COASTAL RESILIENCE CENTER
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Explicit Modelling of Open Channels and Compound Flooding Prediction in ADCIRC

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3rd International Workshop on Waves, Storm Surges, and Coastal Hazards
Oct 1-6, 2023

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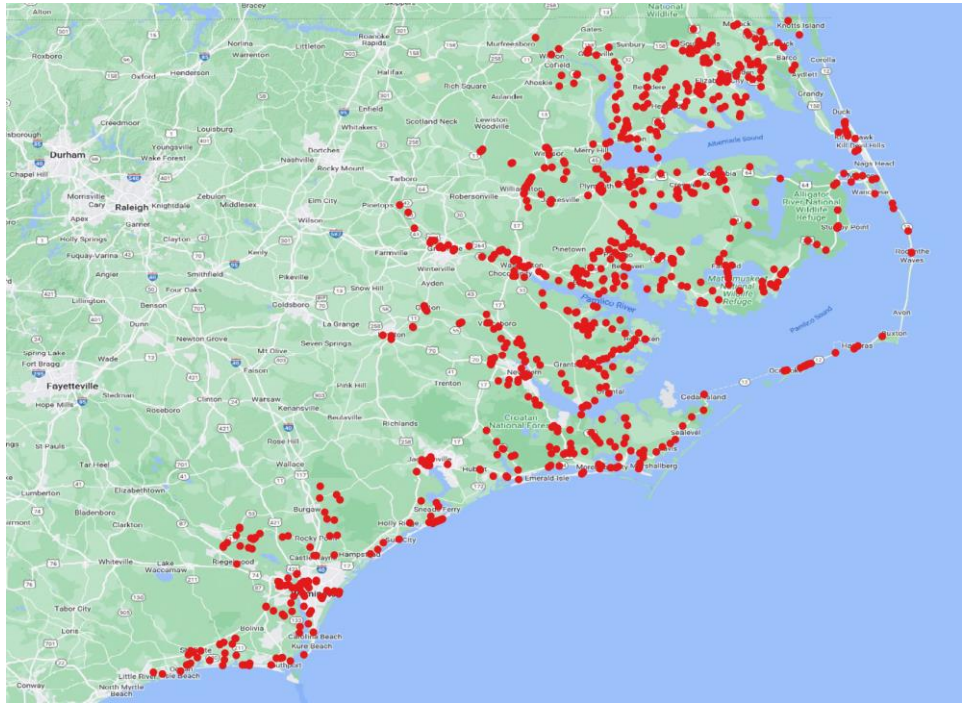
Motivations to Embed Smaller Channels (1/2)

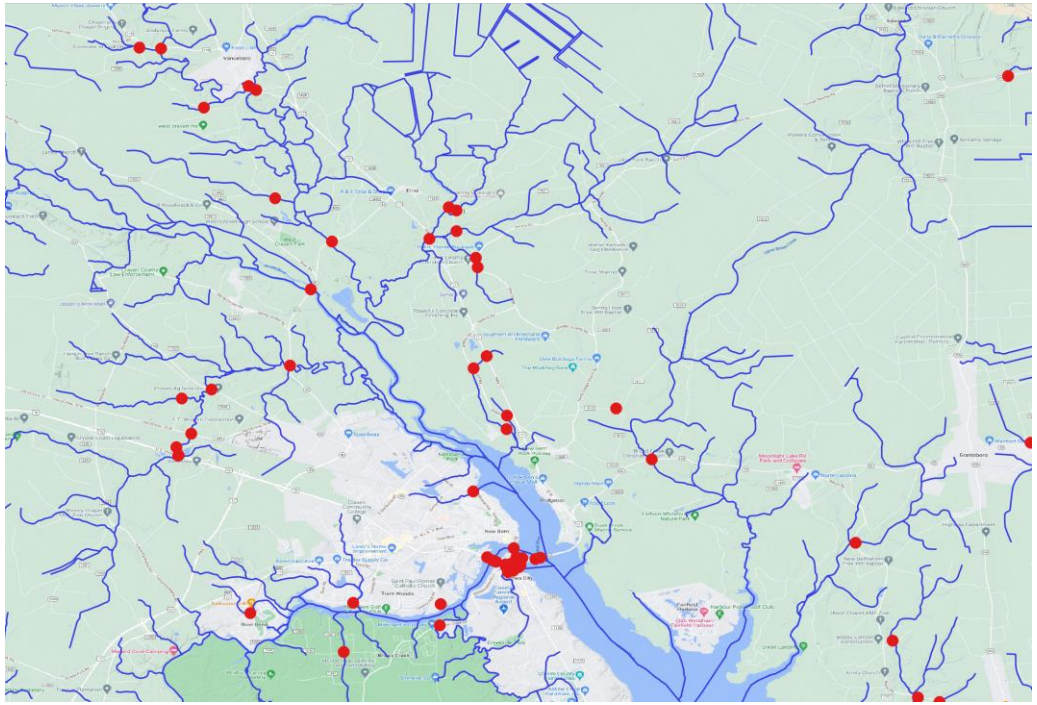
- Detailed prediction for decision makers

Locations monitored by NC State Department of Transport

NWM stream network



Many of the locations are at bridges across channels



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Motivations to Embed Smaller Channels (2/2)

Without properly represented channels, compound flooding predictions pose issues in both flooding and drainage processes.

- Early / delayed flooding
- Fictitious ponding due to lack of drainage

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Approaches to Model Smaller Channels in a Hydrodynamic Model

1. More nodes for higher resolutions along channels

2. Subgrid correction

3. Coupling 1D & 2D (3D) hydrodynamic models

3′. 1D Channels represented by 2D triangular elements[1]

→ This work pursues Approach 3′ and implements it in the ADCIRC hydrodynamic model.

[1] *Bunya, et al., Advances in Engineering Software, 2023.*

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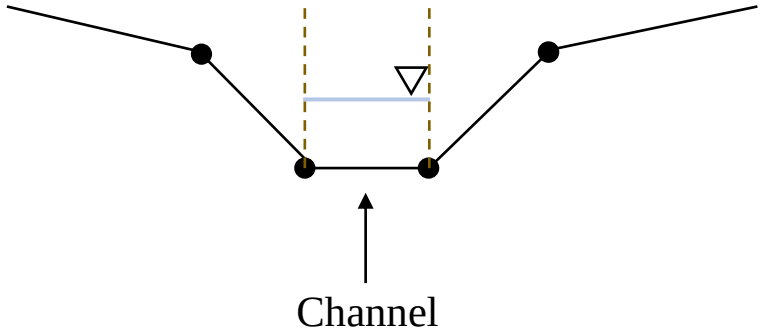
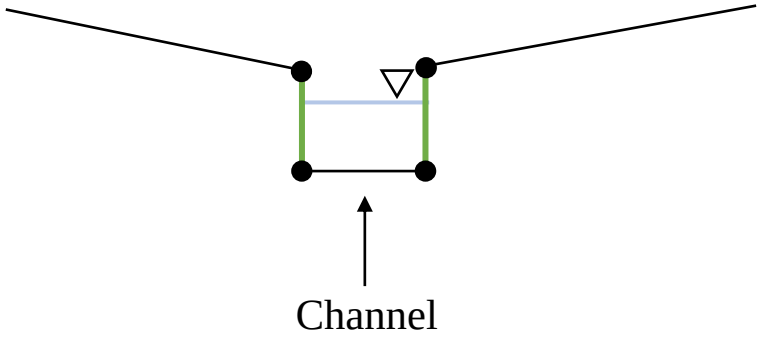
Technique 1: Vertical Element Wall (VEW)

Conventional approach:
Trapezoidal model



→ Requires 3 elements across a channel

New approach - Vertical Element Wall:
Rectangular cross-section model with discontinuous depth representation



→ Requires ONLY 1 element across a channel
(Compact representation of a channel)

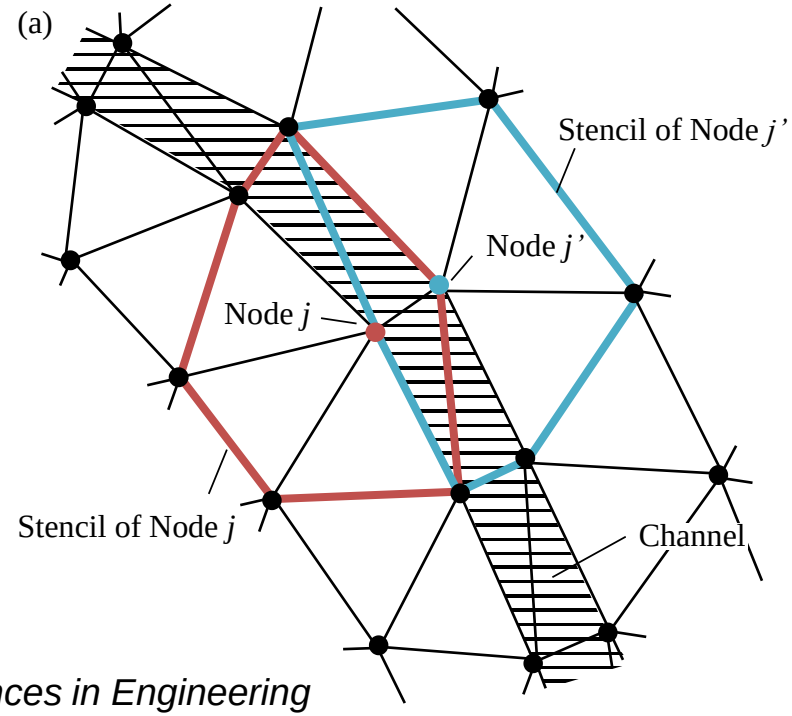
Bunya, et al., Advances in Engineering Software, 2023.

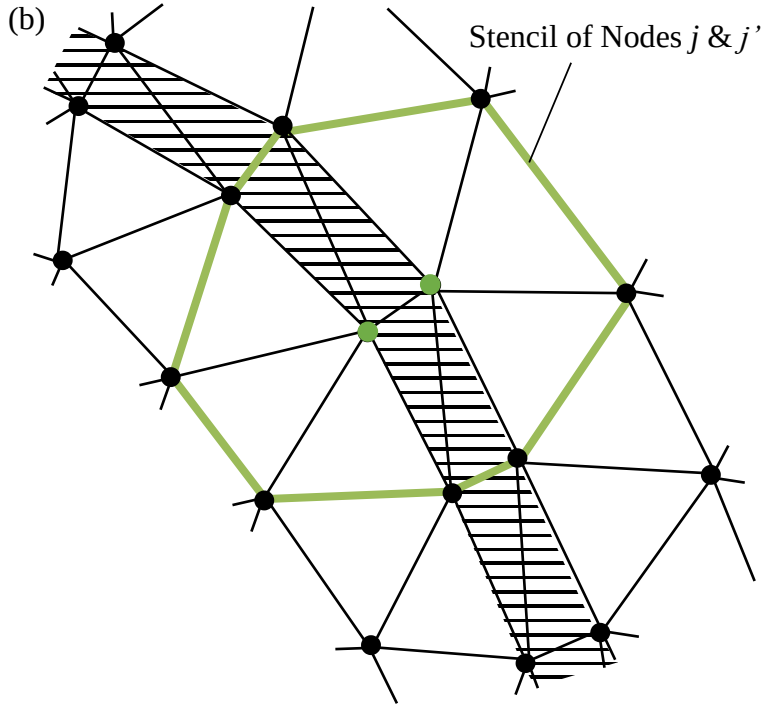
Technique 2: 1D Condensation

Purpose: Eliminate the strict CFL condition due to the small width of a channel for explicit time integration schemes.

Implementation: Expand the stencil by summing up two sets of equations at the paring nodes before finding solutions

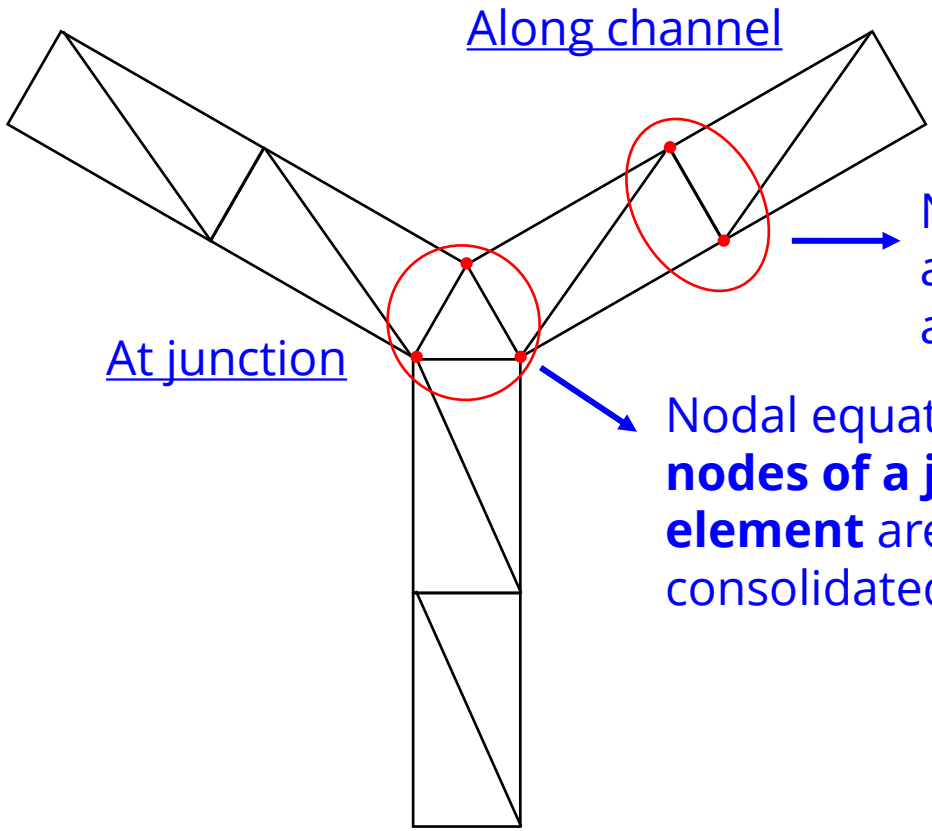
Side effect: The pairing nodes hold the same solutions, i.e., no solution variation in the across-channel direction → 1D solution





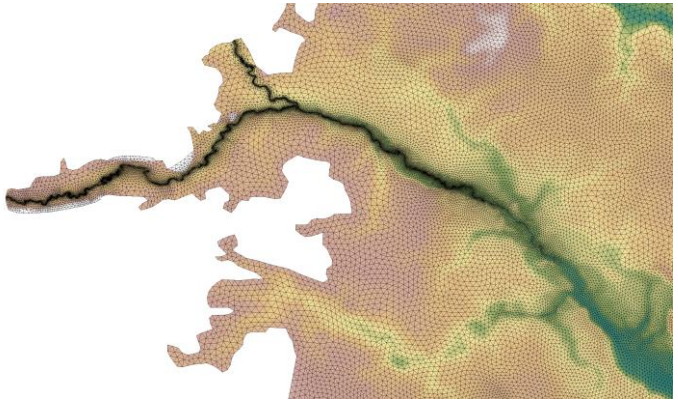
Bunya, et al., Advances in Engineering Software, 2023.

Technique 2: 1D Condensation — At Junctions



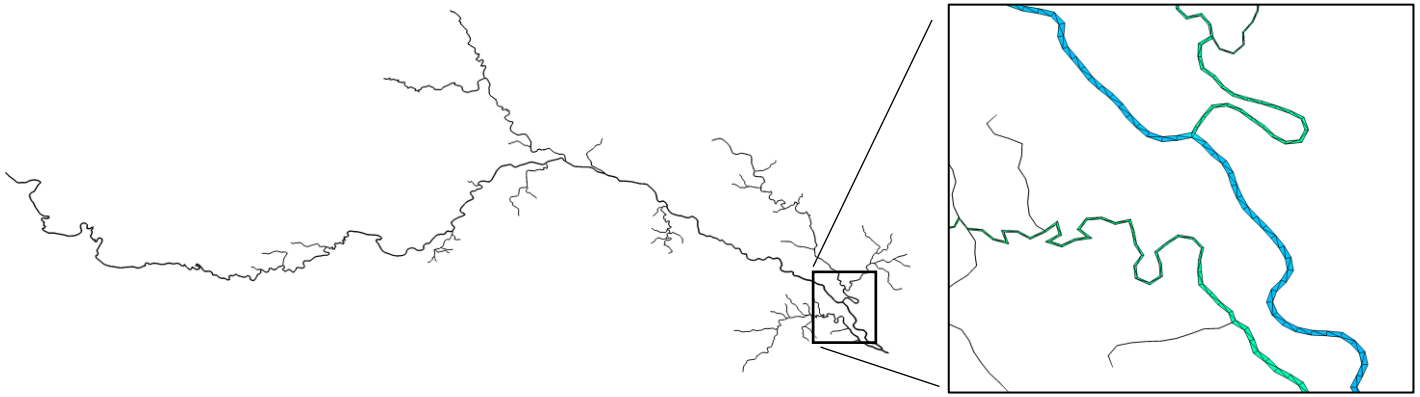
Mesh Generation

Existing mesh

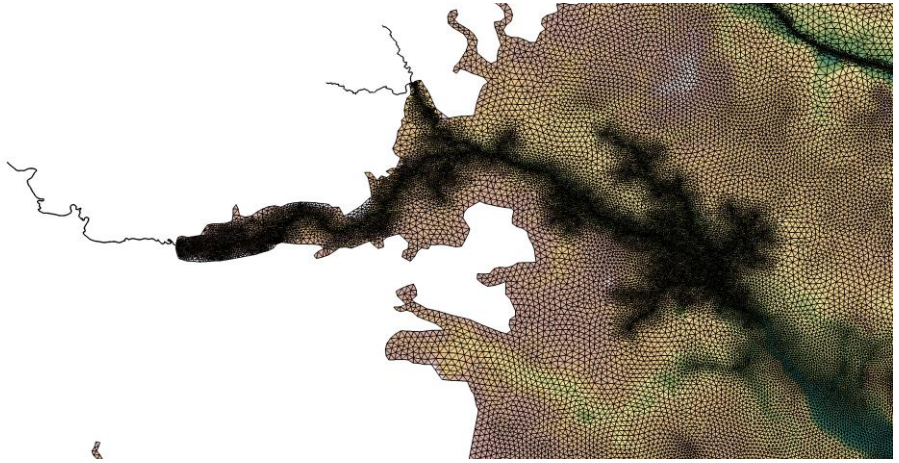


+

Channel mesh



New mesh with embedded channel networks



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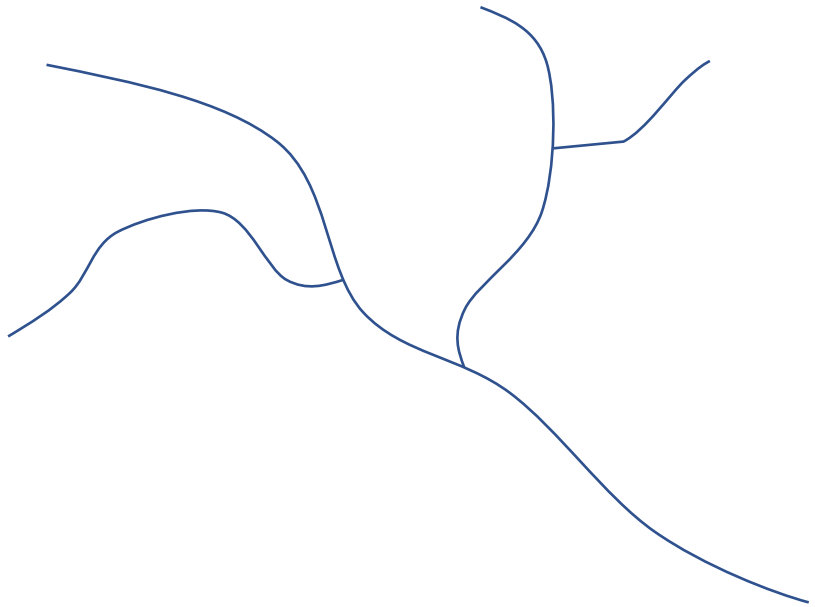
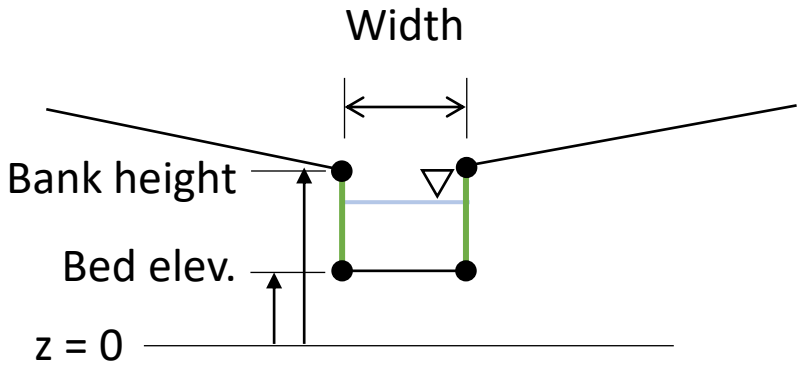
Mesh Generation

- A channel mesh requires
  - Channel center lines and their connectivity
  - Channel attributes: width, bed elevation, and bank height

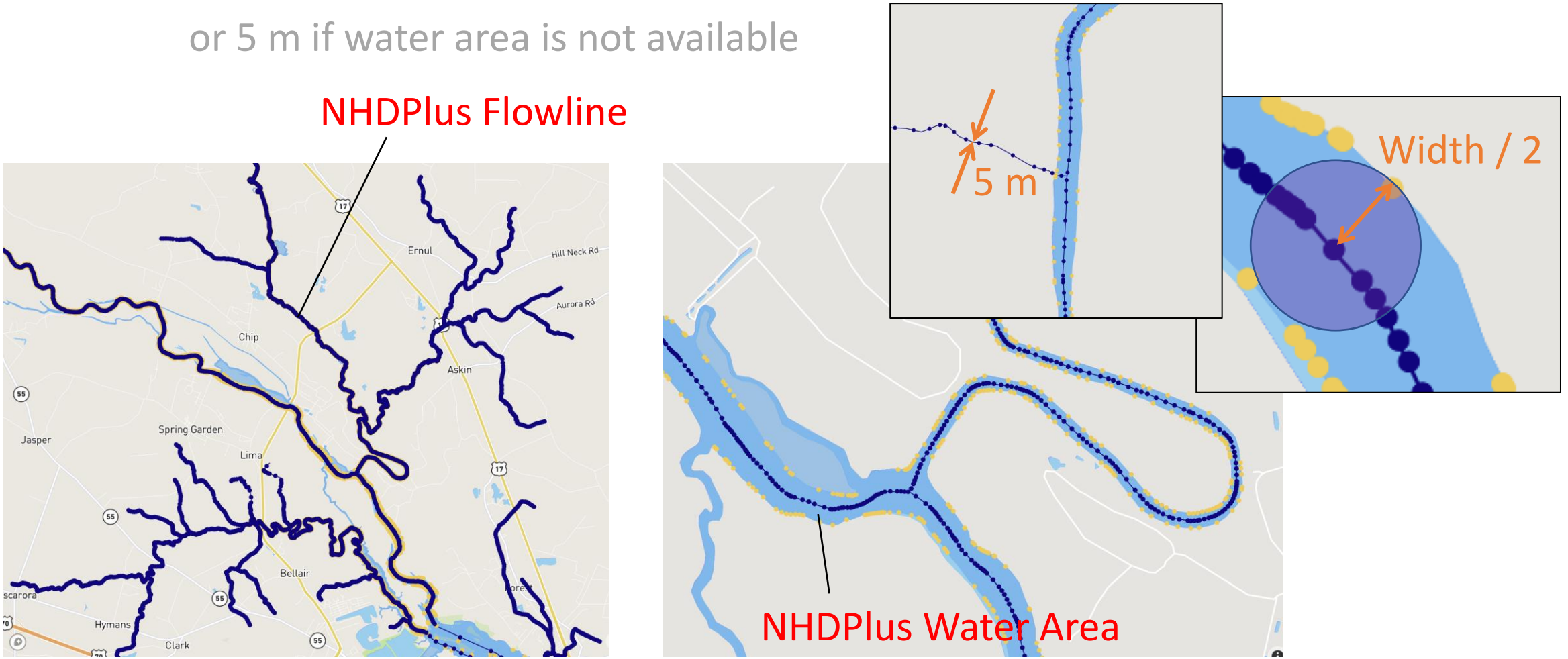




Estimation of Channel Width

Width = Distance from center line to water area boundary x 2

or 5 m if water area is not available



Neuse River and their tributaries

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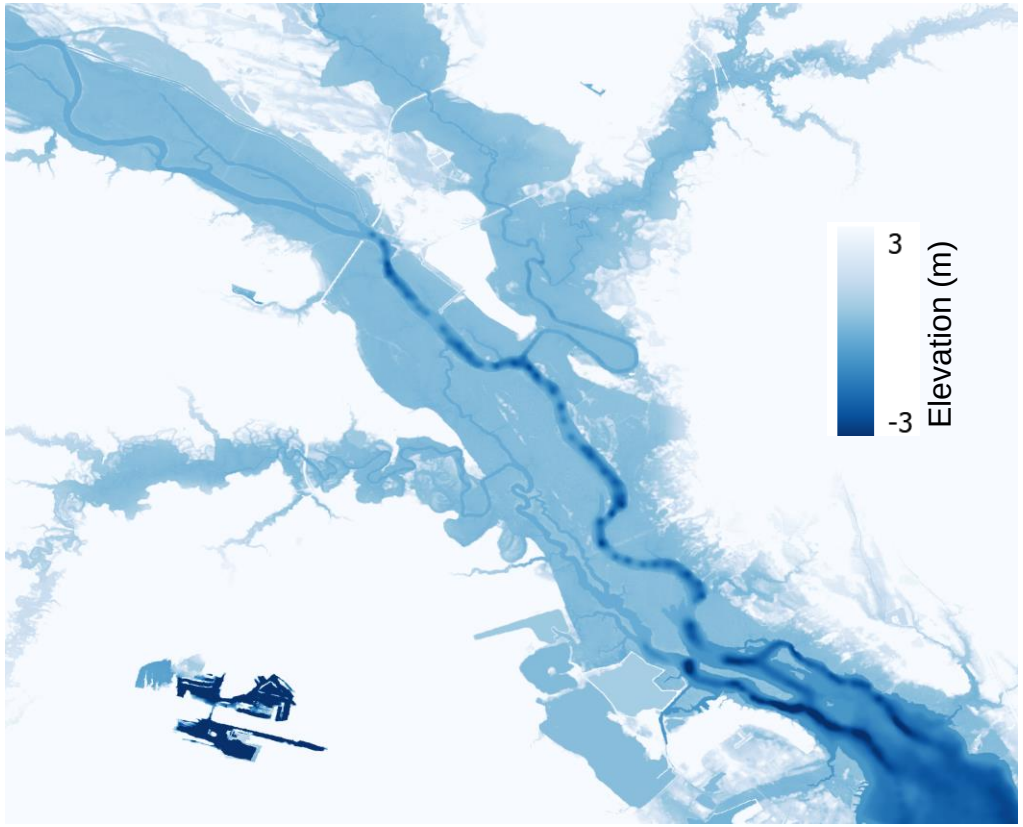
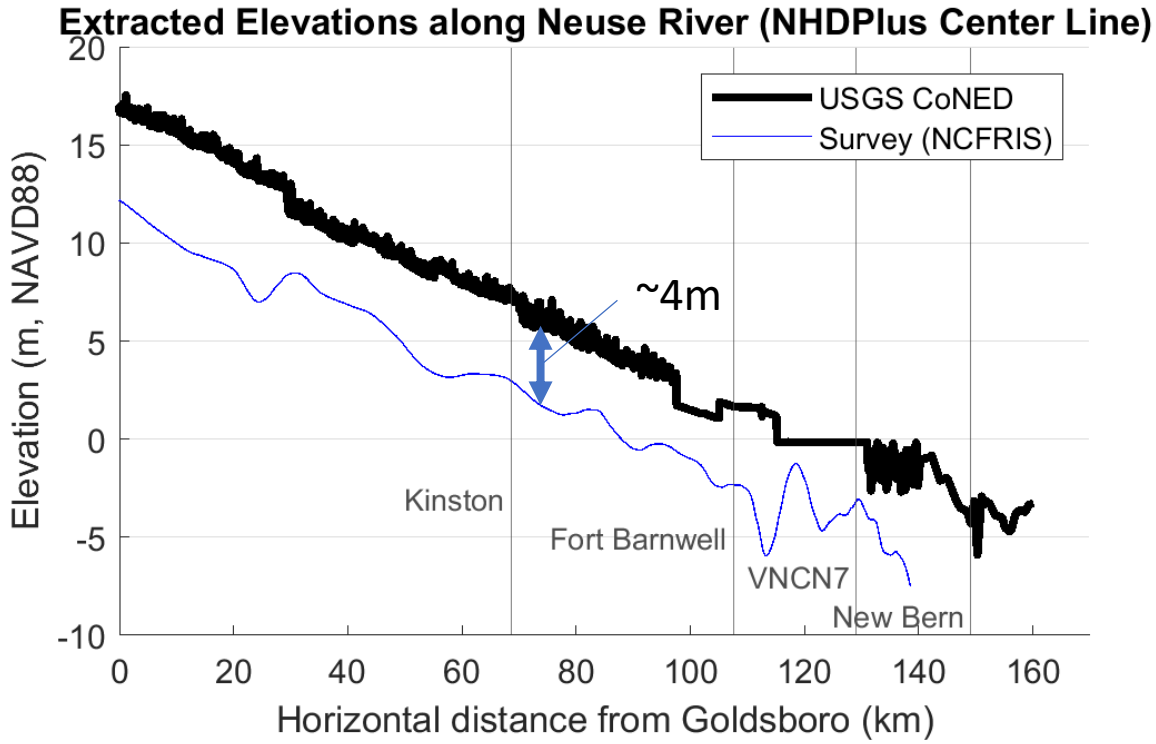
Bed Elevation

Channel bed elevation = DEM (e.g., USGS CoNED DEM) – x m



Neuse River and their tributaries



NCFRIS: North Carolina Flood Risk Information System

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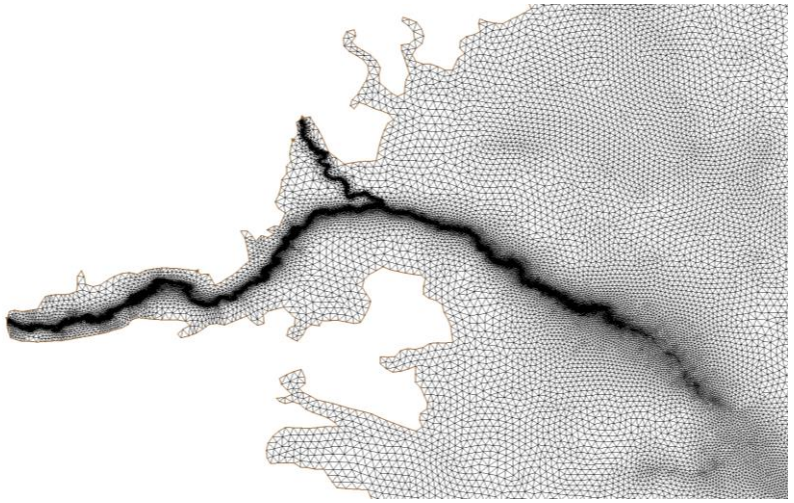
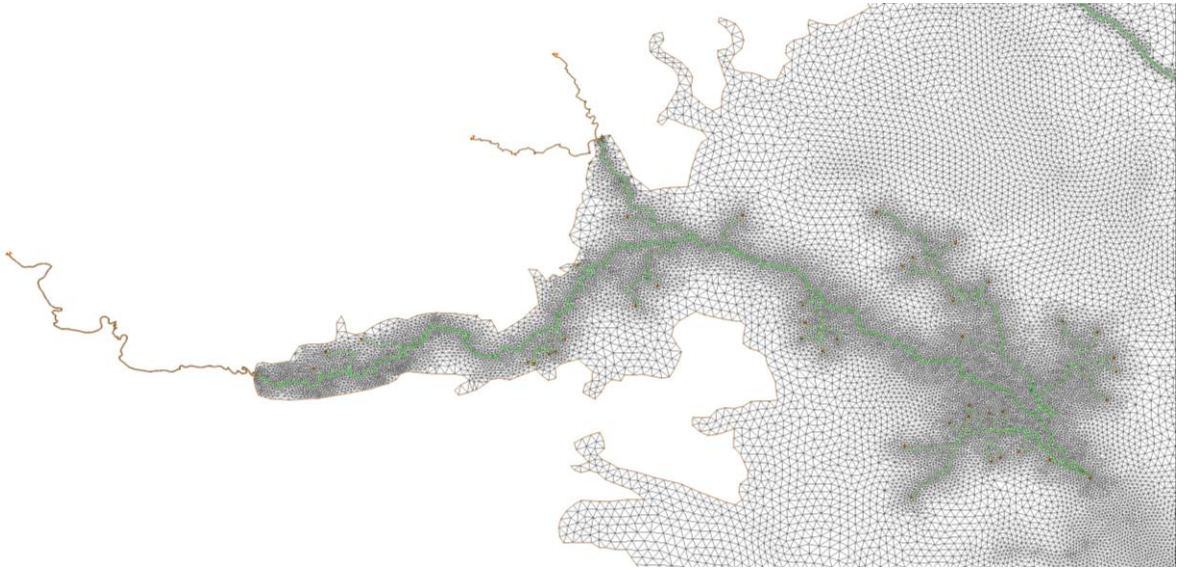
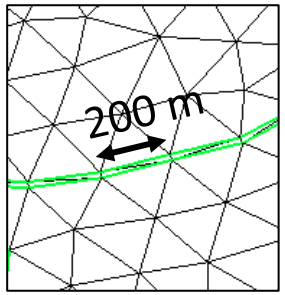
Example

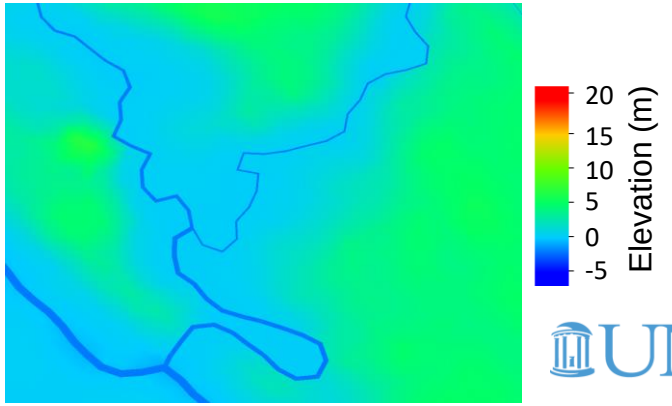
Original mesh, 56K nodes



Updated mesh, 56K nodes







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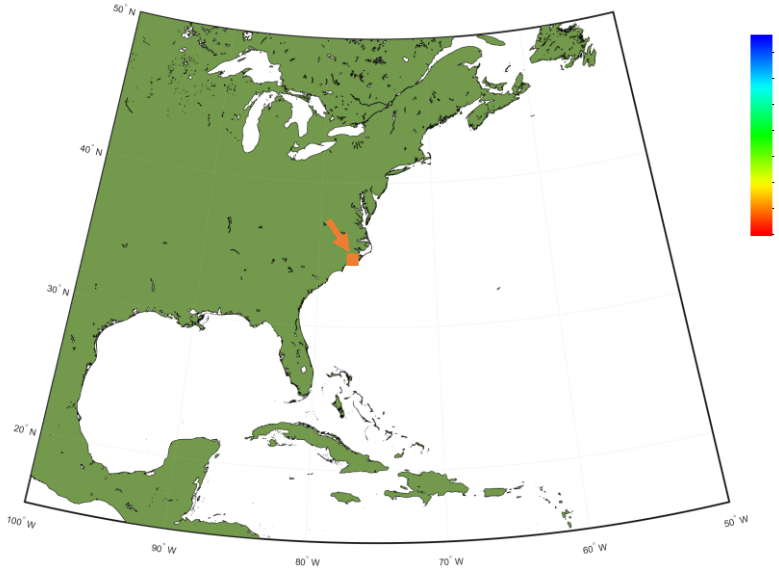
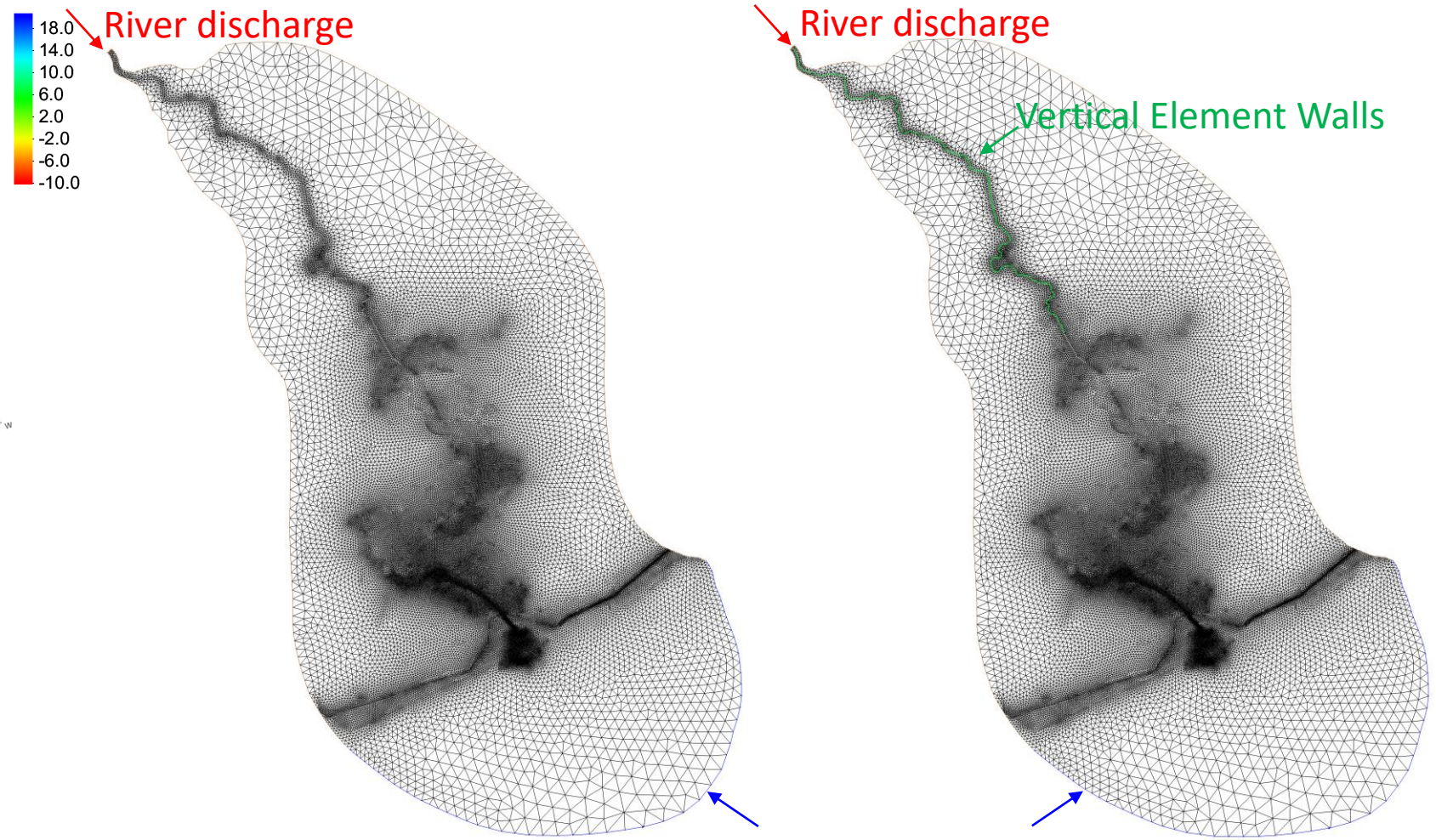
Test 1: Hurricane Florence 2018
Compound flooding, New River, NC, USA



- Time step: 2 sec
- Meteorological forcings:
  Modified OWI product
- Manning's n along channels: 0.02

Without embedded channel

With embedded channel



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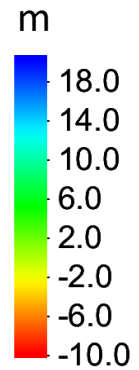
Test 1: Hurricane Florence 2018
Compound flooding, New River, NC, USA

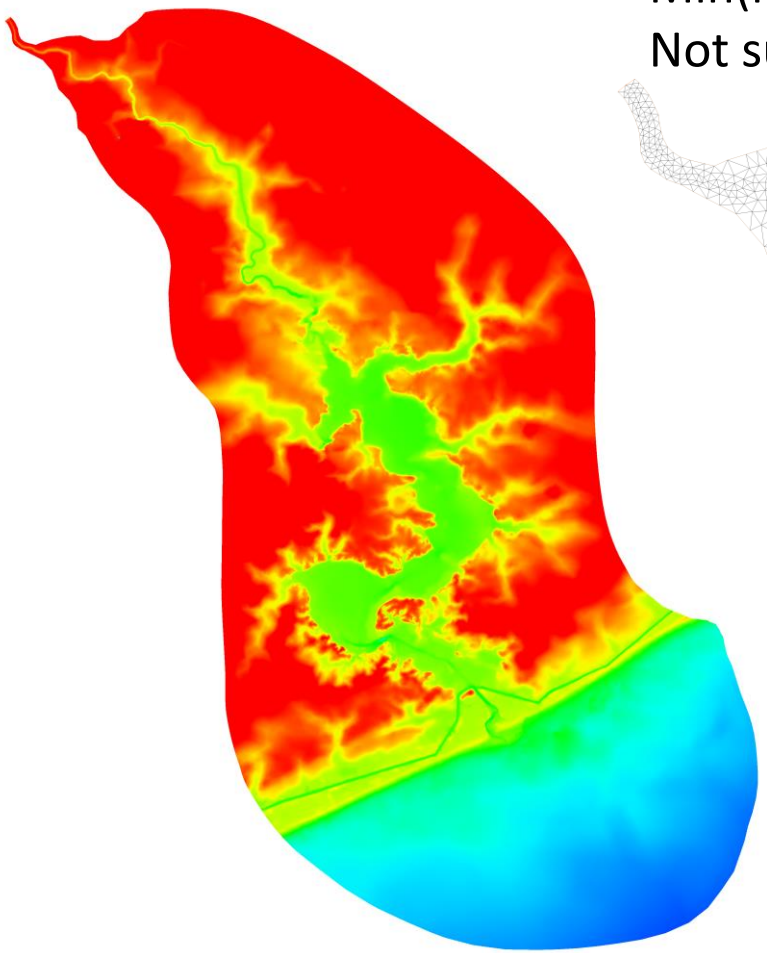
Topography/Bathymetry

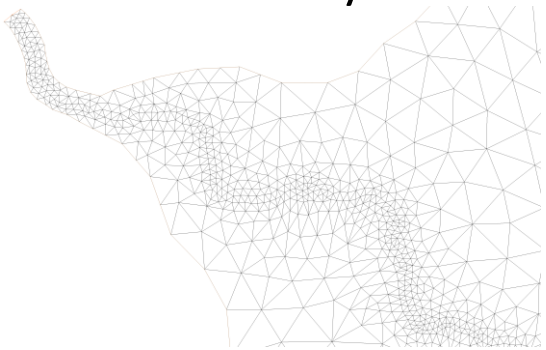


Without embedded channel

Min(h) ~ 100m

Not sufficiently resolved.

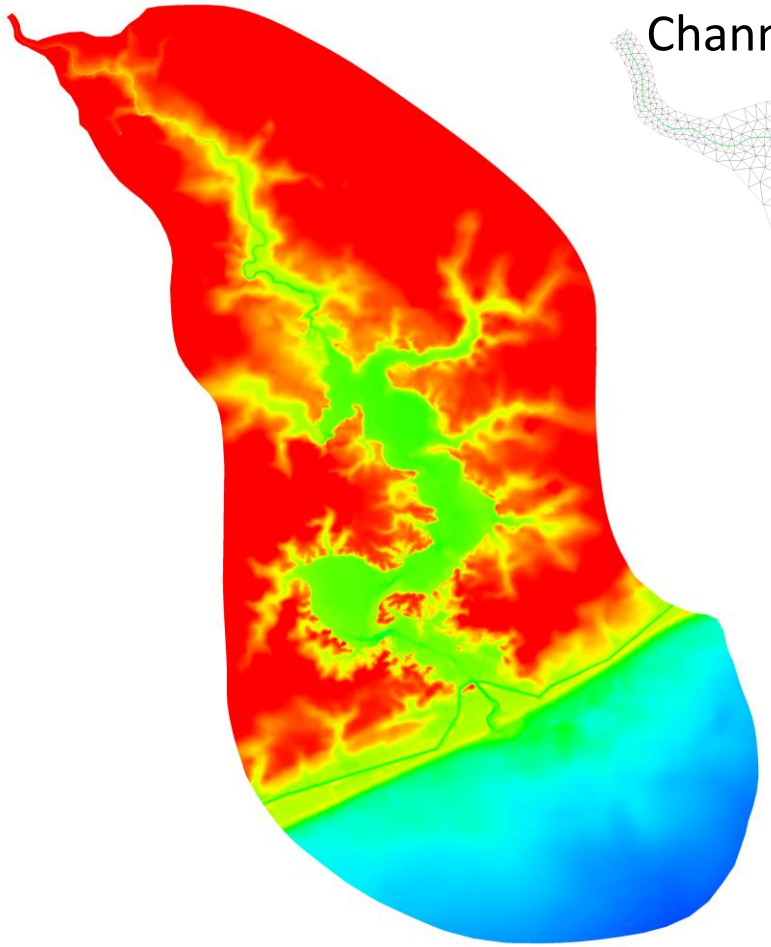


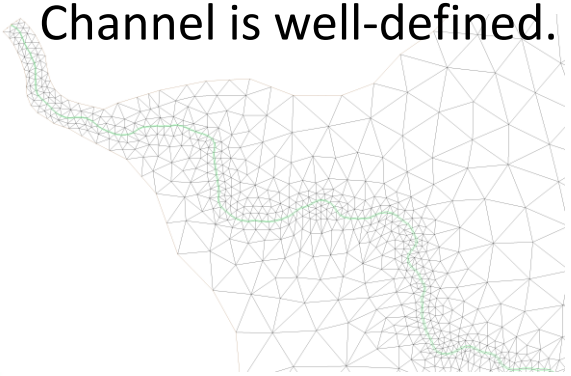


With embedded channel

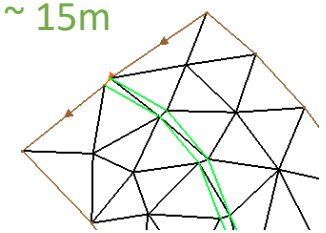
Min(h) ~ 15m

Channel is well-defined.





Channel Width
~ 15m



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Test 1: Hurricane Florence 2018
Compound flooding, New River, NC, USA

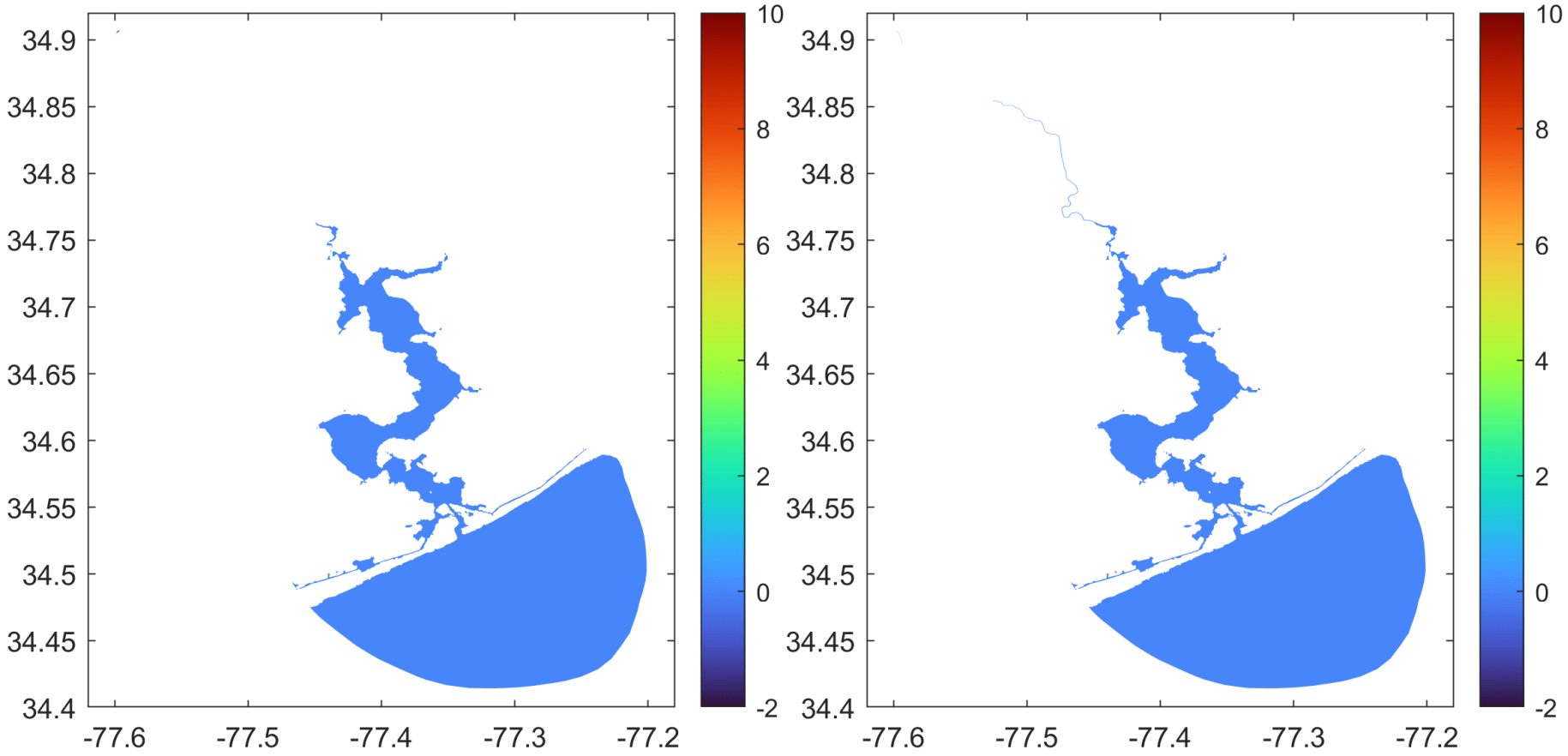
- **The coarse model (left) exhibits unrealistic flooding** on the floodplain even with a small river discharge in the early stage.
- **The VEW1D model (right) exhibits reasonable compound flooding** while holding water in the river until the river discharge is increased due to heavy rainfall.

Without embedded channel

ADCIRC WL 00d00h20m00.00s

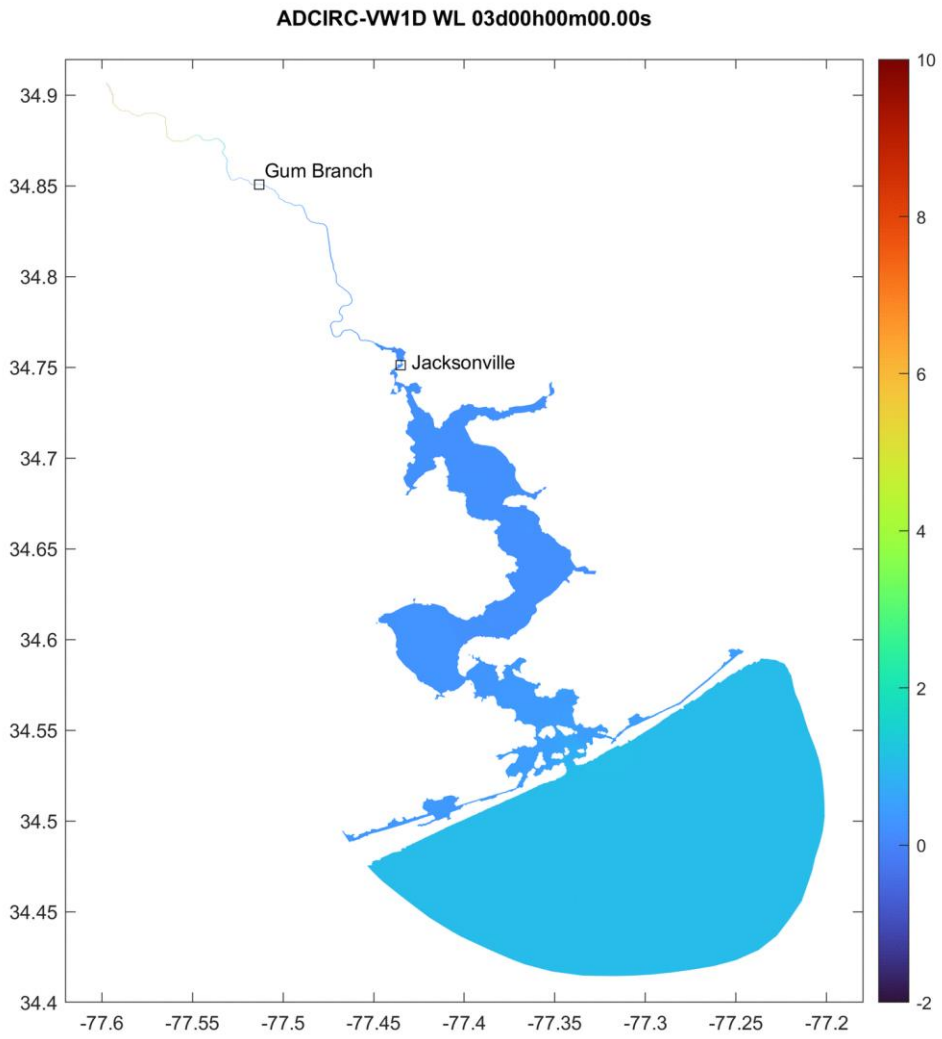
With embedded channel

ADCIRC-VW1D WL 00d00h20m00.00s

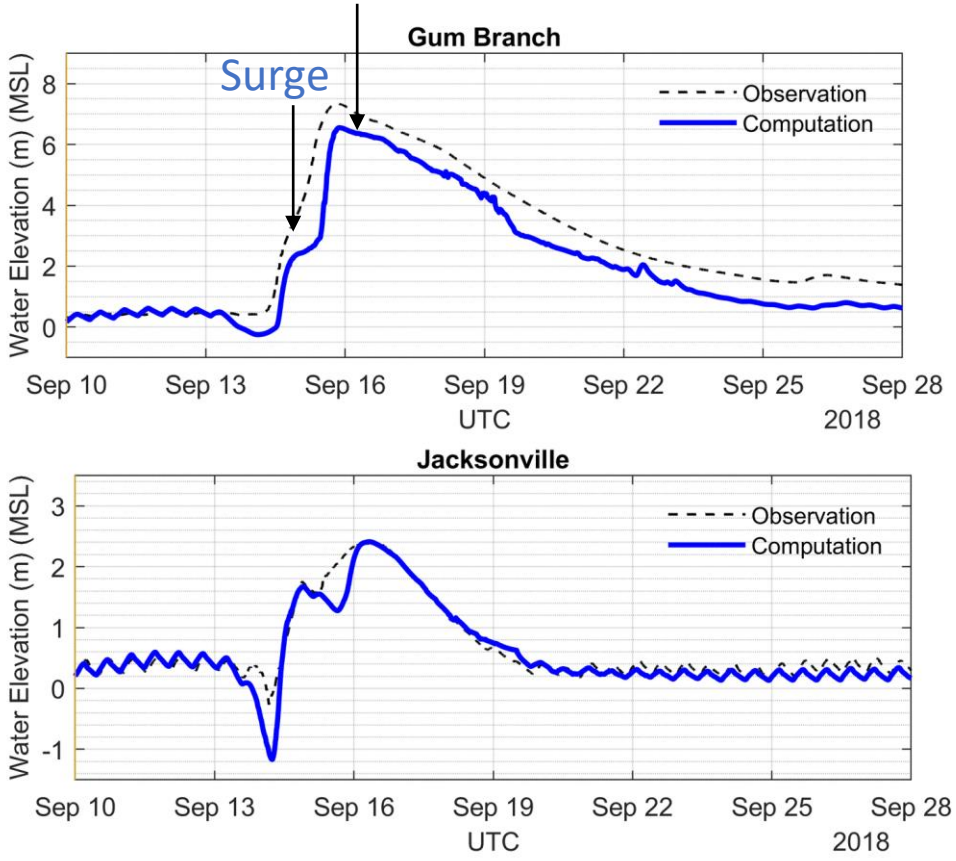


Test 1: Hurricane Florence 2018
Compound flooding along New River, NC, USA

- Both flooding and receding stages agree well with observations.

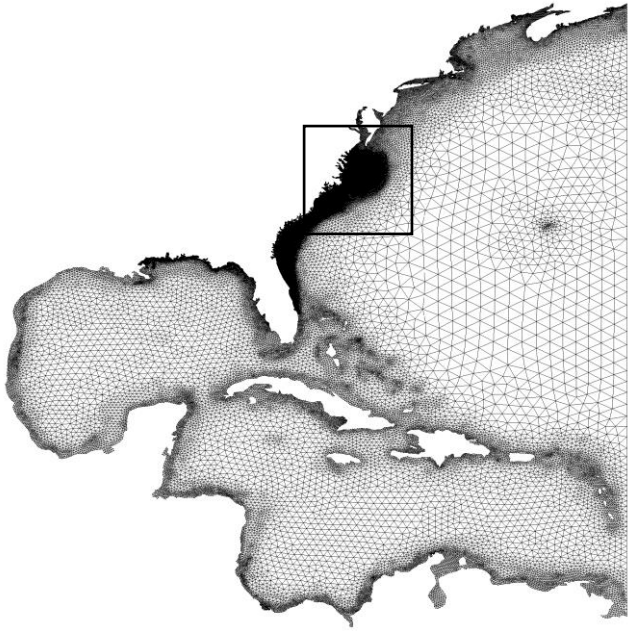


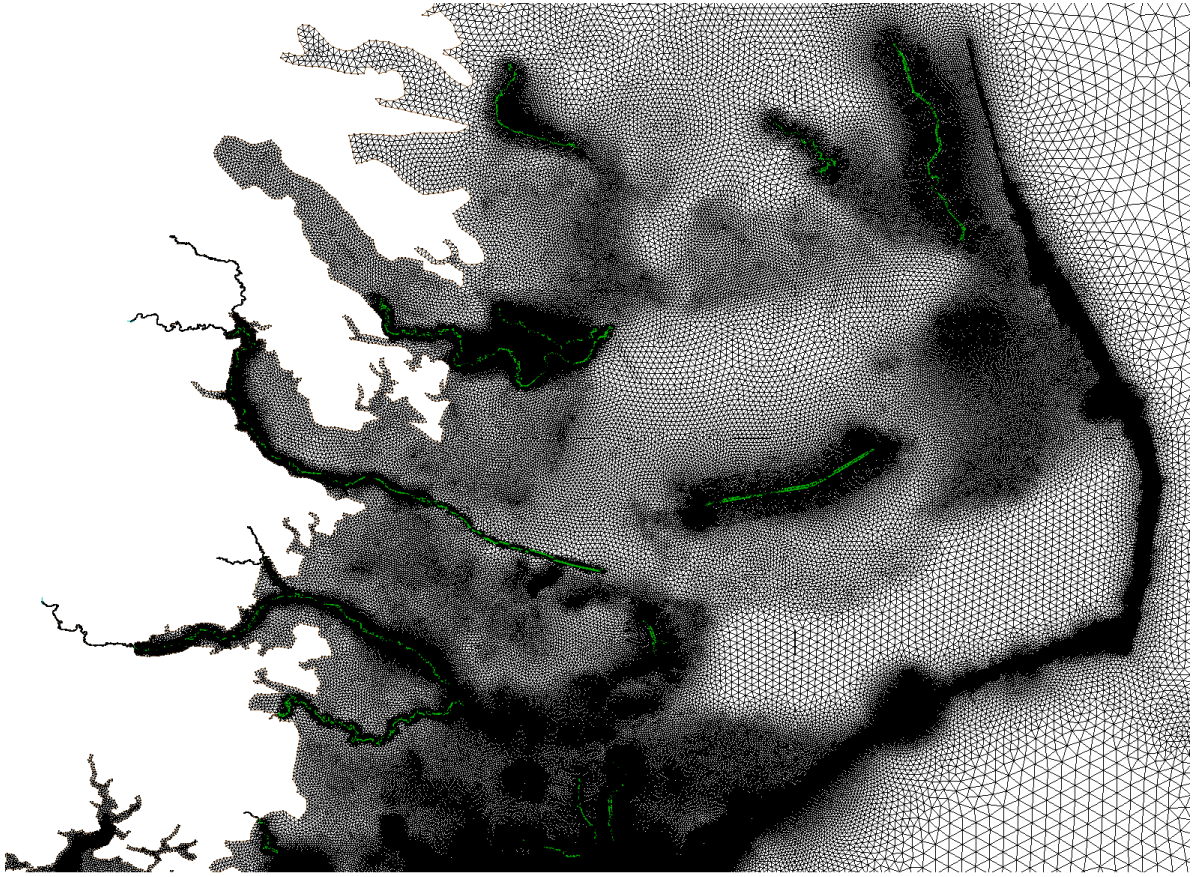
Surge + increased river discharge



Test 2: Florence Compound Flooding Simulation Results, East Coast Model

East Coast model ~ 56K node

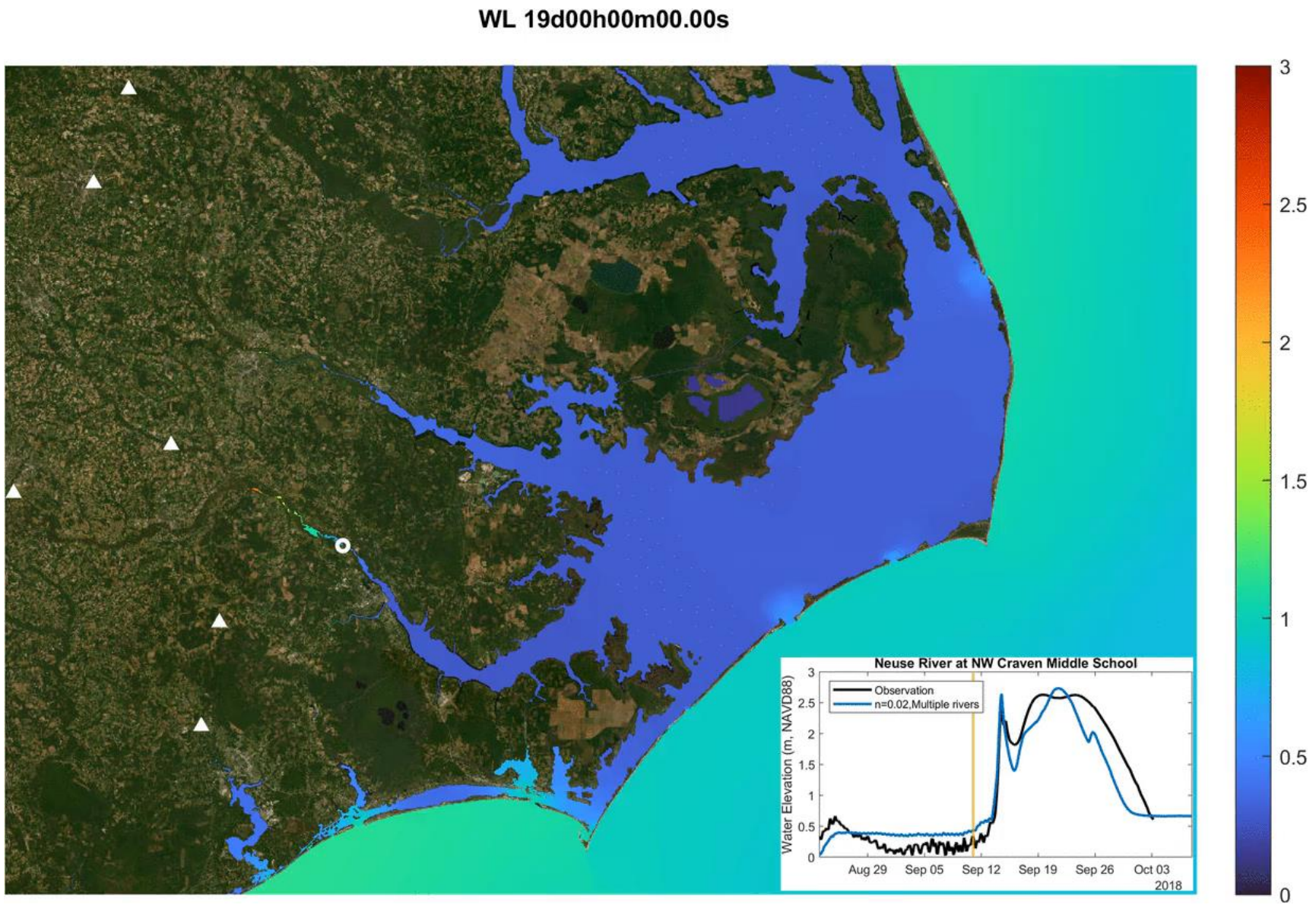




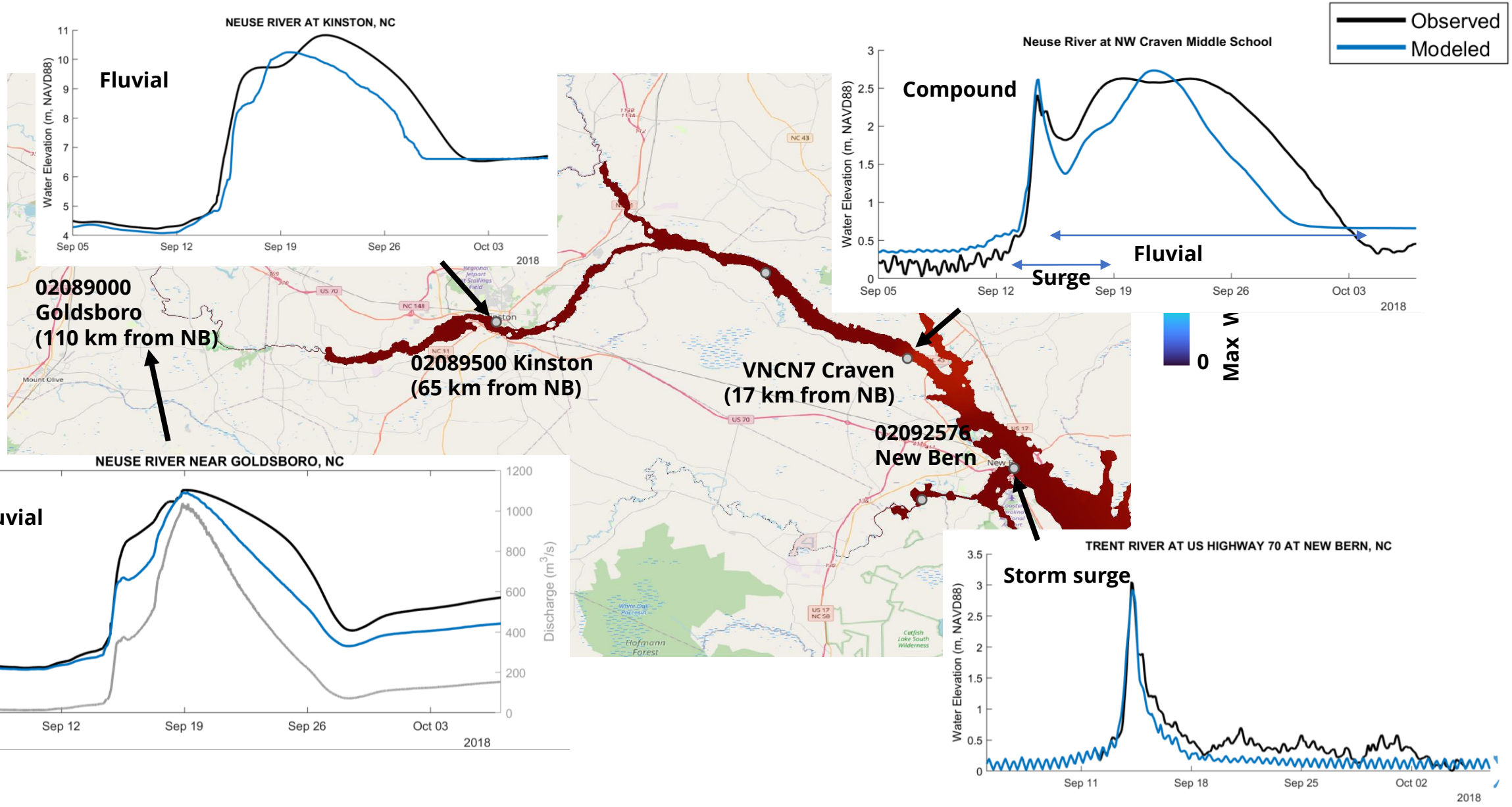
- Time step: 1 sec
- Meteorological forcings:
  Modified OWI product
- Manning's n along channels: 0.023

14 channels are embedded.

Test 2: Florence Compound Flooding Simulation Results, East Coast Model

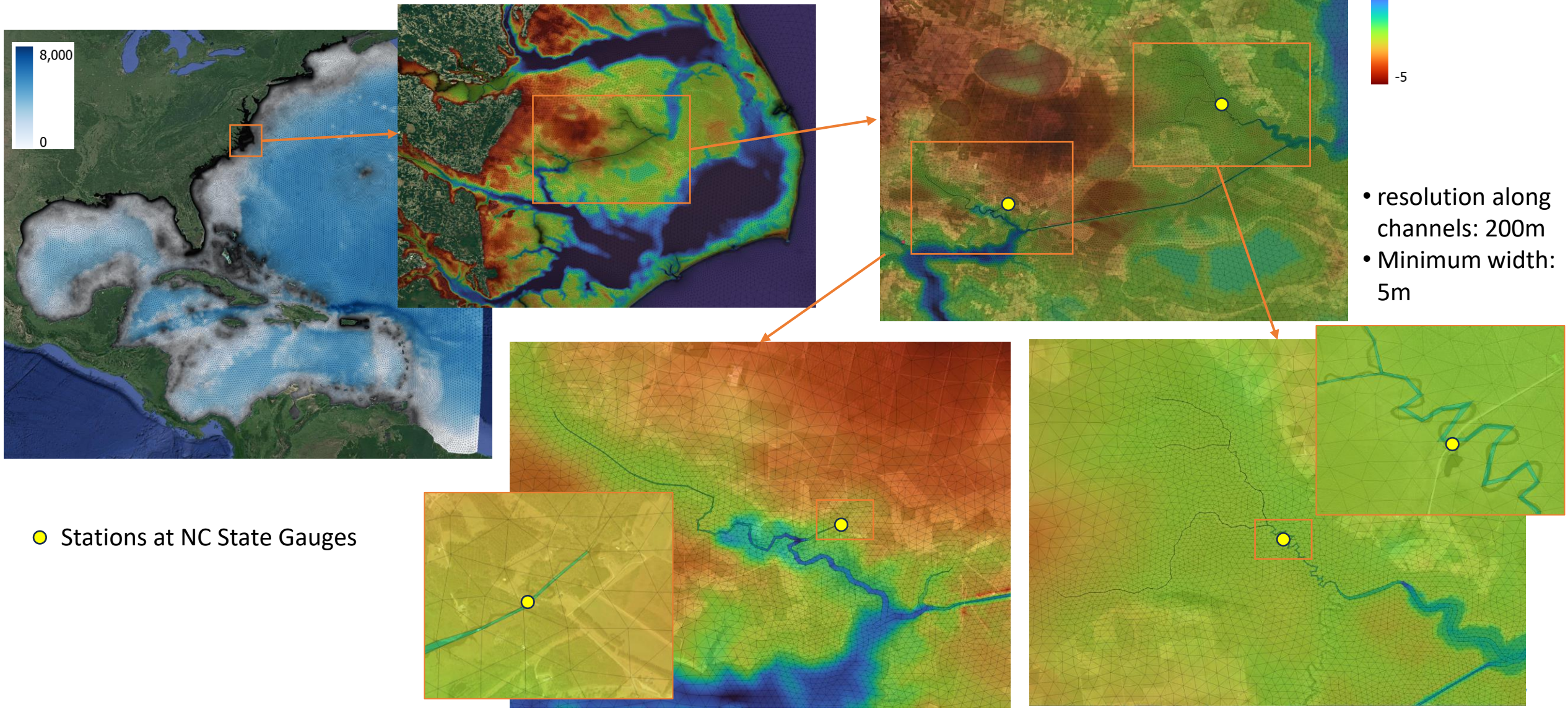


Test 2: Compound Flooding along Neuse River, NC



Test 3: Hurricane Ian 2022

Submerged channels with junctions in East Coast Model



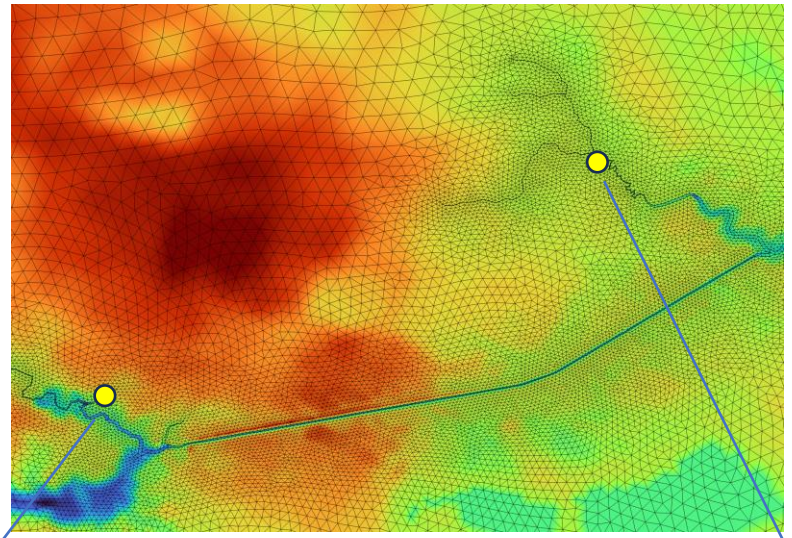
- resolution along channels: 200m
- Minimum width: 5m

Stations at NC State Gauges

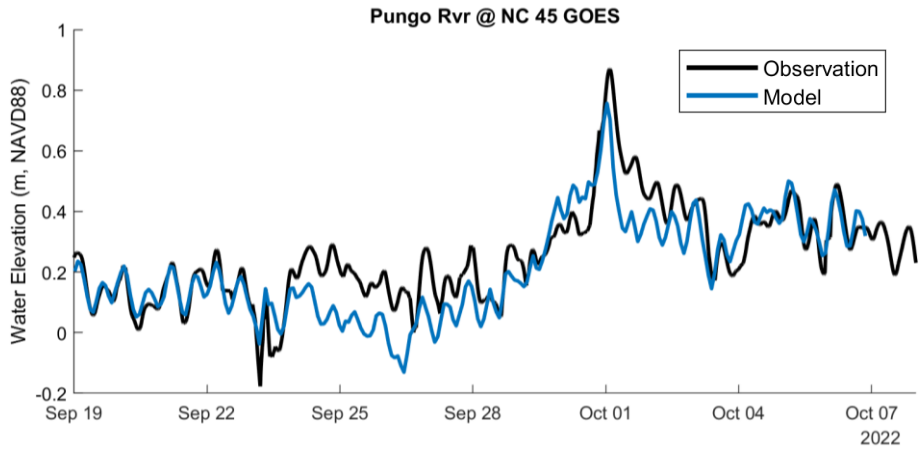
Test 3: Hurricane Ian 2022

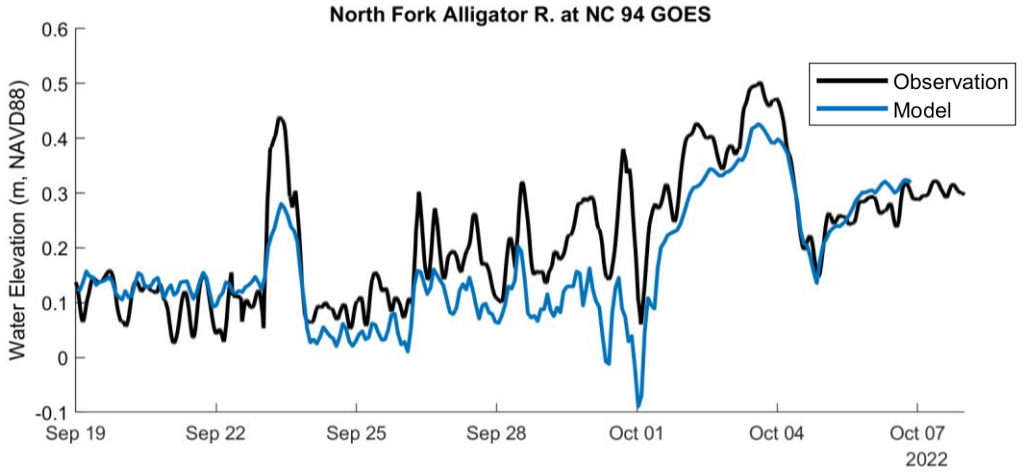
Submerged channels with junctions in East Coast Model

Meteorological Forcings:
NOAA GFS



- Stations at NC State Gauges





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Summary

- An approach to efficiently and seamlessly embed 1D channel networks in ADCIRC model has been developed.
- The method and its implementation have been validated by comparisons with
  - Standard ADCIRC solutions,
  - HEC-RAS solutions,
  - Observed water levels in events including compound flooding during Florence and Ian.
- Finding appropriate channel transect properties (i.e., width, depth and bank height) is non-trivial, but feasible to some extent.

Ongoing/Future Work

- Coupling with National Water Model
- More tests with other scenarios including real time predictions

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Bunya, S, Luettich, R. A., and Blanton, B. O., “Techniques to embed channels in finite element shallow water equation models”, Advances in Engineering Software, 185, 2023.

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Thank you.

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