An Open Source Python Tool for Data-driven Seamless Unstructured Mesh Generation of the Inland-Coastal Transition Zone

Soroosh Mani[1,2](soroosh.mani@noaa.gov), Fei Ye[3](feiye@vims.edu), Linlin Cui[3], Joseph Zhang[3], Saeed Moghimi[1], Edward Myers[1]

1. National Oceanic and Atmospheric Administration, Office of Coast Survey 2. Spatial Front Inc. 3. Virginia Institute of Marine Science

The Problem

Resolving rivers in the mesh is crucial to capturing the tidal cycles and water surface elevation correctly.

There are wo potential approaches:

1) High resolution mesh in the rivers and watersheds using size function —> High computational cost
2) Embed prescribed river mesh into a background mesh —> Traditionally manual and laborious

Prior Development

It is possible to automate the process of extracting river polygons (Ye et. al. 2023). Using high quality topo/bathy data to extract the rivers and including them in the meshing process significantly improves the prediction of water levels.

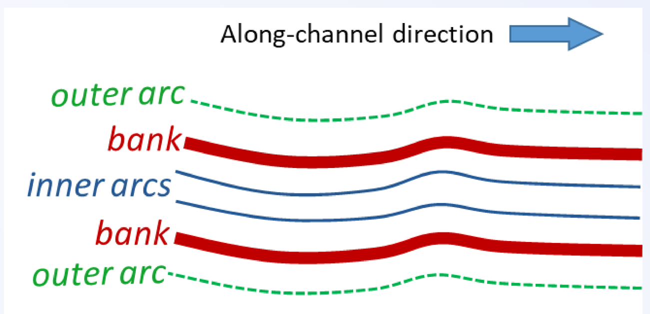

Figure 1 - Schematic of the river arcs extracted from raster data

Other elongated (river-like) features can also be extracted or reconstructed with the help of the *RiverMapper* tool; this includes levees or barrier islands.

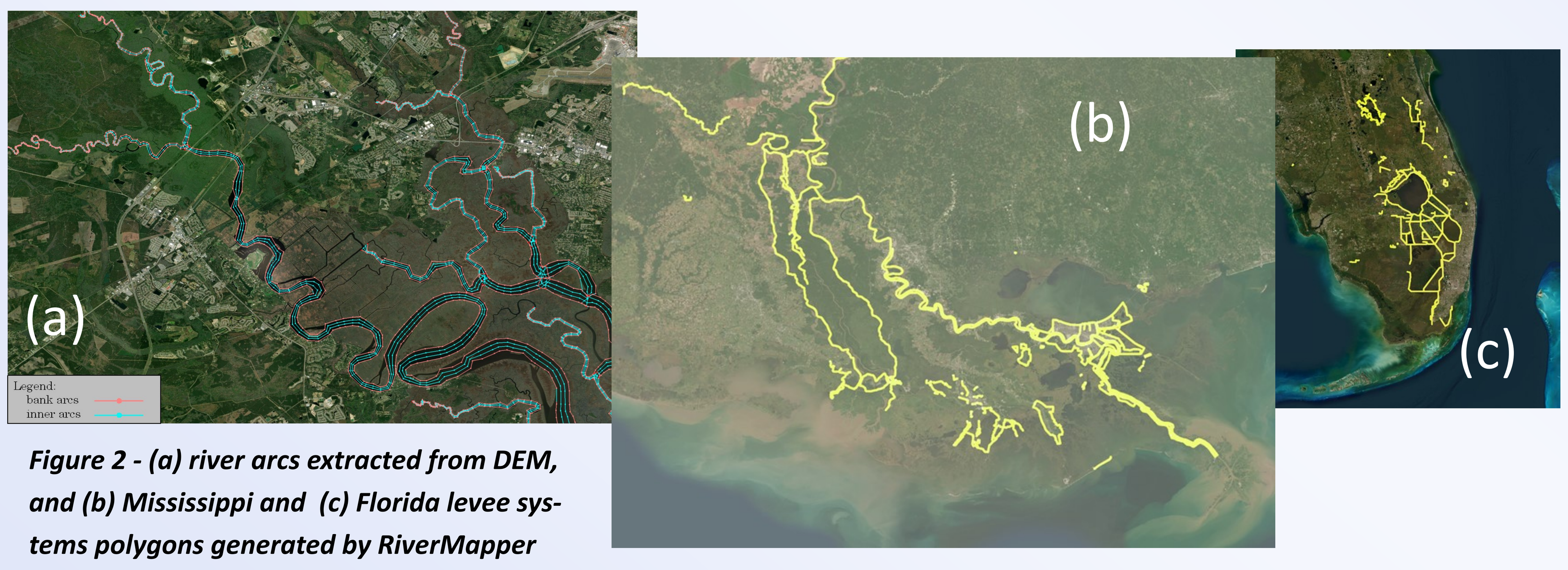

Figure 2 - (a) river arcs extracted from DEM, and (b) Mississippi and (c) Florida levee systems polygons generated by RiverMapper

Effect of River Embedding in STOFS-3D Atlantic

The STOFS-3D-Atlantic results are improved as a result of the inclusion of the levee and river polygons generated using the method above. Both the *interpolated bathymetry* and simulated *water levels* show the improvement.

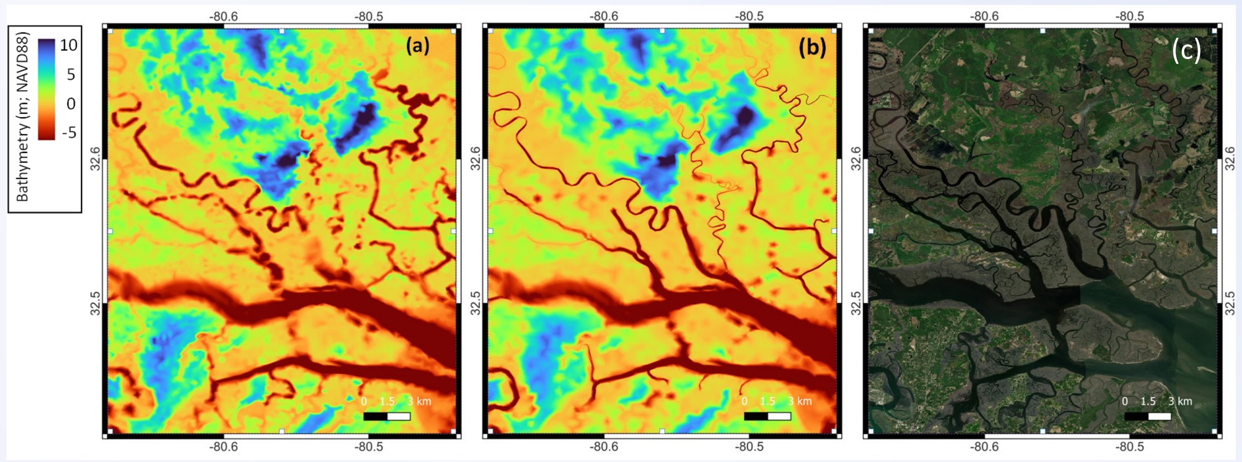

Figure 3 - South Carolina coastal region river network showing: Bathymetry of (a) the old mesh, and (b) improved mesh with arcs embedded and (c) satellite imagery of the region

SCHISM results show water level prediction is improved because of the addition of the missing river connectivity that relieves the catchments.

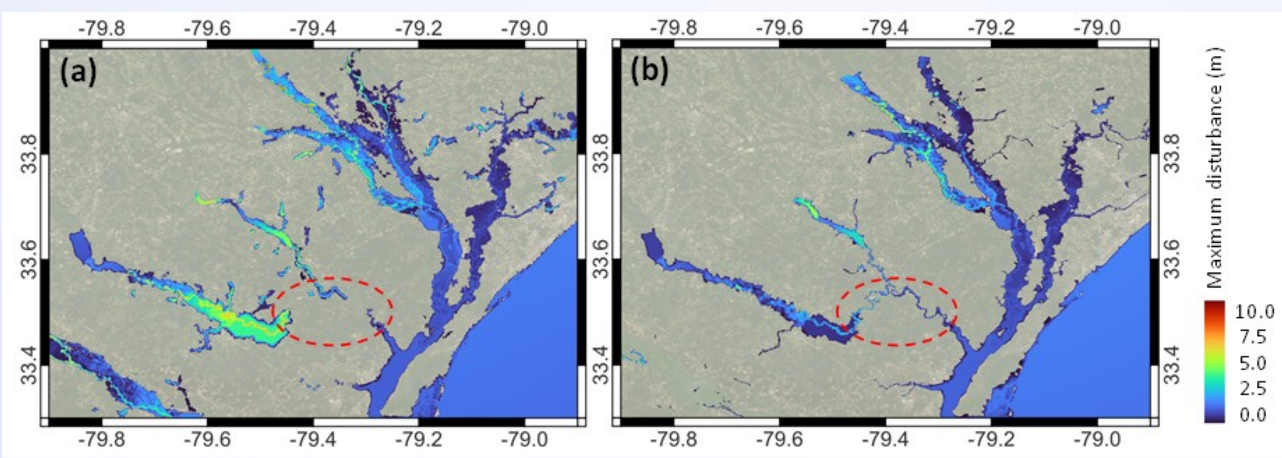

Figure 4 - Comparison of the maximum disturbance for mesh (a) without and (b) with embedded river polygons

Current Development

Embedding rivers and levees using the existing tools results in many small elements in the regions close to the rivers. Moreover, setting up the embedding mesh job is usually manual.

This work is an attempt to **automate the last mile** of this process while relaxing the transition quality constraints.

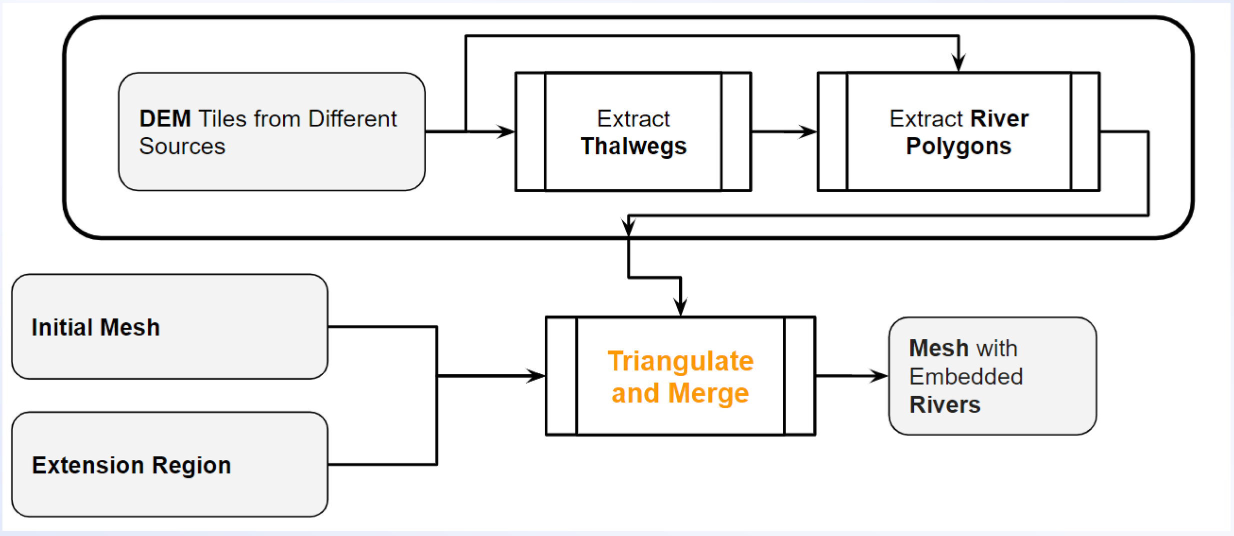

Figure 5 - Schematic of the whole meshing process

Methodology

The focus of this work is the **embedding process**, hence the extracted river polygons (Fig 6a) are taken as input. Also while it's possible to use tools, such as OCSMesh to generate the full mesh, here it is assumed a coast-to-ocean mesh (initial mesh - Fig 6b) is provided as input. The embedding tool then *extends* the initial mesh on the floodplain based on the input *embedding/extension region* shape (Fig 6c) and embeds the rivers.

It is also possible to use this tool to *modify* the initial mesh and embed rivers directly in the initial region instead.

The embedding process has the following steps:

- River polygons are triangulated and the elements are clipped to constrain them to the embedding region (Fig 6d)
- A mesh (i.e. *extension mesh*) is generated automatically for the embedding region
  - This mesh takes the river mesh size into account.
- Extension mesh is clipped (Fig 6e) by the rivers to prepare for merging all into a unified domain mesh
- The meshes are combined, this includes river mesh, initial mesh, and extension mesh (Fig 6f)
  - Currently the focus is on improving the **merging process** iteratively
  - After merging, some post processing might be required to remove problematic elements

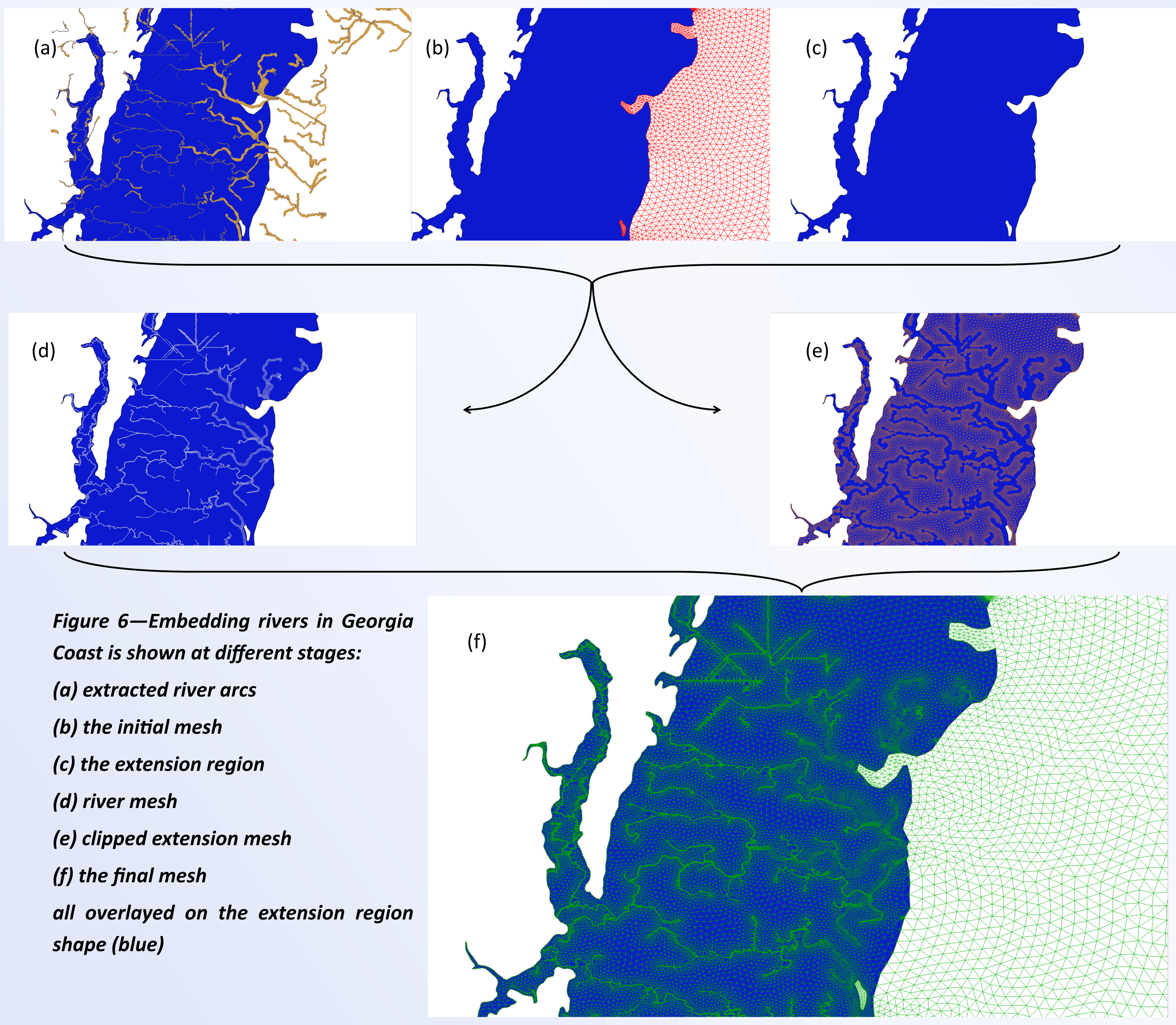

Figure 6—Embedding rivers in Georgia Coast is shown at different stages:
(a) extracted river arcs
(b) the initial mesh
(c) the extension region
(d) river mesh
(e) clipped extension mesh
(f) the final mesh
all overlayed on the extension region shape (blue)

Snapshots of Embedding Results in Different US Regions

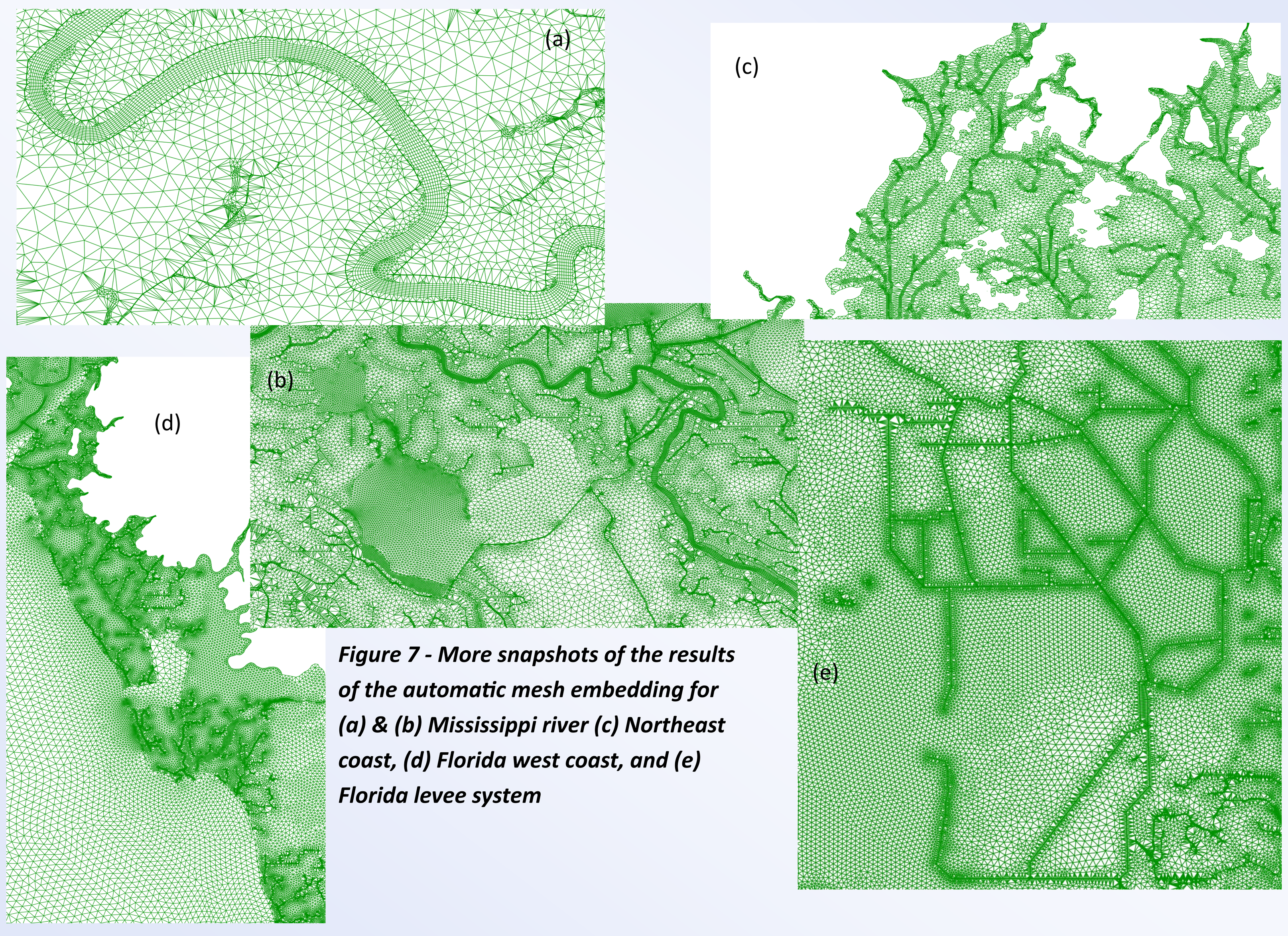

Figure 7 - More snapshots of the results of the automatic mesh embedding for (a) & (b) Mississippi river (c) Northeast coast, (d) Florida west coast, and (e) Florida levee system

References

- Ye, F., Cui, L., Zhang, Y.J., Wang, Z., Moghimi, S., Myers, E., Seroka, G., Zundel, A., Mani, S. and Kelley, J.G., 2023. A parallel Python-based tool for meshing watershed rivers at continental scale. *Environmental Modelling & Software*, *166*, p.105731
- Ye, F., Zhang, Y.J. , Cui, L., Yu, H.C., Yang, Z., Seroka, G.N., , Moghimi, S., Myers E.P., 2022. Enhancement of the Three-Dimensional Surge and Tide Operational Forecast System for the Atlantic (STOFS-3D-Atlantic). *AGU Fall Meeting Abstracts 2022,* H53B-08
- Mani, S., Calzada, J.R., Moghimi, S., Zhang, Y.J., Myers, E., Pe'eri, S., 2021. OCSMesh: a data-driven automated unstructured mesh generation software for coastal ocean modeling. *NOAA Technical Memorandum NOS CS ; 47* DOI: 10.25923/csba-m072
- Zhang, Y.J., Ye, F., Stanev, E., & Grashorn, S., 2016. Seamless cross-scale modeling with SCHISM. Ocean Modelling, 102, pp. 64-81.
- https://github.com/schism-dev/RiverMeshTools
- https://github.com/noaa-ocs-modeling/Ocsmesh