Development of 2D Unstructured Meshes Using a Sizing Function Derived from Euclidean Distances to Coastal Features for the NWM Hydrodynamic Engine (D-Flow FM) Model

Henok Kefelegn[1,2], Henok Kefelegn[1], Richard Gibbs[2], Julio Zyserman[2], Trey Flowers[2], Edward Clark[2], Hassan Mashriqui[3], Js Allen[2], Jason Ducker[2], and Ryan Grout[2]

[1]NOAA Office of Water Prediction, National Water Center
[2]NOAA Office of Water Prediction, National Water Center, Tuscaloosa, AL, United States
[3]National Oceanic and Atmospheric Administration (NOAA), Office of Water Prediction, National Weather Service (NWS), Silver Spring, United States

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Abstract

Generation of 2D meshes with reduced number of elements while yielding accurate results is a major challenge in coastal numerical models. High-quality 2D unstructured meshes were generated using sizing functions, which were computed from Euclidean distances to coastal features at given spatial locations and assigned element sizes based on calculated distances. The coastal features consist of National Water Model (NWM) streamlines, National Hydrography Dataset (NHD), NOAA Medium Resolution Shoreline and bathymetric features from the United States Army Corps of Engineers (USACE). This approach allows improved integration of the hydrodynamic D-Flow Flexible Mesh (D-Flow FM) model into the hydrological NWM and results in an optimum number of computational points. The method grants the user flexibility to control element sizes and avoids manual iterative procedures by determining an optimal element-sizing function that defines small element scales in regions where geometrical and physical characteristics exist, with larger scales elsewhere. Newly created continental-scale meshes on the Atlantic Ocean, Gulf of Mexico and Pacific Ocean coastlines demonstrate the application of the proposed method for automatic generation of unstructured, high-quality 2D meshes.

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H. Kefelegn[2], R. Gibbs[2], J. Zyserman[2], T. Flowers[2], E.P. Clark[2], H. Mashriqui[1], J. Allen[2], J. Ducker[2], R. Grout[2]

[1]NOAA Office of Water Prediction, Silver Spring, MD

[2]NOAA Office of Water Prediction, National Water Center, Tuscaloosa, AL

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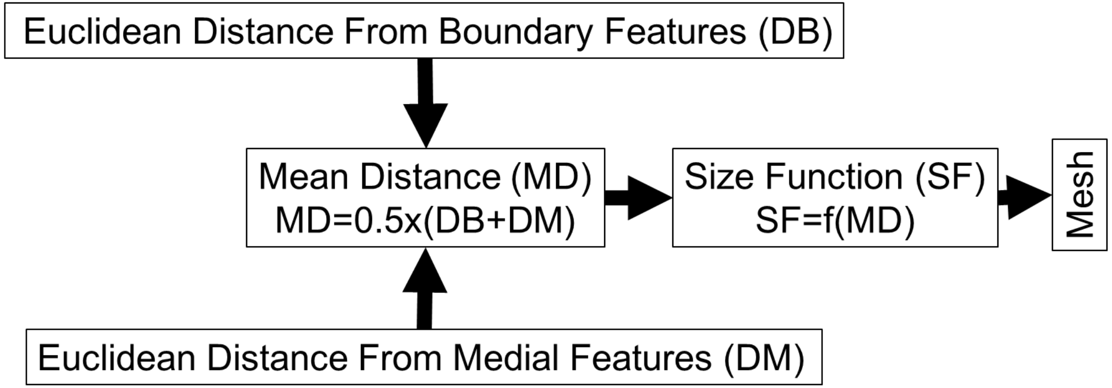
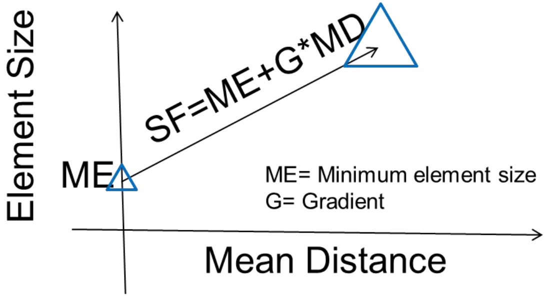
Introduction

- Goal: To generate an element sizing function for construction of high-quality 2D unstructured mesh.
- Element sizing function based on proximities of coastal features from
  - ❑ National Water Model (NWM) streamlines
  - ❑ National Hydrography Dataset (NHD)
  - ❑ NOAA Medium Resolution Shoreline and
  - ❑ Bathymetric features from the United States Army Corps of Engineers (USACE).
- Finer elements for fine geometric details and coarser elsewhere.
- Input: Complex geometry of coastal features and user assigned element gradation.
- Output: High-quality mesh.

Mesh Generation Method

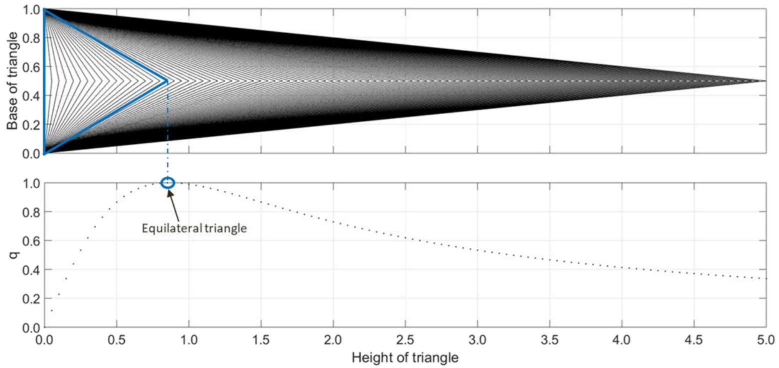




Quality Assessment

$$qALS = \frac{4\sqrt{3}\,A}{l_1^2 + l_2^2 + l_3^2}$$

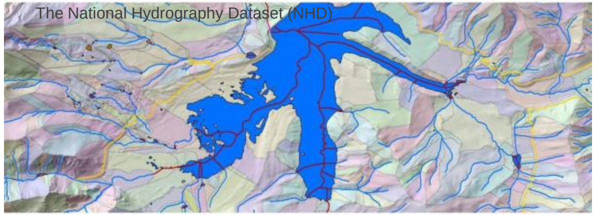
Bhatia et al 1990; Sarrate et al 2003; Bank et al 1997

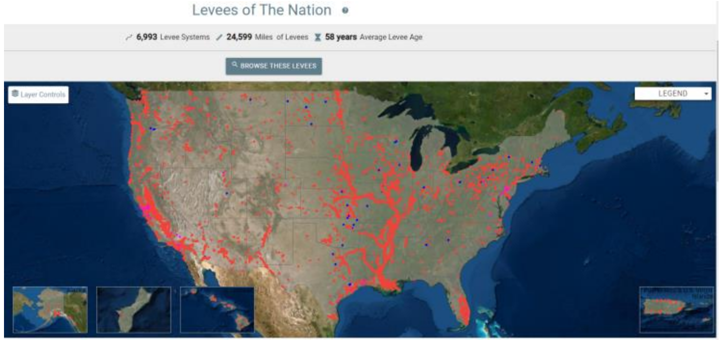


Kefelegn, Henok, "Automatic Shoreline Digitization and Mesh Element Sizing for Hydrodynamic Modeling" (2020). LSU Doctoral Dissertations. 5133. https://digitalcommons.lsu.edu/gradschool_dissertations/5133

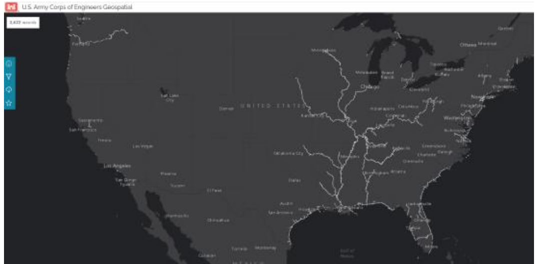
Model Domains (~+10 m, MSL & ~-2 m, MSL)

NWM Streamflow Output Points (~2.7 mil)



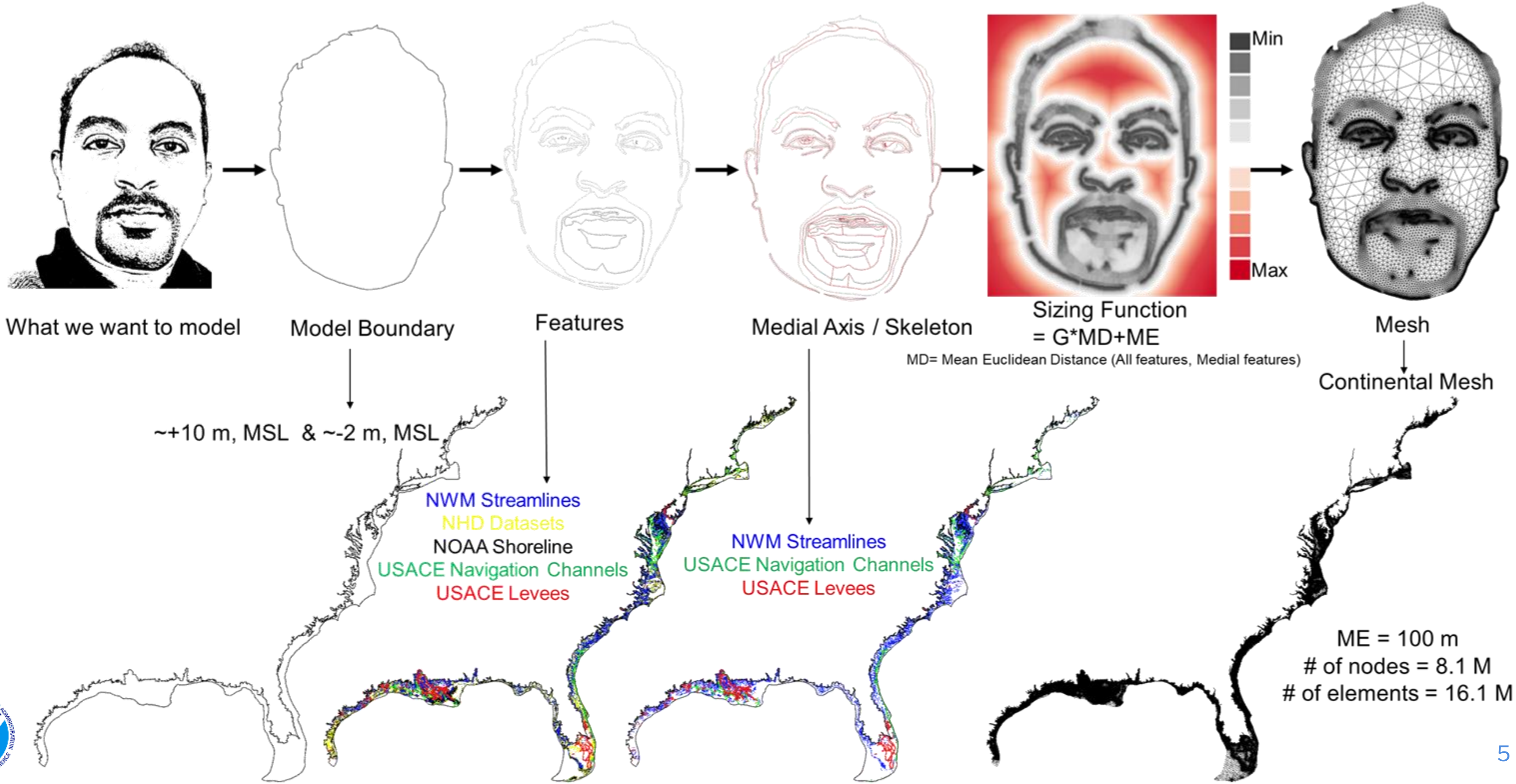


National Channel Framework

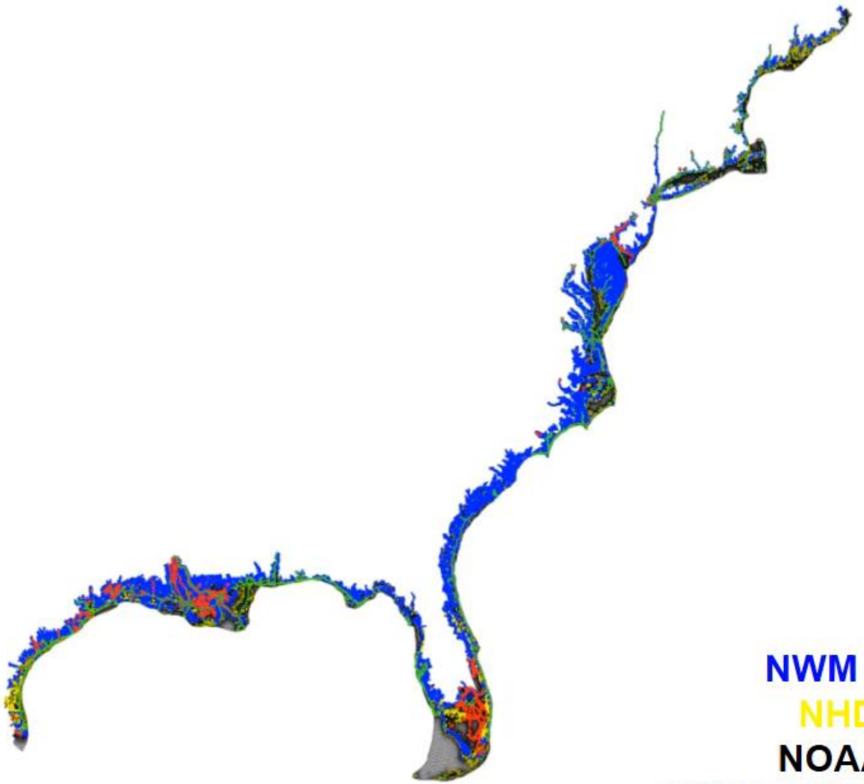


	Pacific	Gulf & Atlantic
Domain Area (km²)	64,881	329,572
NWM Reach Length (km)	10,682	105,135
NHD Waterbody Area (km²)	166	7,010
USACE Levee Length (km²)	5,603	6,503
USACE Leveed Area (km²)	6,076	23,343
USACE Navigation Channel Area (km²)	159	1,525
USACE Navigation Channel Length (km	4,093	24,691

Continental Mesh Development

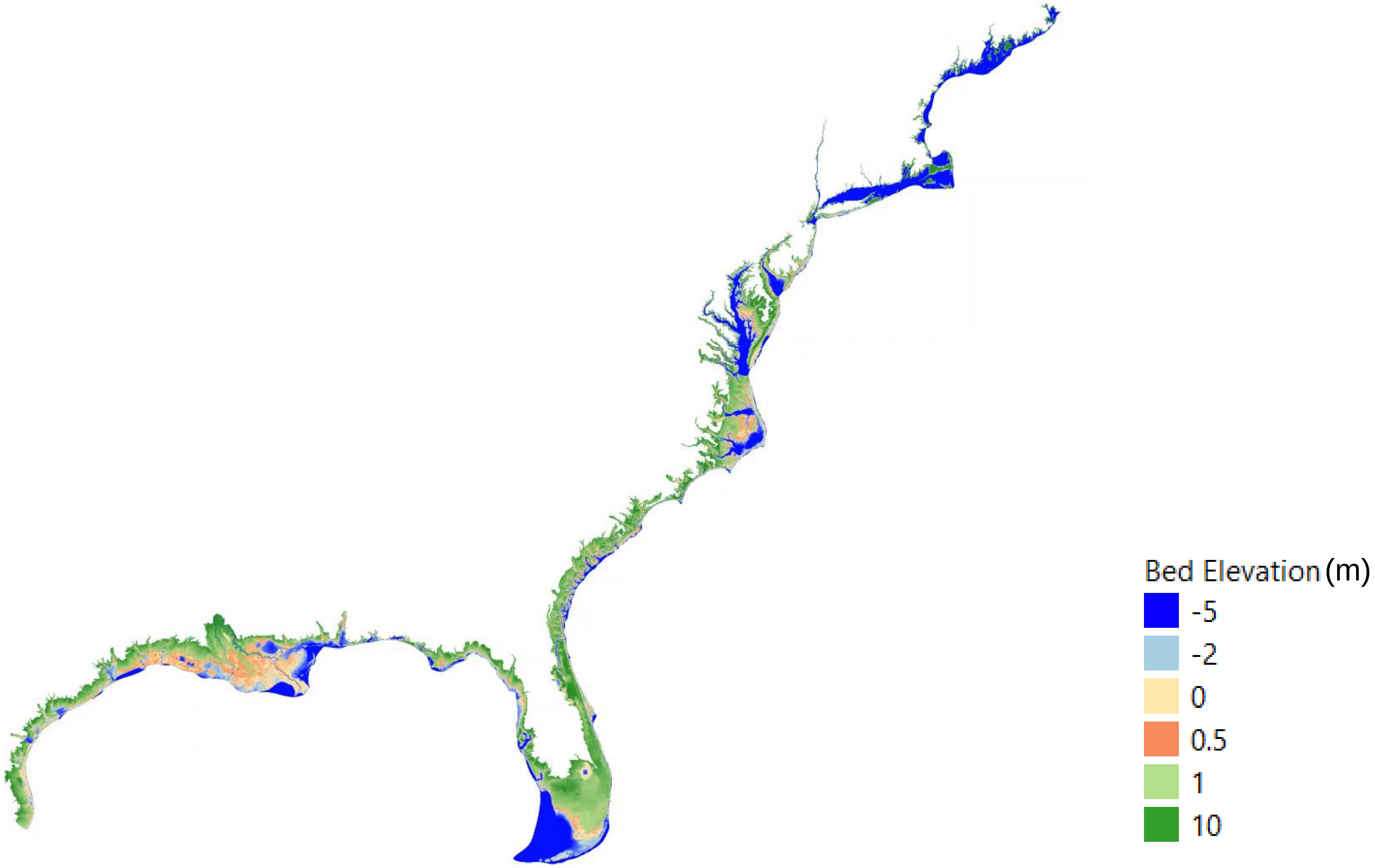


Continental-Scale Mesh (Atlantic & Gulf of Mexico)

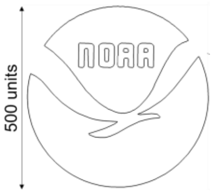


NWM Streamlines
NHD Datasets
NOAA Shoreline
USACE Navigation Channels
USACE Levees

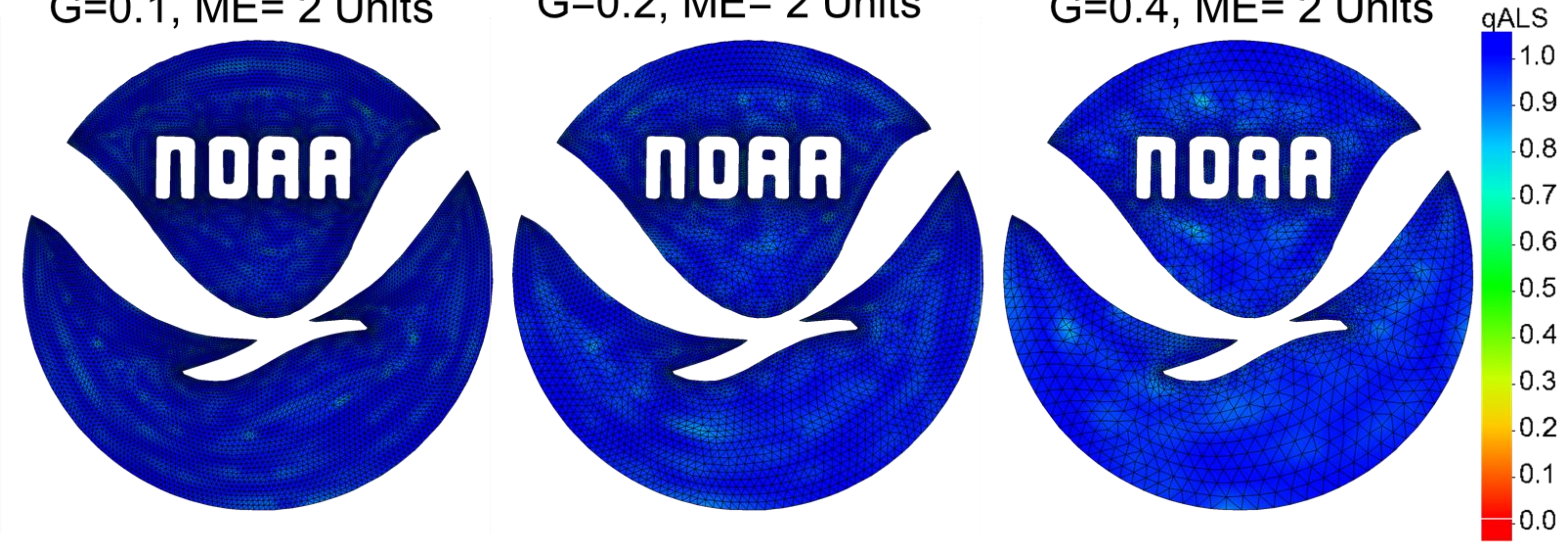
Continental-Scale Mesh (Atlantic & Gulf of Mexico)



Mesh Quality Assessment



G=0.1, ME= 2 Units | G=0.2, ME= 2 Units | G=0.4, ME= 2 Units

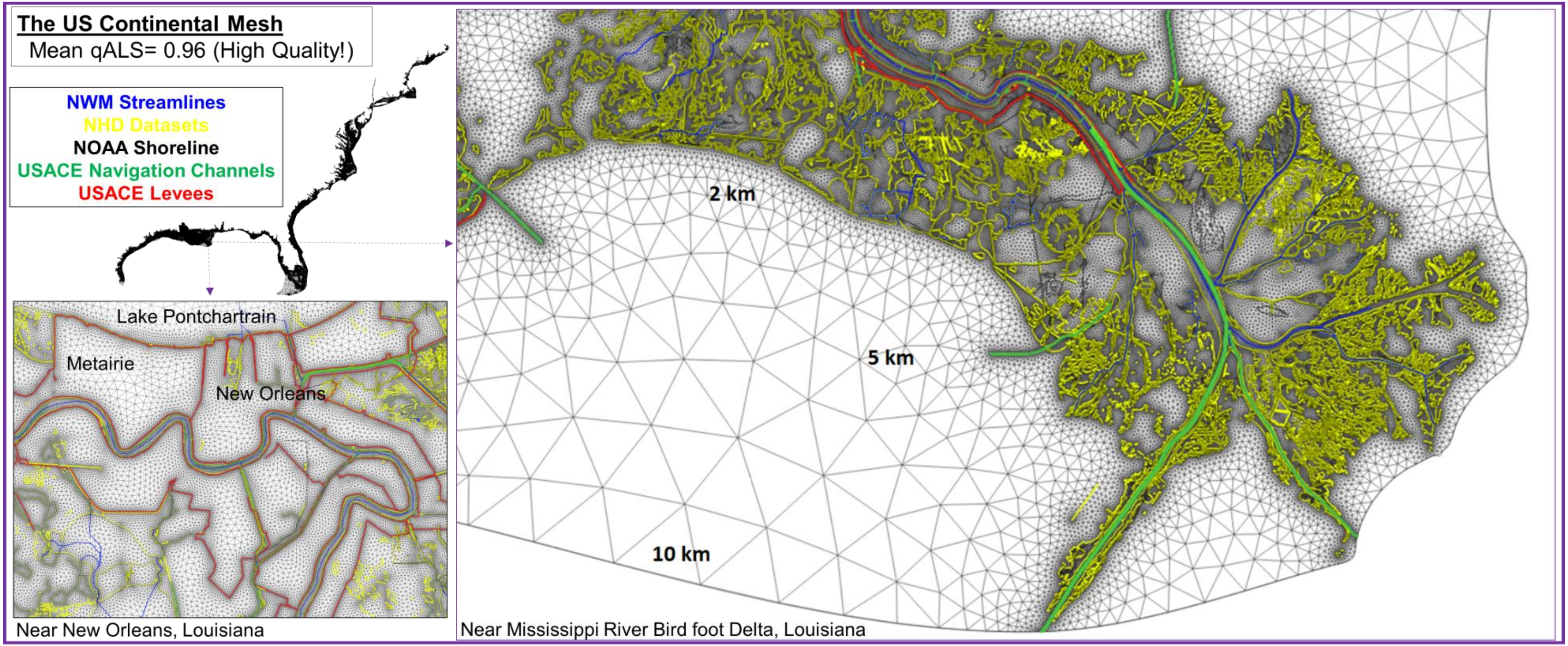


# of nodes = 11908
# of Elements = 22480
Mean qALS= 0.969

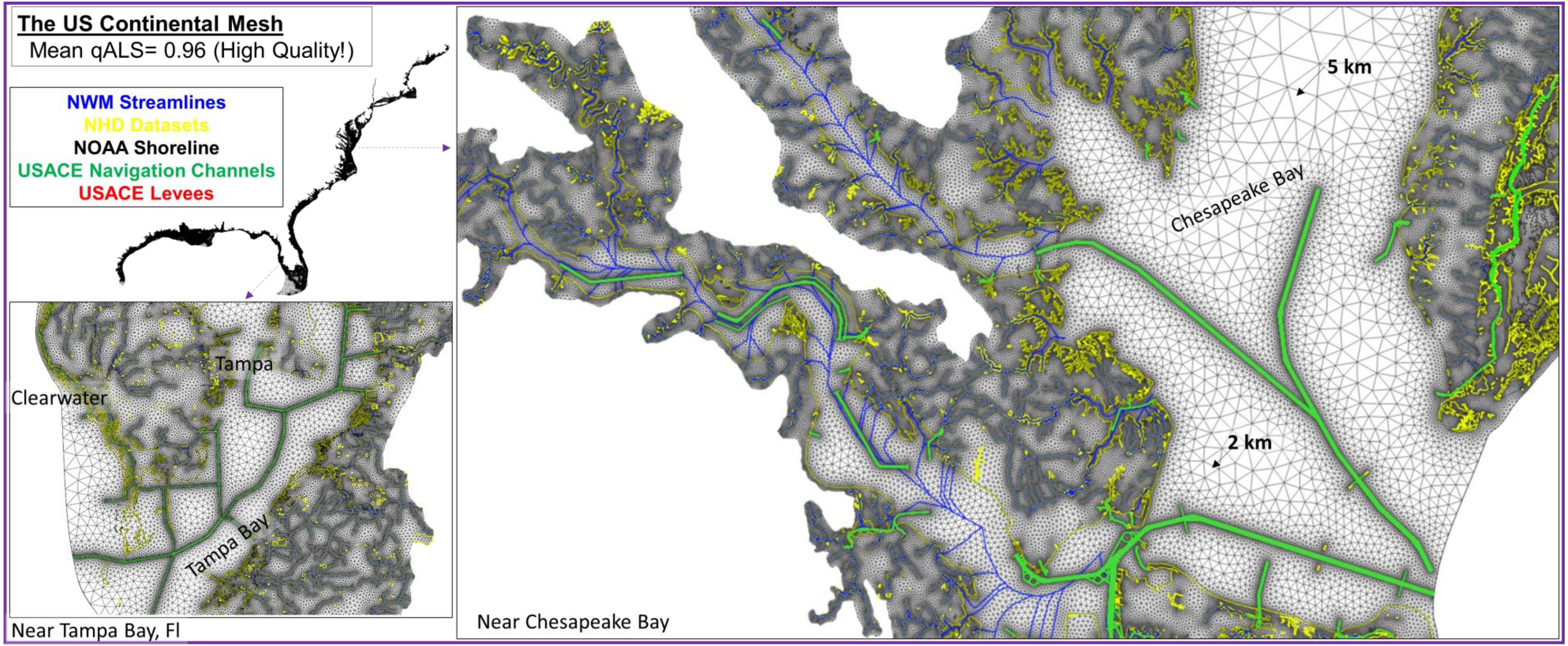
# of nodes = 6545
# of Elements = 12011
Mean qALS= 0.961

# of nodes = 3180
# of Elements = 5549
Mean qALS= 0.956

Mesh Quality

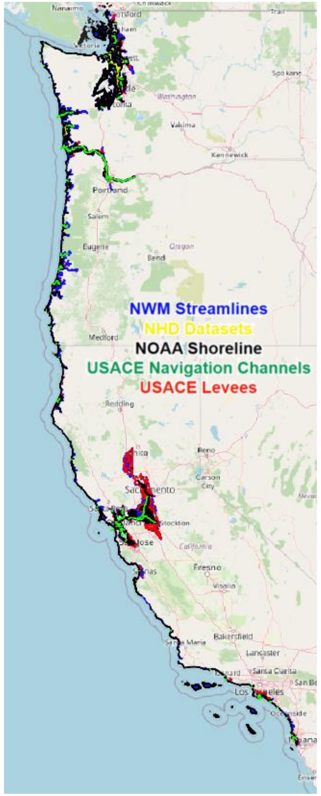


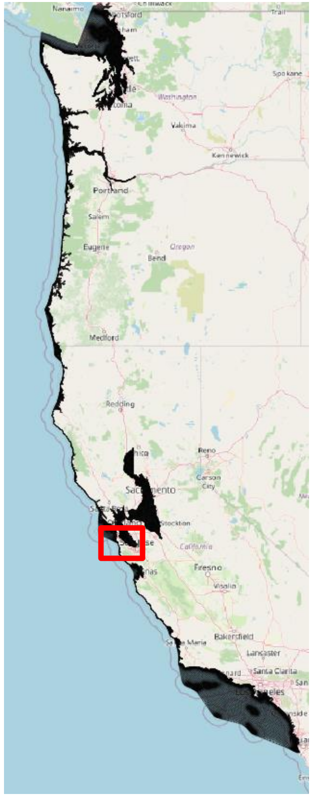
Mesh Quality Cont.

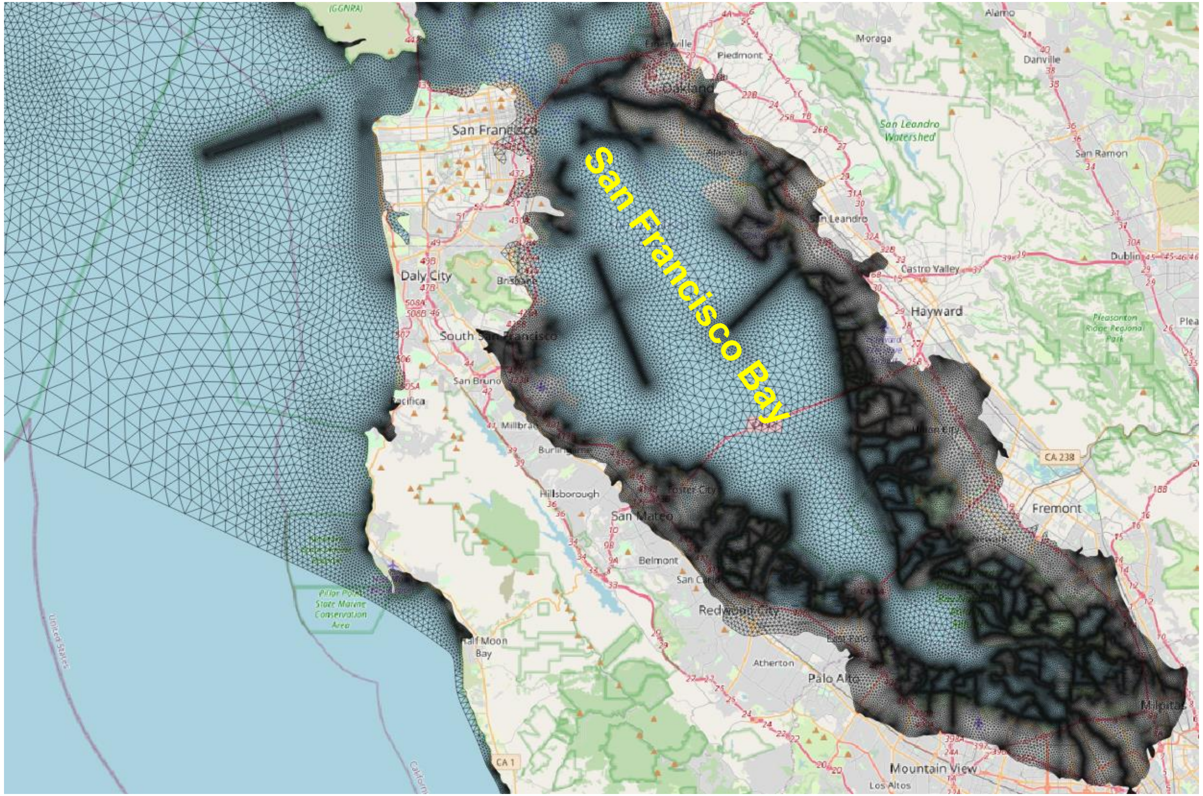


Continental-Scale Mesh (Pacific)

Mesh 1: 50 m resolution, G = 0.2, # of nodes: 3.2 M, # of elements: 6.3 M, qALS = 0.963

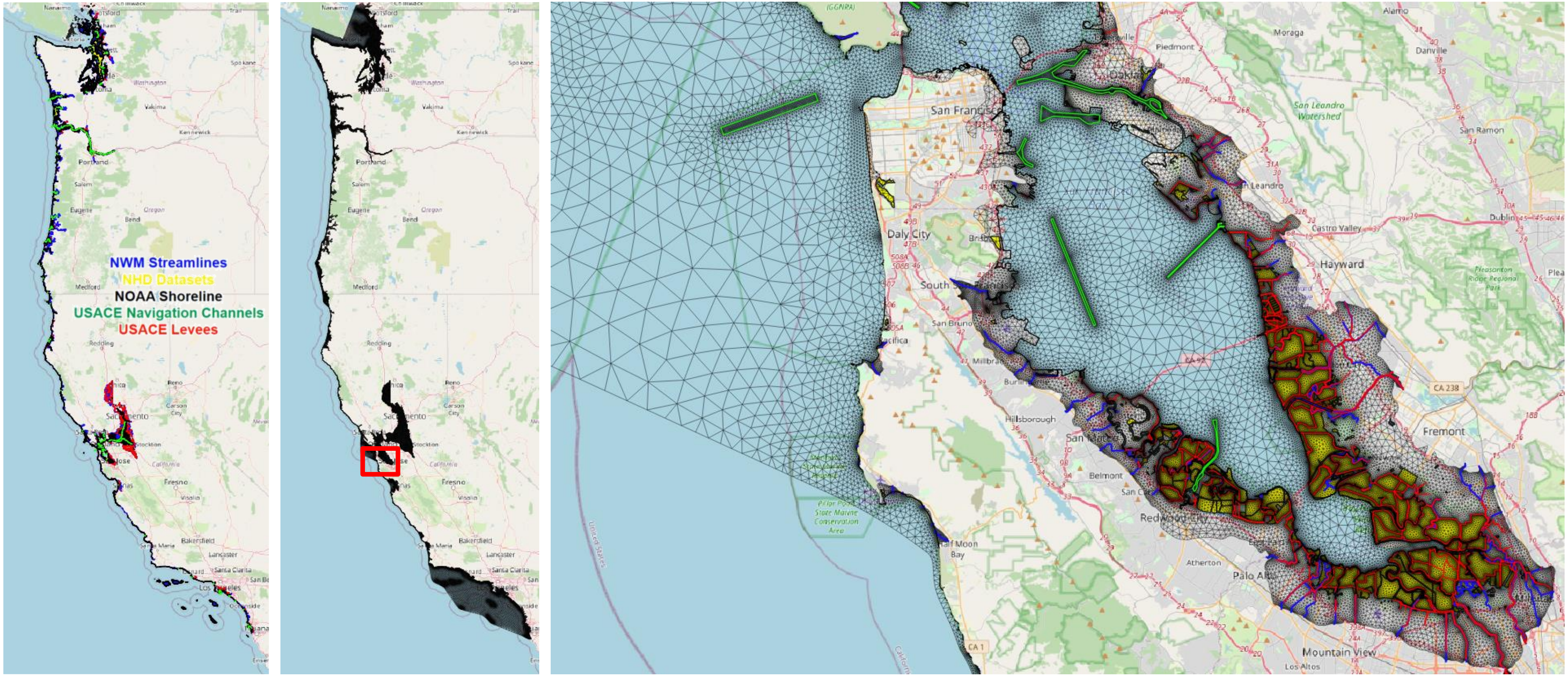






Continental-Scale Mesh (Pacific)

Mesh 1: 50 m resolution, G = 0.4, # of nodes: 1.8 M, # of elements: 3.5 M, qALS = 0.957



\+ Levees lines + Navigation Channels + US Medium SL + NWM Streamlines + NHD Water body

Conclusions

- A new method was developed to define small elements in the region where coastal features exist and larger elements elsewhere.
- The method grants the user flexibility to adjust the gradient and avoid manual iterative procedure.
- Quality assessment shows that the new algorithm is capable of producing high quality meshes.
- Newly created continental-scale meshes on the Atlantic Ocean, Gulf of Mexico and Pacific Ocean coastlines demonstrate the application of the proposed method for automatic generation of unstructured, high-quality 2D meshes.
- The method allows improved integration of the hydrodynamic D-Flow Flexible Mesh (D-Flow FM) model into the hydrological NWM and results in an optimum number of computational points.

Thank You!

Henok Kefelegn, Ph.D.

henok.kefelegn@noaa.gov

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