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Parameter Governing Impact and Damage Due to Erosion of Barrier Islands by Hurricanes

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Abstract

In this study, a method for systematically creating model setups for the numerical model XBeach was developed, applied, and used to evaluate the vulnerability of a barrier island to hurricane forcing. XBeach is a computer model that accurately simulates hydrodynamics (i.e., waves and surge) and the resulting morphological change (i.e., erosion) on barrier islands during storm events. A pre-existing topography grid of Bay Head, NJ, a town located on a barrier island, is used in all simulations. The basic method was developed from a previously validated simulation of Hurricane Sandy (2012). This method included the preliminary development of files coded using MATLAB and the process of running simulations remotely using the Alabama Supercomputer. Then, the method was generalized such that additional synthetic storms could be created and sea level rise could be introduced, depending on user needs. Through additional model runs, this method is being used to systematically identify model output parameters most relevant to assessing barrier island vulnerability.

Keywords: Barrier Islands, XBeach, Synthetic Storm

1. Introduction

Common along the U.S Atlantic and Gulf of Mexico coasts, barrier islands are low-lying, narrow landforms existing parallel to the mainland coast and serve as the first line of protection against high intensity storms as well as provide important ecological services to maritime ecosystems. Exposure to storms, such as hurricanes, causes these landforms to be vulnerable to damage by severe erosion of the barrier island. A series of storm impact regimes are often used to describe four storm impact levels and their predictions of barrier island changes[1]. Each impact regime is characterized by storm surge and wave runup, referred simply as runup, which is a measure of the level of flooding experienced by the island. The swash regime, the first impact level, characterizes runup to be confined to the foreshore of the beach; the collision regime consists of the runup colliding with the base of the foredune ridge; runup exceeds the elevation of initial coastline protection during the overwash regime; and the initial protection being exceeded by the base of swash motion indicates the final impact level, the inundation regime[1]. Two of the most severe storm impacts include: overwash, shown in Figure 1, and breaching, displayed in Figure 2. Overwash is the onshore transport of sand from dunes, and breaching is the creation of a channel or inlet through a barrier island. In order to aid in the construction of stronger coastal communities, research concerning the storm characteristics that most affect the erosion and destruction of barrier islands is imperative. This project created a method for developing model setups for synthetic storms. The model outputs from those storms were used to identify parameters most relevant to assessing barrier island vulnerability.

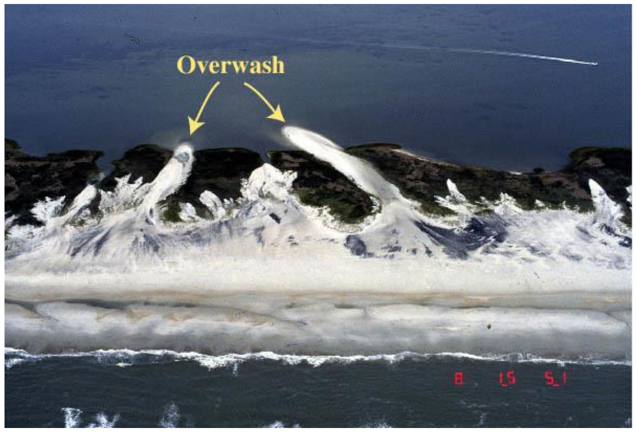

Figure 1. Overwash of eastern United States barrier island caused by Hurricane Katrina[5].

The use of quantitative observations, such as pre- and post- storm surveys of barrier island topography and hydrodynamic storm data collected from sources like the National Oceanic and Atmospheric Association (NOAA), can be used to formulate a hypothesis, such as, "A barrier island without engineered reinforcement, such as a seawall, will experience more extreme damage due to erosion during high-impact storms." This hypothesis can then be tested with a numerical model that simulates the impacts of a storm at a given location[2, 3]. In this study, the developed method uses the numerical model XBeach, which is a computer model that accurately simulates hydrodynamics (i.e., waves and surge) and the resulting morphological change (i.e., erosion) on barrier islands during storm events to test hypotheses such as this[4].

2. Methods

XBeach is forced using wave and water level data as offshore boundary conditions on a pre-existing, previously validated, topography grid created for Bay Head, NJ, a township located on a barrier island (Figure 3). The validation of this grid was performed by forcing Hurricane Sandy wave and surge data and comparing post-storm surveys to final simulated topography output by XBeach[3]. During Hurricane Sandy, several barrier islands along the New Jersey and New York coastline were overwashed and breached. XBeach was used to study processes causing overwash and breaching at the New Jersey location[3]. However, there is a need to determine the impacts due to storms other than Hurricane Sandy. Since the occurrence of hurricanes is relatively rare, synthetic, user-defined storms are used in this project. In this study, each model setup is simulated on the Alabama Supercomputer (ASC) such that multiple processors can be used, thereby reducing overall run time. A process for uploading and downloading data from the supercomputer is also developed in this project. Therefore, a two-component method for systematically creating simulations of synthetic storms is created from this study.

Figure 2. Breaching of southeastern United States barrier island caused by Hurricane Katrina[6]

Figure 3. Study area in Bay Head, NJ

3. Results and Discussion

A research method (Figure 4) was developed in order to systematically create inputs of synthetic storms for use in XBeach. The results of the synthetic, non-historical storms are compared to results obtained from the same model using storm forcing from Hurricane Sandy. Then, the model results of the synthetic storm are analyzed to determine storm parameters that most greatly affect barrier island erosion.

The process is divided into two major components: 1) creating inputs for XBeach that accurately define the synthetic storm; and 2) simulating the storm on the ASC and analyzing model results. The model inputs used to create the synthetic storm are coded within MATLAB using the detailed .m files (available upon request) before being uploaded to the supercomputer. In addition to access to MATLAB and a supercomputer similar to the ASC, time-dependent wave and surge and pre-storm topography files are needed in order to create a numerical model that accurately represents a barrier island being impacted by a hurricane. After extracting data from various online resources (see Figure 4), the hydrodynamic storm data and topography grid are translated into a format understood by the numerical model and are transferred to the supercomputer for simulation.

Once the simulation is completed, results are downloaded from the supercomputer and analyzed in MATLAB. The numerous analytical options MATLAB provides, such as visual animations, allow a researcher to view extensive temporally and spatially varying data that, without a visualization tool like MATLAB, would remain a mysterious group of numbers within the output file.

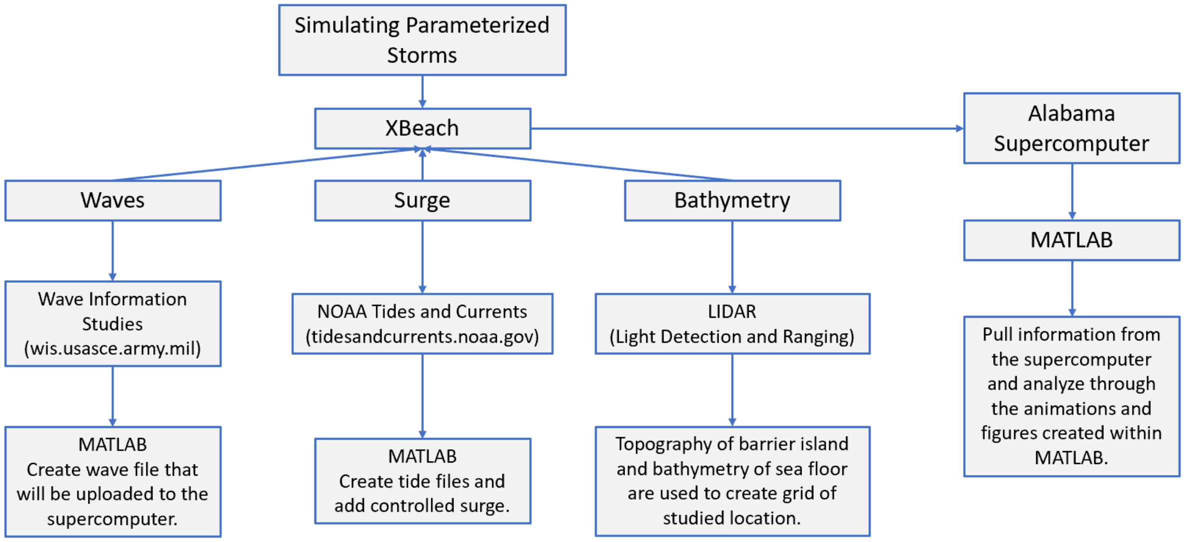

Figure 4. Method flowchart

To test the research method developed, the storm forcing of Hurricane Sandy was simulated as Storm 1. Storm 2, a synthetic storm, was created using the same grid, topography and bathymetry, as Storm 1, but the method shown in Figure 4 was used to extract waves, tides, and surge from resources such as Wave Information Studies and NOAA's Tides and Currents data.

Figure 5 illustrates barrier island topography, z_b, which was identified as an important parameter when quantifying the damage done to the barrier island due to erosion. The spikes in the middle of the graph represent the buildings on the island. On the right of the graph (Atlantic Ocean side), sediment is eroded from the dune and deposited in the nearshore region by both Storms 1 and 2. Sediment deposition on the left side (bay side) of the buildings represents the overwash caused by the storms.

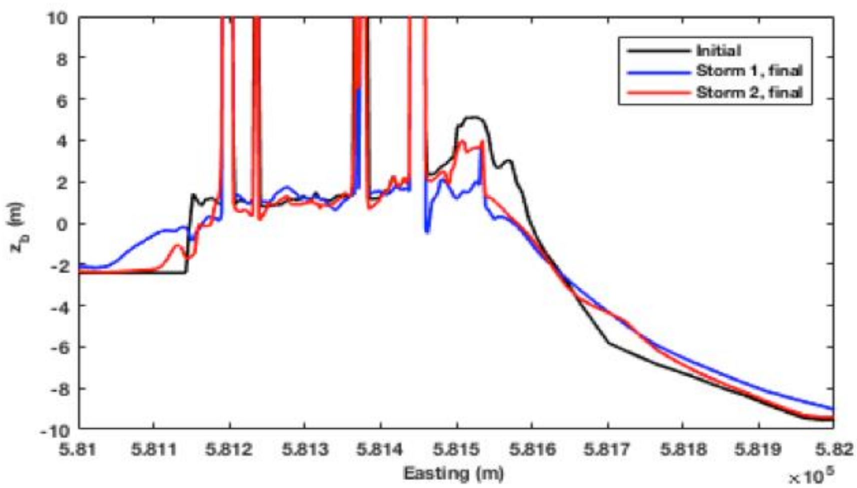

Figure 5. Initial and final plot of Bay Head, NJ bathymetry (Atlantic Ocean on right side of figure)

The successful development of this research method allows systematic creation of synthetic storms and simulation using XBeach so that any researcher conducting like-minded research may follow the outlined steps. It is also useful for simulating future impacts due to climate change, such as rising sea levels. The method described in Figure 4 was applied and the water levels varied by a prescribed amount of sea level rise to estimate future changes in the barrier island. This method allows researchers to create more storms and, in turn, more data to analyze and draw conclusions. The outlined process essentially has the ability to create infinite amounts of data. This is especially important when studying locations such as New Jersey where these high impact storms do not occur often enough to collect a significant amount of data.

4. Conclusion

Researchers propose that the use of multi-level protection off the coast of high-risk communities will aid in the mitigation of damage due to high impact storms such as hurricanes. Improving the means of identifying the vulnerability of barrier islands is among the primary acts dedicated to the protection of coastal zones. Using the method developed in this study, several more synthetic storms including sea level rise will be simulated in order to obtain model output data for a range of storm conditions. Further, an algorithm will be created using the parameters found to be most relevant for analyzing vulnerability of the island, such as *zb* described previously. Compiling these data, a correlation between storm parameters and barrier island vulnerability (inundation, overwash, breaching, etc.) will be quantified and used as a predictive measure for the impact of future storms.

5. References

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