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Impact of Changes in Morphology on Extent and Duration of Inundation During Tropical Cyclones

Jayaram Veeramony
Code 7322, Naval Research Lab
1009 Balch Blvd
Stennis Space Center, MS 39529
phone: (228) 688-4835 fax: (228) 688-4759 email: jay.veeramony@nrlssc.navy.mil

Allison Penko
Code 7434, Naval Research Lab
1005 Balch Blvd
Stennis Space Center, MS 39529
phone: (228) 688-4823 fax: (228) 688-4823 email: allison.penko@nrlssc.navy.mil

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LONG-TERM GOALS

The long term goal is to accurately predict the onset, peak and duration of inundation in coastal regions that are vulnerable to tropical and extratropical storm systems.

OBJECTIVES

In 2014, a Naval Research Laboratory (NRL) Rapid Transition Project (RTP) "Coastal Surge and Inundation Prediction System" was completed and transitioned to the Naval Oceanographic Office (NAVOCEANO) for operational use. The model predicts the peak and onset of inundation well within the requirements set forth by the US Navy. However, the predicted duration of inundation, a quantity that is necessary for mustering humanitarian assistance and disaster response teams, is severely under-estimated. The objective of this research is to assess the importance of morphological changes that occur during an extreme event such as hurricanes to the duration of inundation in coastal regions.

APPROACH

The FLOW and WAVE components of the Delft3D modeling suite are used to predict the water levels, currents and wave heights due to high winds. We will use the three-way coupled system that includes the morphological component of Delft3D (MOR) in addition to the FLOW and WAVE components to determine whether:

1. Changes in morphology due to tropical storms cause significant changes in surge and inundation?
2. Inclusion of morphology in the modeling system improve predictions of waves and currents.

Data collected during Hurricane Ike will be used to quantify the answers to these questions. To address Task 1, a systematic comparison of model performance with and without coupled morphologic change are being conducted using the best available wind field, bathymetry and topography. Sediment and bathymetry data was acquired through USGS databases. To address Task 2, we will determine the fidelity of the model to predict morphologic change during extreme storms by comparing the predictions to field data. In addition, we will compare observed waves and water levels, including those measured along the beach and behind the dunes by the USGS to model.

WORK COMPLETED

We have successfully ran coupled Delft3D FLOW-WAVE-MOR simulations at Sabine Pass during Hurricane Ike to assess the effects of morphology changes on inundation predictions. Different morphology options including sediment transport formulations, morphology computation depth thresholds, sediment size distributions, and morphological acceleration and sediment transport factors were tested to determine the optimum settings for sediment transport during surge and inundation events.

RESULTS

We performed a sensitivity analysis on several morphology module options. Varying the morphology computation depth thresholds between 0.1-1.0 m had negligible effects on the simulation results. Three sediment transport formulations (van Rijn, 1993; Meyer-Peter-Muller, 1948; and Soulsby/van Rijn, 1997) were also tested. The Soulsby/van Rijn formulation resulted in only slightly less sediment transport than the default van Rijn (1993) formulation. The Meyer-Peter-Muller formula resulted in an order of magnitude less transport, likely due to the formula only including bedload and not suspended load. Varying the morphological acceleration and sediment trasport factors did have a significant effect on the results. Since this research is studying an extreme event, we chose to use an acceration factor of 1. We varying the sediment transport factors from 1 to 100; however, comparisons to measured bathymetric change would provide more insight to a realistic sediment transport factor. Lastly, an additional sediment size class was included in a simulation. The final simulation results did not change; however, with the additional class, the model will then output the transport of each class separately, a capability that could be useful in the future for examining sediment sorting.

The following results were obtained using the (default) van Rijn (1993) sediment transport formulation, a depth threshold for morphology computations of 0.1 m, a morphological acceleration of 1.0, and a sediment transport factor of 100. Comparisons of water level estimates with and without the Delft3D coupled morphology module indicate that the morphologic change induced by Hurricane Ike had minimal impact on the duration of inundation (Figure 1).

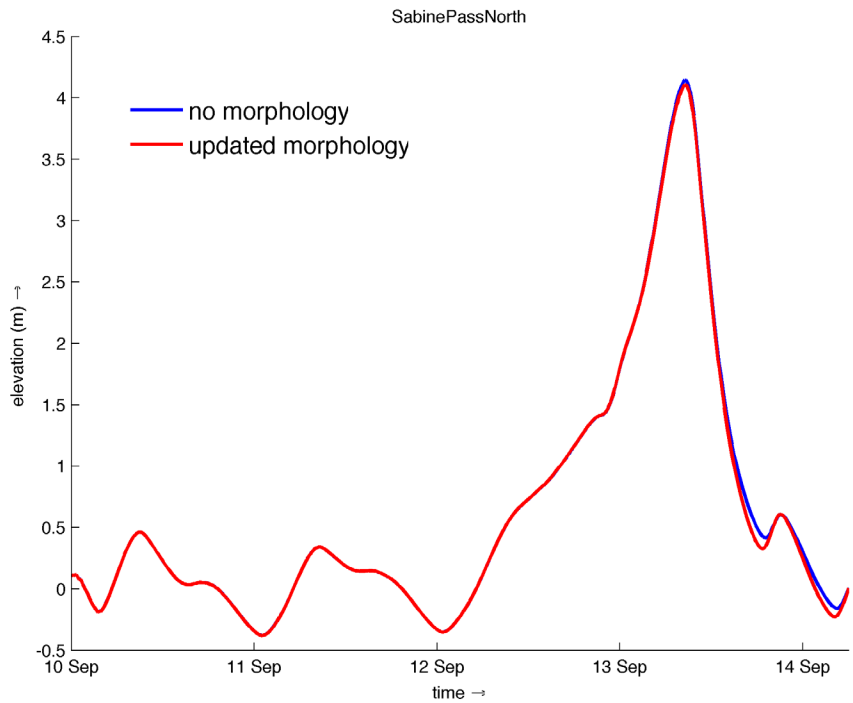

Figure 1: Water levels at Sabine Pass North without (blue line) and with (red line) the effect of morphologic change.

The majority of the morphologic change occurred in the inlet during the passage of the storm. Figure 2 shows the water depth at the end of the simulations with and without the morphologic updating. The retreating surge causes a channel and large shoal to form in and at the entrance to the Pass, respectively.

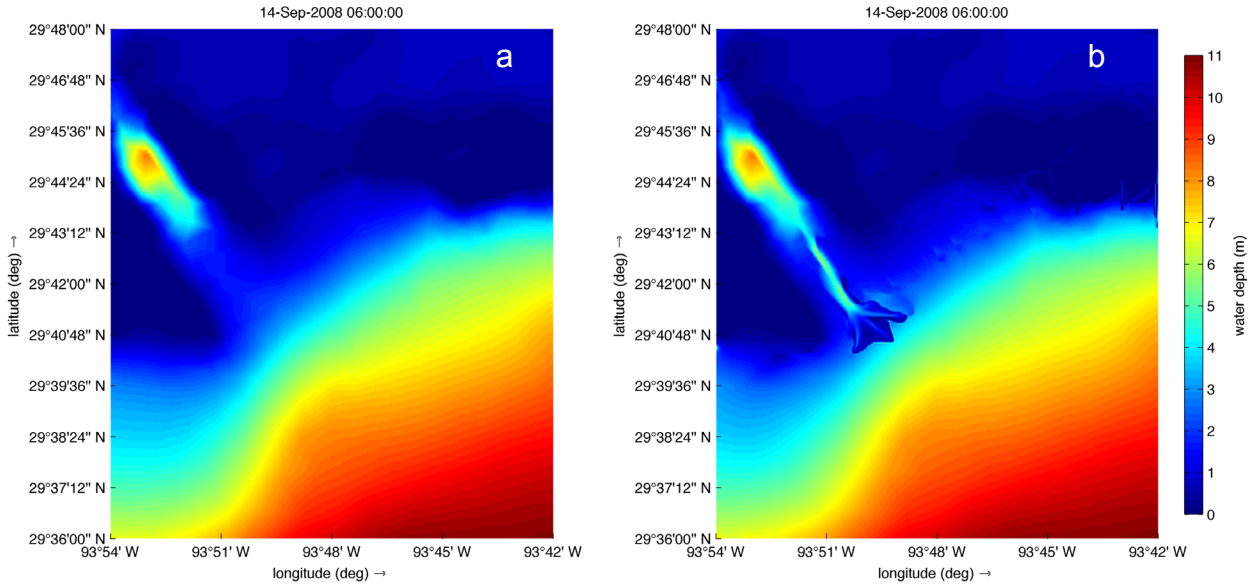

Figure 2: Water depth in the simulation domain (a) without and (b) with morphological updating.

Ongoing work includes expanding the model domain for the sediment transport computation, comparing the results of the morphologic change results to LIDAR surveys of topography to assess the fidelity of the model to correctly simulation morphologic changes. We will also compare wave and currents predicted by the coupled WAVE-FLOW-MOR modeling system to measured data.

IMPACT/APPLICATIONS

This work indicates that the coupled Delft3D WAVE-FLOW-MOR modeling system has the potential to predict the morphologic change caused by extreme events, which can greatly impact Navy operations and humanitarian efforts in hurricane response.

RELATED PROJECTS

2013 COMT project "A Puerto Rico/U.S. Virgin Islands surge and wave inundation model testbed," Principal Investigator: Andre Van der Westhuysen (NOAA/PR), http://testbed.sura.org/node/522