Tides and Waves for the National Weather Service River Forecast System
Report for the Period Spanning December 1, 2007 – November 30, 2008

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In addition to the previously reported work with regards to the St. Johns River, the University of Central Florida is cooperating with the Hydrology Laboratory of the NWS Office of Hydrologic Development and the LMRFC (Lower Mississippi River Forecast Center) to develop a two-dimensional storm tide model for the Pascagoula River. The major goals of this research are: 1) To include the Pascagoula River in a modification of an existing modeling domain that incorporates the entire East Coast of the United States, Gulf of Mexico and Caribbean Sea such that astronomic tides and storm surge can be accurately modeled. 2) To develop a shelf-based domain for the Pascagoula River that will produce results comparable to the large-scale domain from Goal 1. This research will result in a model that directly incorporates a full accounting of the hydraulic conditions for flood/river forecasting, especially with regards to flood forecasts and flood forecast mapping in the study area.

The hydrodynamic model employed for calculating tides and surges is ADCIRC-2DDI (ADvanced CIRCulation Model for Shelves, Coasts and Estuaries, Two-Dimensional Depth Integrated). The finite element based model solves the shallow water equations in their full nonlinear form. It can be forced with elevation boundary conditions, flux boundary conditions, and tidal potential terms, all of which result in the full simulation of astronomic tides. In addition, dynamic wind fields for a given hurricane or tropical storm event (e.g. Hurricane Katrina) are converted to spatially variable and time-independent wind surface stresses and incorporated into the ADCIRC-2DDI model along with atmospheric pressure variations to permit the simulation of a storm tide.

The overall work is comprised by the following four tasks: 1) Modification of an existing unstructured, finite element mesh for the WNAT (Western North Atlantic Tidal) model domain by adding the Pascagoula riverine systems to produce a basis model, such that astronomic tides and storm surge can be accurately modeled. 2) Development of a shelf-based model for the Pascagoula River that can produce results comparable to the large-scale domain from Task 1. 3) Verification of a coarse resolution WNAT model which can be employed to provide boundary conditions for the open water locations of a continental shelf-based model. 4) Improvement of the shelf-based model by investigating the influence of estuarine marshes, barrier islands and bottom drag coefficient assignment methodology. Such improvements will provide higher accuracy and more flexibility due to a more complete consideration of the physics.

Since the last report, a 1.5-m floodplain mesh was constructed to allow for the overtopping of the river banks. This floodplain model was applied in an astronomic tide simulation to show improvement upon earlier model results which involved an in-bank-only hydrodynamic description. It is learned from these model intercomparisons that the floodplains become important towards modeling astronomic tides within the Pascagoula River. It is further concluded that a 1.5-m boundary is sufficient to capture any tidally driven storage because of the minimal tidal amplitudes within the Pascagoula River (less than 1 m).

Next, the inlet-based floodplain mesh was incorporated into the WNAT-53K model domain to produce a large-scale computational mesh that focuses on the local region of interest. The resulting large-scale modeling domain employs a refined coastline and has the barrier islands located along the Gulf Coast meshed over in order to allow for the wetting and drying of elements. Winds and pressures associated with Hurricane Katrina (August 23 to 30, 2005) are applied over the large-scale computational mesh which included a high resolution of the Pascagoula River.

The localized domain is tested by imposing the hydrograph boundary condition together with local winds and pressures. It is demonstrated that a hydrograph generated from the WNAT-53K model can be applied on the open-ocean boundary of the localized floodplain mesh in order to produce results in the interior that are identical to those produced by the comprehensive mesh. If a localized domain is demanded, it is necessary to account not only for the local wind and pressure forcing, but also for the remote effects of the wind and pressure forcing. These remote effects of the meteorological forcings can only be captured by a large-scale model domain. However, the remote meteorological effect can be incorporated into a localized domain through a storm surge hydrograph that is calculated by a large-scale computational domain. The local winds and pressures together with the hydrograph boundary forcing (generated by a large domain) then become sufficient to drive the localized mesh.

The following journal publications/manuscripts, dissertations and theses acknowledge NA04NWS4620013 as a direct result of research performed up to the end of this reporting period.

1. Parrish, D.M. and S.C. Hagen, "Incorporating spatially variable bottom stress and Coriolis force into 2D, a posteriori, unstructured mesh generation for nonlinear oceanic and coastal tidal models," *International Journal of Numerical Methods in Fluids*, In Publication (July 2008).
2. Funakoshi, Y., S.C. Hagen, and P. Bacopoulos "Coupling of Hydrodynamic and Wave Models: A Case Study for a Hurricane Floyd (1999) Hindcast," *Journal of Waterway, Port, Coastal, and Ocean Engineering*, Scheduled: Vol. **134**, Issue **6** (November 2008).

3. Parrish, D.M. and S.C. Hagen, "2D, unstructured mesh generation for oceanic and coastal tidal models from a localized truncation error analysis with complex derivatives," *International Journal of Computational Fluid Dynamics*, **21 (7&8)**, 277–296 (August 2007).
4. Salisbury, M.B. and S.C. Hagen, "The Effect of Tidal Inlets on Open Coast Storm Surge Hydrographs," *Coastal Engineering*, **54 (3)**, 377–391 (2007).
5. Dietsche, D., S.C. Hagen, and P. Bacopoulos, "Storm Surge Simulations for Hurricane Hugo (1989): On the Significance of Inundation Areas," *Journal of Waterway, Port, Coastal, and Ocean Engineering*, **133 (3)**, 183–191 (2007).
6. Hagen, S.C., A. Zundel and S. Kojima,, "Automatic, Unstructured Mesh Generation for Tidal Calculations in a Large Domain," *International Journal of Computational Fluid Dynamics*, **20 (8)**, 593–608 (2006).
7. Bacopoulos, P., S.C. Hagen, Y. Funakoshi, A.T. Cox, and V.J. Cardone, "The Role of Meteorological Forcing on the St. Johns River (Northeastern Florida)," *Journal of Hydrology*, In Review as of 06-06-08.
8. Kojima, S., "Optimization of an Unstructured Finite Element Mesh for Tide and Storm Surge Modeling Applications in the Western North Atlantic Ocean," M.S. Thesis, Department of Civil and Environmental Engineering, University of Central Florida, Orlando (Summer 2005).
9. Salisbury, M.B., "The Effect of Tidal Inlets on Open Coast Storm Surge Hydrographs: A Case Study of Hurricane Ivan (2004)," M.S. Thesis, Department of Civil and Environmental Engineering, University of Central Florida, Orlando (Fall 2005).
10. Funakoshi, Y., "Coupling of Hydrodynamic and Wave Models for Storm Tide Simulations: A Case Study for Hurricane Floyd (1999)," Ph.D. Dissertation, Department of Civil and Environmental Engineering, University of Central Florida, Orlando (Fall 2006).
11. Parrish, D.M., "Target Element Sizes for Finite Element Tidal Models from a Domain-Wide, Localized Truncation Error Analysis Incorporating Bottom Stress and Coriolis Force," Ph.D. Dissertation, Department of Civil and Environmental Engineering, University of Central Florida, Orlando (Summer 2007).
12. Wang, Q., "Finite Element Modeling of Tides and Currents of the Pascagoula River," M.S. Thesis, Department of Civil and Environmental Engineering, University of Central Florida, Orlando (Summer 2008).
13. Takahashi, N., "A High-Resolution Storm Surge Model for the Pascagoula Region, Mississippi," M.S. Thesis, Department of Civil and Environmental Engineering, University of Central Florida, Orlando (Fall 2008).