

AdcircViz: A Visualization Application for Distributed ADCIRC-based Coastal Storm Surge, Inundation, and Wave Modeling

*A JHT 2013 Project
End of First Year Progress Report*

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Abstract

High-resolution predictions of coastal storm surge, inundation, and waves generally require substantial computational resources, particularly in a forecast, real-time mode. Considering that a given storm only threatens a portion of the US coastline, high resolution is only needed in the coastal areas threatened by active storms and simultaneous and comprehensive spatial coverage of the entire US East and Gulf of Mexico coasts is unnecessary. Regional forecast systems using the ADCIRC tide, storm surge, and wave model have been operating in several risk-prone areas of the US East and Gulf coasts for the past several years. The ADCIRC grids are high-resolution regional discretizations of the topography, bathymetry, critical hydraulic structures, and land cover embedded in a larger scale coarser ADCIRC grid to simplify offshore/open boundary conditions. These systems use high-performance- computing (HPC) resources that are often locally provisioned but can be located at any available facility (e.g., NOAA's "jet" HPC systems in Boulder, CO).

To simplify the mechanics of conducting ADCIRC predictions in real-time, ADCIRC developers at the University of North Carolina (UNC) have created the automated and portable ADCIRC Surge Guidance System (ASGS) to provide end-to-end ADCIRC forecasts. However, the distributed nature of ASGS instances requires an efficient way to discover, gather, organize and visualize the distributed results from multiple ASGS instances and other models. Therefore, UNC's Renaissance Computing Institute (RENCI) has developed a "data grid" to federate ASGS instances and provide uniform access to forecasts. This simplifies knowing which systems are running and when solutions become available. To access and visualize results, we have developed AdcircViz, a MATLAB-based visualization application that provides robust access to ASGS forecasts in the data grid. In this two year project, we will deploy, extend, and support AdcircViz and work with the National Hurricane Center (NHC) storm surge team and JHT staff to make AdcircViz readily available for their operational environment. We will demonstrate the preliminary application version, gather requirements for and implement new capabilities, and provide documentation and support during active storms for which ASGS instances are running. While our project focus is on ASGS based results, the data grid methodology and AdcircViz application can be applied to other models if providers use recently developed community standards for storing and serving model results.

This document reports on the project's accomplishments to date and anticipated activities in the next 6-month period.

1) Overview of the AdcircViz Project

The community of expert ADCIRC system operators is organizing around an ADCIRC Data Grid that effectively creates a single collection of ADCIRC results. This is illustrated in Figure 1. The content of each THREDDs server is harvested into a master catalog file that AdcircViz retrieves and presents to the user through the GUI.

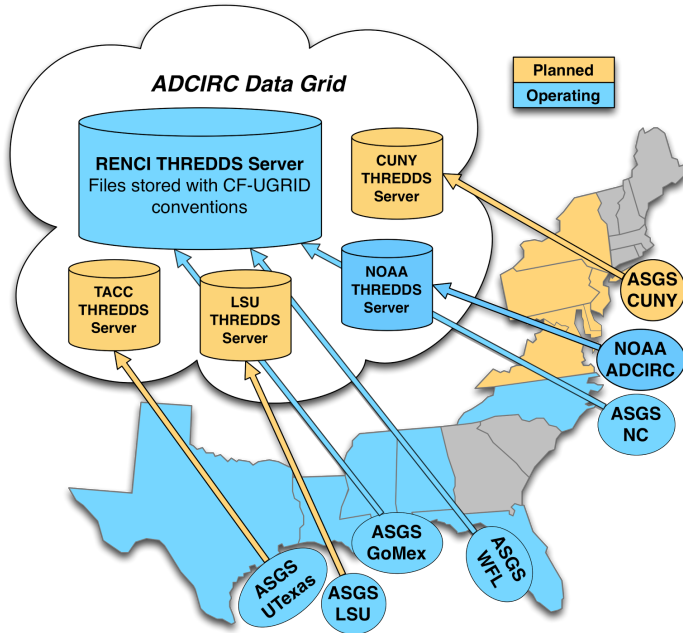


Figure 1: Current set of THREDDs servers (blue) that comprise the ADCIRC Data Grid. NOAA Coast Survey Development Laboratory has configured a server to host their experimental ADCIRC simulations. These simulations, computed for both tropical events and daily weather conditions, can be directly accessed and visualized with AdcircViz. **The University of Texas at Austin’s Texas Advanced Computing Center (TACC) has started to implement a THREDDs server for their real-time ADCIRC forecasts that are focused on the low-lying and vulnerable Texas coast.**

AdcircViz relies on making connections to an THREDDs Data Server (TDS) using the OPeNDAP data transfer protocol through the MATLAB toolbox nctoolbox. This [toolbox](#), which uses the Unidata netCDF java class as the data access layer, is used extensively to open netCDF data files and access metadata, without accessing the data components until they are needed (called *lazy loading*). Each graphic is generated using MATLAB functions and tools “on the fly”. The color map, color limits and color increment are specified by the user with default values appropriate to the scalar field being rendered. The default colormap is one similar to the NOAA colormap currently used for NHC surge maps (Figure 2).



Figure 2: Default AdcircViz Colormap based on the colormap used for NHC storm surge graphics.

For the original proposal to the JHT program, we developed a prototype AdcircViz implementation to demonstrate the feasibility of the approach. This version of AdcircViz (Figure 3) included the ability to visualize several scalar fields from ADCIRC (namely maximum water level, time-dependent water level, maximum significant wave height, time-dependent wind speed, and the maximum wind speed) for all ensemble members contained in an ASGS simulation directory. The data and metadata for populating the application are extracted from ADCIRC files posted on a THREDDs server (opendap.renci.org:1935). The files are in netCDF format with strict adherence to the CF-UGRID conventions and standards, and in a

specific directory (folder) hierarchy that defines information such as storm name and advisory number. This prototype version was extensively tested during the 2012 Atlantic hurricane season, particularly during Hurricane Isaac. We have also tested AdcircViz with large Hurricane Katrina simulations in a hindcast mode, and this has proven to be a useful way to examine existing non-forecast simulations, as long as the files adhere to the CF-UGRID conventions and are manually put onto a THREDDs server.

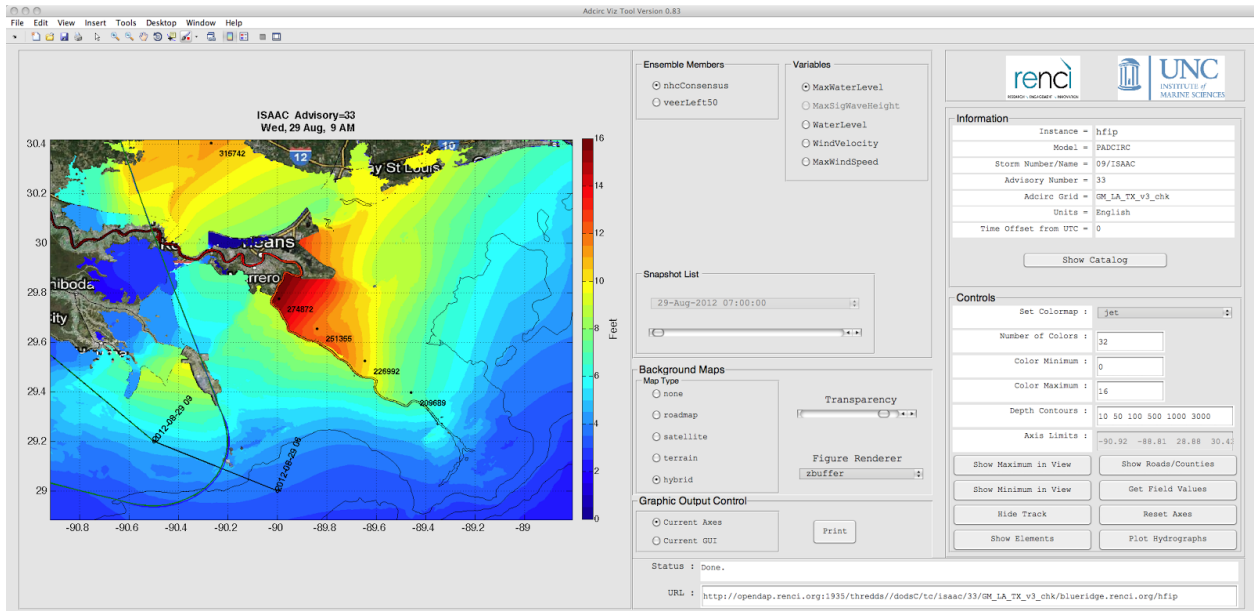


Figure 3: Prototype AdcircViz application developed for the original proposal to JHT. This version was extensively tested during the 2012 Atlantic hurricane season and deployed to test/evaluation users for 2013.

2) Status, Advancements and Progress to Date

The current version of AdcircViz was made available to the NHC Storm Surge Unit (SSU) for deployment and initial evaluation prior to the 2014 Atlantic hurricane season. A presentation describing the project was made at the recent 2014 Interdepartmental Hurricane Conference, and afterward we met with the storm surge unit to discuss specific requirements for AdcircViz, including specific features, code access, machine/operating system dependencies, and how to optimally engage for bug fixes and feature requests.

During initial testing at the NHC, it was noted that the GUI response can be sluggish. To explain this behaviour, note that the underlying MATLAB toolbox nctoolbox exploits the Java netCDF “lazy-loading” feature. This means that when an ADCIRC data file is opened in MATLAB, *only* the metadata in the netCDF file is initially transferred to MATLAB. If the ADCIRC grid contained in the data file has not been previously downloaded in the current application version, then the grid variables are also extracted from the netCDF file. Lazy-loading functionality is critical to overall application performance and is *in lieu* of downloading the entire netCDF data structure, most of which is not needed.

This means that AdcircViz is already downloading only the minimum amount of data to make display images, and that some amount of slow response is expected due to the size of the ADCIRC model grids and any local internet speed issues. In an effort to mitigate the impact of local internet speed issues, we have established a virtual machine at RENCI into which NHC can remote-desktop and operate AdcircViz. This alternative puts AdcircViz in direct connection with the THREDDs server (the VM and THREDDs servers

are on the same internal network). This option has not been tested by NHC yet, but this will be evaluated between hurricane seasons.

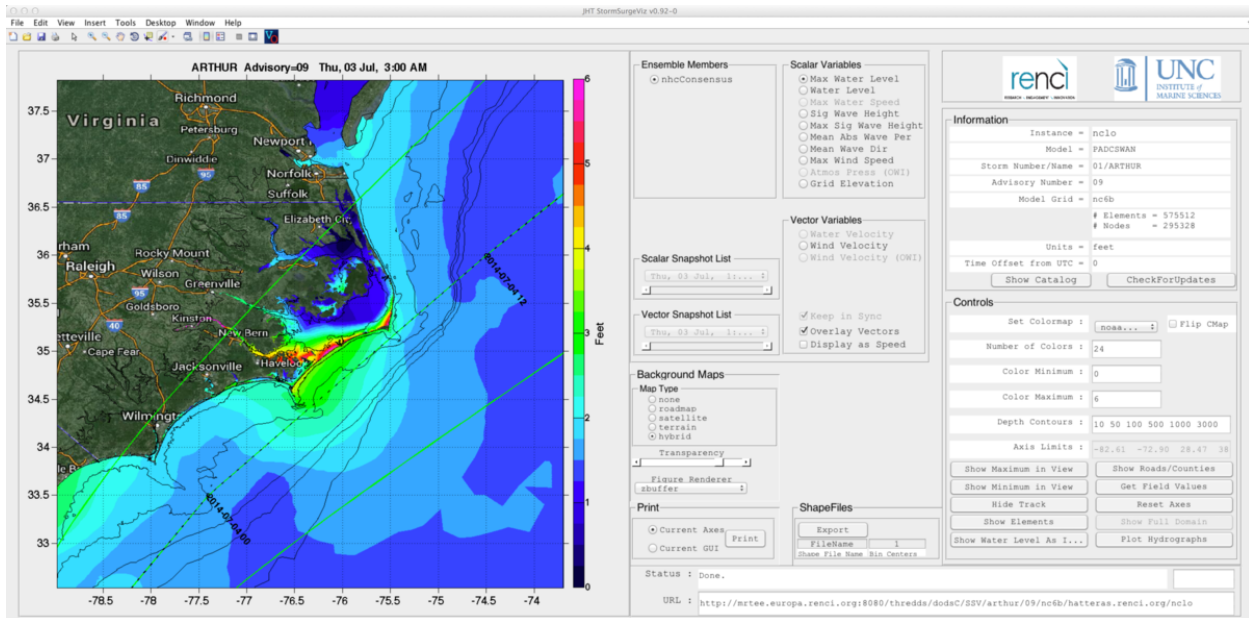


Figure 4: AdcircViz showing the RENCi Adcirc Surge Guidance System forecast for Hurricane Arthur, Advisory 09. The colors are the maximum water level, including tides and wave setup, over the duration of the forecast simulation. The dashed line is the forecast storm track, with the uncertainty lines in green.

Due to a relatively quiescent Atlantic hurricane season, there have been few “real time” opportunities to rigorously evaluate AdcircViz as a tool within the NHC’s SSU. However, Hurricane Arthur, which made landfall on the North Carolina coast on August 27, provided an opportunity to exercise AdcircViz. We (RENCI) were able to monitor the status of the forecast system during the event. Each new advisory’s simulation results were detected by AdcircViz and were immediately available to AdcircViz. Figure 4 shows the maximum water level [ft MSL] for Hurricane Arthur, Advisory 09.

Project accomplishments in March-August 2014:

Documentation: The user’s guide for StormSurgeViz (see the Rebranding description below) has been substantially expanded and refined, providing overviews and details of its capabilities and features.

Catalog Updating: Since the original deployment of AdcircViz to the NHC SSU, we have implemented an automatic check for updates to the THREDDS catalog. If updates are detected, an alert box is opened that informs the user of new simulation data in the catalog. The catalog polling interval default is 15 minutes and can be set (or turned off) in the application’s options file.

Local Mode: We have implemented a “local mode” that does not need THREDDS catalog access, allowing users to point at CF-UGRID compliant files on local disk or at an OPeNDAP URL. RENCi uses this local mode to examine many non-forecast simulation output, providing more opportunities to find and remedy software issues.

THREDDs implementations: A significant component of the overall approach is to establish THREDDs servers at individual modeling sites and expose the catalog to AdcircViz in a consistent way. At the time of

the proposal to JHT, there was only one THREDDs server, hosted at [RENCI/UNC](#). NOAA's Coast Survey Development Lab (CSDL) has recently installed a [THREDDs server](#) to serve experimental ADCIRC-based simulations. Figure 5 shows a CSDL extratropical ADCIRC simulation as posted on their THREDDs server. The CSDL ADCIRC grid is a version of the ec_95d grid, with inundation-supporting overland areas added in the northern Gulf of Mexico and North Carolina and Chesapeake Bay areas. Additionally, we have worked extensively with the University of Texas's Advanced Computing Center (TACC) to install and configure a THREDDs Data Server to serve their very high resolution ADCIRC forecasts for the Texas coast. This implementation is not yet complete, but we expect to finalize this server between hurricane seasons.

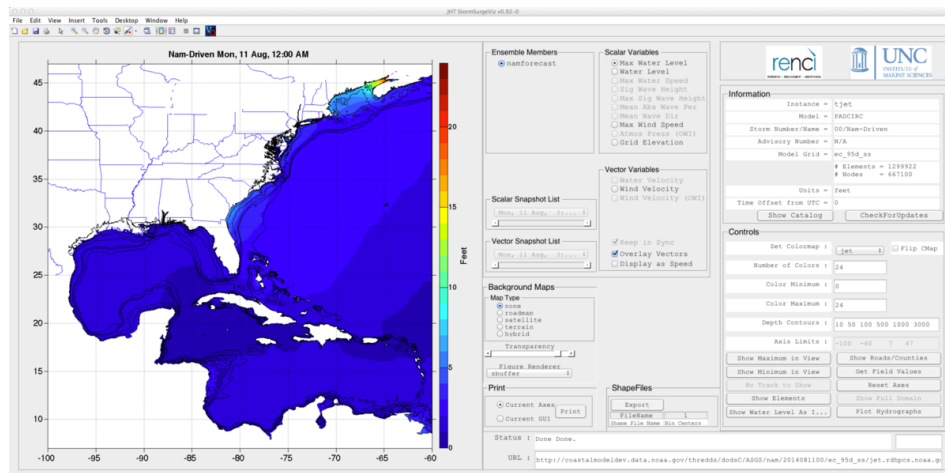


Figure 5: AdcircViz showing the NOAA CSDL Adcirc Surge Guidance System forecast for August 11, 2014, 00Z. The colors are the maximum water level, including tides and wave setup, over the duration of the forecast simulation. The very high tides in the Bay of Fundy in the Gulf of Maine are evident. Note the THREDDs server being pointed to, in the "URL" section of the GUI, in the lower right.

Rebranding: Related to the THREDDs server implementation and using AdcircViz to enable NHC SSU to access and visualize storm surge model output from models other than ADCIRC, we have renamed the AdcircViz application to StormSurgeViz and refactored some of the MATLAB code to present a model-neutral, UGRID visualization application. The project GitHub page has been updated to reflect the rebranding. The new project GitHub landing page ([here](#)) is shown in Figure 6.

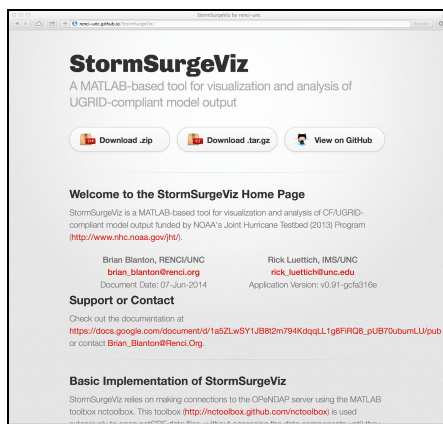


Figure 6: StormSurgeViz project GitHub landing page. This page provides easy access to the code, as well as links to documentation and support.

3) Year 2 Activities and Goals

There are several aspects of the StormSurgeViz under development for year 2 of the project, focused on enabling the NHC to access and visualize storm surge model output beyond ADCIRC results available on THREDDS servers.

Community Outreach: In conversations with the NHC and JHT program, there is a need to enable the storm surge modeling community at large to provide storm surge hazard assessments to the NHC SSU during active tropical cyclone periods. StormSurgeViz and the underlying THREDDS Data Server mechanics could be used for this “community outreach” purpose. RENC/UNC will devote resources to enabling this in between hurricane seasons. This past summer, the NHC drafted a letter for distribution to the community that describes the need for a consistent interface to the variety of storm surge models. Specifications for this interfacing already exist, as contained in the CF-UGRID conventions and related work of the NOAA IOOS Coastal and Ocean Modeling Testbed (COMT). RENC/UNC will work with the NHC to refine both the letter and the documentation needed for other groups to implement the THREDDS Data Server and the required metadata in the simulation output files. This is further described below.

THREDDS server configuration instructions: In working with the University of Texas to implement a THREDDS server, we noted that the document describing the implementation was not complete, due to version differences in the underlying web server used by THREDDS (apache tomcat). We will update the document to reflect the most recent tomcat version, more clearly outline the implementation/installation process, and provide example/test data sets that can be deployed on new THREDDS servers.

NcML: NcML is an xml markup language for netCDF files. It allows for augmenting netCDF metadata, aggregation of multiple netCDF files, and other features *without* modifying or altering the actual netCDF files. [The NOAA IOOS Coastal and Ocean Modeling Testbed has learned that modelers are reluctant to modify the model code to output specific netCDF metadata requirements to comply with standards and conventions such as CF-UGRID. NcML has proven to be essential to “marking up” the metadata for compliance without any changes to the underlying model output files. Our THREDDS server configuration document will include coverage of NcML, leveraging the experiences and outcomes of the IOOS testbed.

StormSurgeViz modifications: StormSurgeViz will be modified (extended) to work from the standardized NcML descriptions. The mechanics of handling the UGRID data structures will not change.

4) A note about SLOSH visualization

Since SLOSH uses a rectangular grid, it is straightforward to “convert” SLOSH to CF-UGRID. We have recently demonstrated this capability by mapping a SLOSH output file from the NOAA IOOS Coastal and Ocean Modeling Testbed into a UGRID-compliant triangular description. We are developing a workflow that can be used to perform this conversion “on-the-fly” so that the existing internal StormSurgeViz mechanics can be used for SLOSH. Figure 7 shows a Hurricane Ike (2008) maximum water level result from SLOSH within StormSurgeViz. However, in order for StormSurgeViz to access SLOSH results, the solution files need to be posted on a THREDDS server in the appropriate directory structure and with an accompanying catalog file. RENC can host the results and make the catalog file, but we need to identify how the solutions will get from where the results are computed to RENC’s THREDDs server.

