An Integrated Real-Time Hydrodynamic and Coastal Risk Assessment Model

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Abstract : The Northeast Coast of the US faces damaging effects of coastal flooding and winds due to Atlantic tropical and extratropical storms each year. Historically, several large storm events have produced substantial levels of damage to the region; most notably of which were the Great Atlantic Hurricane of 1938, Hurricane Carol, Hurricane Bob, and recently Hurricane Sandy (2012). The objective of this study was to develop an integrated modeling system that could be used as a forecasting/hindcasting tool to evaluate and communicate the risk coastal communities face from these coastal storms. This modeling system utilizes the ADvanced CIRCulation (ADCIRC) model for storm surge predictions and the Simulating Waves Nearshore (SWAN) model for the wave environment. These models were coupled, passing information to each other and computing over the same unstructured domain, allowing for the most accurate representation of the physical storm processes. The coupled SWAN-ADCIRC model was validated and has been set up to perform real-time forecast simulations (as well as hindcast). Modeled storm parameters were then passed to a coastal risk assessment tool. This tool, which is generic and universally applicable, generates spatial structural damage estimate maps on an individual structure basis for an area of interest. The required inputs for the coastal risk model included a detailed information about the individual structures, inundation levels, and wave heights for the selected region. Additionally, calculation of wind damage to structures was incorporated. The integrated coastal risk assessment system was then tested and applied to Charlestown, a small vulnerable coastal town along the southern shore of Rhode Island. The modeling system was applied to Hurricane Sandy and a synthetic storm. In both storm cases, effect of natural dunes on coastal risk was investigated. The resulting damage maps for the area (Charlestown) clearly showed that the dune eroded scenarios affected more structures, and increased the estimated damage. The system was also tested in forecast mode for a large Nor'Easters: Stella (March 2017). The results showed a good performance of the coupled model in forecast mode when compared to observations. Finally, a nearshore model XBeach was then nested within this regional grid (ADCIRC-SWAN) to simulate nearshore sediment transport processes and coastal erosion. Hurricane Irene (2011) was used to validate XBeach, on the basis of a unique beach profile dataset at the region. XBeach showed a relatively good performance, being able to estimate eroded volumes along the beach transects with a mean error of 16%. The validated model was then used to analyze the effectiveness of several erosion mitigation methods that were recommended in a recent study of coastal erosion in New England: beach nourishment, coastal bank (engineered core), and submerged breakwater as well as artificial surfing reef. It was shown that beach nourishment and coastal banks perform better to mitigate shoreline retreat and coastal erosion.

Keywords : ADCIRC, coastal flooding, storm surge, coastal risk assessment, living shorelines

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