Modeling Total Water Levels at Naval Station Norfolk

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**Abstract**

The projected rise in 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. Here, we evaluate the combined impacts of hurricanes and climate change on the TWL and associated coastal flooding at and near Naval Station Norfolk (NSN) on the US east coast. Numerous methods were employed for the TWL prediction including empirical models, hydrodynamic models (D-Flow FM, ADCIRC, and NearCoM), a wave action-based wave model (SWAN), and a phase-resolving wave model (FUNWAVE-TVD). Two wind forces were used, a modeled wind force (ERA5) and a parametric wind force (Holland Model: HM). The models were used to predict the peak surge characteristics (magnitude, timing, and duration) and flood area characteristics (extent, average, and maximum flood depth) at NSN during four historical hurricanes (Irene, Isabel, Sandy, and Michael). Sensitivity analysis was carried out for the climate change impacts (sea level rise (SLR) and wind speed (WS)), hurricane characteristics (central pressure drop (PD) and radius of maximum wind (RMW)), and the potential inaccuracies in the model inputs (storm track error, bathymetry accuracy, and mesh resolution).

All hurricanes show high sensitivity to climate change impacts, SLR and WS, and changes in the hurricane track. It was found that 23% - 40% of NSN might be vulnerable to flooding by 2150. In addition, the simulated wave height reflected high sensitivity to the wind speed enhancement where up to 50% increase in the predicted wave height was obtained associated with a 22.5% increase in the wind speed. Given that NSN do not face the open ocean, it is more at risk from surge and SLR to TWL than the contribution from wave forcing. Both NEARCOM and FUNWAVE-TVD predicted alongshore currents and wave setup along the coast, but the small wave setup does not lead to additional inundation in NSN.

Shifting the hurricane track showed quantifiable impacts in the vicinity of RMW where shifting Hurricane Isabel 54 nm to the east resulted in a potential flooding of 43.6% (D-Flow simulation) of NSN. Modifying the PD or the RMW showed marginal impacts on the model outputs. Although minor inaccuracies in the used bathymetry (up to 1m) and low-resolution mesh (up to 1km) showed limited influence on the TWL prediction, they have a significant influence on the flood area and wave height estimation. Therefore, the decision of the appropriate resolution of the model must be judged based on user need. If the main aim is to predict the water level and peak surge, lower-resolution fast simulations can be conducted. Conversely, if the main purpose is to predict coastal flooding (areal extent) associated with different extreme events, higher resolution, yet computationally expensive, simulations are essential.