Improving Accuracy of Real-Time Storm Surge Inundation Predictions

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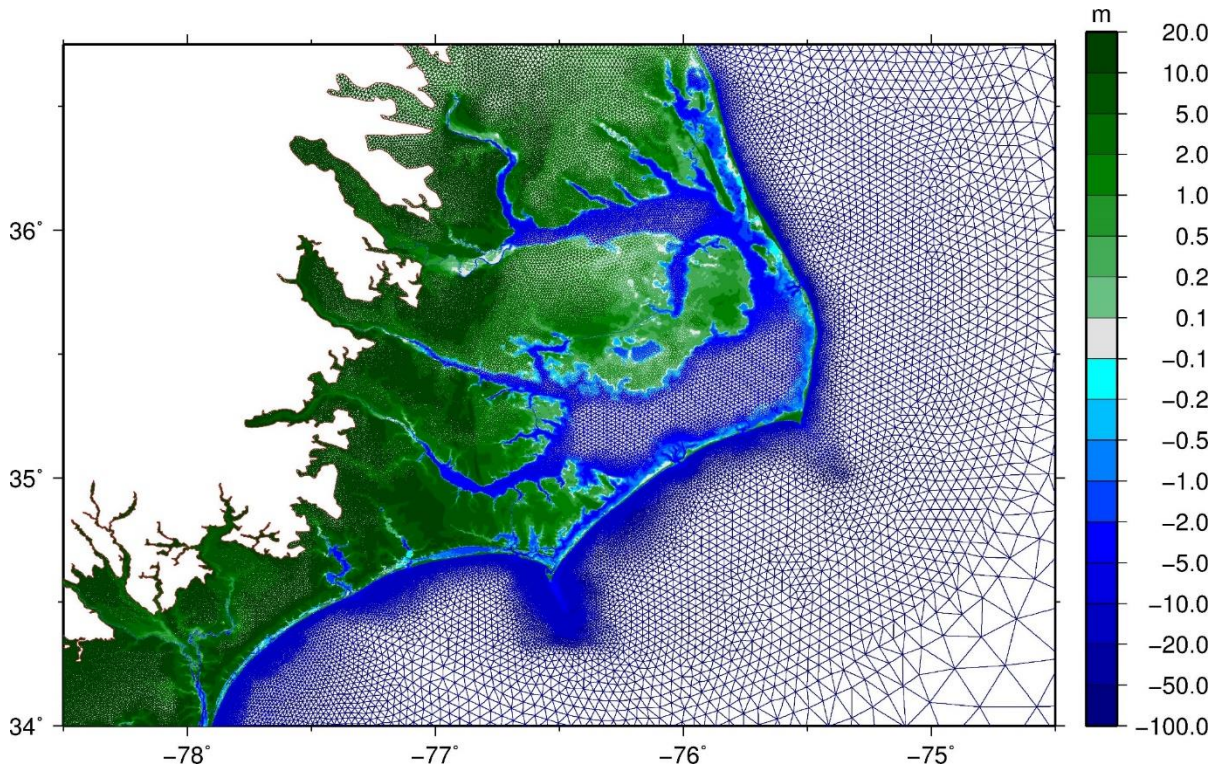
NSF

NC9 Mesh

In North Carolina, we often use the NC9 mesh to study storm surge along our coast

- Contains about 620k vertices
- 90% of resolution is in NC coastal regions
- 56% of resolution represents overland regions
- Typical element sizes:
  - 100-200 m along barrier islands and inlets
  - 300-600 m in most overland regions
- Ideal for forecasting in NC



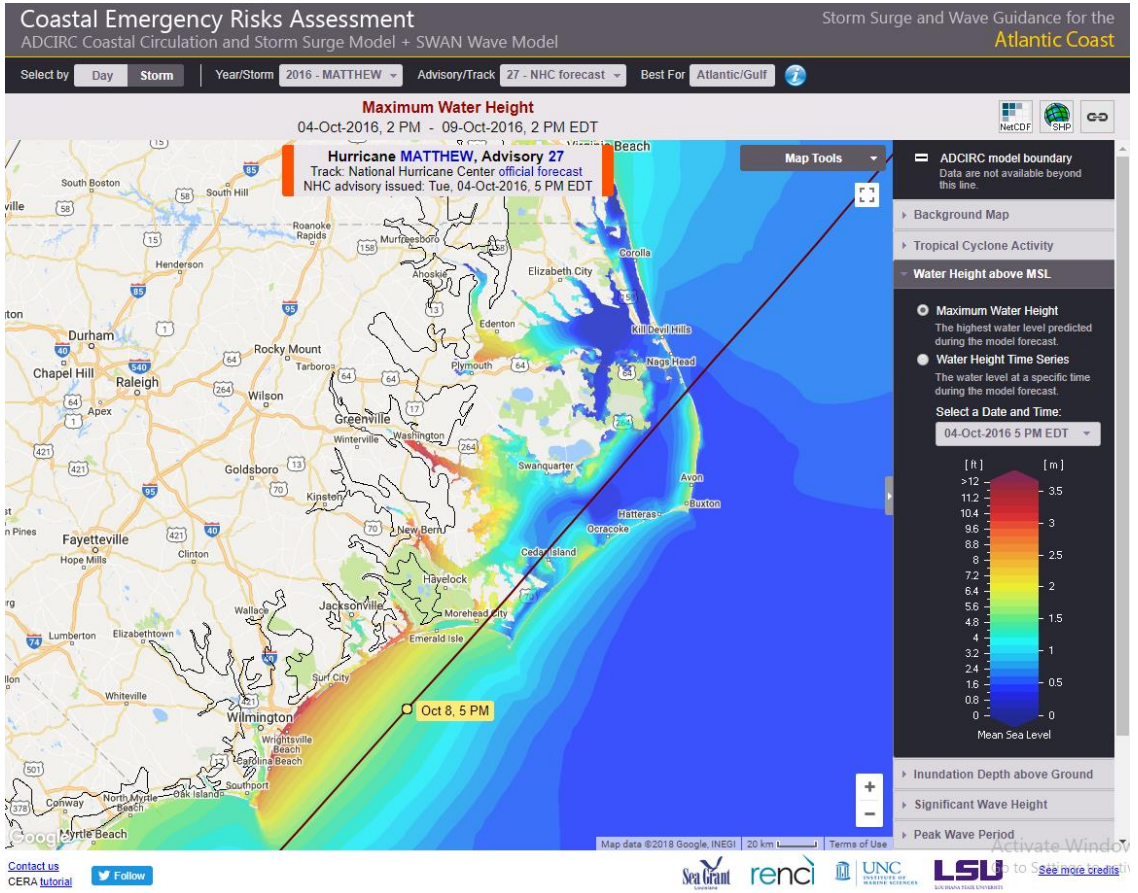
Real-Time Forecasting with ADCIRC

General process:

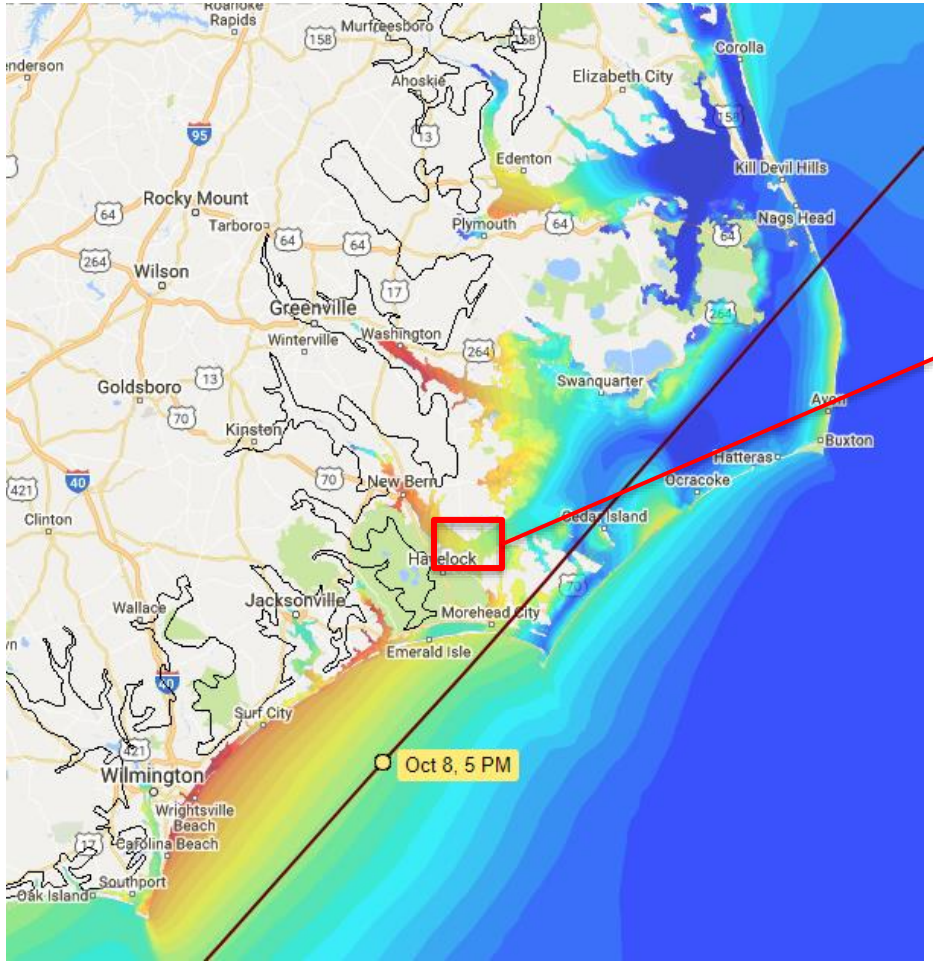
- NHC issues an advisory every 6 hours during a storm
- Several ADCIRC simulations are run within 60-90 minutes of each advisory
- Results are visualized in real-time via applications like CERA

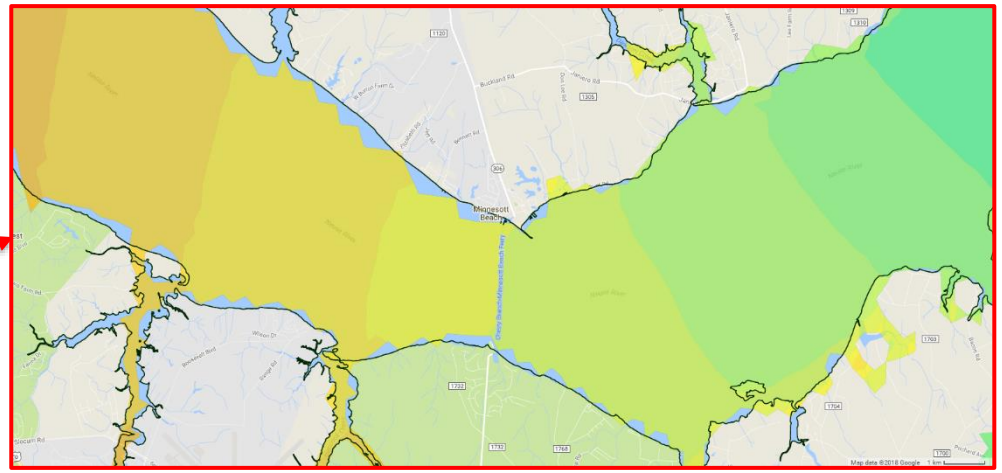
Forecasts are useful for decision-makers in coastal communities

Forecasts should be as fast as possible without sacrificing too much in accuracy

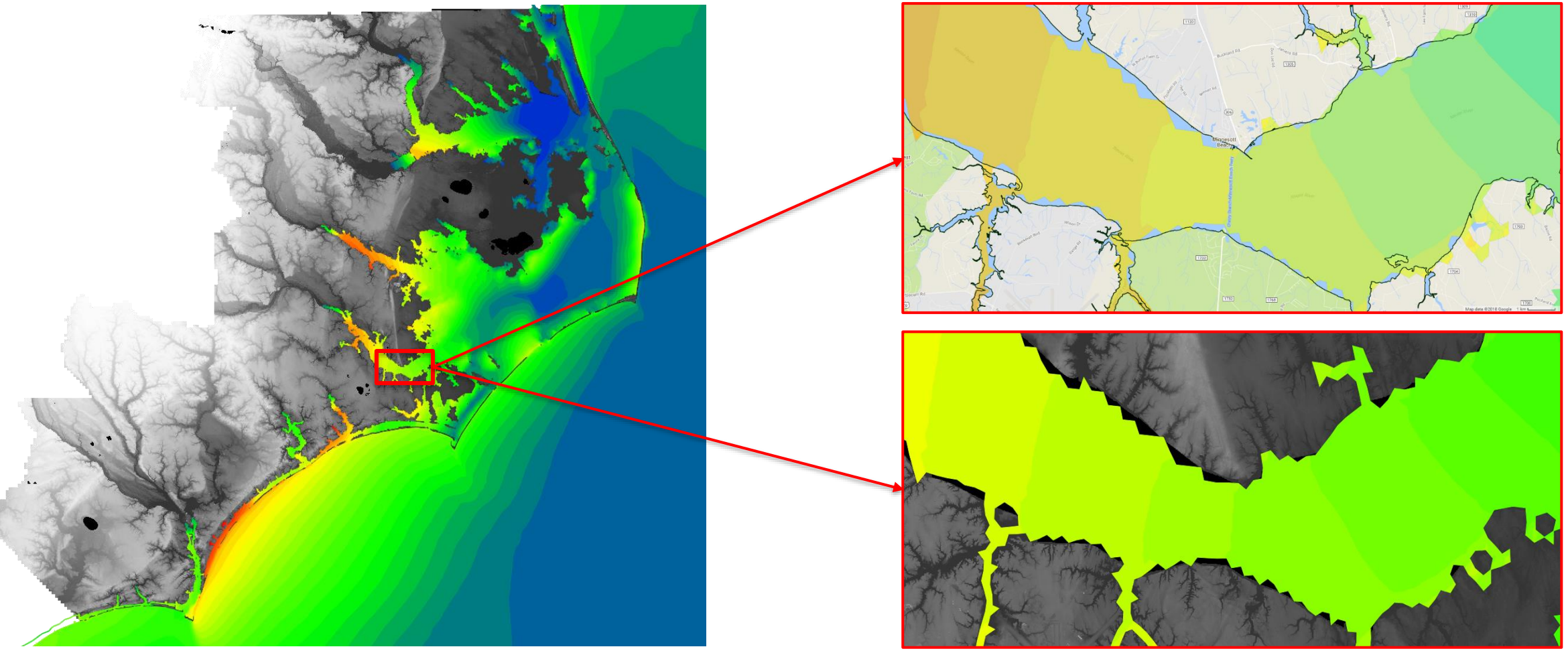


Limitations of ADCIRC



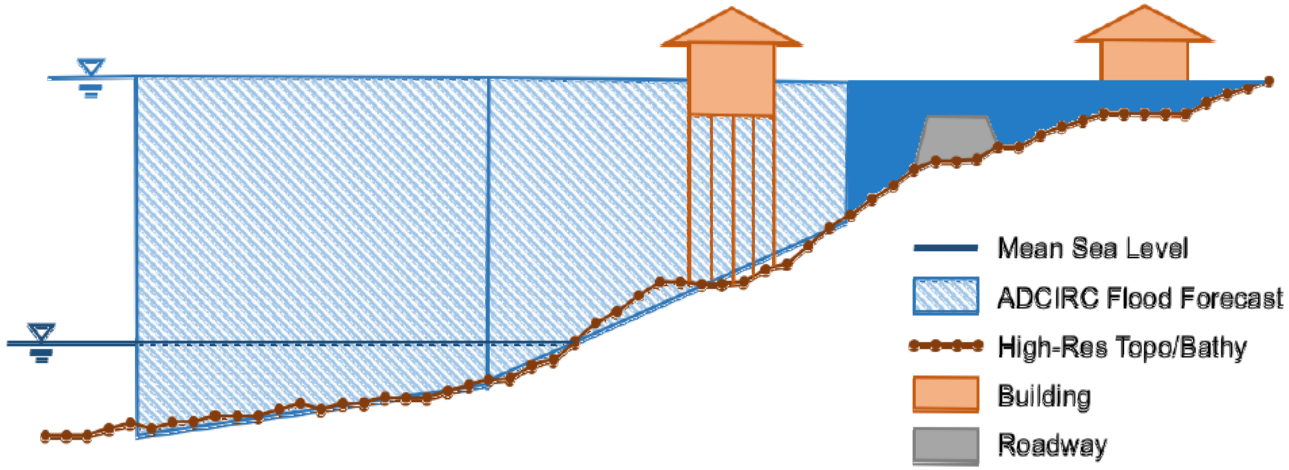


How can we improve local-scale flooding predictions?



Objectives

1. Extrapolate ADCIRC results to intersect a higher resolution DEM
2. Create fully-automated process for use in real-time forecasting
3. Create process that runs in 10-20 minutes
4. Evaluate accuracy using a high-resolution ADCIRC mesh



GRASS GIS

Geographic Resources Analysis Support System (GRASS, grass.osgeo.org)

- Efficient tool for working with large raster datasets
- Easily automated using Python scripts
- Accessible via command line for use in HPC environments
- Open-source – module source code can be modified

GRASS GIS

Bringing advanced geospatial technologies to the world.

A Raster Method for Enhancing Resolution

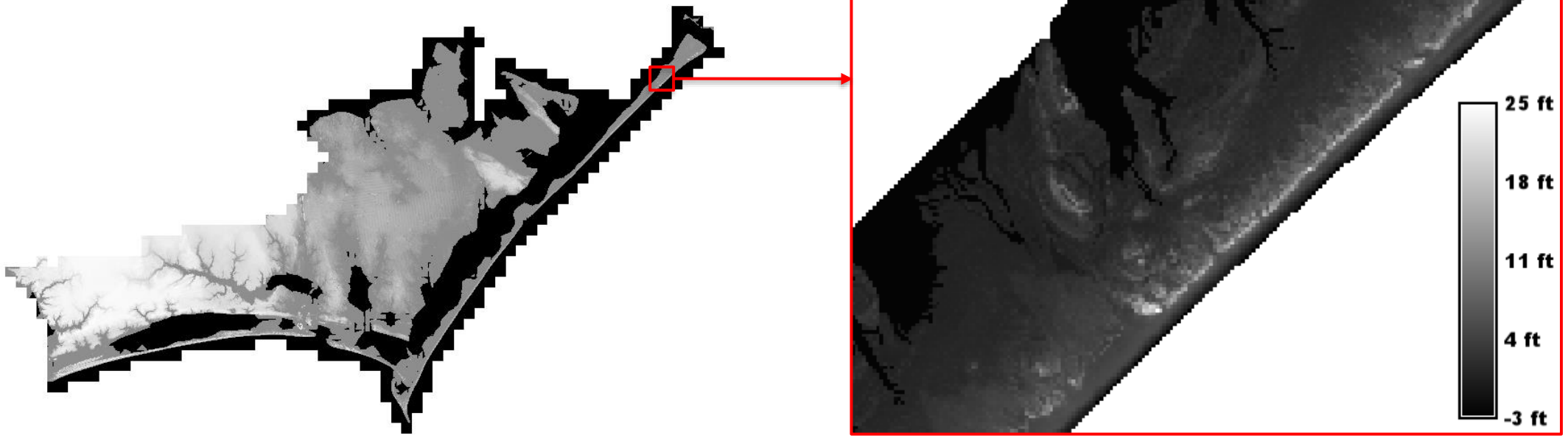
Using GRASS, the general steps are:

1. Interpolate ADCIRC points to a raster at 15-meter resolution (same as DEM)
    - Moving from ~600k vertices to ~430 million raster cells for NC
    - We created files with pre-computed inverse-distance weights to speed this up
2. Extrapolate water level raster into small-scale channels and floodplains
    - Expand raster outward only where water levels are greater than ground surface
    - Remove isolated (not hydraulically-connected) cells
3. Convert the new, “enhanced” raster to polygon format for easy distribution

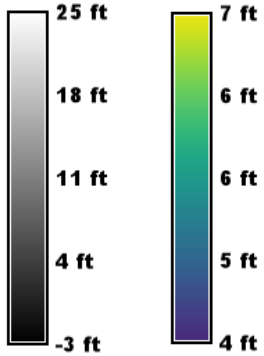
Examples in Carteret County

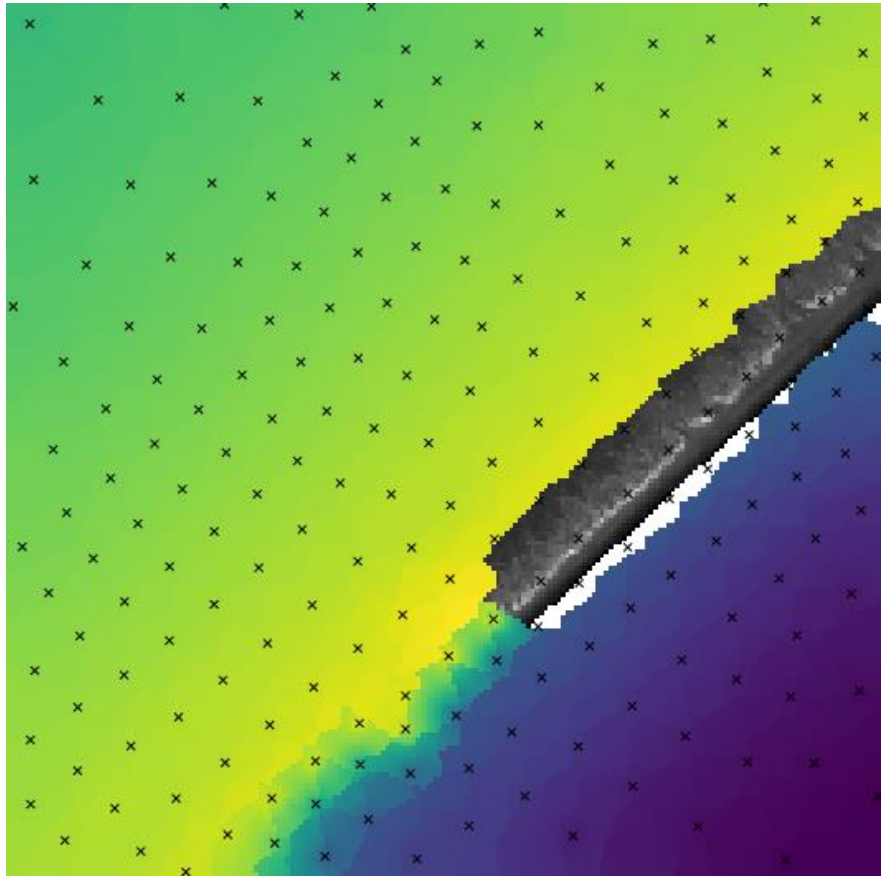
Carteret County was a good place to start:

- Contains barrier islands, estuaries, low-lying topography
- Is vulnerable to flooding



Examples in Carteret County

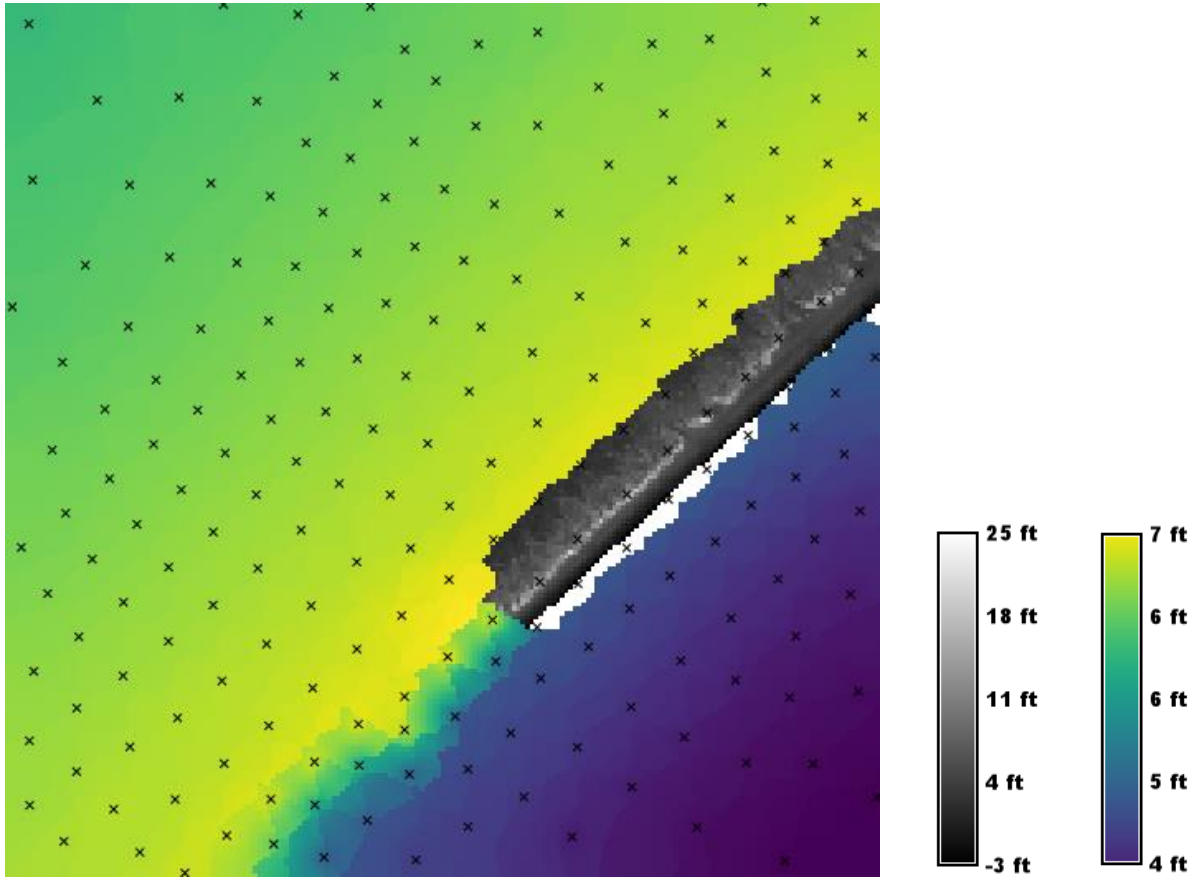




DEM

ADCIRC raster overlying DEM
(mesh vertices shown for scale)

Examples in Carteret County



ADCIRC raster overlying DEM
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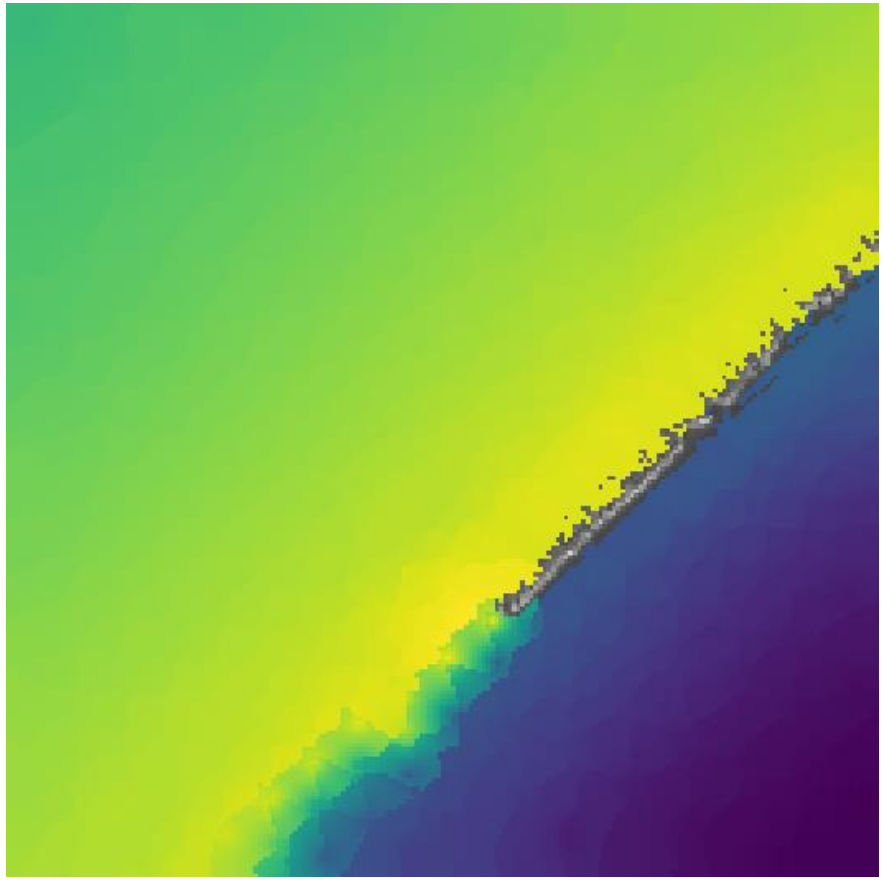


Enhanced ADCIRC raster

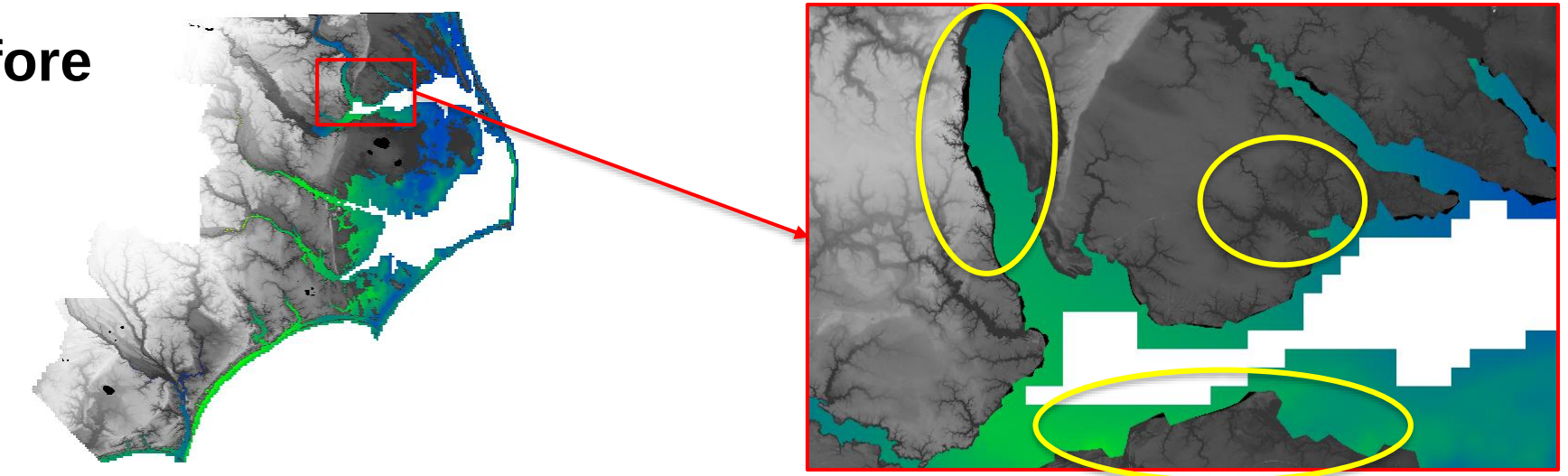
Enhanced Guidance for Entire NC Coast

We need this method to be *fast*:

- Interpolation of ADCIRC points is still most time-consuming step
- Entire process was taking **40-50 minutes** at first, and clearly needed to be parallelized
  - Scripts were tweaked to allow for parallel processing on up to 16 cores
  - DEM was divided into horizontal strips with overlap of 500 cells
  - Conversion to polygons cannot be parallelized
- With parallelization, the entire process now takes **12-15 minutes** to run on the NCSU computing cluster
- Results were shared automatically with NC Emergency Managers during the 2017 hurricane season

Enhanced Guidance for Entire NC Coast

Before



After

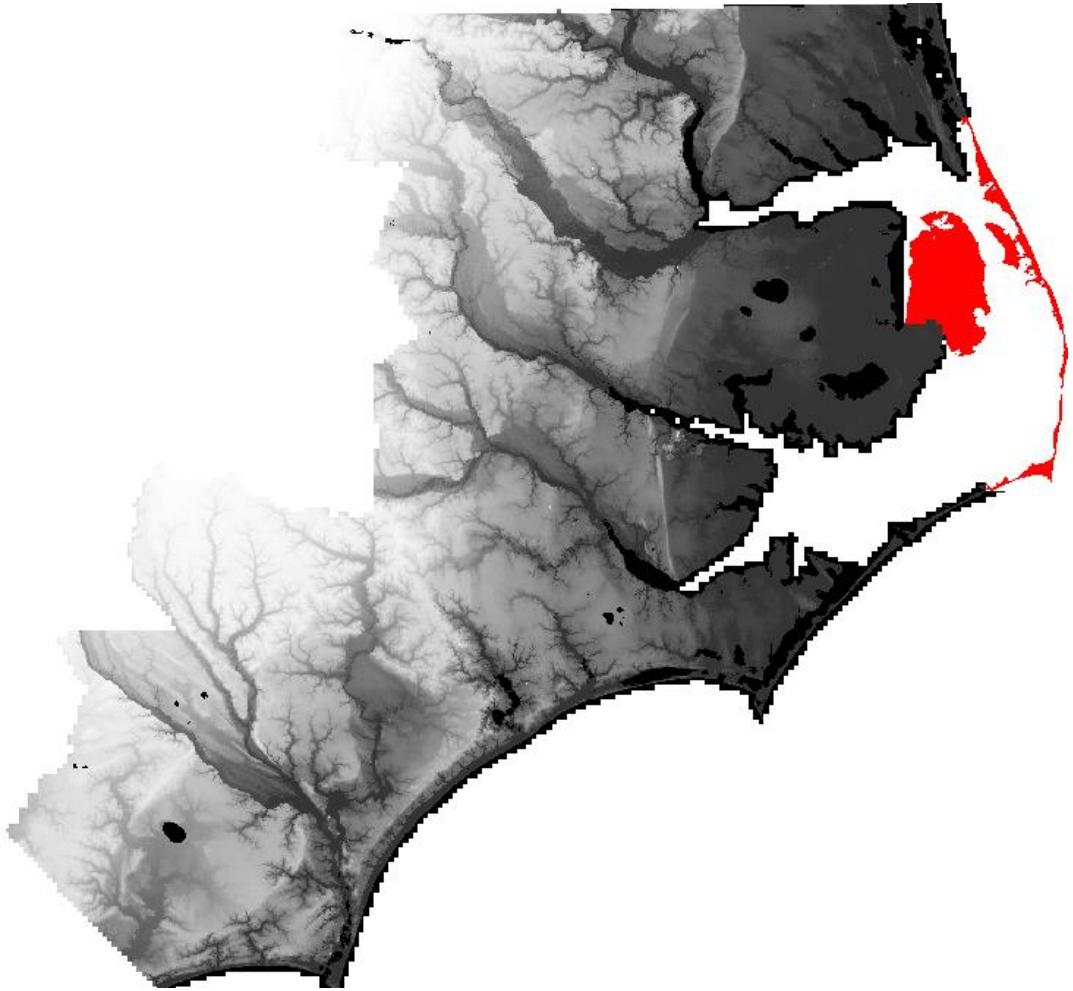
Evaluating Accuracy using a High-Resolution Mesh

Our process does not incorporate physics.

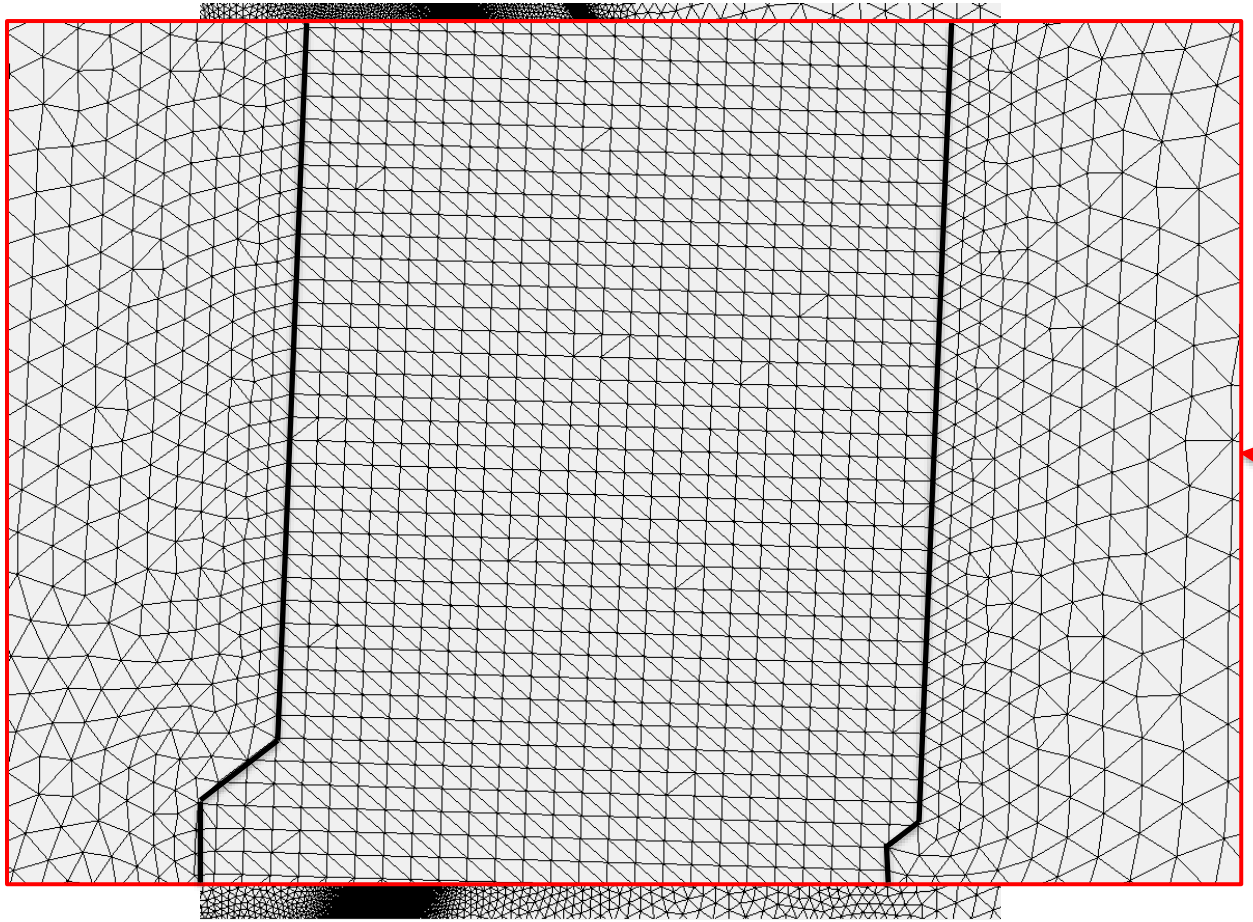
If we could run ADCIRC at a similar 15-m resolution, how would the results compare?

To answer this, we developed a high-resolution mesh for Dare County, NC:

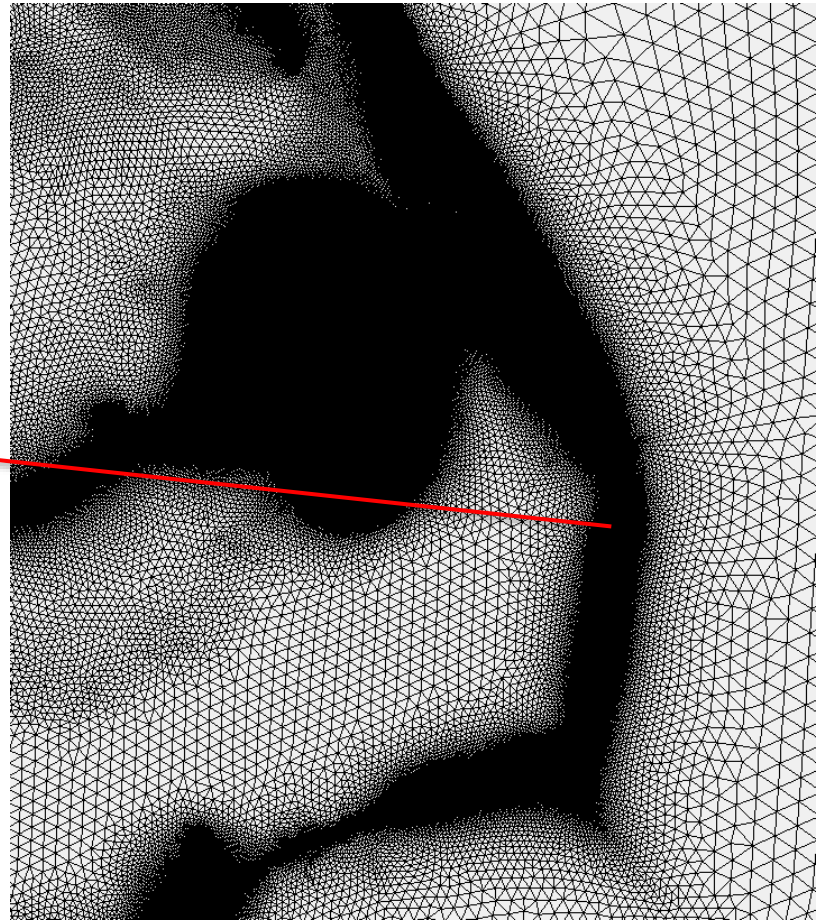
- Modified from the NC9
- Overland vertices in Dare correspond exactly to DEM cells via a 1-to-1 conversion
- Contains 5.7 million total vertices



Mesh Comparison in Dare County

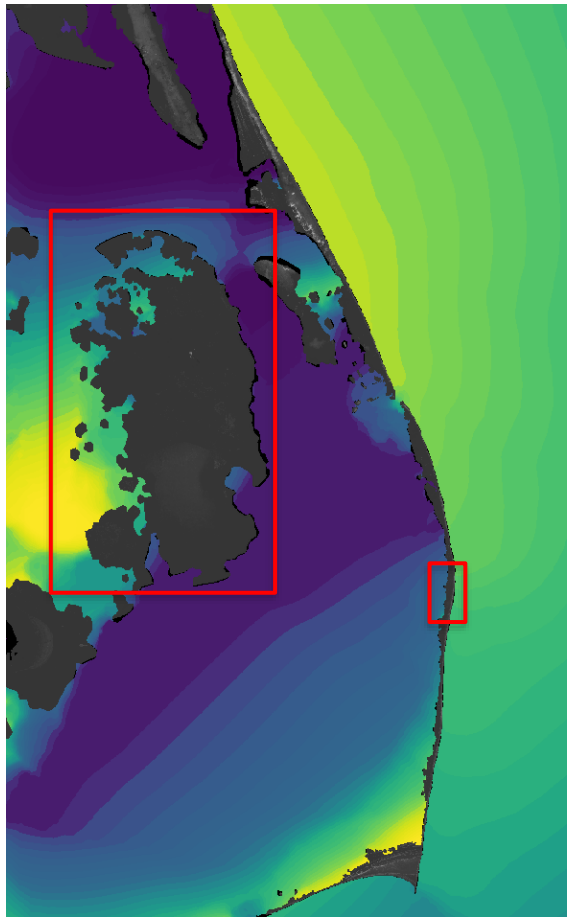


NC9 in Dare

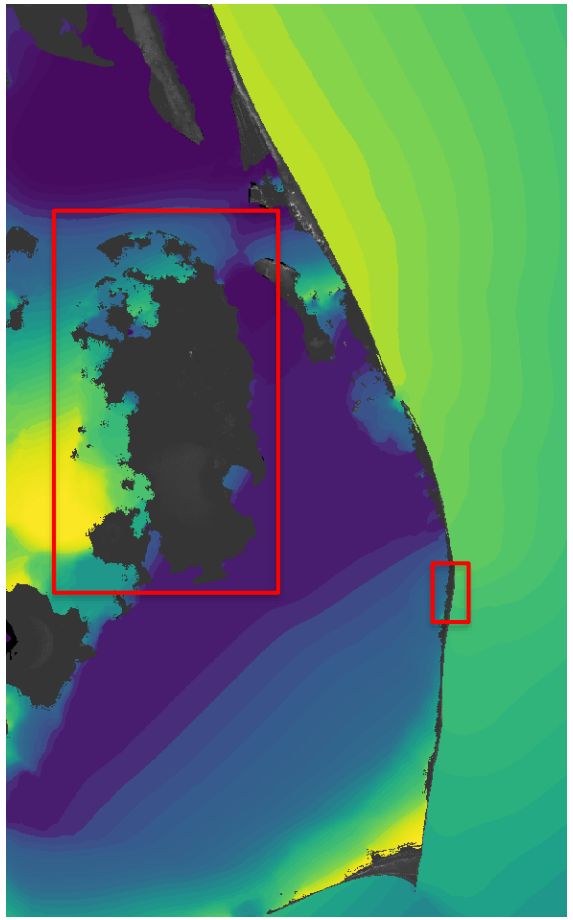


High-Res Mesh in Dare

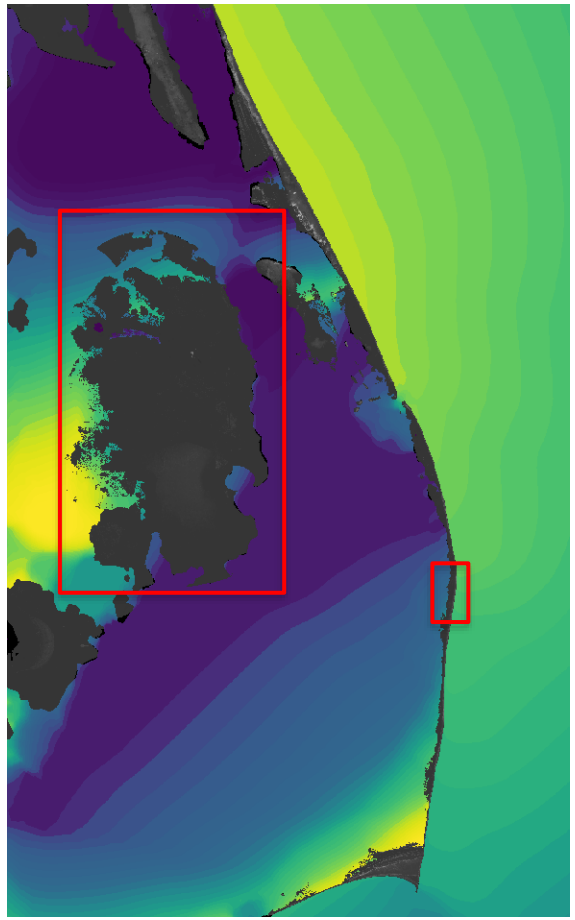
Comparing Enhanced Res. with High-Res. ADCIRC



NC9

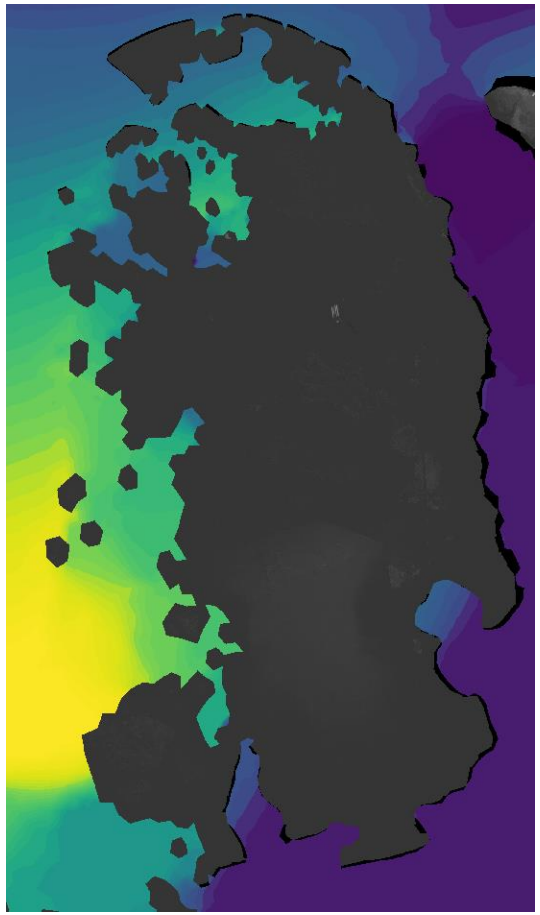


NC9 Enhanced

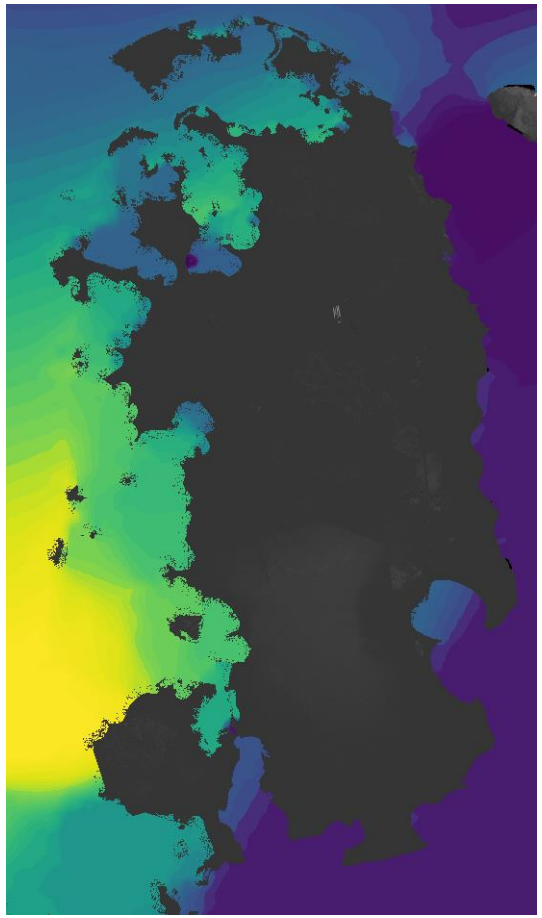


High-Resolution Mesh

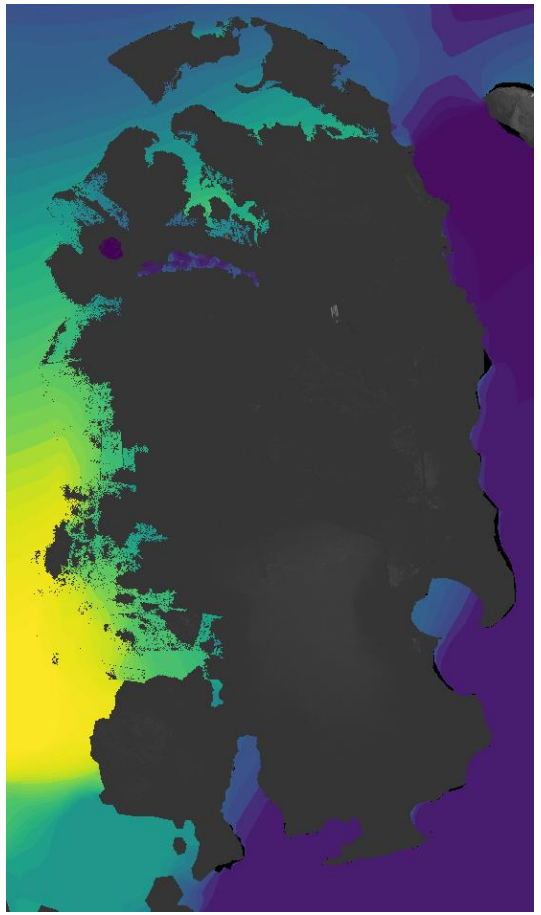
Inland Dare Comparison



NC9



NC9 Enhanced

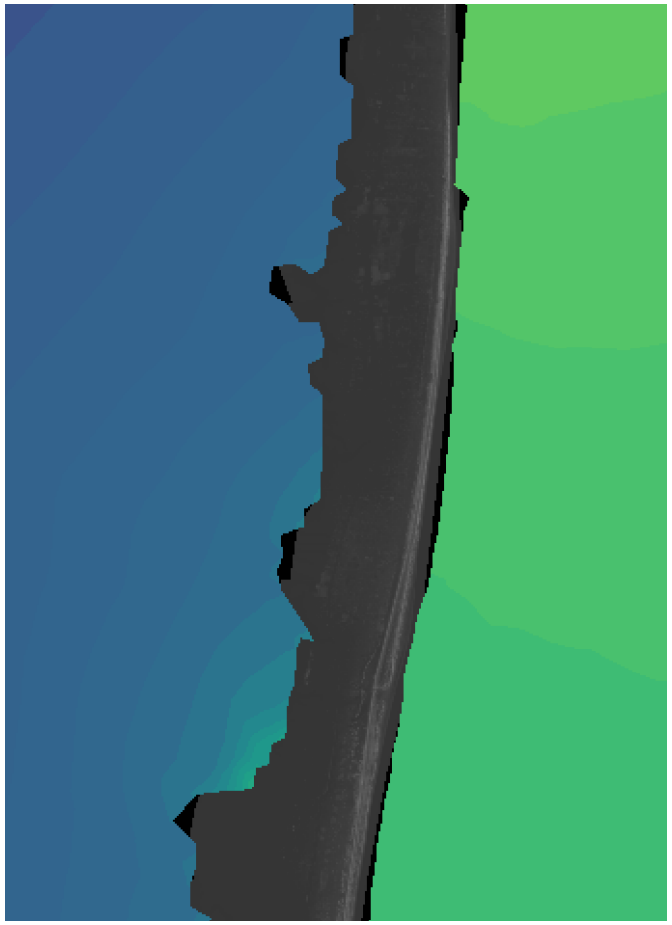


High-Resolution Mesh

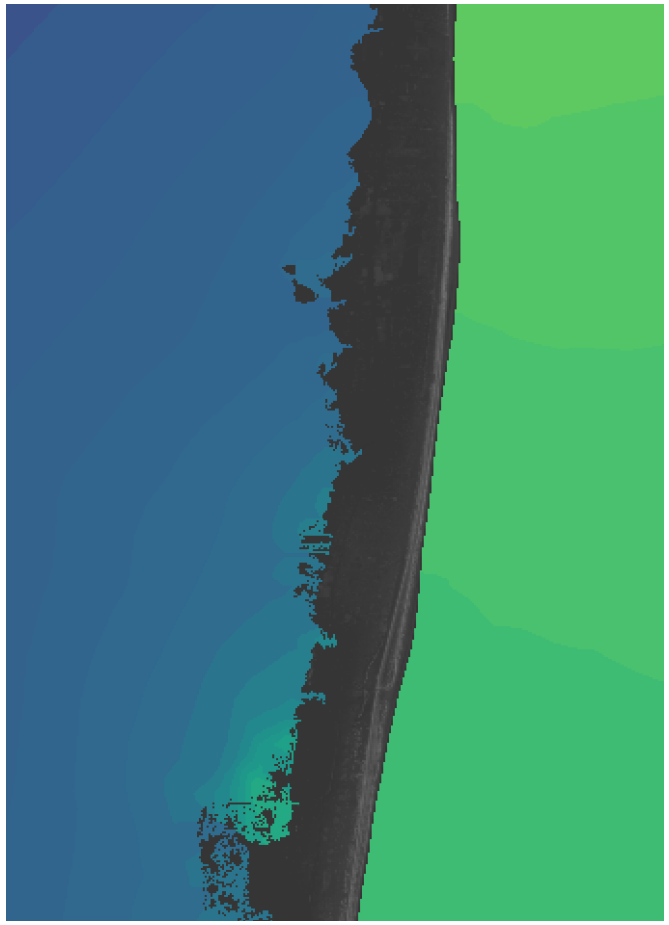
Inland Dare Comparison

Run	Flooded Cells	% of Land Area
NC9	664018	21.2
NC9 Enhanced	897052	28.6
High-Res. Mesh	457340	14.6

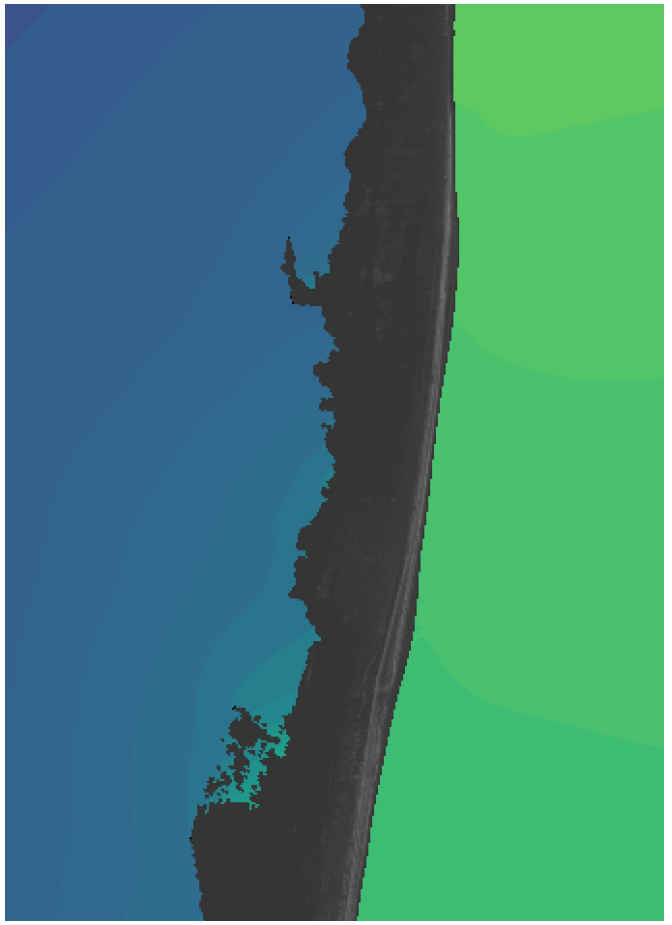
Barrier Island Comparison (Near Salvo, NC)



NC9



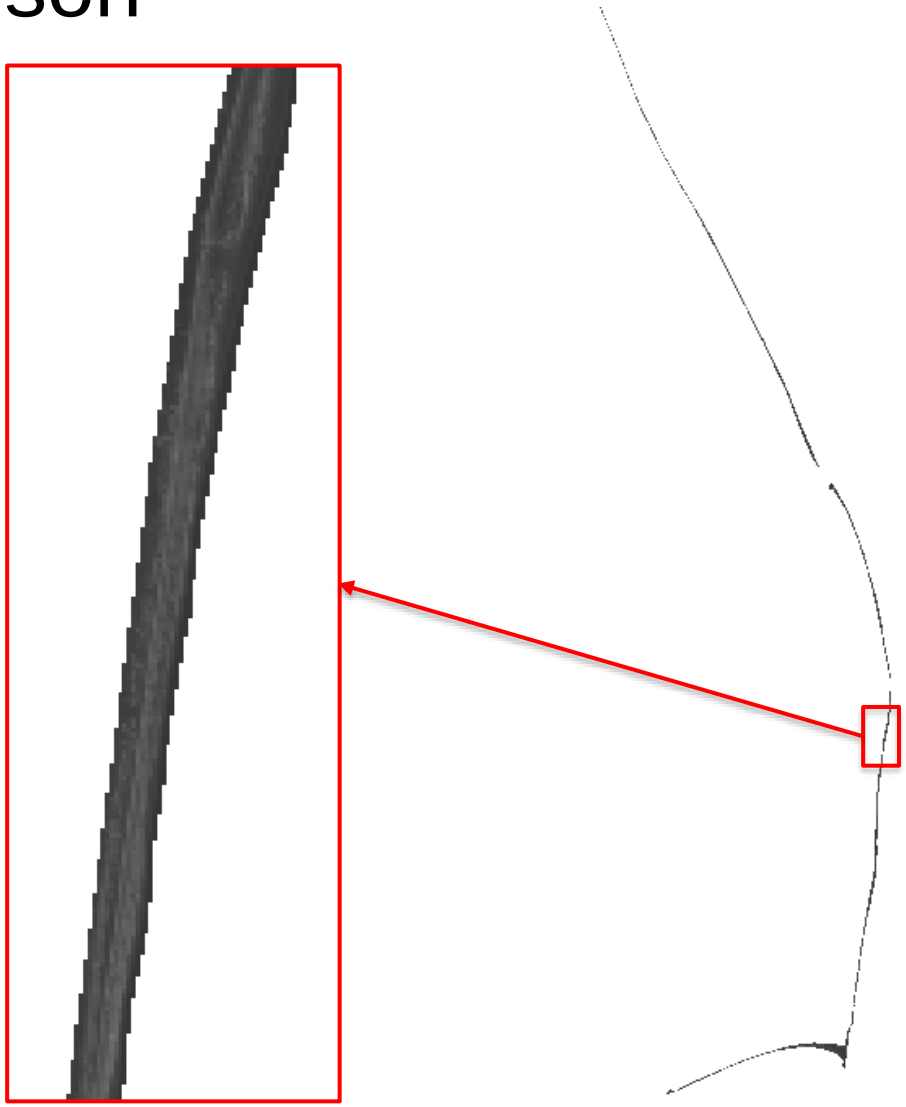
NC9 Enhanced



High-Resolution Mesh

Barrier Island Dune-Area Comparison

Run	Flooded Cells	% of Land Area
NC9	1137	1.0
NC9 Enhanced	9654	8.8
High-Res. Mesh	9396	8.6



Conclusions

- NCEM is very happy with this guidance
  - They have said the enhanced guidance is a much better match to the flooding they observed during Matthew
- The enhanced resolution may work better in some areas than in others
  - May be a better predictor in steeper regions
- This is a tool for *forecasting*, better methods are available for hindcasting (e.g., high-resolution ADCIRC meshes or subdomain inundation modeling)
- This is not a rigid process; some methods can change depending on needs of end-users