THE CONTRIBUTION OF WAVE RUNUP TO COASTAL FLOODING AT NORFOLK (VA, USA) DURING EXTREME EVENTS

Christopher Lashley, University of Delaware, clashley@udel.edu
Jack Puleo, University of Delaware, jpuleo@udel.edu
Fengyan Shi, University of Delaware, fyshi@udel.edu

RATIONALE

The projected rise in both sea level and storm intensity will increase the likelihood of flooding at coastal U.S military facilities over the coming decades. As the threat of coastal flooding increases, so too will the need for accurate forecasting tools to guide the design and assessment of coastal defenses.

Coastal flooding occurs when the total water level (TWL) elevation exceeds that of the natural (e.g. dune) or built (e.g. levee) coastal defense. Operational models that estimate the TWL typically consider the combined effect of mean sea level (MSL), high tide, and storm surge. However, the extent to which storm waves run up the beach or structure is often neglected, as either computationally demanding numerical or site-specific empirical models are required to accurately resolve the components of wave runup. These components include a time-averaged surface elevation at the shoreline (wave setup) and time-varying fluctuations about that mean (swash), which may be further divided into high-frequency (sea and swell, SS) and low-frequency (infragravity, IG) motions. Therefore, any prediction tool used to estimate wave runup must account for breaking waves, which drives wave setup and infragravity motions.

While neglecting wave runup allows for rapid hazard assessment on a large scale, studies have shown that its exclusion can lead to a significant underestimation in the TWL (Serafin et al., 2017).

OBJECTIVES

In this study, we assess the contribution of the individual components of wave runup (wave setup, SS and IG wave motions) to the TWL at the Norfolk Naval Station and its surrounding region (VA, USA) – a mesotidal area characterized by a mild continental shelf and exposed to hurricanes and nor'easters.

METHODS

We used the fully nonlinear FUNWAVE-TVD numerical wave model (Shi et al., 2012) to carry out the analysis, as it resolves both SS and IG wave motions and the generation of wave setup due to breaking waves. The model was forced with offshore measurements of significant wave height, peak wave period, wave direction and directional spreading for named storms, provided by the City of Norfolk (Fig. 1). Surge data, for model input, was obtained from a nearby USGS water level (WL) sensor (Fig. 1). The model was validated qualitatively, considering flood extent, using community reports of flood and tide-related damage along the coast (Fig.1, data available from: https://data.norfolk.gov).

RESULTS AND CONCLUSIONS

Results so far indicate that the relative contribution of wave runup and its components to the TWL varies depending on the offshore wave conditions, local bathymetry and surge generated. Using the numerical model to vary the forcing parameters (wave characteristics and water levels), the conditions that result in wave-driven flooding versus surge-driven flooding at Norfolk are identified.

Regardless of the dominant mechanism, the inclusion of wave runup leads to higher TWL estimates. This finding supports previous studies that advocate for the inclusion of wave-induced water levels in the development of coastal hazard maps and may aid the City of Norfolk in their coastal resilience planning. Finally, the community reports proved to be a valuable source of information where quantitative data is lacking; highlighting the value of citizen science.

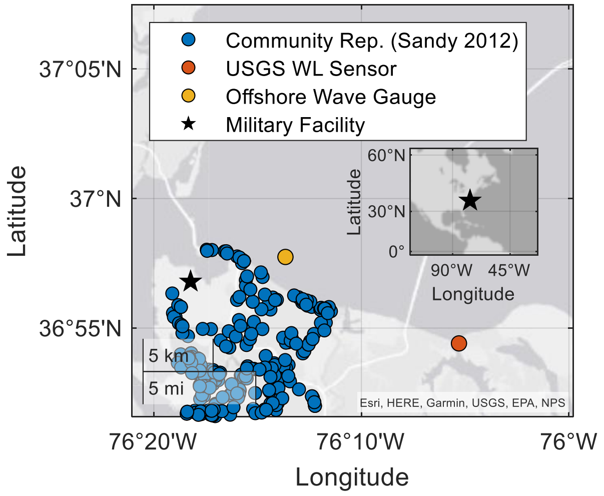

Figure 1 – Northern coast at Norfolk (VA,USA) with inset showing location relative to the US East Coast.

REFERENCES

Serafin, K. A., Ruggiero, P., and Stockdon, H. F. (2017). "The relative contribution of waves, tides, and nontidal residuals to extreme total water levels on U.S. West Coast sandy beaches." *Geophysical Research Letters*, 44(4), 1839-1847

Shi, F., Kirby, J. T., Harris, J. C., Geiman, J. D., and 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