Wave Transformation and Runup Variability due to Wave Phase Uncertainty

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INTRODUCTION

Wave runup is a significant portion of total water levels, particularly during storms (Sallenger, 2000). This makes accurate prediction of wave runup paramount. Wave runup can be estimated using simplified empirical models (e.g. Stockdon et al 2006) or simulated using phase-resolved Bousinesq models (Shi et al 2007, Lynett et al 2002) or non-hydrostatic models (e.g. Zijlema et al 2011). These models typically have a variety of offshore boundary input options ranging from spectral to time series, with the most broadly used being spectral parameterizations (e.g. JONSWAP, TMA, etc.) or direct spectral input, both of which neglect phase information at the offshore boundary. Recent research has highlighted the importance of the offshore boundary condition and wave phase at modeling wave runup (e.g. Fiedler et al 2019, Rutten 2021). This work pays careful attention to the consequences of the bound infragravity (IG) wave and explores the influence that unknown phase information can have on predicted wave transformation and resultant wave runup in the context of field observations.

COASTAL MODEL TEST BED

This work was conducted within the framework of the Coastal Model Test Bed (CMTB) at the U.S. Army Engineer's Research and Development Center's Field Research Facility in Duck, NC. The CMTB is a numerical testing environment that leverages the FRF's observational dataset to facilitate model-data comparisons and targeted model development.

PHASES EFFECTS ON WAVE RUNUP

A phase-resolved 1D wave model was setup at Duck to model a single hour (14 March 2018 at 0 UTC) with multiple phase realizations of the same offshore boundary condition measured at the 8m-array (H_s=1.99m, T_p=13.5s). The local bathymetry (measured 13 March 2022) and wave conditions were alongshore uniform and shore normal, respectively. Beach topography measurements (O'Dea, et al 2019) from the 0 hour UTC were fused with the measured bathymetry. The domain was extended 6km offshore of the measured bathymetry to allow for the generated waves to equilibrate over a constant depth. The model was forced with an offshore boundary truncated to remove offshore energy, and then interpolated to a 1D equal energy binned spectra (nf=100) to ensure a completely random seed for the phase information (no repeat cycle). The model was run for 100 hours of simulated time and the simulation time series was subset into individual ensemble members of variable length to evaluate differences in phase realizations of the same spectral forcing.

Initial results (Figure 1) show the IG energy needs to travel a significant cross-shore distance over flat bottom (~6km) to equilibrate and become bound. While there is variability of energy distribution between ensemble members for H_s sea-swell, the predominant variability appears in the IG band. Inside the surf-zone, the variability in the IG is greater than 25% of the average IG wave height. Ongoing analysis is focused on extending these results to wave runup and different conditions.

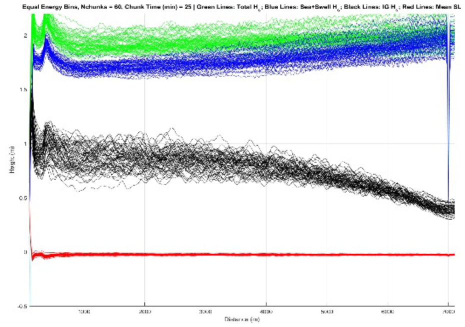

Figure 1- Cross-shore evolution of H_s (green), H_{s_ss} (blue), H_{s_IG} (black), and wave setup (red), with varying phases applied at the offshore boundary over 25-minute ensembles. Domain has flat bottom from offshore boundary to 1km cross-shore coordinate and measured bathymetry inshore from that point.

REFERENCES

Fiedler, J. W., Smit, P. B., Brodie, K. L., McNinch, J., & Guza, R. T. (2019). The offshore boundary condition in surf zone modeling. Coastal Engineering, 143, 12-20.

Kim, D. H., Lynett, P. J., & Socolofsky, S. A. (2009). A depth-integrated model for weakly dispersive, turbulent, and rotational fluid flows. Ocean Modelling, 27(3-4), 198-214.

O'Dea, A., Brodie, K. L., & Hartzell, P. (2019). Continuous coastal monitoring with an automated terrestrial lidar scanner. Journal of Marine Science and Engineering, 7(2), 37.

Rutten, J., Torres-Freyermuth, A., & Puleo, J. A. (2021). Uncertainty in runup predictions on natural beaches using XBeach nonhydrostatic. Coastal Engineering, 166, 103869.

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

Stockdon, Hilary F., Rob A. Holman, Peter A. Howd, and Asbury H. Sallenger Jr. (2006): "Empirical parameterization of setup, swash, and runup." Coastal engineering 53, no. 7 573-588.

Sallenger Jr, Asbury H. "Storm impact scale for barrier islands." Journal of coastal research (2000): 890-895.

Zijlema, Marcel, Guus Stelling, and Pieter Smit. "SWASH: An operational public domain code for simulating wave fields and rapidly varied flows in coastal waters." Coastal Engineering 58, no. 10 (2011): 992-1012.