DAWSON – UT-Austin
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DHS Coastal Resilience Center
Year 6 ADCIRC Project Workplan
[July 1, 2020 – June 30, 2021]

1. **Title**. Accurate and Fast Spectral Wave Modeling and Coupling with ADCIRC

2. **Principal Investigator**.

Clint Dawson, University of Texas at Austin

3. **Other Participants/Partners**.

Don Resio, University of North Florida, and Casey Dietrich, North Carolina State University.

4. **Short Description**.

Computer models are currently being used to understand and predict coastal flooding due to tropical and extratropical storms. These models must be able to efficiently perform large numbers of simulations, operate in real-time and provide actionable results. The focus of this project is to improve upon existing wave modeling capabilities in terms of both accuracy and computational effort in support of coupled wave-storm surge coastal flooding predictions.

5. **Abstract**.

The ADCIRC coastal circulation and storm surge modeling system has been optimized for large-scale parallel computing hardware and has shown to be scalable up to thousands of processing cores. Given meteorological and tidal information, ADCIRC (ignoring wave physics) can produce a five-day prediction of water levels and velocities within a reasonable time frame for decision-makers, usually 15-30 minutes. With enough computing resources, ensembles of model runs can also be performed to account for uncertainty, e.g., for forecasting applications.

During storm events, waves and currents interact to produce coastal flooding, erosion and structural damage. ADCIRC by itself does not account for wind-driven waves. These phenomena are governed by short-wave physics not captured in ADCIRC and must be represented using a separate model that specifically addresses these physics. ADCIRC has been coupled with wave models such as SWAN, STWAVE, WAVEWATCHIII, etc. that are used by the USACE, NOAA, FEMA and other federal and state agencies. However, coupling existing short-wave models to ADCIRC increases computational complexity significantly, sometimes doubling or tripling the time to prediction versus ADCIRC alone.

Short-wave physics are modeled by a wave action density equation with time, geographic space (x-y), direction and frequency as independent variables. This five-dimensional equation is often solved implicitly in time using a finite volume or some other approach in spatial and spectral variables. In addition, complex source terms in the equations are used to capture sub-grid scale physics, and these source terms models have gone through many 'generations.' Most models are

now considered to be in their third generation (3G). Evaluating these source terms is often the most computationally demanding part of spectral wave modeling.

Recent work by co-PI Resio and collaborators has shown that these existing models contain outdated physics that cannot properly replicate the shape of directional wave spectra (Resio and Ardag, 2018a; 2019a, Ardag) and require large computer run times, due to the numerical methods and stability issues associated with the Discrete Interaction Approximation due to its improper formulation. Since improved spectral shape capabilities was offered as the primary motivation for transitioning to this class of model, it seems logical to revisit the need for using models which demand at least an order of magnitude execution time more than second generation (2G) models which contain the same physics in a more parameterized form. Furthermore, recent papers by Hao and Shen (2019), Zakharov et al. (2017); and Ardag and Resio (2019b) have shown that the physics of wave generation and wave momentum transfer into currents are better represented using the 2G physics. Such a model will have improved spectral shapes and breaking characteristics based on new theoretical and numerical work shown and reference in Hao and Shen (2019). This is expected to provide a more universal representation of waves in the coastal zone without the need for extensive site-specific tuning.

For consistency with ADCIRC and potentially other hydrodynamic models, the new model will be executed in a time-stepping mode, rather than in a steady-state mode (such as STWAVE). This new model will be capable of running with substantially longer time steps and with no iteration to attain a solution, while maintaining high quality results. This is primarily due to its parametric treatment of all source term required for arbitrary-depth execution. Using a previous deep water version of this class of model in deep-water testing (Hanson et al., 2009), the 2Gmodel performed about 40 times faster than the 3G models tested. Given that the 3G models have added features, such as iteration and more complex forms of the wind input and dissipation source terms, a 2G model is likely to result in execution- time improvements over current 3G models in the range of 80 – 100 today.

The first goal this project addresses is therefore: **Based on recent research, the physics of wave models can be improved to increase both the accuracy and efficiency of storm surge predictions. The wave model developed by Resio et al will be tested and encapsulated for incorporation into the ADCIRC Prediction System (APS).**

The second goal of this project is to incorporate and test the new wave physics within the APS. ADCIRC developers are working with a team at NOAA to develop a coupled ADCIRC/WaveWatchIII (WWIII) model using the NUOPC framework. We will build upon this framework in this phase of the project.