Improving Accuracy of Real-Time Storm Surge Inundation Predictions Using GRASS GIS

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MOTIVATION

- The Advanced CIRCulation model (ADCIRC, adcirc.org) is used in North Carolina to predict storm surge during tropical storm events.
- Prediction of the extent of coastal flooding may be limited by resolution of the ADCIRC mesh, because topography is smoothed out and **small-scale features such as roadways and small channels cannot be represented**.

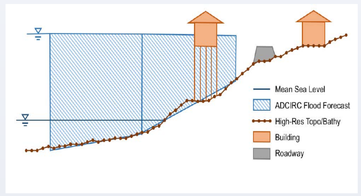


Figure 1. Schematic of problem. ADCIRC flood forecasts do no often match the high-resolution topography.

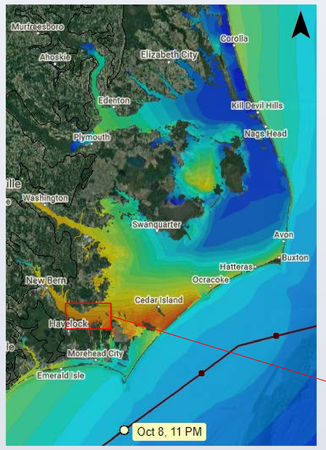
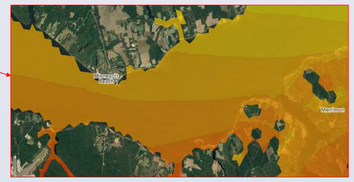


Figure 2. ADCIRC maximum water levels for Hurricane Matthew visualized on the Coastal Emergency Risks Assessment (CERA) website.

- The polygon boundary shown in the Figure 2 zoom, representing the predicted extent of flooding, is irregular. This is an artifact of the model resolution.
- Improving this flooding boundary is of interest to North Carolina Emergency Management (NCEM), as they are concerned with the smaller, building-to-building scale.



CONCEPTUAL PROBLEM

- In Figure 3, the coarse-resolution storm surge polygons (colors) do not match well with the high-resolution Digital Elevation Model (DEM) (greyscale).
- 4-foot water levels *should* be extended to inundate adjacent areas where the topography is less than or equal to 4 feet.

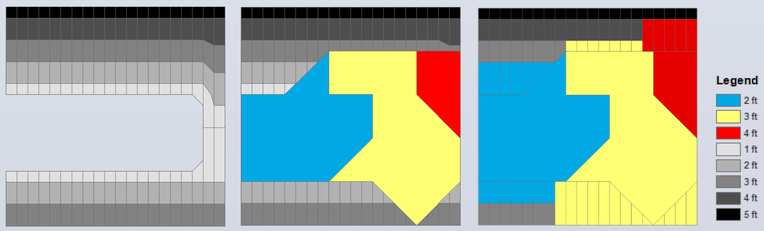
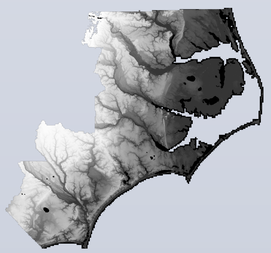


Figure 3. Toy conceptual problem for storm surge in an estuary.

- This concept of "enhancing the resolution" of ADCIRC using a high-resolution DEM makes use of a combination of Python codes and the **Geographic Resources Analysis Support System (GRASS),** an open-source GIS software.
- The DEM used for this project covers 32 coastal North Carolina counties at **50-foot resolution**, totaling more than **430 million grid cells**.



METHODOLOGY

Figure 4. 50-ft DEM for Carteret County, NC.

- Initial tests were performed on a small sub-region of Carteret County, NC, before moving onto the entire county and then the entire coast of North Carolina.
- The general steps are:
  - Interpolate ADCIRC points to a raster at 50-foot resolution (Figure 5b).
  - Expand ADCIRC raster outward only where the water levels are greater than the ground elevation.
  - Remove isolated (not hydraulically-connected) cells (Figure 5c).
  - Convert the new "grown" raster to polygon format for distribution.

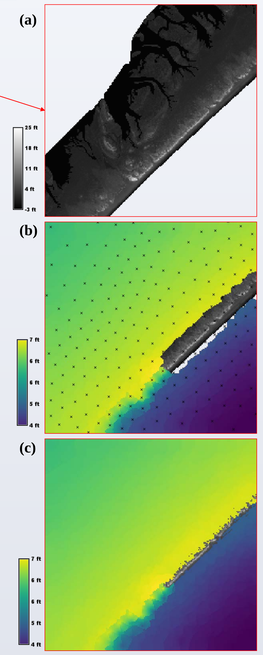


Figure 5. Initial test region in Carteret County. (a) DEM only. (b) Interpolated ADCIRC raster overlying DEM, where points represent ADCIRC grid nodes. (c) Enhanced resolution surface.

RESULTS IN CARTERET COUNTY, NC

- Figures 6 and 7 show before and after the enhanced resolution on the county scale.
- Analyzing a Carteret County building dataset for a Hurricane Matthew Hindcast:
  - Before enhancement: **2,435 buildings are predicted to be flooded.**
  - After enhancement: **3,886 buildings are predicted to be flooded.**
  - This is a **60 percent increase.**

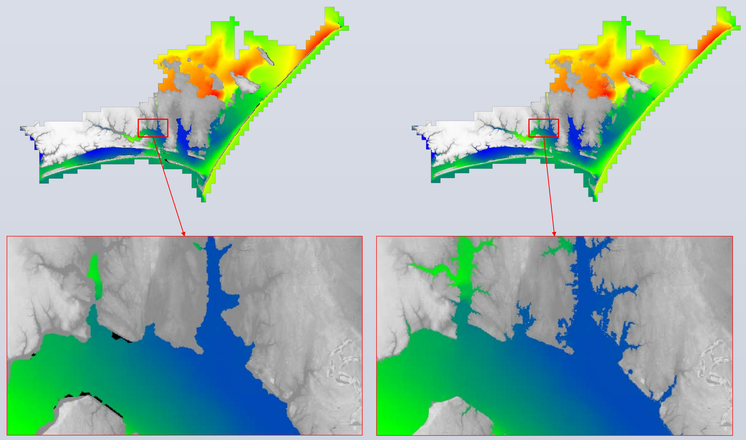


Figure 6. ADCIRC water level raster before enhancing resolution. Note that in some areas water is not reaching the mean shoreline.

Figure 7. ADCIRC water level raster after enhancing resolution. Flooding is extended across low-lying topography such as small-channels and floodplains.

STATE LEVEL RESULTS

- For all of coastal North Carolina, we get similar results:

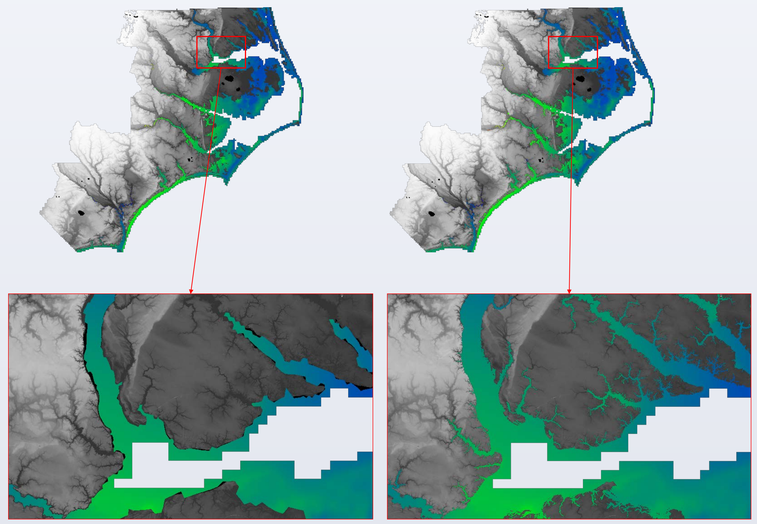


Figure 8. ADCIRC water level raster before enhancing resolution.

Figure 9. ADCIRC water level raster after enhancing resolution.

- Lower-lying floodplains (darker grey colors in Figures 8 and 9) that should be flooded are now flooded (Figure 9).
- The boundary of the flooding has more definition, characteristic of the high-resolution DEM.

SPEED AND REAL-TIME FORECASTING

- At first, enhancing resolution took close to 1 hour to run, due mainly to the costly interpolation. To speed this up:
  - A text file containing precomputed Inverse-Distance Weights was created for each ADCIRC mesh.
  - The code was parallelized for running on up to 16 processors.
- Now, the program takes **13-15 minutes** to process ADCIRC results for a tropical storm using the latest North Carolina mesh.

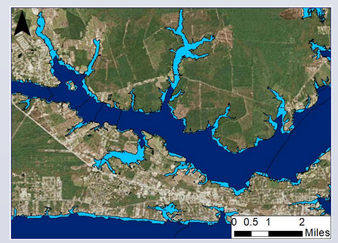


Figure 10. Example of final product in polygon format, Newport River near Morehead City, NC. Dark blue is original ADCIRC surface, light blue is enhanced surface.

- Results are currently being shared with NCEM during storm events.

CONCLUSIONS AND FUTURE WORK

- A post-processing tool has been developed that improves accuracy of ADCIRC storm surge forecasts using a high-resolution DEM.
- Future work will consider how neglecting the physics of inundation impacts the resulting enhanced surface.
  - This will involve running ADCIRC with 50-ft grid resolution over land and comparing to the results of the extrapolation.