Hindcasts of Winds and Surge during Hurricane Matthew (2016): Balancing Large-Domain Coverage and Localized Accuracy

Ajimon Thomas[1], J.C. Dietrich[1],
R.A. Luettich[2], J.G. Fleming[3], B.O. Blanton[4], T. Asher[2]
S.C. Hagen[5], M.V. Bilskie[5], P. Bacopoulos[6]

[1]Civil, Construction and Environmental Engineering, North Carolina State University;
[2]Institute of Marine Sciences, UNC Chapel Hill;
[3]Seahorse Coastal Consulting; [4]Renaissance Computing Institute, UNC Chapel Hill;
[5]Center for Coastal Resiliency, Louisiana State University
[6]Florida Department of Environmental Protection

COASTAL RESILIENCE CENTER
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Hurricane Matthew (2016) – Synoptic History

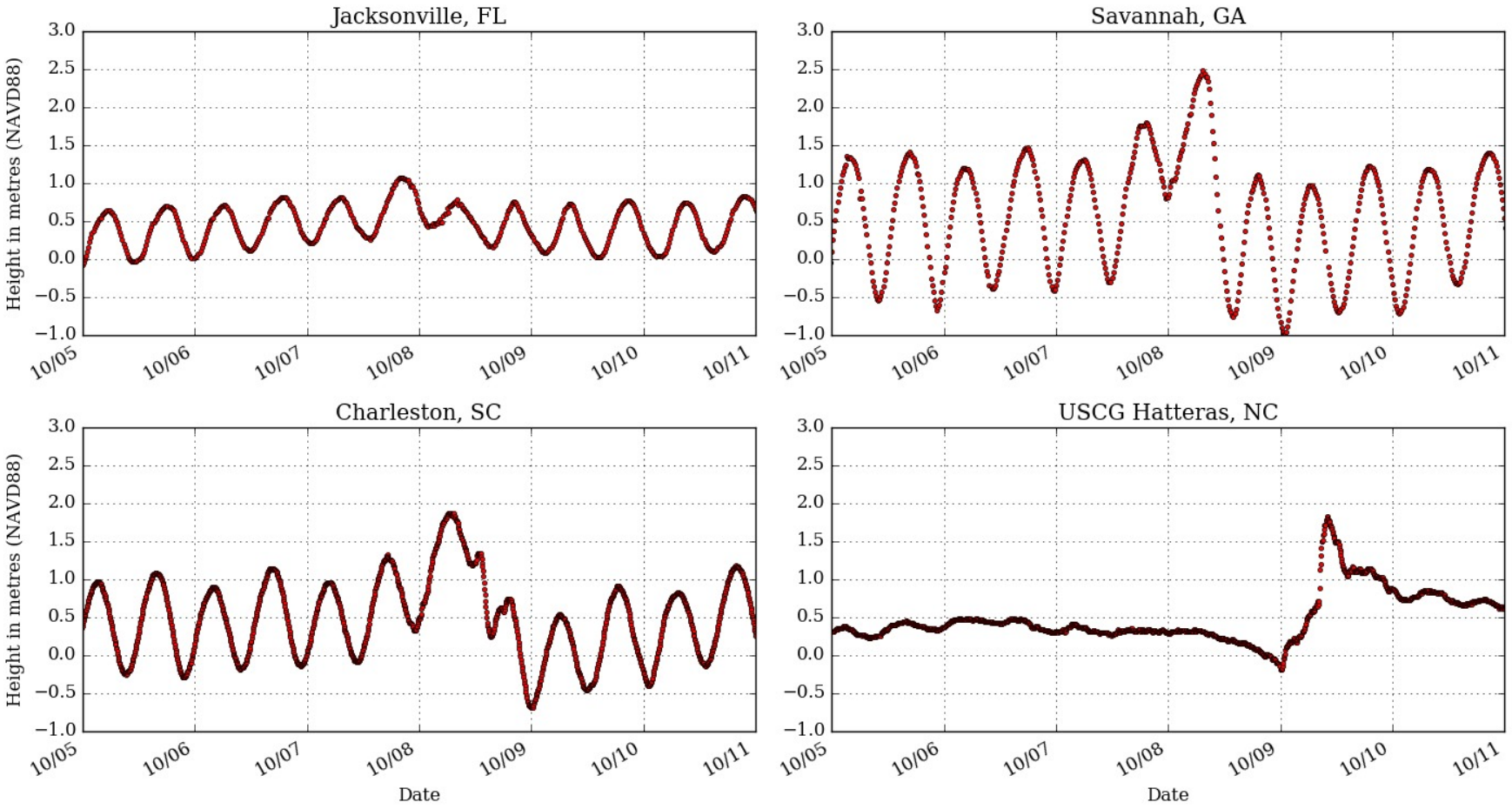
Source: NOAA

Summary of Observations during Matthew

Extensive observations along the US East Coast

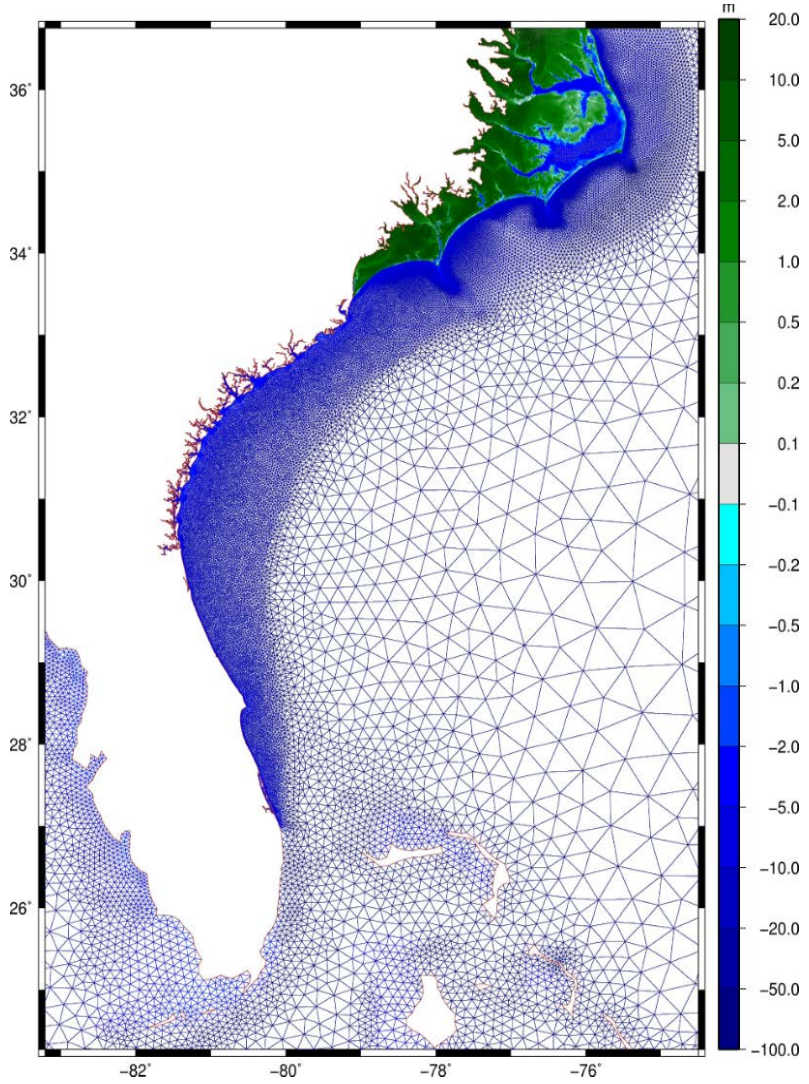
Data Source	Wind Speed	Wind Direction	Surface Pressure	Significant Wave Height	Water Levels	High Water Marks
NOAA	6	6	2		30	
NDBC	87	86	88	36		
USGS-PERM					284	
USGS-DEPL	6	7	8		19	621
USGS-STS			217		216	
NC FIMAN	10	10	10		8	
TOTAL	**109**	**109**	**325**	**36**	**557**	**621**

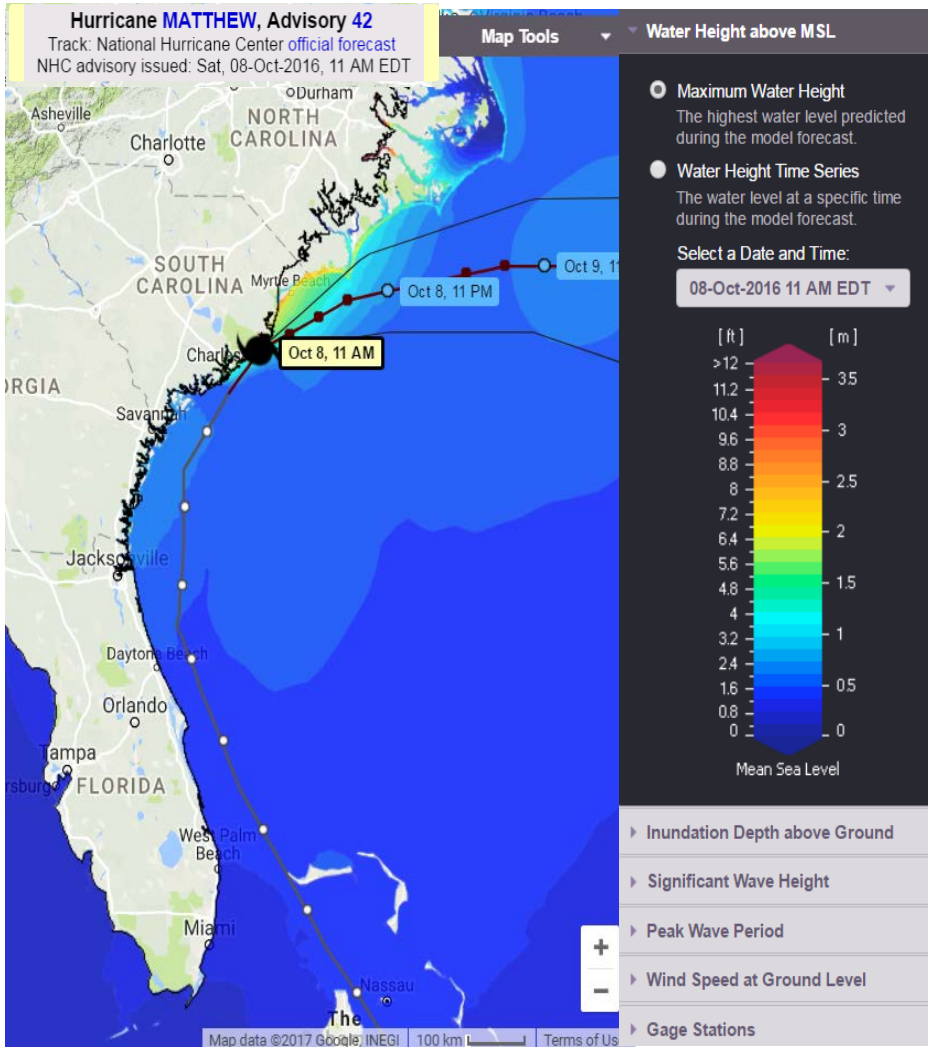
Observations at Selected Stations (South to North)



Forecasting during Matthew

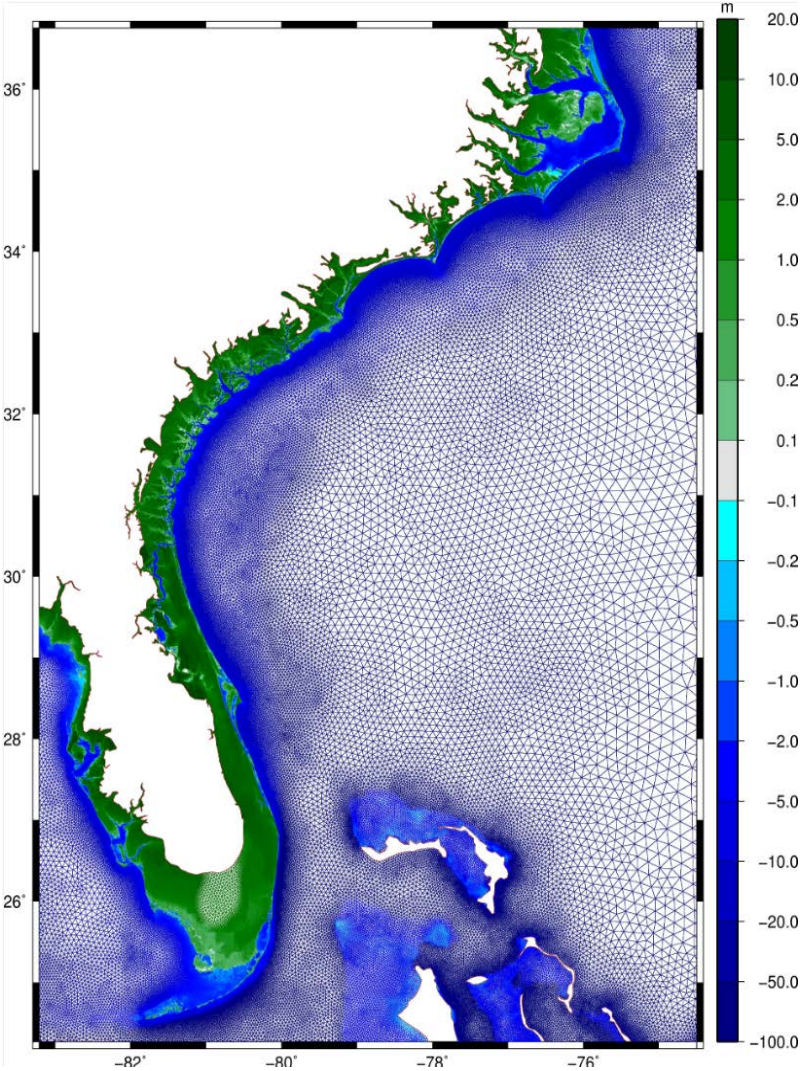
Focus on North Carolina

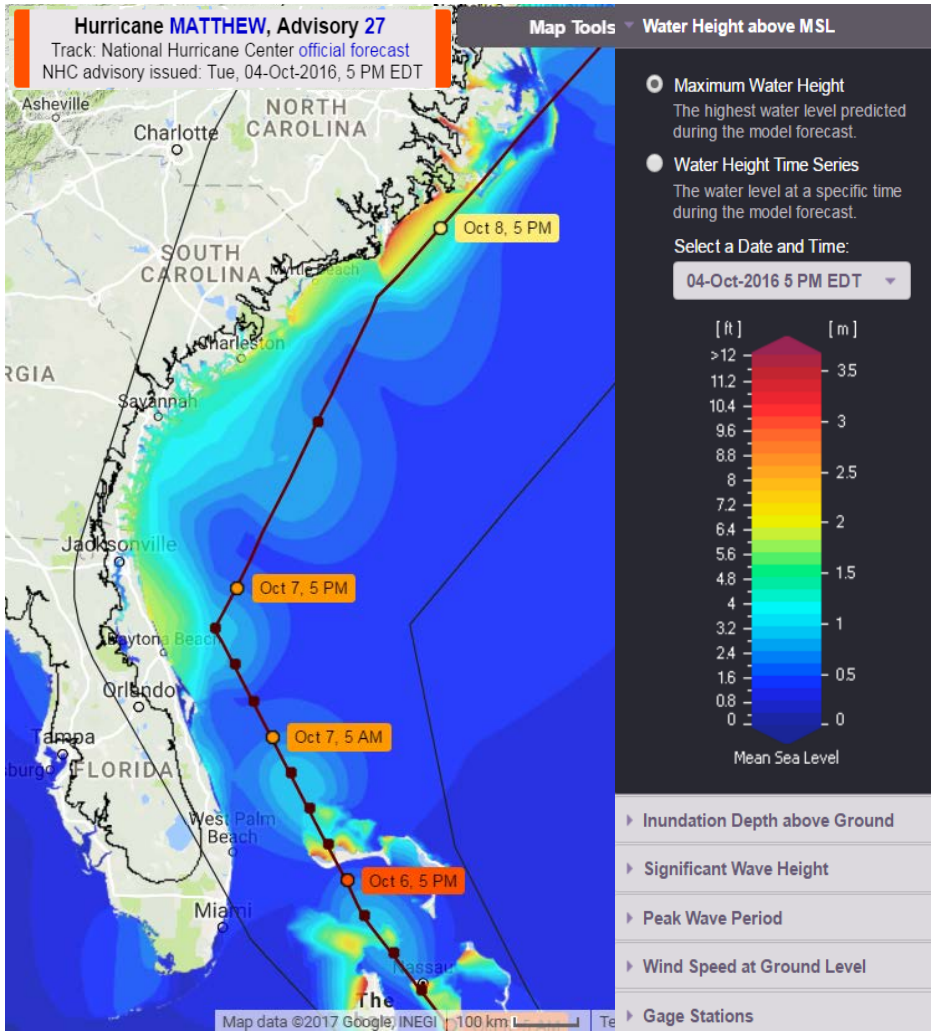




Forecasting during Matthew

Focus on the East Coast





Goals and Objectives

Part 1 : Impact of Matthew on the East Coast

- Use one mesh, but explore different atmospheric forcing sources
- Evolution of wind fields during Matthew
- How did the impact differ between inland and coastal regions?

Part 2 : Implications of using different meshes

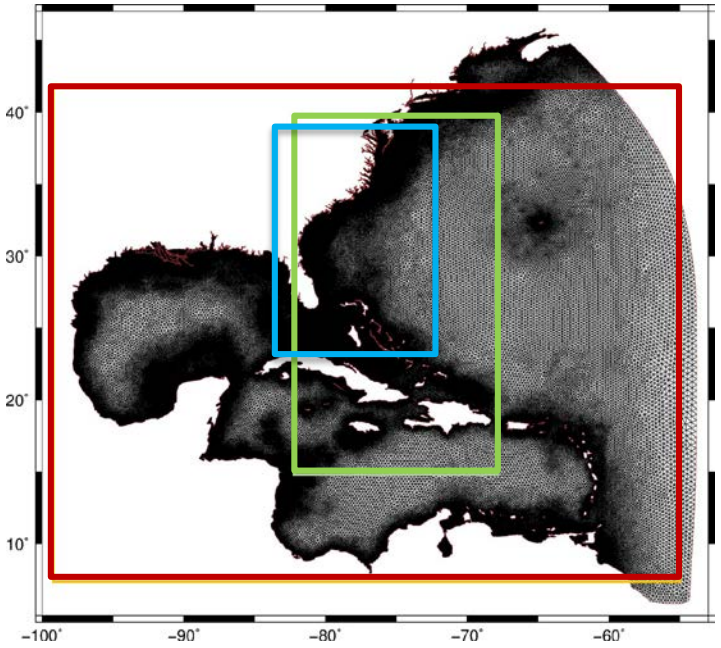
- Explore different meshes
- How does each mesh represent coastal regions and flood plains?
- Identify regions where each mesh performs better

Part 1 – Wind Models

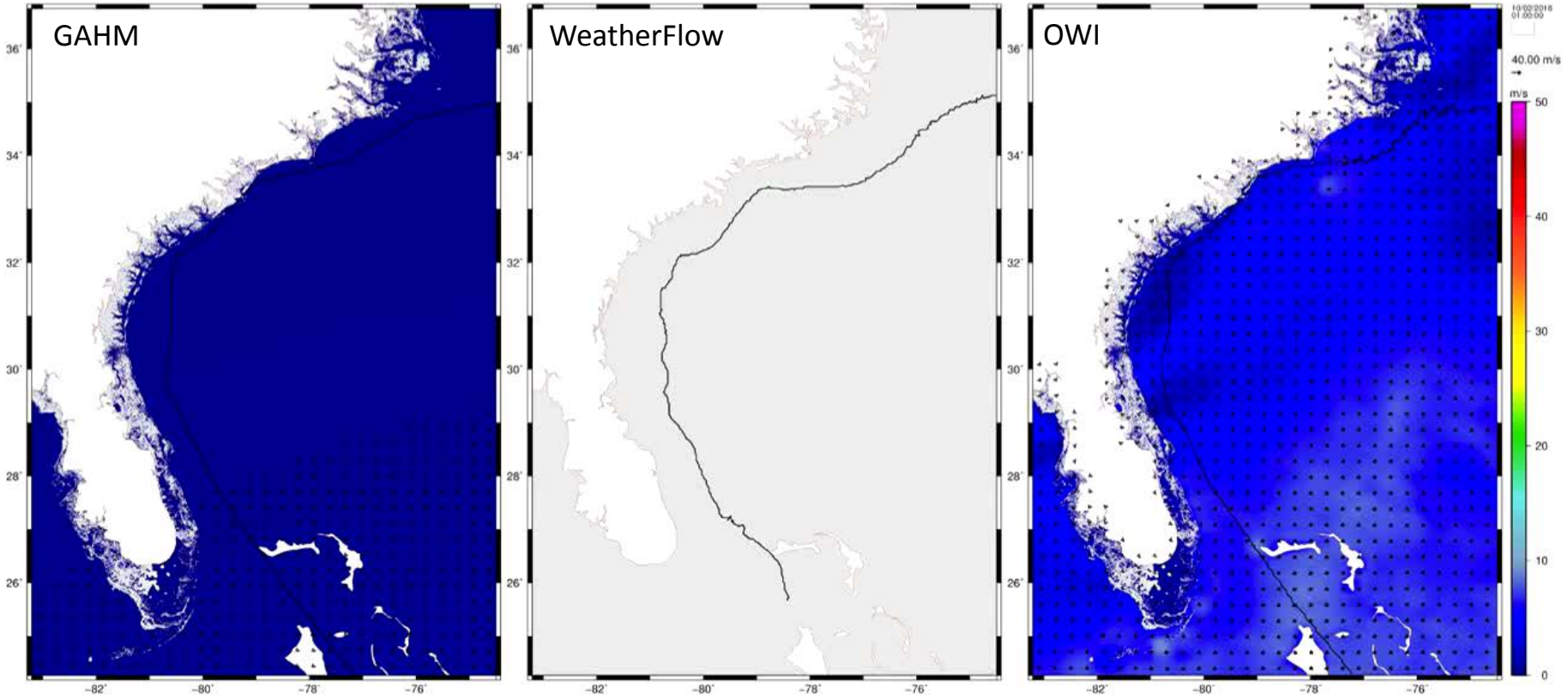
1. The Generalized Asymmetric Holland Model (GAHM)
   - Eliminates the assumption of cyclostrophic balance from AHM
   - Makes use of multiple isotachs in the NHC wind advisories
   - 10/02/2016 00:00 to 10/10/2016 00:00

2. Winds from WeatherFlow Inc.
   - Region grid at resolution of 1/37º
   - 10/06/2016 20:00 to 10/09/2016 20:00
   - 10 min intervals

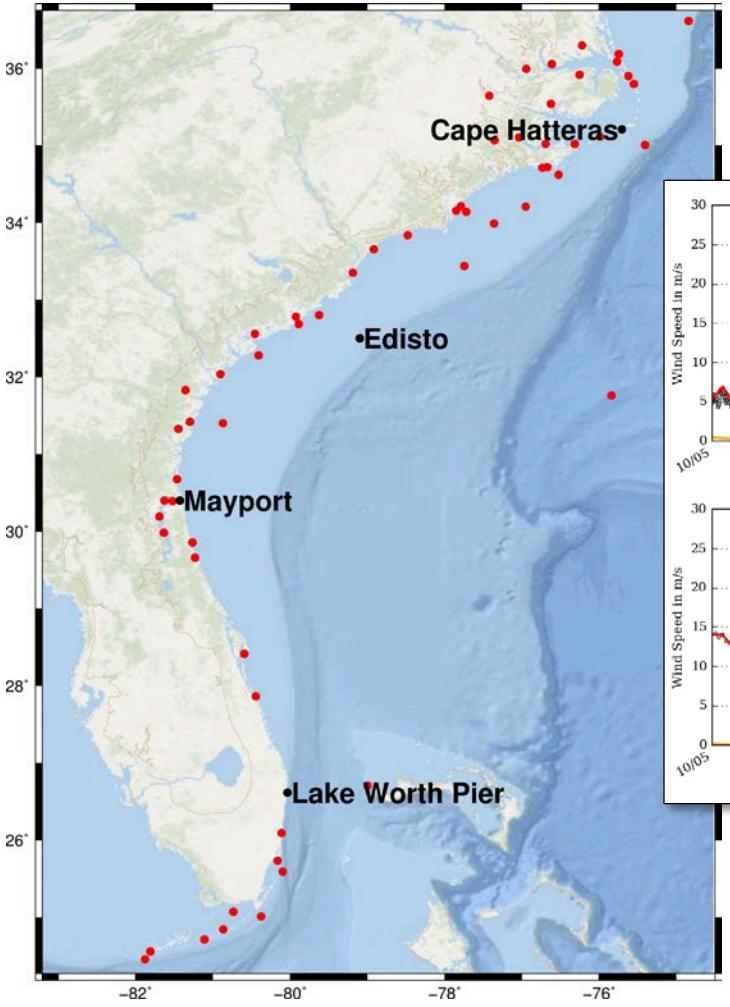
3. Winds from OceanWeather Inc. (OWI)
   - Fields are provided on multiple grids
   - Basin grid at resolution of 1/4º
   - Region grid at resolution of 1/20º
   - 10/01/2016 00:00 to 10/11/2016 00:00
   - 15 min intervals

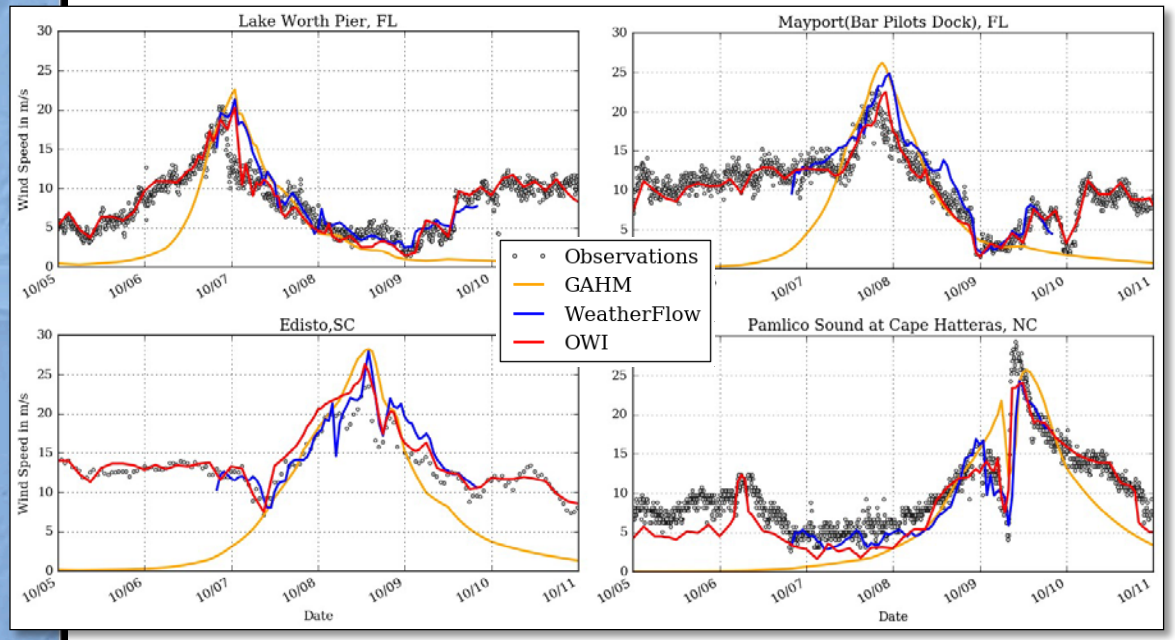


Part 1 – Evolution of Wind Fields



Part 1 – Wind Speeds Comparison (from South to North)





Part 1 – Error Metrics

1. Root Mean Squared Error

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} E_i^2}$$

2. Mean Normalized Bias

$$\text{B}_{\text{MN}} = \frac{\frac{1}{N}\sum_{i=1}^{N} E_i}{\frac{1}{N}\sum_{i=1}^{N} |O_i|}$$

O_i is the observed value
E_i is the error (modelled minus observed)
N is the number of observations

Wind Model	Stations	RMSE (m/s)	Bias
GAHM	109	5.066	-0.467
WeatherFlow	84	2.973	0.175
OWI	109	1.937	0.086

Part 2 – Meshes for Hindcasts on Specific Domains

HSOFS Mesh

- Hurricane Surge On-Demand Forecasting System
- For providing operational surge and tide predictions to U.S. East Coast and Gulf
- Avg. resolution of 500 m along the coast
- Extends inland to a smoothed version of the 10-meter topographic contour at most places
- All major rivers systems on the US East and Gulf Coast are included

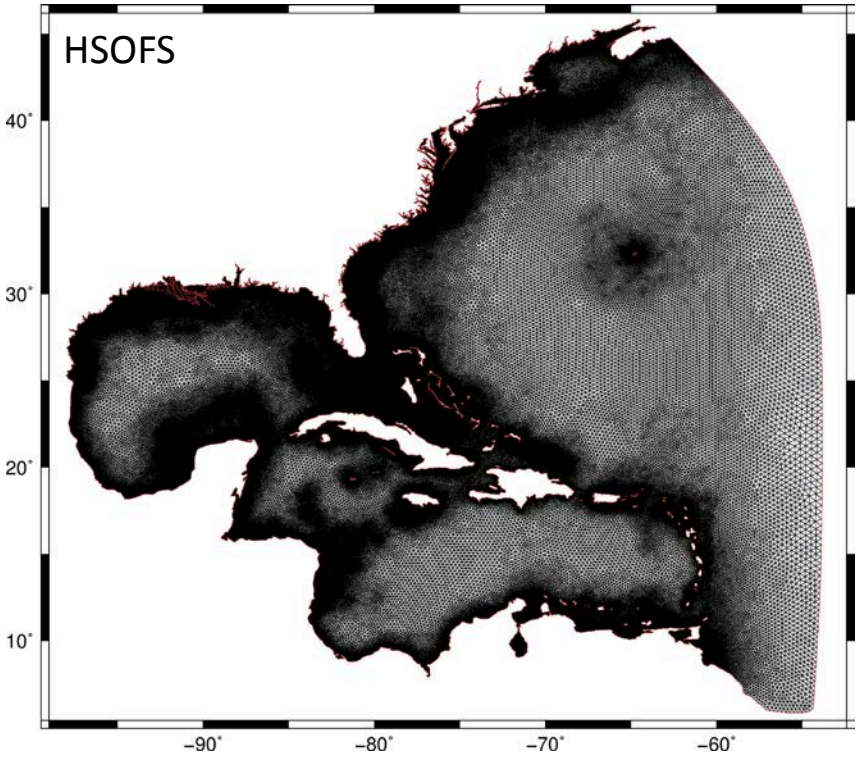
NC9 Mesh

- North Carolina version 9.99 with rivers
- FEMA Flood Mapping Study for running hundreds of simulations for hypothetical storms
- More than 90% of the resolution within coastal NC
- In North Carolina, the mesh extends inland to the 15 m contour which allows for storm surge flooding
- In NC, there is sufficient resolution to represent major features

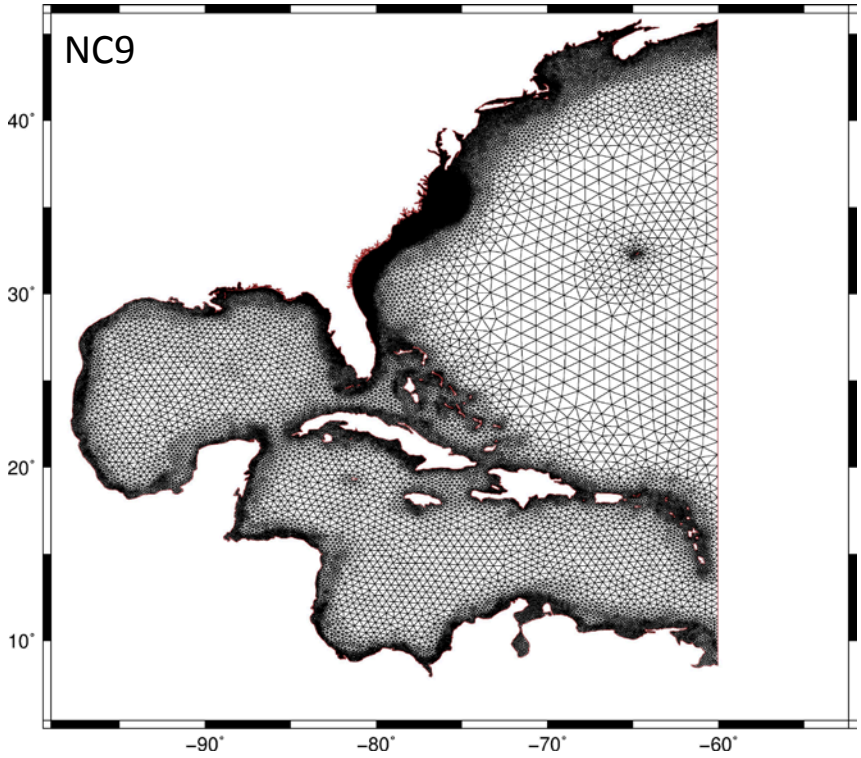
EFL-SAB Mesh

- East Florida – South Atlantic Bight Mesh
- Developed by our collaborators at LSU
- Around one-third of its resolution is concentrated on the St. Johns river system in East Florida

Part 2 – Extent of Meshes

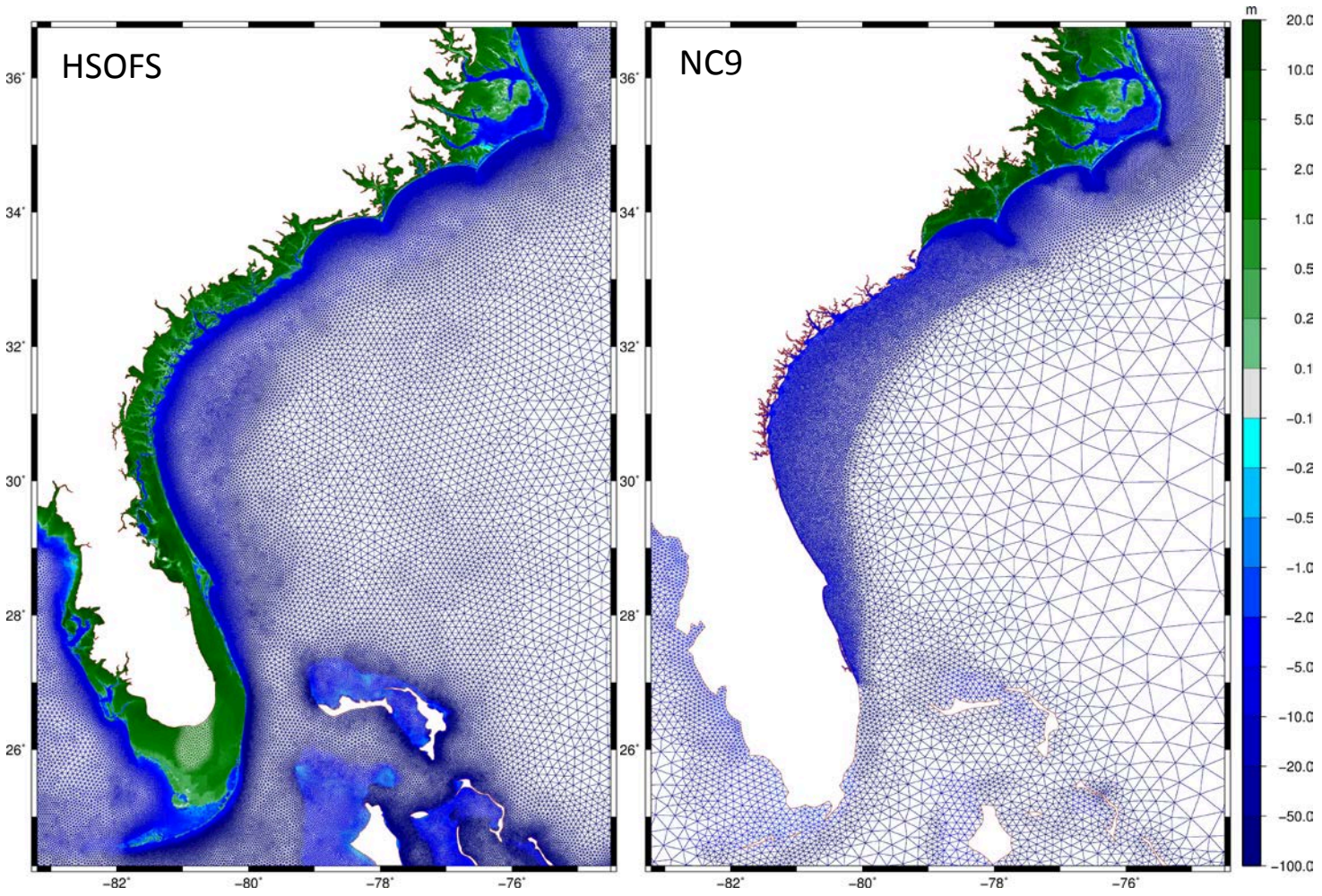


1,813,443 nodes

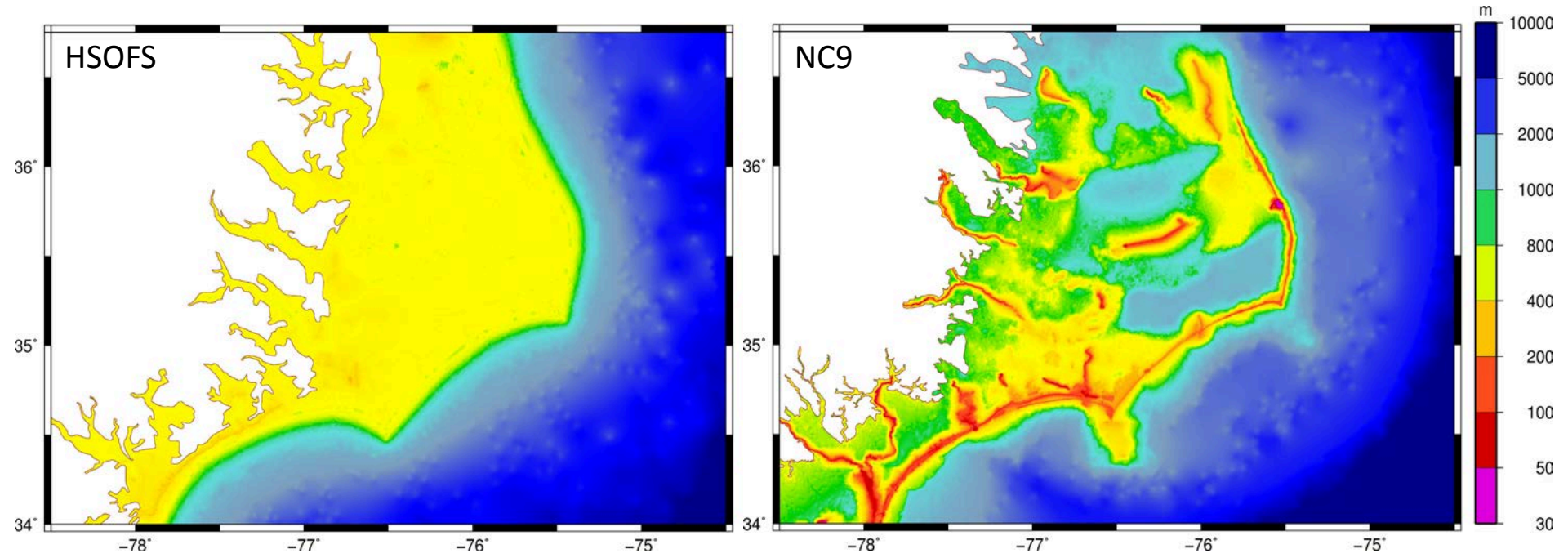


624,782 nodes

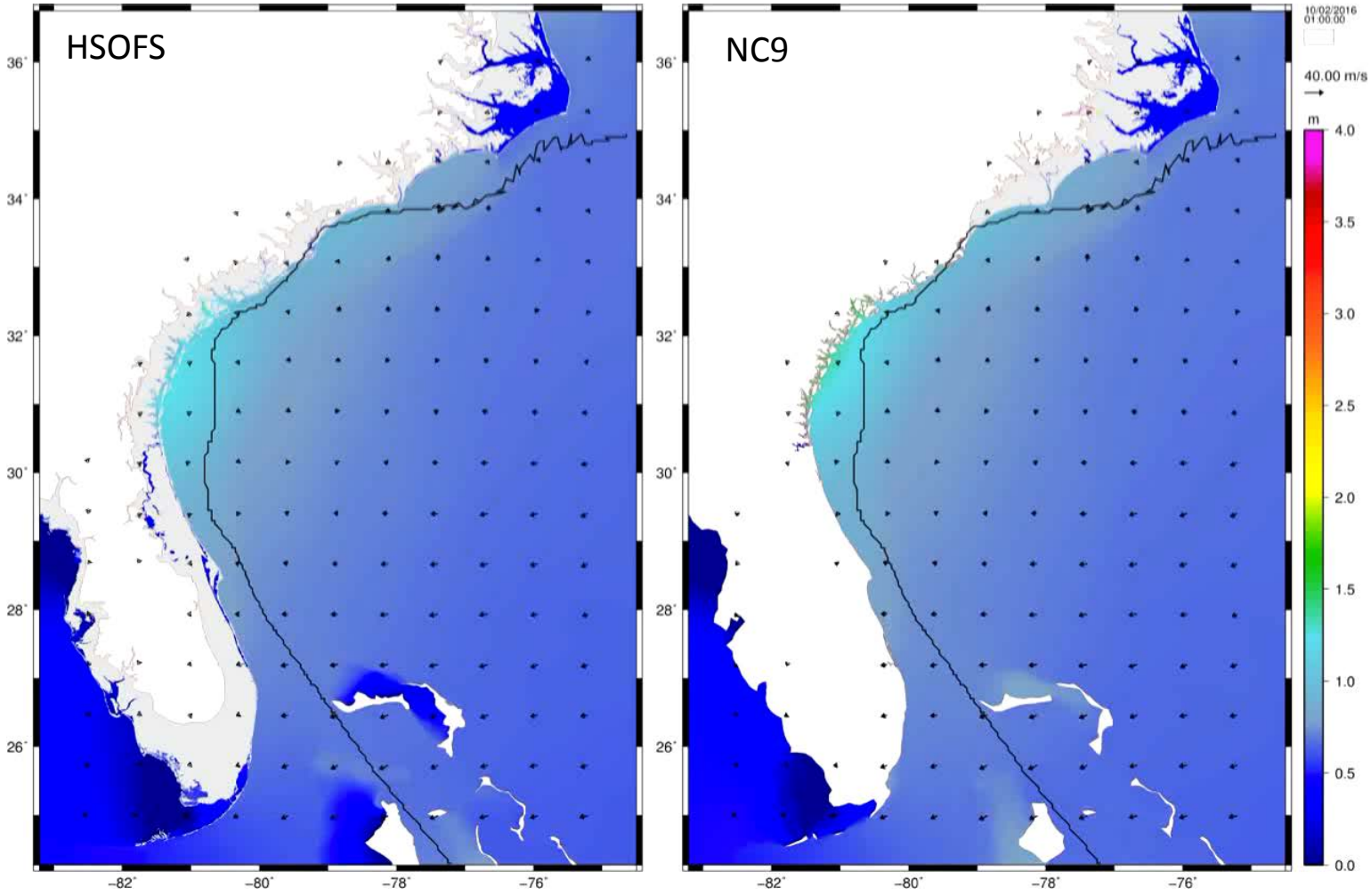
Part 2 – Bathy/Topo for the U.S. East Coast



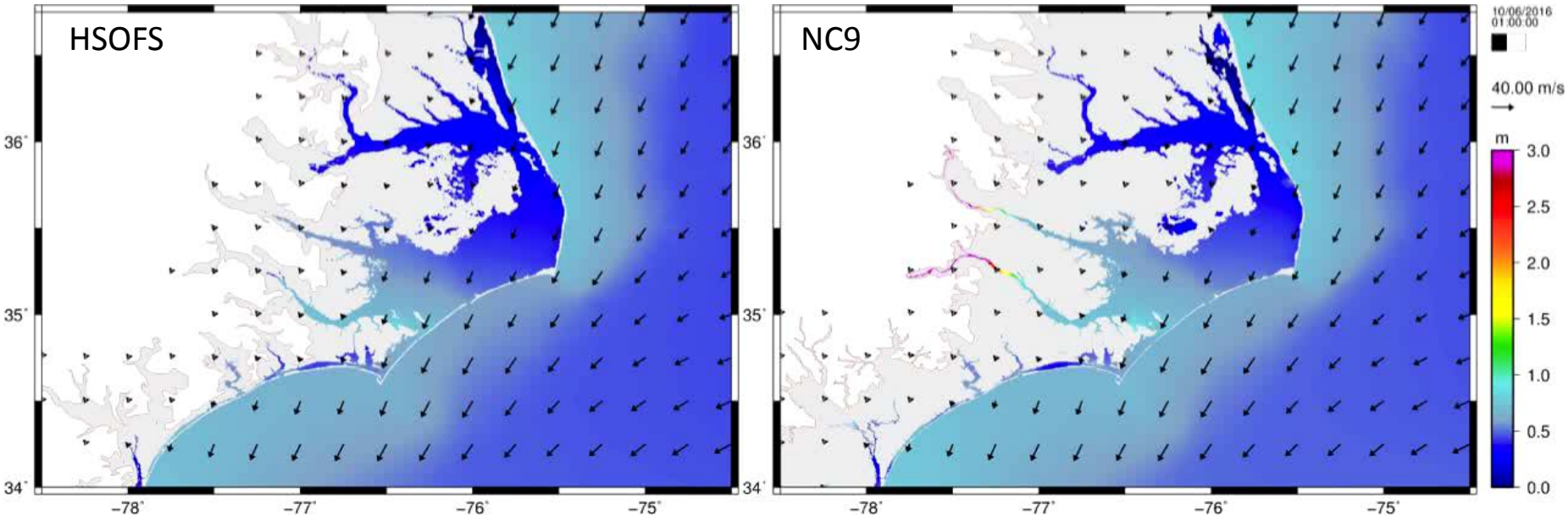
Part 2 – Element Spacing for the NC Region



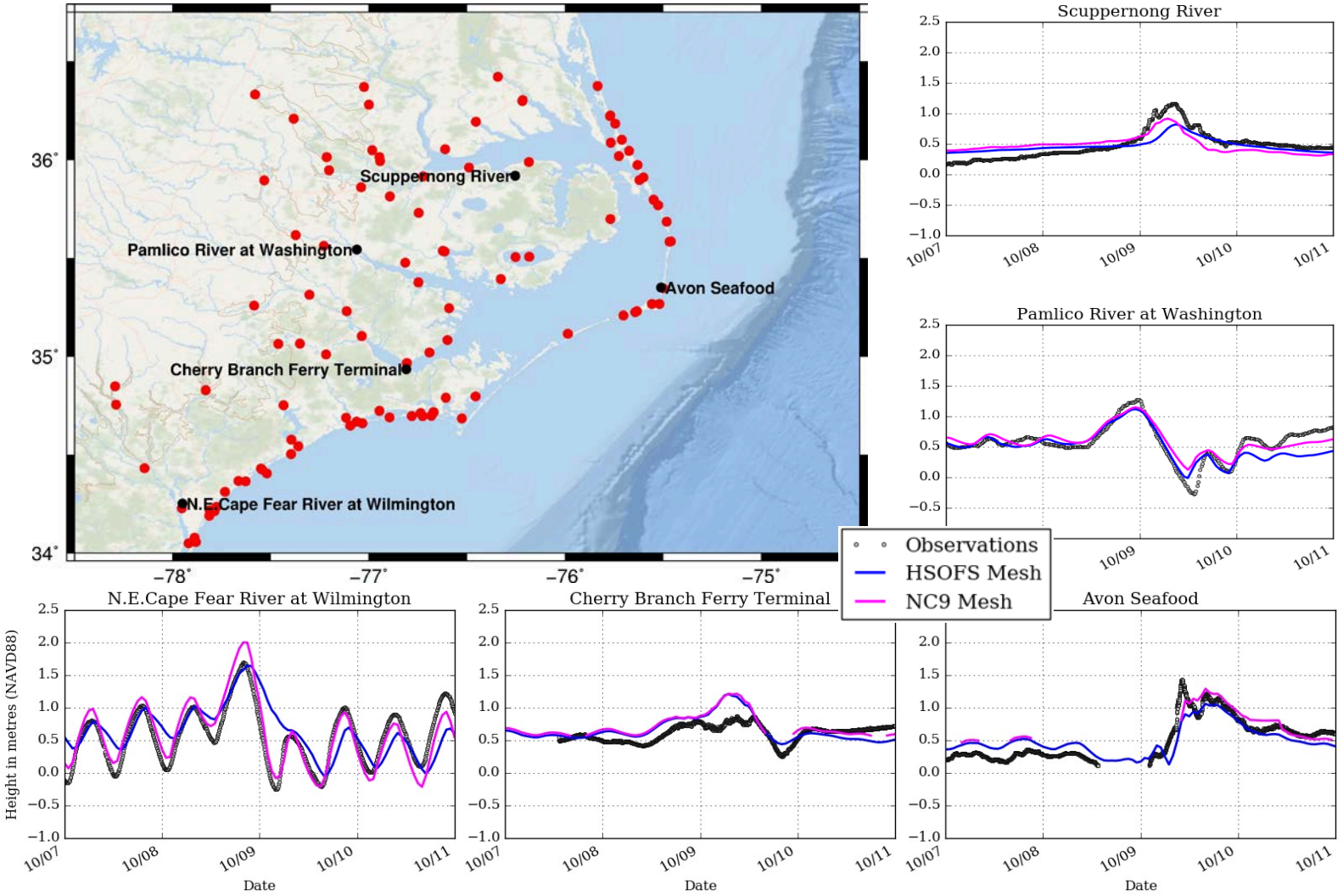
Part 2 – Evolution of Water Levels Along the US East Coast



Part 2 – Evolution of Water Levels in NC



Part 2 – Water Levels Comparison

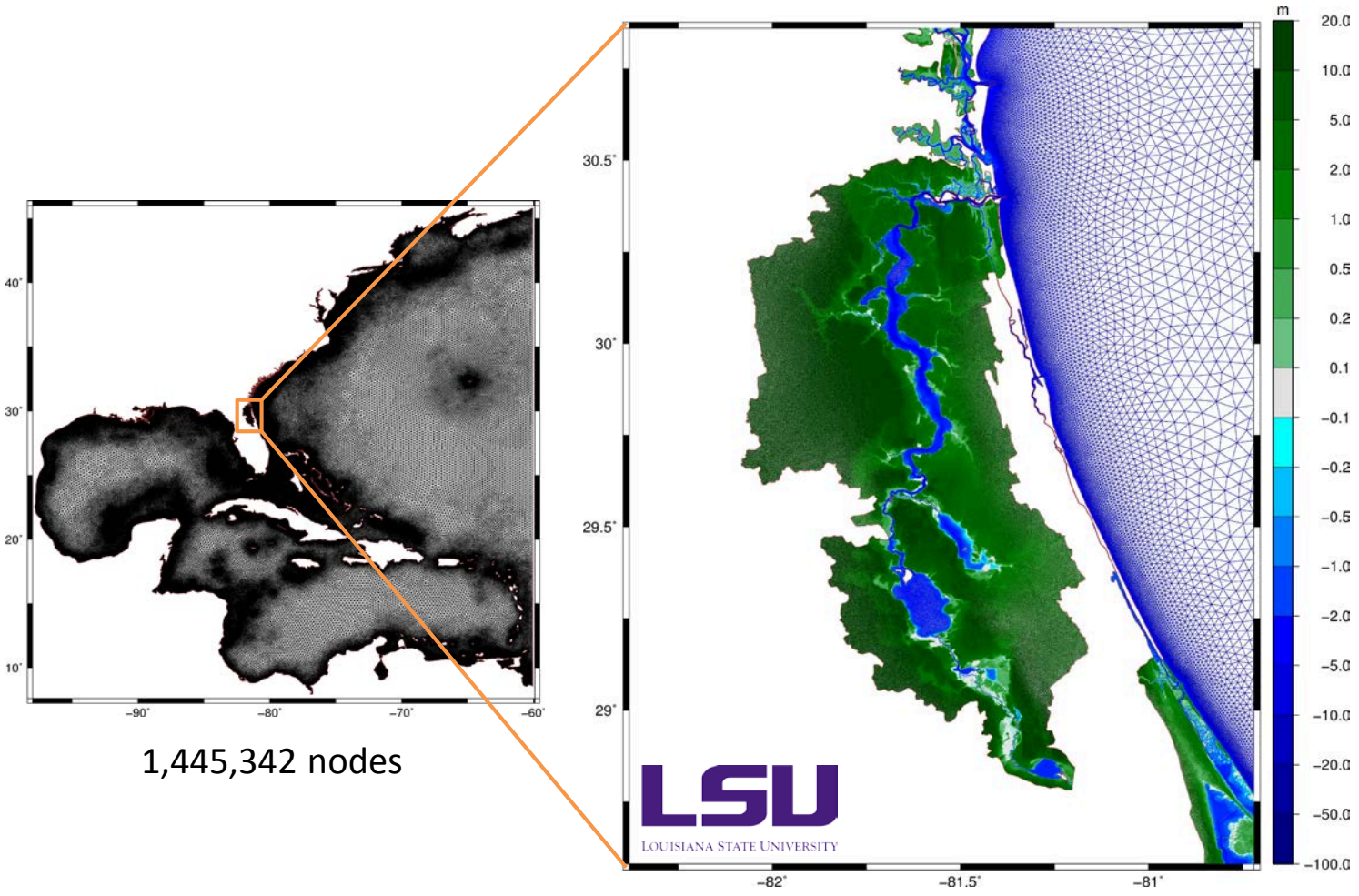


Part 2 – Error Metrics

Mesh	Stations	RMSE (m)	Bias
HSOFS (NC Stations)	90	0.264	0.089
NC9 (NC Stations)	90	0.240	0.153
HSOFS (All Stations)	310	0.295	0.377

- Given its constraints on mesh resolution in coastal regions, the HSOFS mesh does remarkably well at representing Matthew's impacts
- With higher resolution along its coastline of interest, the NC9 mesh allows for better performance at many gauges, but not necessarily everywhere

Future Work



1,445,342 nodes