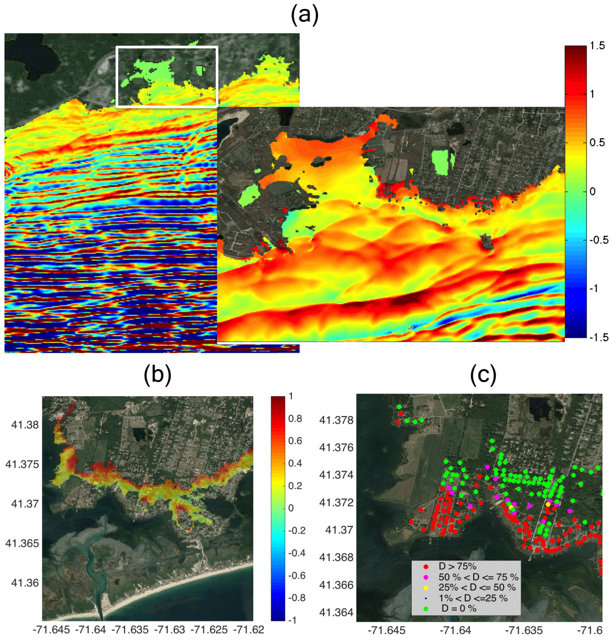

Fig. 1: 100-y storm simulation with FTVD (over a 3.7 m storm surge). (a) Surface elevation snapshot (m) in Charlestown, RI area; (b) positive difference in controlling wave crest elevation vs. STWAVE simulations; (c) damage to structures (%) from maximum NACCS damage curves (colored dots are individual houses divided into 4 classes, depending on construction type).

REFERENCES

Grilli A.R., Spaulding M. L., Oakley B. A. and C. Damon 2017. Mapping the coastal risk for the next century, including sea level rise and changes in the coastline: application to Charlestown RI, USA. *Nat. Hazards*, 1-26, doi:10.1007/s11069-017-2871-x.

Schambach, L. 2017. A comparison of wave and erosion modeling methods for the 100-year storm in Southern Rhode Island. *MS Thesis*, University of Rhode Island.

Schambach L., Grilli A.R., Grilli S.T., Hashemia M.R., J. King 2017. Assessing the impact of extreme storms on barrier beaches along the Atlantic coastline: Application to the southern Rhode Island coast. *Coastal*

Engng.,133,26-42.

Shi F., Kirby, J.T., Harris J.C., Geiman J.D. and S.T. Grilli 2012. A high-order adaptive time-stepping TVD solver for Boussinesq modeling of breaking waves and coastal inundation. *Ocean Modelling*, **43-44**, 36-51.