UNIVERSITY TRANSPORTATION RESEARCH CENTER

RESEARCH BRIEF

PROJECT TITLE: PREDICTION OF IMPACT ON TRANSPORTATION SYSTEM DUE TO COASTAL FLOODING UNDER CLIMATE CHANGE CONDITIONS

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Global warming and climate change are reshaping our world in many ways. One of their most obvious evidences is sea level rise due to melting of polar glaciers and arctic ice. It is estimated that global sea level rise is at an alarming rate of 0.18cm/yr during 1961-2003, it is even higher at 0.3cm/yr during 1993-2003, and research estimates that sea level could range from 0.8 to 2 m by 2100 under glaciological conditions. Another important consequence of global warming is pattern change and increased variance of precipitation around the world; precipitation increasing and hurricanes becoming stronger and more frequent in high latitudes (Northern Hemisphere). The Northeast region is projected to see an increase in winter precipitation on the order of 20 to 30 percent.

Coastal flood evolution involves multi-physics/multi-scale phenomena and currently there is no appropriate modeling tool to predict impact of coastal flooding on transportation systems. In prediction of flooding at transportation systems, two crucial issues have to be addressed: 1) desired accuracy and resolution in time and space for flooding at transportation systems, 2) modeling of storm surges with sharp fronts (such as Tsunami in Japan on March, 2011). In view of current status of conditions, the most promising and feasible approach is hybrid method that couples different well-tested models designed for individual water flows.

In this project, a hybrid framework that couples shallow water models (SWMs) and circulation models (CMs) is proposed. This frame work is implemented in coupling a Godunov-type SWM with the finite volume method coastal ocean model (FVCOM), and its feasibility and performance are demonstrated with numerical experiments of typical flows and applications to practical problems. It is shown that the coupling approach is able to utilize the advantages of the two models, while avoiding their deficiencies. The proposed approach can simultaneously predict multiphysics processes at distinct scales such as surge bores, expansion waves and vortex flows, which cannot be well modeled by them individually. In addition, compared with FVCOM, the coupling method may substantially reduce computation time while maintaining the same solution accuracy. Given the fact that there are a number of similar SWMs and CMs in the coastal ocean community, this approach is significant since it can also be implemented for them to capture multiphysics and multiscale phenomena. The developed FVCOM/SWM system is tested in simulation of coastal flooding, including that at traffic roads and bridges, at Delaware Bay coast in sea-level rise conditions.

In addition, effort has also been made to couple FVCOM to a small-scale fully three dimensional CFD model that solves full Navier-Stokes equations. This approach is brand new, and it can directly predict hydrodynamic forces acting on transportation facilities such as bridge piers.

Above results appear in the following publications:

H. S. Tang, S. Kraatz, X. G. Wu, W. L. Cheng, K. Qu, and J. Polly. Coupling of shallow water and circulation models for prediction of multiphysics coastal flows: Method, implementation, and experiment. Ocean Engineering, 62(2013), 56-67

H. S. Tang, K. Qu, X. G. Wu. An overset grid method for integration of CFD and GFD models to simulate multiphysics coastal ocean flows. J. Comput. Phys., submitted, 2013