Operational Modeling of the Hurricane Storm Surge using ADCIRC

by

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Introduction

This paper describes the operational implementation of the hydrodynamic Advanced Circulation (ADCIRC) model for predicting the hurricane storm surge. ADCIRC is a finite element model capable of simulating tidal circulation and storm surge propagation over very large oceanic domains while providing high resolution in areas of complex shoreline and bathymetry. The code has been vectorized for optimum computational time and rigorously tested against analytical “annulus flow” tests to assess numerical accuracy. However, ADCIRC has only been utilized as a research tool despite its operational potential. Described below are plans to run operational storm surge forecasts during the 1998 Atlantic hurricane season.

Operational implementation

The first step for storm surge simulations is retrieving the National Hurricane Center's tropical marine advisory forecast through a "Family of Services" data provider, and from the web site http://www.nhc.noaa.gov as a backup. The marine advisory forecast, which is issued every 6 h at 03, 09, 15, and 21 Zulu

time, contains projected intensity (defined as the maximum sustained wind speed in knots) storm center locations, and storm size (in terms of Radius of 34 knot wind) out to 72 h. An example for Hurricane Danny is shown below:

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WTNT24 KNHC 171443
 TCMAT4
 TROPICAL STORM DANNY FORECAST/ADVISORY NUMBER   4
 NATIONAL WEATHER SERVICE MIAMI FL   AL0497
 1500Z THU JUL 17 1997

 AT 10 AM...CDT...1500 UTC...A TROPICAL STORM WARNING AND A HURRICANE
 WATCH ARE IN EFFECT FROM CAMERON LOUISIANA TO ORANGE BEACH IN
 EASTERN ALABAMA.

 TROPICAL STORM CENTER LOCATED NEAR 28.3N  91.9W AT 17/1500Z
 POSITION ACCURATE WITHIN  60 NM

 PRESENT MOVEMENT TOWARD THE NORTHEAST OR  35 DEGREES AT  4 KT

 ESTIMATED MINIMUM CENTRAL PRESSURE 1007 MB
 MAX SUSTAINED WINDS  45 KT WITH GUSTS TO  55 KT
 34 KT..... 30NE  60SE  30SW   0NW
 12 FT SEAS.. 30NE  60SE  30SW   0NW
 ALL QUADRANT RADII IN NAUTICAL MILES

 REPEAT...CENTER LOCATED NEAR 28.3N  91.9W AT 17/1500Z
 AT 17/1200Z CENTER WAS LOCATED NEAR 28.1N  92.2W

 FORECAST VALID 18/0000Z 28.7N  91.7W
 MAX WIND  50 KT...GUSTS  60 KT
 50 KT... 25NE  25SE   0SW   0NW
 34 KT... 50NE 100SE  30SW   0NW

 FORECAST VALID 18/1200Z 29.3N  91.0W...INLAND
 MAX WIND  55 KT...GUSTS  65 KT
 50 KT... 25NE  25SE   0SW   0NW
 34 KT... 50NE 100SE  30SW   0NW

 FORECAST VALID 19/0000Z 30.0N  90.5W...INLAND
 MAX WIND  30 KT...GUSTS  40 KT

 REQUEST FOR 3 HOURLY SHIP REPORTS WITHIN 300 MILES OF 28.3N  91.9W

 EXTENDED OUTLOOK...USE FOR GUIDANCE ONLY...ERRORS MAY BE LARGE

 OUTLOOK VALID 19/1200Z 31.0N  90.0W...INLAND
 MAX WIND  25 KT...GUSTS  35 KT

 OUTLOOK VALID 20/1200Z 33.5N  89.0W...INLAND
 MAX WIND  25 KT...GUSTS  35 KT

 NEXT ADVISORY AT 17/2100Z

 AVILA
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The next step involves "parsing" out the necessary track and intensity forecasts from the advisory which will be used to initialize the storm surge forecasts. This is accomplished by using a perl script. Perl, which stands for "Practical Extraction and Report Language," is a programming language optimized for scanning arbitrary text files and extracting information from the text files. Fortunately, NHC advisories contain consistent phrasing such that forecast latitude and longitude, as well as intensity, can be easily extracted. For example, current intensity always follows the phrase "MAX SUSTAINED WINDS," and predicted intensity always follows the phrase "MAX WIND."

Since these forecasts are in 12-h increments, an Akima spline routine interpolates to 1-h increments. This information is used to generate 1-h "snapshots" of the tropical cyclone wind field using a PBL hurricane model (Cardone, Greenwood, and Grennwood 1992). Finally, the PBL wind fields are nested with the ADCIRC model to forecast the spatial distribution of the storm surge. Currently, ADCIRC is run on the University of Mississippi Cray J916 supercomputer since the entire Atlantic, Gulf of Mexico, and Caribbean Sea basin is used. The supercomputer simulation is completed within 3h. However, smaller coastal domains may be used for simulations on UNIX workstations if necessary.

Forecast example --- Hurricane Danny (1997)

Due to the finite element structure of the grid, high resolution of the coastal bathymetry and coastline is captured, resulting in detailed storm surge forecasts. An example of Hurricane Danny (1997) is presented in Figure 1 for its Louisiana landfall. Danny caused moderate storm surge damage in Southeast Louisiana, particularly around Grand Isle and Port Sulphur where a 1-3 m storm surge flooded cars and buildings, and damaged boats docked in several harbors.

Future work

In addition to operational storm surge forecasts, future development is being considered for coupling with the Quasi-Lagrangian Model (QLM), which is being run operationally at User Systems Enterprises, Inc. The QLM model is being nudged by SSMI-, ERS-, and TOPEX-derived surface winds, resulting in improved marine surface wind forecasts. A coupled QLM-ADCIRC model system should result in improved tide forecasts, and better surge forecasts resulting from episodic mid-latitude storm systems such as “Northeasters.”

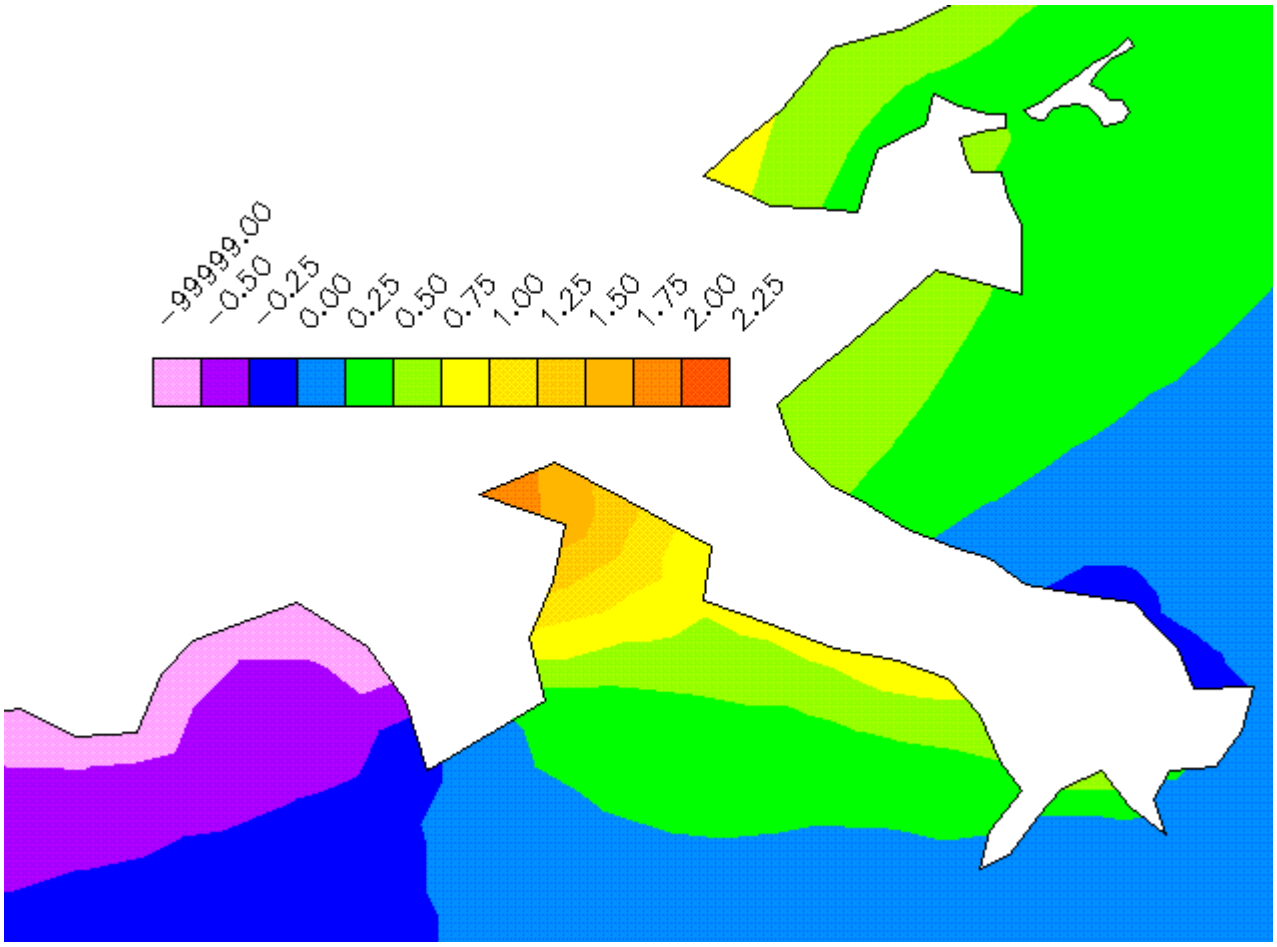

Figure 1. ADCIRC simulation of Hurricane Danny (1997) at landfall in Southeast Louisiana. Water elevation levels are shown in meters. Note the negative water elevations west of landfall, and 1-2 m elevations in the Mississippi River Delta consistent with observations. –99999 indicates where the ocean floor has become exposed in regions of strong negative surge due to offshore winds.