Subgrid Corrections in Finite-Element Models of Storm-Driven Coastal Flooding

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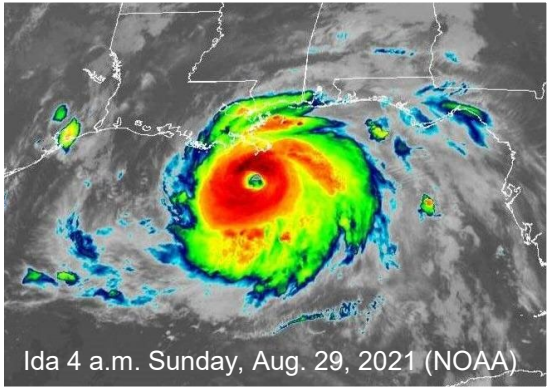
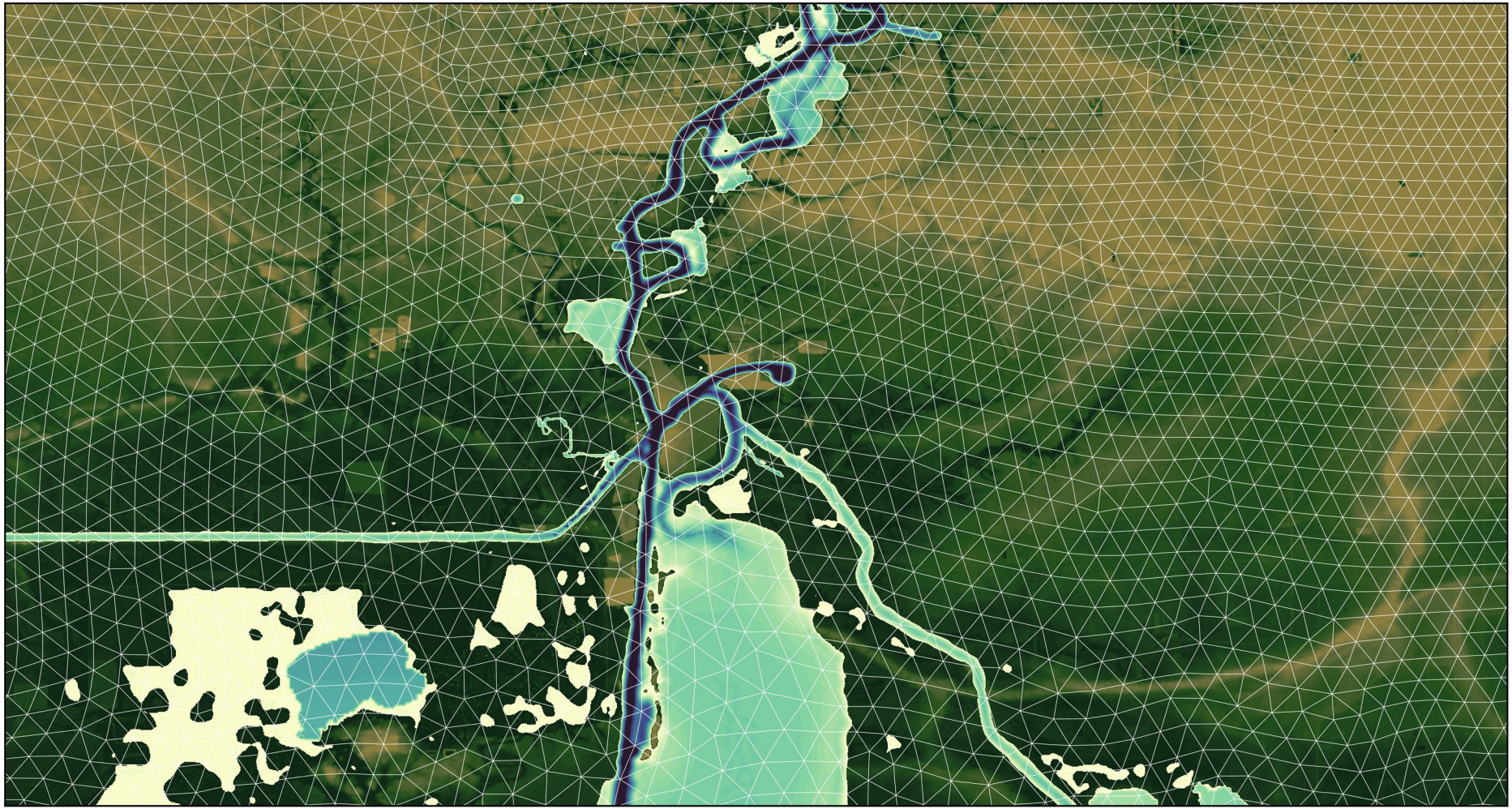
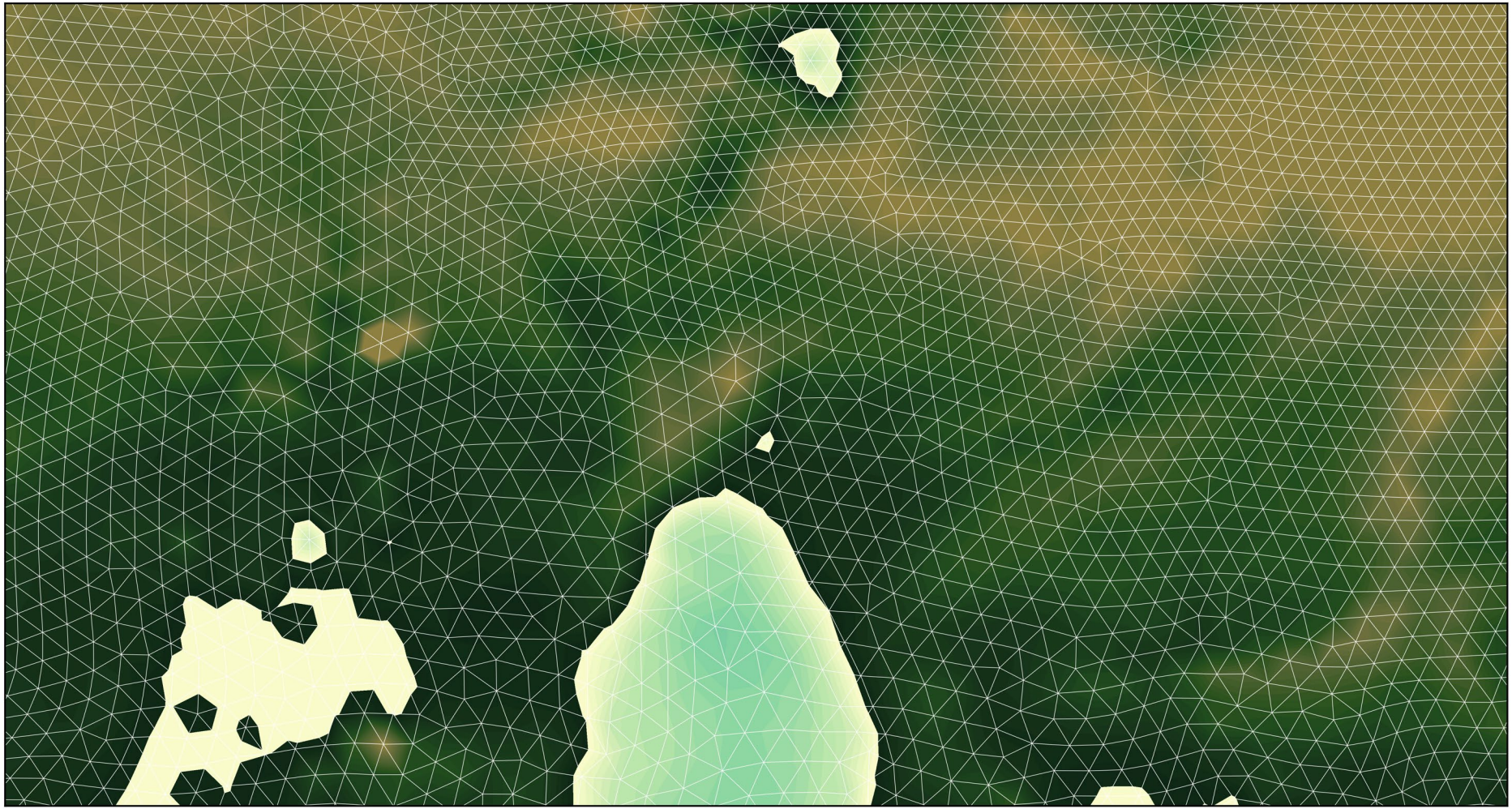


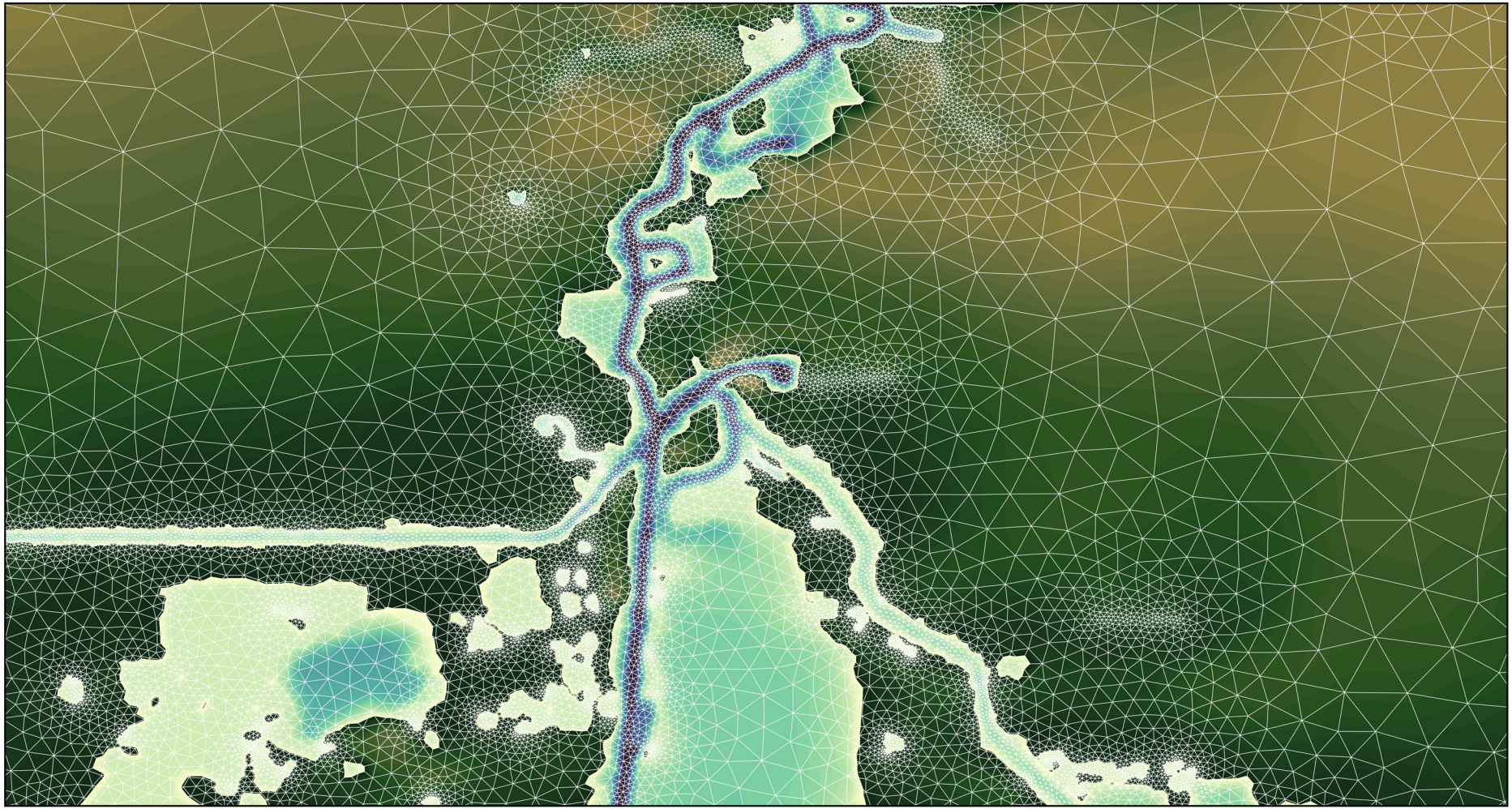
Ida 4 a.m. Sunday, Aug. 29, 2021 (NOAA)

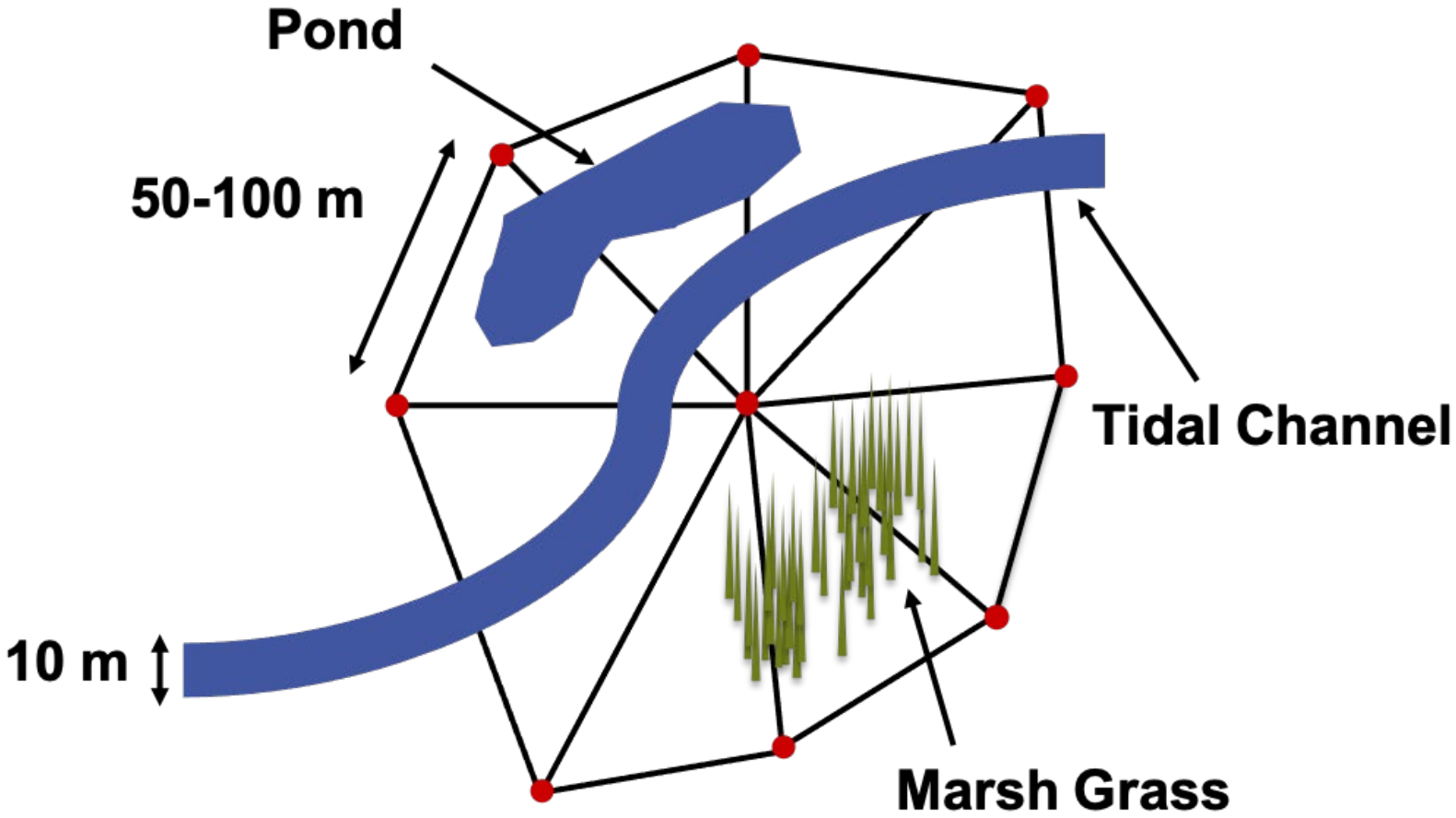
Buildings and roads are submerged Monday in Lafitte, La. (Michael Robinson Chavez/The Washington Post)

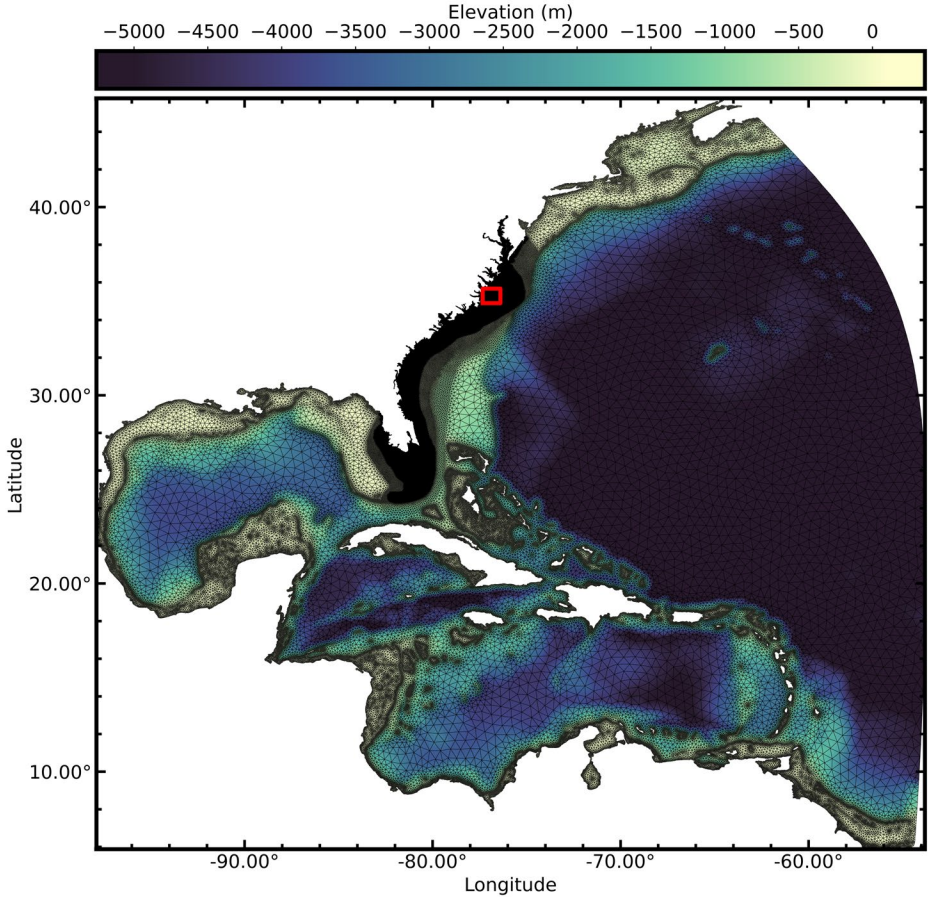
Shreveport
Hattiesburg
LOUISIANA
Baton Rouge
Covington
Gulfport
Lafayette
New Orleans

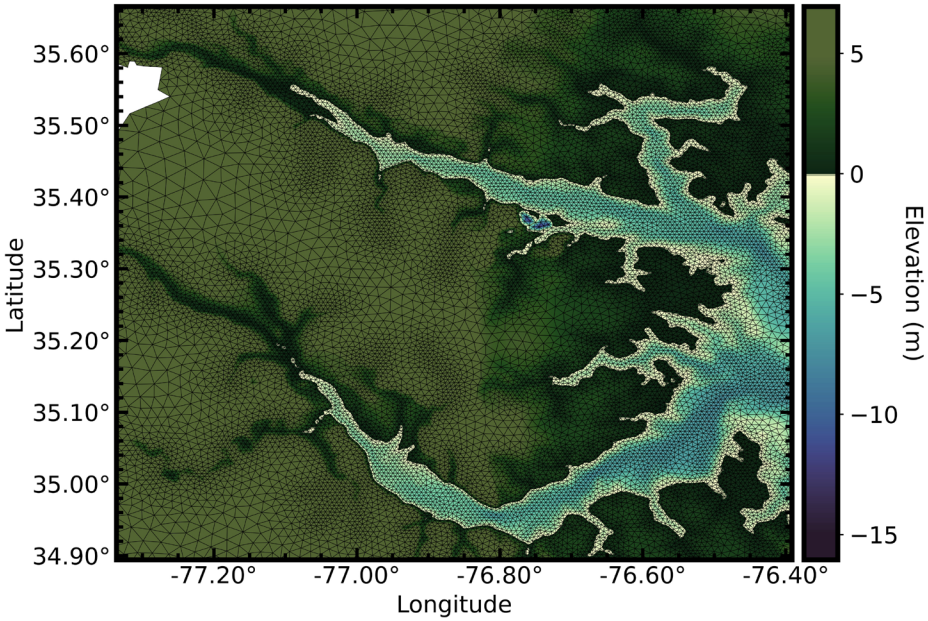


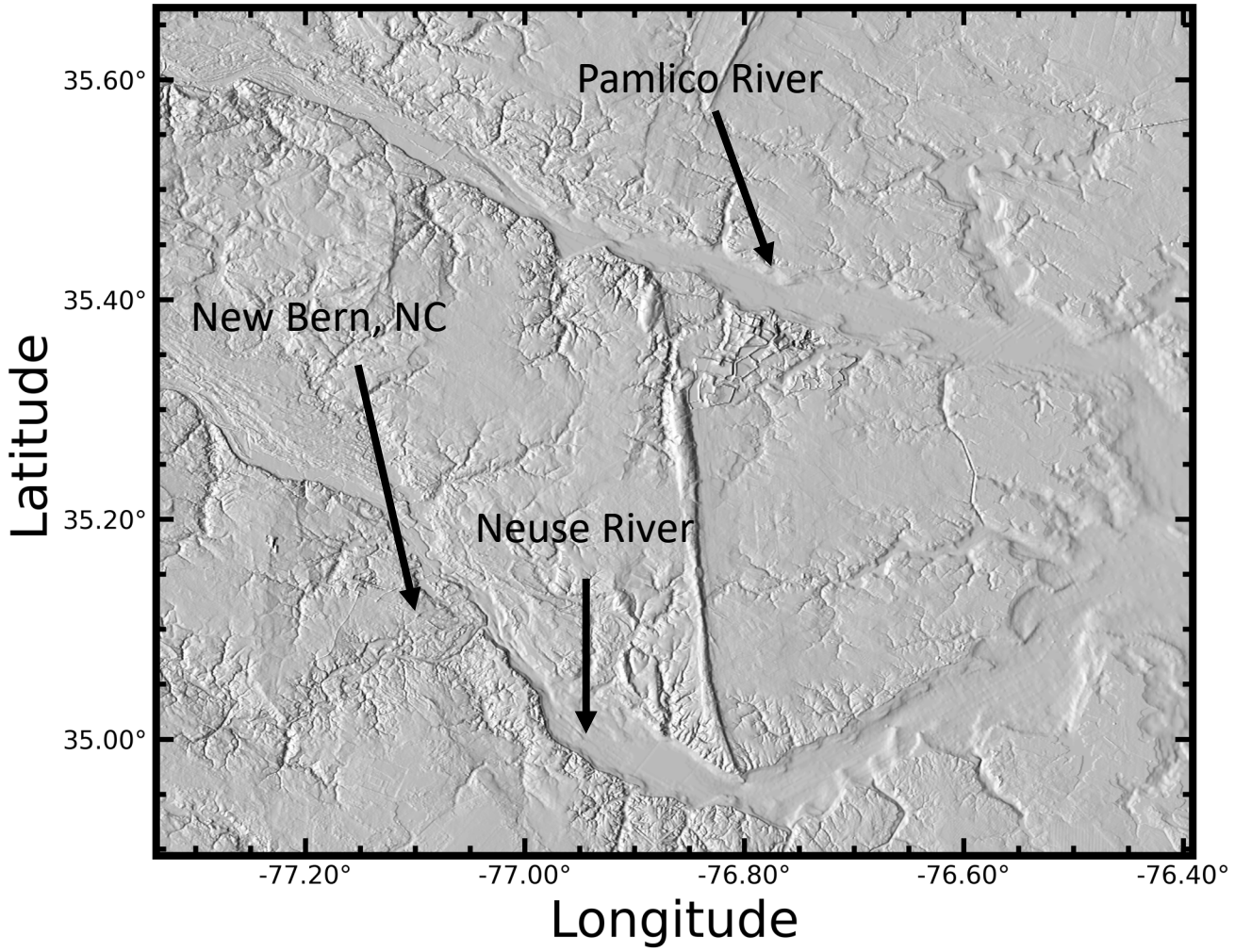


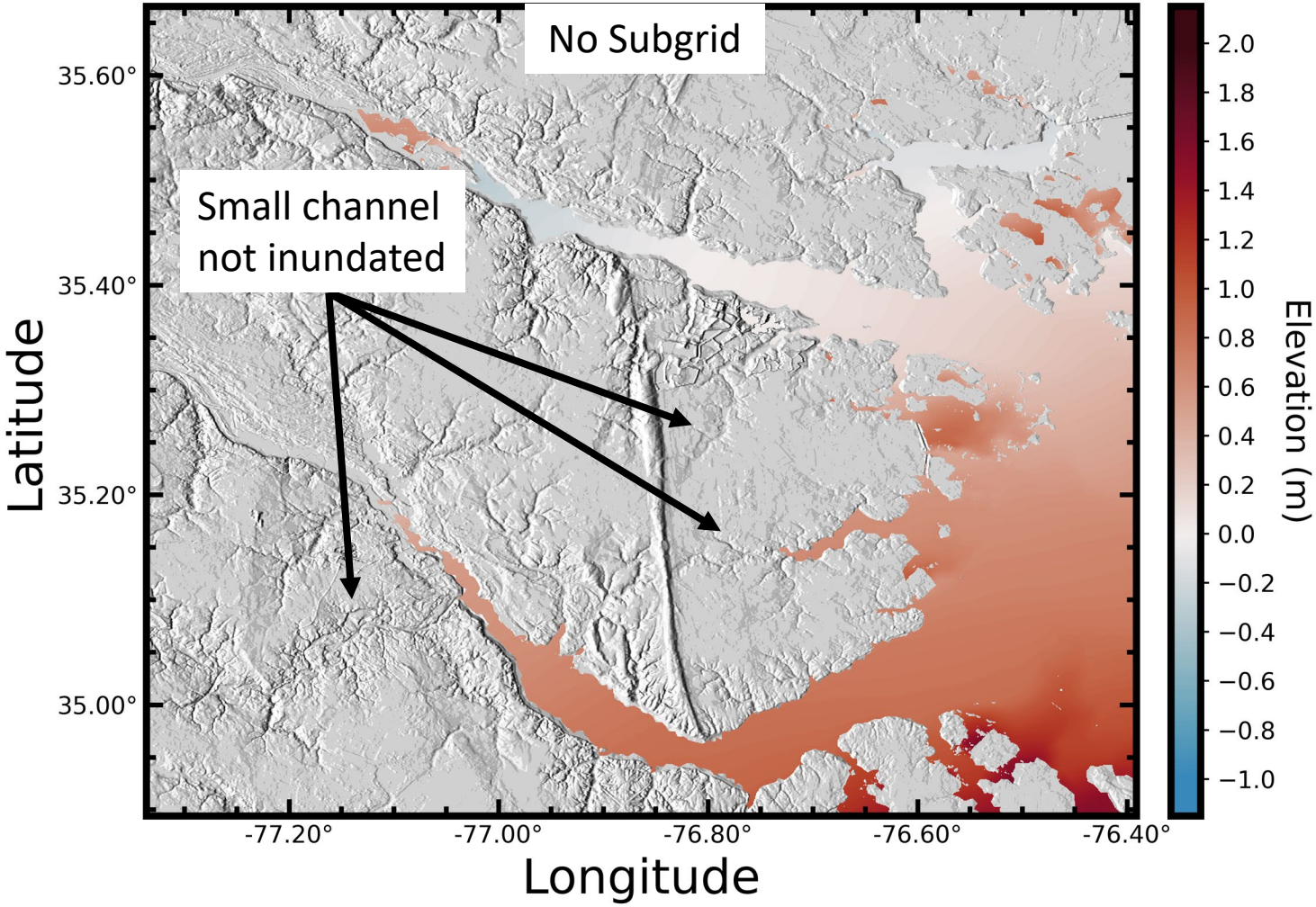


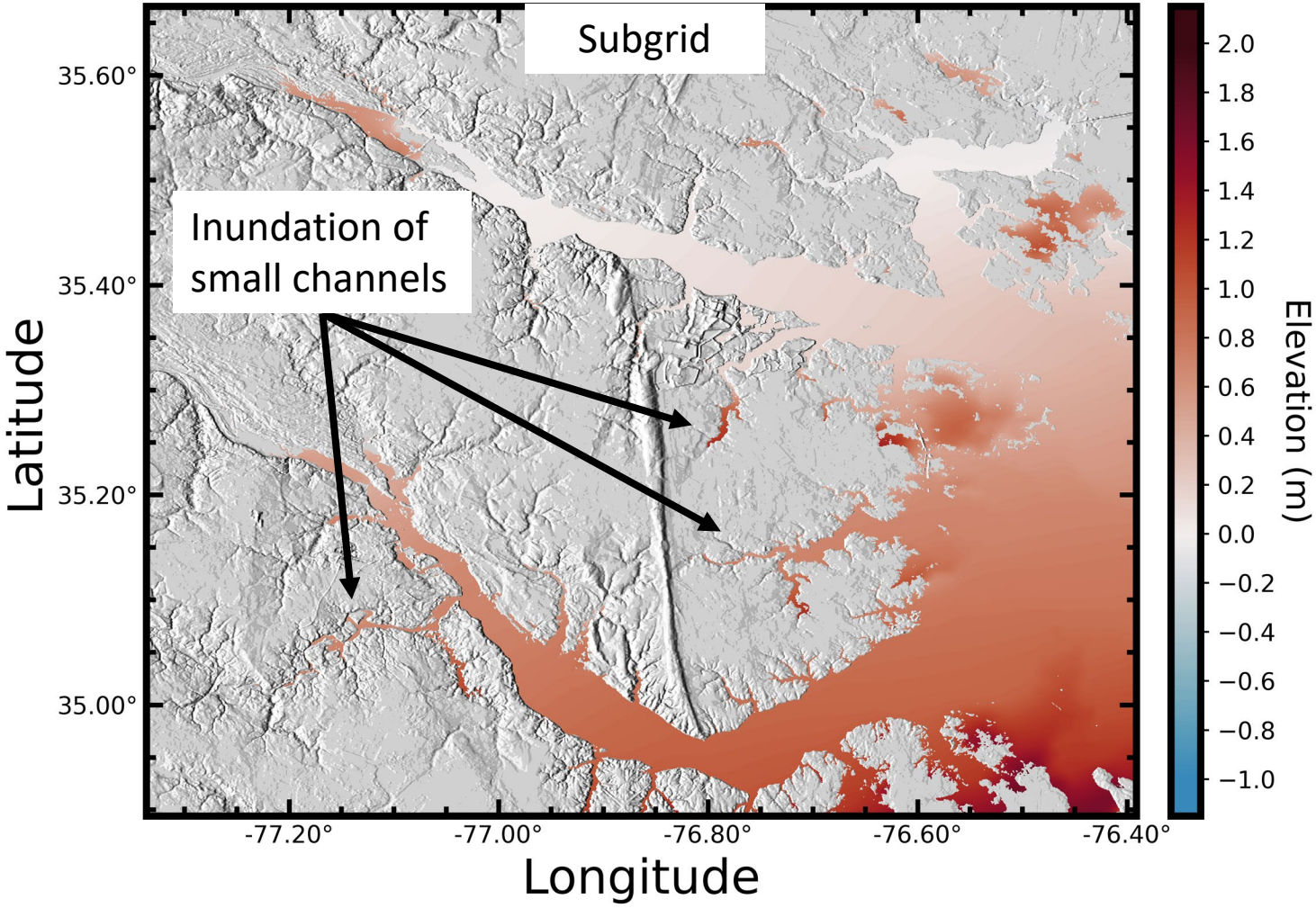

Pond
50-100 m
Tidal Channel
10 m
Marsh Grass

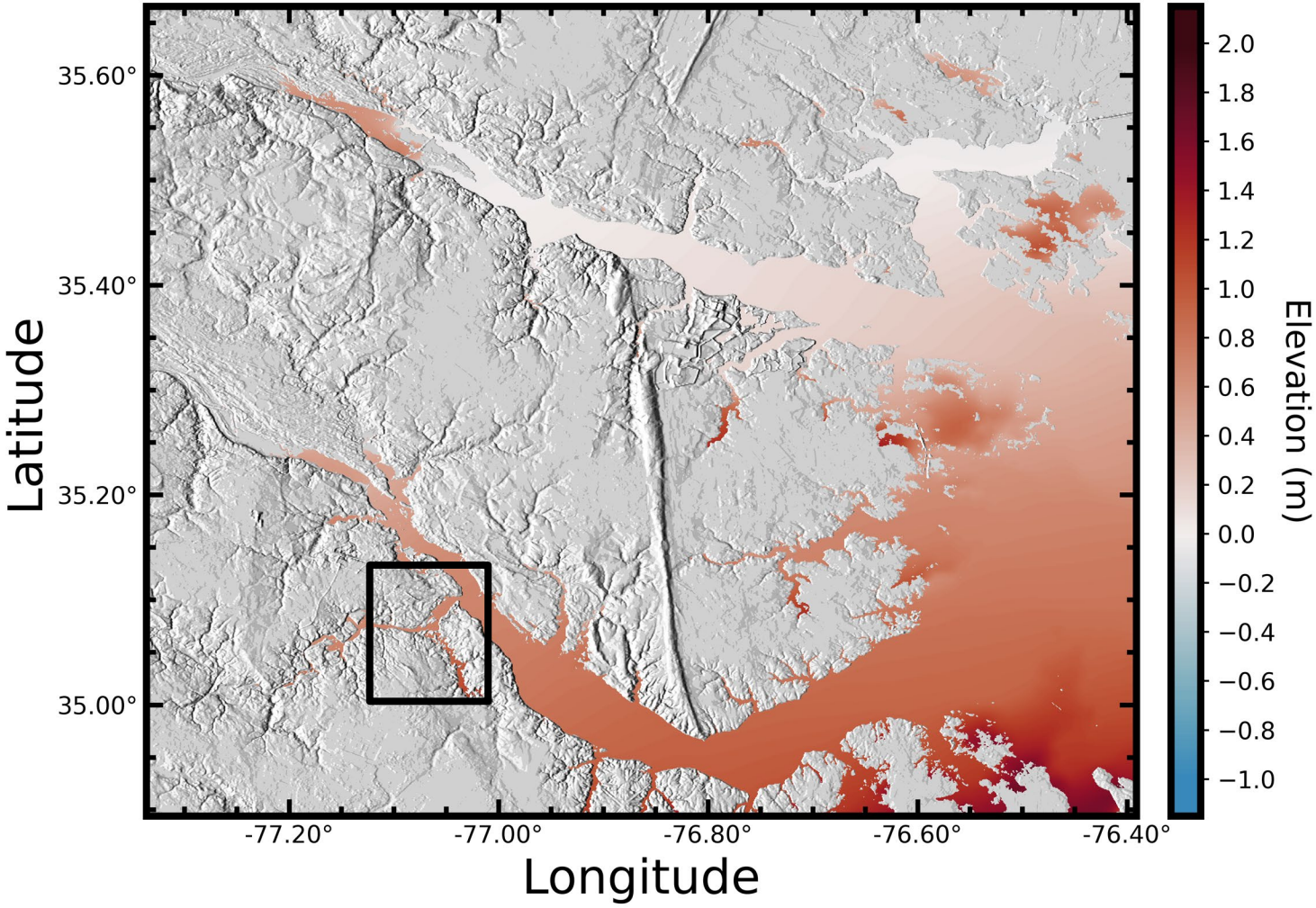

Elevation (m)
−5000 −4500 −4000 −3500 −3000 −2500 −2000 −1500 −1000 −500 0
40.00°
30.00°
20.00°
10.00°
Latitude
-90.00°
-80.00°
-70.00°
-60.00°
Longitude

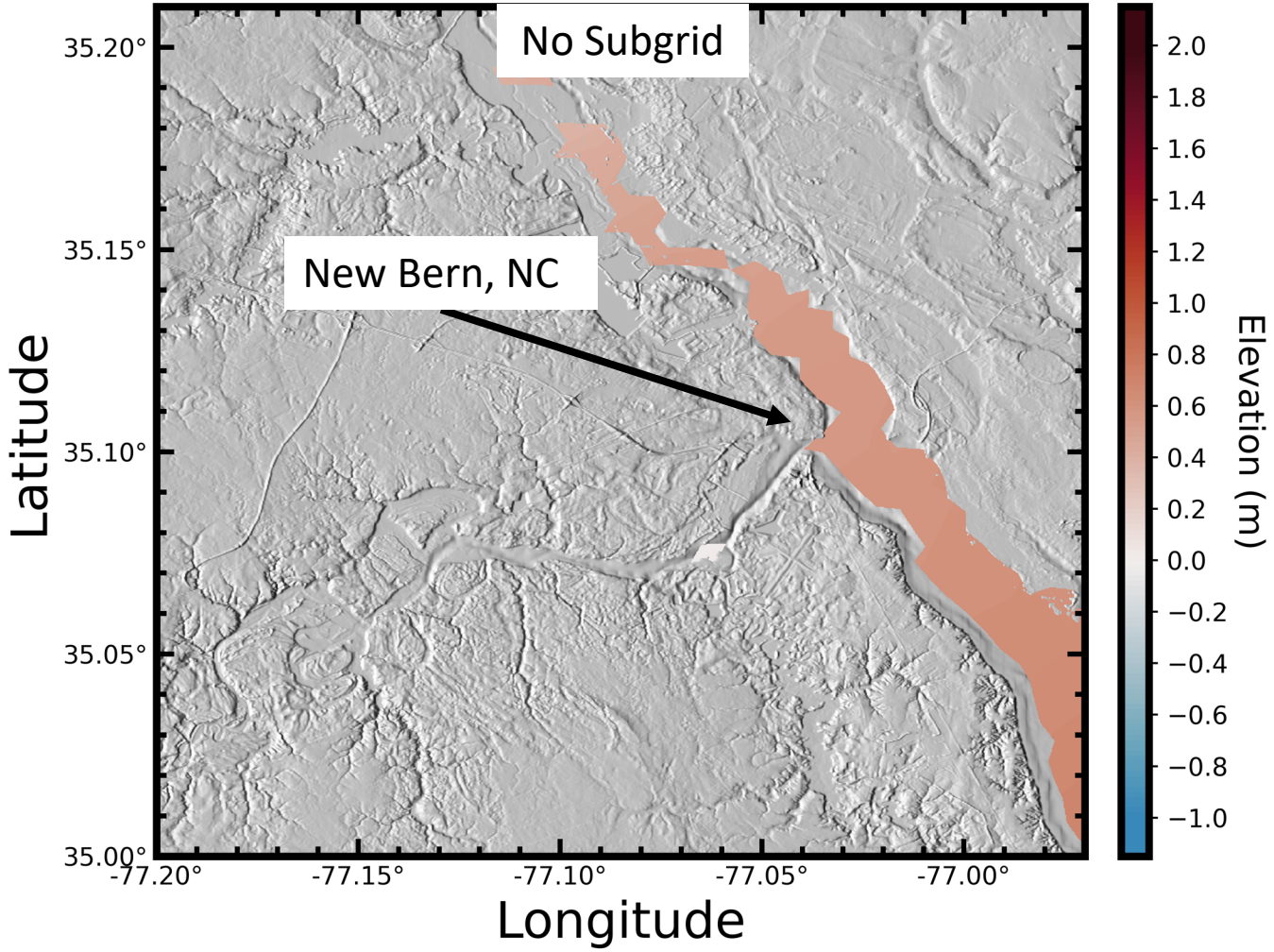

35.60°
35.50°
35.40°
35.30°
35.20°
35.10°
35.00°
34.90°
Latitude
-77.20°
-77.00°
-76.80°
-76.60°
-76.40°
Longitude
5
0
−5
−10
−15
Elevation (m)

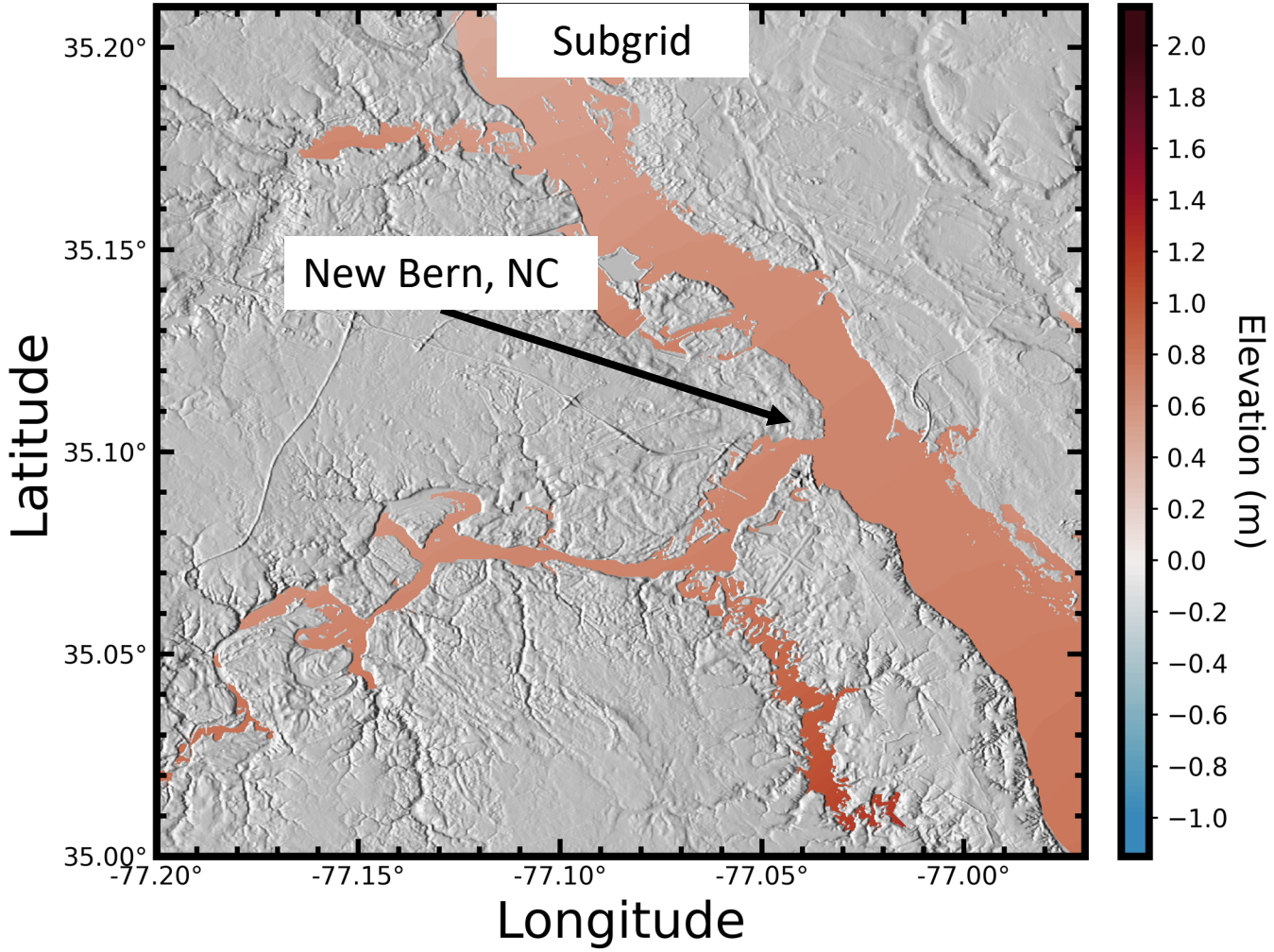

Pamlico River
New Bern, NC
Neuse River
35.60°
35.40°
35.20°
35.00°
Latitude
-77.20°
-77.00°
-76.80°
-76.60°
-76.40°
Longitude


No Subgrid
Small channel
not inundated
35.60°
35.40°
35.20°
35.00°
Latitude
-77.20°
-77.00°
-76.80°
-76.60°
-76.40°
Longitude
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
Elevation (m)


Subgrid
Inundation of small channels
Latitude
35.60°
35.40°
35.20°
35.00°
-77.20°
-77.00°
-76.80°
-76.60°
-76.40°
Longitude
Elevation (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0


Latitude
35.60°
35.40°
35.20°
35.00°
-77.20°
-77.00°
-76.80°
-76.60°
-76.40°
Longitude
Elevation (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0


No Subgrid
New Bern, NC
35.20°
35.15°
35.10°
35.05°
35.00°
Latitude
-77.20°
-77.15°
-77.10°
-77.05°
-77.00°
Longitude
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
Elevation (m)


Subgrid
New Bern, NC
Latitude
35.20°
35.15°
35.10°
35.05°
35.00°
-77.20°
-77.15°
-77.10°
-77.05°
-77.00°
Longitude
Elevation (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0

Conclusion

- Implemented subgrid corrections into the Advanced Circulation (ADCIRC) hydrodynamic model.
- Performed a hurricane storm surge simulation of Matthew (2016) with and without subgrid corrections.
- Demonstrated that subgrid corrections increased accuracy and flow connectivity when run on a coarsened mesh.

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Subgrid corrections in finite-element modeling of storm-driven coastal flooding

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ABSTRACT

Coastal flooding models are used to predict the timing and magnitude of inundation during storms, both for real-time forecasting and long-term design. However, there is a need for faster flooding predictions that also represent flow pathways and barriers at the scales of critical infrastructure. This need can be addressed via subgrid corrections, which use information at smaller scales to 'correct' the flow variables (water levels, current velocities) averaged over the mesh scale. Recent studies have shown a decrease in run time by 1 to 2 orders of magnitude, with the ability to decrease further if the model time step is also increased.

In this study, subgrid corrections are added to a widely used, finite-element-based, shallow water model to better understand how they can improve the accuracy and efficiency of inundation predictions. The performance of the model, with and without subgrid corrections, is evaluated on scenarios of tidal flooding in a synthetic domain and a small bay in Massachusetts, as well as a scenario with a real atmospheric forcing and storm surge in southwest Louisiana. In these tests we observed that the subgrid corrections can increase model speed by 10 to 50 times, while still representing flow through channels below the mesh scale to inland locations.

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