INVESTIGATE INNOVATIVE COASTAL PROTECTION METHODS (IKE DIKE AND SHUTTER) FOR HOUSTON SHIP CHANNEL AND GALVESTON COASTLINE USING NUMERICAL MODELS (HYBRID OF ADCIRC)

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Abstract
Galveston bay with the Houston Ship channel could become potential source of concern to the region because of the industrial activities and the potential exposure to residential neighbor hoods. In the past 100 years, Galveston has had the highest number of hurricanes. In this study, Galveston Island and Houston ship channel was numerically modeled using Advanced Circulation (ADCIRC) for storm surge estimation. Galveston and Houston ship channel protection against storm surge has become a national issue especially after the hurricane Ike in 2008. The advantage of ADCIRC usage for numerical modeling was investigated to resolve complex fluid dynamics in shallow straits and near-coastal zones with high resolution modeling.

Introduction
The event of hurricane Ike in 2008 in the Gulf of Mexico east of Galveston Island has raised the need for coastal protection for Galveston and surrounding region. Hurricane Ike, in Texas Gulf Coast, caused approximately $30 billion in damage and killed nearly 200 people. Galveston, Houston ship channel with the port of Houston are vital for the state of Texas and for the United State government. In fact, based on Bay Area Houston Economic Partnership reports, about 46 percent of the U.S. aviation fuel, 20 percent of the nation's gasoline supply and 40 percent of its chemical-feed stocks are made in the Gulf Coast area (Rice SSPEED). To prevent Galveston coast against a potential more devastating storm surge, a new storm surge barrier proposed by Dr. Bill Merrill, Professor of Marine Sciences at Texas A&M at Galveston, is being considered. The new levee named Ike Dike is to extend 60 miles from High Island to south of the San Luis pass with a height of 17 feet to protect Galveston Bay and the surrounding area. This will add up to the existing Galveston 10 miles long and 15.6 feet high seawall proven not sufficient during hurricane Ike.

At present, there are only a handful of European countries that manage or construct large sea-resistant storm flood surge barriers. These are the United Kingdom, The Netherlands, Italy and Russia. So, knowledge of these unique objects is scarce and demands very specific knowledge and experience. Especially now when climate change and sea level rise are recognized facts that should be taken into account (Coastal Portal, 2010).

Through the years, computer models were developed to estimates the storm surges generates by hurricanes. This is done using the hurricanes parameters (pressure, radius of max winds, location, direction, forward speeds) and the landing point topography and bathymetry.

The Sea, Lake, and Overland Surge from Hurricanes (SLOSH) is a computerized model developed by the National Weather Service (NWS) to estimate storm surge heights and winds resulting from historical, hypothetical, or predicted hurricanes. SLOSH is used by the National Hurricane Center (NHC) for the exclusive benefit of NWS, US Army Corps of Engineers (USACE), and Emergency Management personnel (FEMA et al, 2003). It is the primary computerized model used by US official to assess a foregoing hurricanes effect on the predicted landing point to issue emergency evacuation if required.

A more research oriented application name Advanced Circulation (ADCIRC) for storm surge numerical modeling was developed (Luettich and Westerink, 2004) for better estimation of hurricane storm surge. The advantage of utilizing ADCIRC is its ability to map intricate shoreline and the corresponding topography needed to resolve complex fluid dynamics (Desback et al, 2010). ADCIRC unstructured grid allows modeling complex coastal regions at fine spatial scale (Chu et al, 2010)

ADCIRC Model

Coastal areas are characterized by geometrically complex features which include bathymetry, rivers, channels, bays, wetlands and man made structures (dunes, levees, harbors and transport systems). Accurate modeling of hurricane or tsunami induced coastal flooding has been limited by the use of fixed size computational domains and the lack of sufficient clarity in the grid resolution. The fixed size computational domain limits the volume of water involved in the event. Grid resolution is important to capture the varying natural features such as bathymetry and coastal profile with man made structures and barriers. ADCIRC has a large domain-unstructured grid approach to compute hurricane and storm surge. The large domain allows the storm surge to naturally and accurately propagate from deep waters on to continental shelf and adjacent coastal region. The use of unstructured grid resolves important flow features on a localized basis, accurately solving the flow features on a localized basis. In order to develop proper and adequate coastal protection, it is critical to capture the flow features and transport of sediments as the storm surge propagates and recede thorough the Galveston bay and Houston Ship channel.

Local Modeling

The use of basin size domains with highly localized grid resolution significantly improves the predictive ability of computational models of hurricane storm serge in very complex flood plains.

ADCIRC-SMS Model Controls

SMS is used to input the important parameters to the ADCIRC model. There are six different tabs that are used to input the data. The tabs include the following: (1) General, (2) Timing, (3) Files, (4) Tidal/Harmonics, (5) Wind and (6) Sediment options.
(1) General Tab: it includes the model, initial condition, Coriolis option (forces due to the latitude), solver type, number of iterations per time step, generalized properties (lateral

viscosity) and bottom friction(for greater than 10 m use a value of 0.005 and for shallow water use a value of 0.02).

Modeling approach

For this study of hurricane storm surge in the Gulf of Mexico around Galveston, two models with two different shoreline resolutions were created. The first model encompassed the domain between longitudes 93.0 W to 96.3 W and latitude 27.6 N and 30.0 N, (Figure 1).

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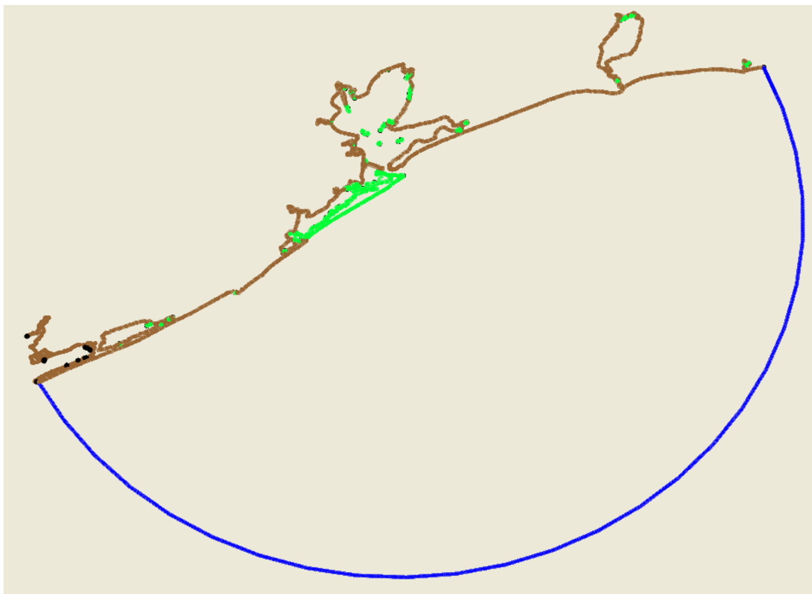

Figure 1: Model 1: Shoreline and ocean boundary.

The second model encompassed the domain between longitude 94.2 W to 95.4 W and 28.8 N to 29.9 N, see Figure 2.

Model 1 is the biggest domain. It was defined to check the global effect of the hurricane around Galveston. And model 2 was especially defined to investigate the effect of hurricane storm surge on Galveston and Houston ship channel precisely. ADCIRC two-dimensional depth integrated (2DDI) model was used and Surface Water Modeling System (SMS) is the preprocessing and post-processing software.

Coastline

The coastline data were imported from National Geographical Data Center (NGDC). Model 1 shoreline has a resolution of 1:250,000 and model 2 has a resolution of 1:70,000. It can be observed from Figure 1 that with lower resolution of coastline data, Houston ship channel does not appear compare to the model 2 in Figure 2.

Bathymetry

The bathymetry data were also imported from National Geographical Data Center (NGDC). The resolution of the bathymetry data extracted can also be variable with a limitation on the maximum matrix of data that can be extracted at once. The bathymetry of model 1 has a resolution of 1 minute, (Figure 3).

Figure 2: Model 2: Shoreline and ocean boundary.

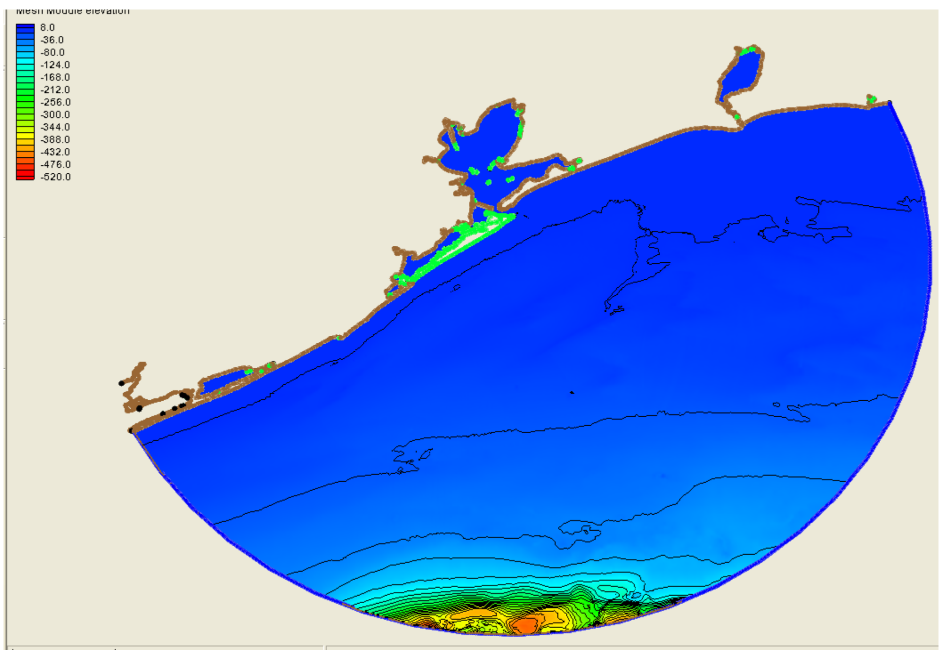

Figure 3: Model 1: Shoreline and ocean boundary and the bathymetry.

The bathymetry of model 2, (Figure 4), has a resolution of 3 sec. Since the resolution of the coastline of this model is higher and more intricated and better bathymetry resolution is then required. Due to the limitation on the maximum data matrix that can be extracted at once, a smaller model is required for accuracy using NDGC data center.

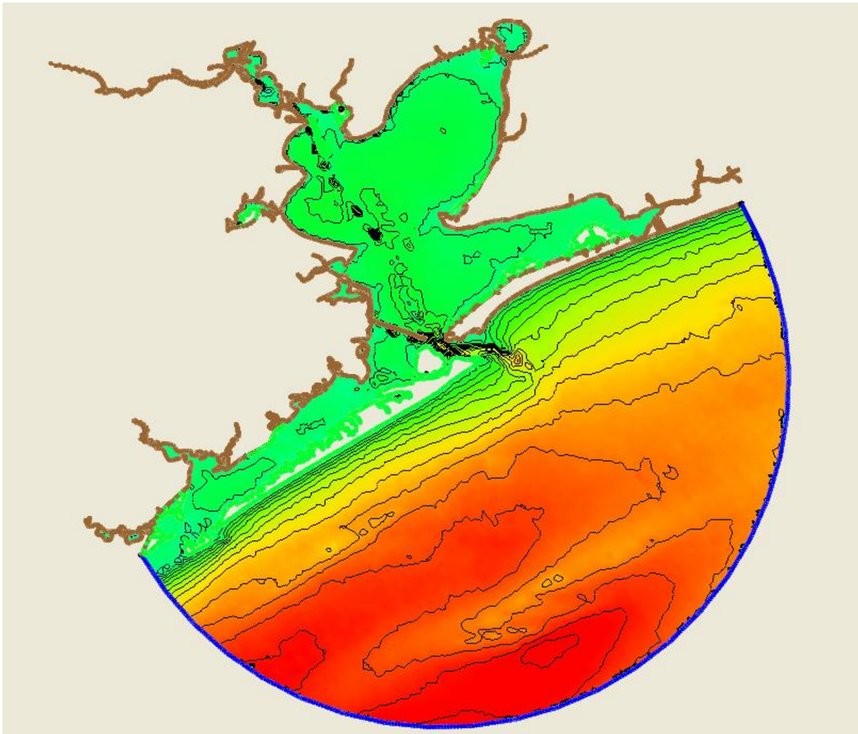

Figure 4: Model 2: Shoreline and ocean boundary with the bathymetry.

Protection Systems

There are a number of methods to protect the coastal are from storm serge and coastal flooding. The immediate focus is on evaluating the potential of Ike Dike and the new shutter system (Vipulanandan et al. 2010) separately and together.

Analysis

In the analysis section, with the ability of unstructured grid, the finite element mesh is generated to be fine around location of interest. The single meteorological wind forcing function is being used for the hurricane simulation.

The models were run on University of Houston Texas Learning and Computation Center super computers.

Conclusion

It is crucial to review potential protection systems of Texas coast, especially Galveston and Houston ship channel, against hurricane storm surge to avoid an economical catastrophe. ADCIRC is a very useful numerical tool for an assessment of the best solution. An approach of storm surge numerical modeling using ADCIRC was presented. A more extensive modeling work is in progress.

Acknowledgment

The ADCIRC, PC and parallel, code were provided by Dr Luettich, Professor at University of North Carolina at Chapel Hill. Thanks to TLC2 (Texas Learning and Computer Center) for the training in the use of the supercomputer at the University of Houston.

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