Multiple Tributary Model (MTM) Development – Initiation of Fine-scale Tributary Models in the Tidal James River

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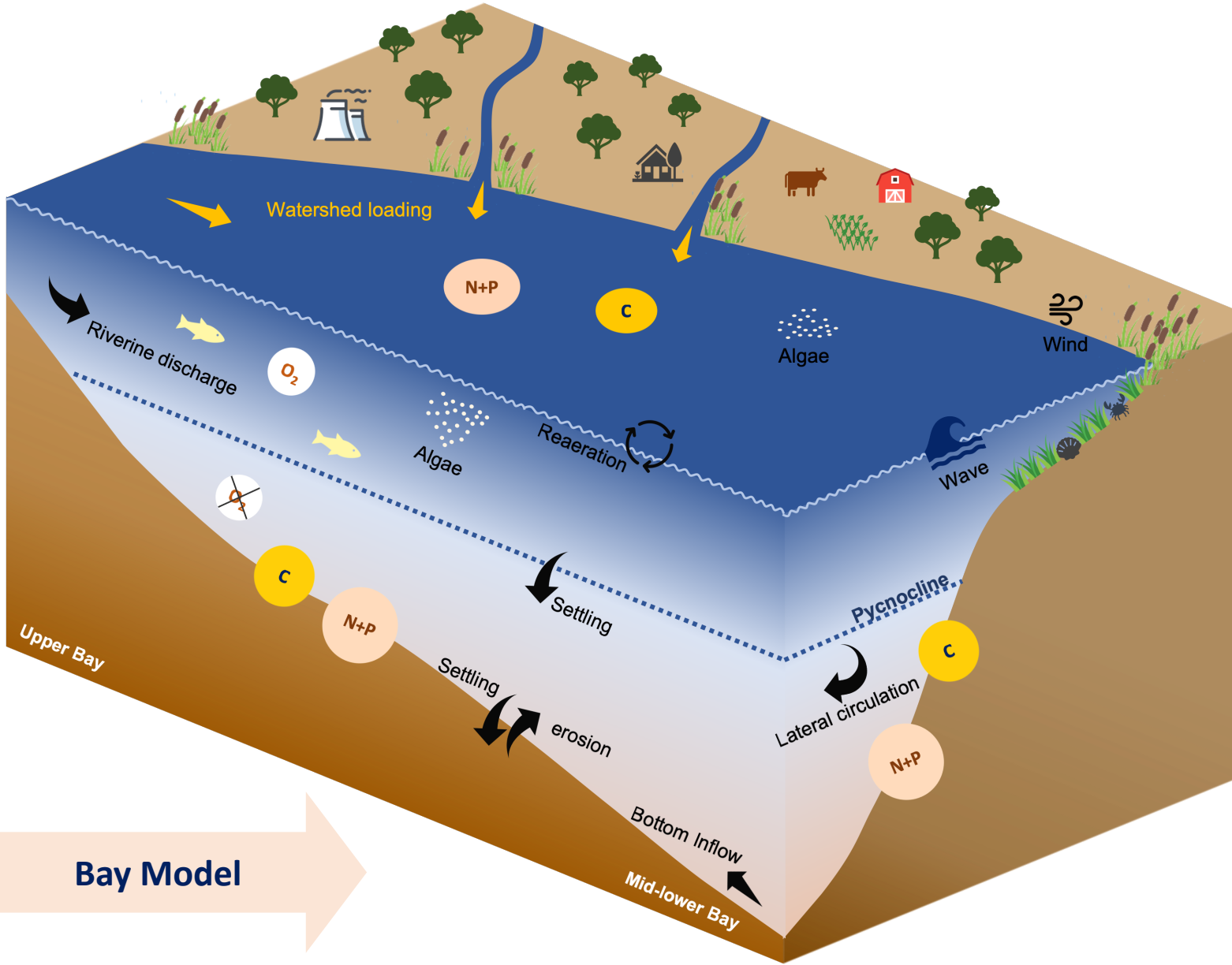
Modeling Quarterly Review, October 7, 2021

Overview

Dissertation

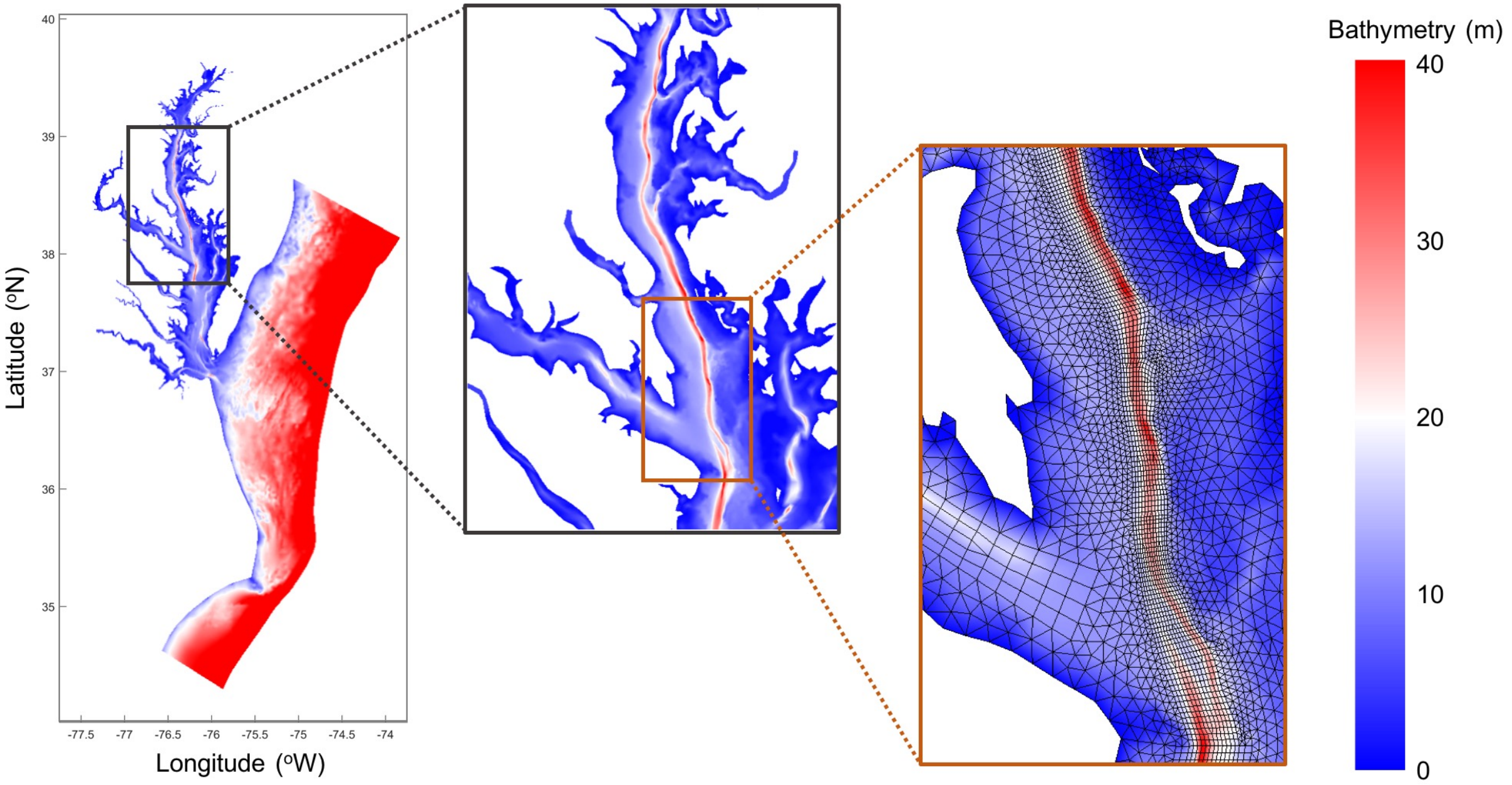
Toward a Comprehensive Water Quality Model for the Chesapeake Bay Using Unstructured Grids

- A productive ecosystem
  - Living resources and habitats
  - Agriculture, industry and fishery
- A complex system
  - Interaction between hydrodynamical and biochemical processes
  - Large Watershed
  - Geometry and sediment interactions
  - Human impacts
  - Climate change
  - Multiple issues such as hypoxia, HAB



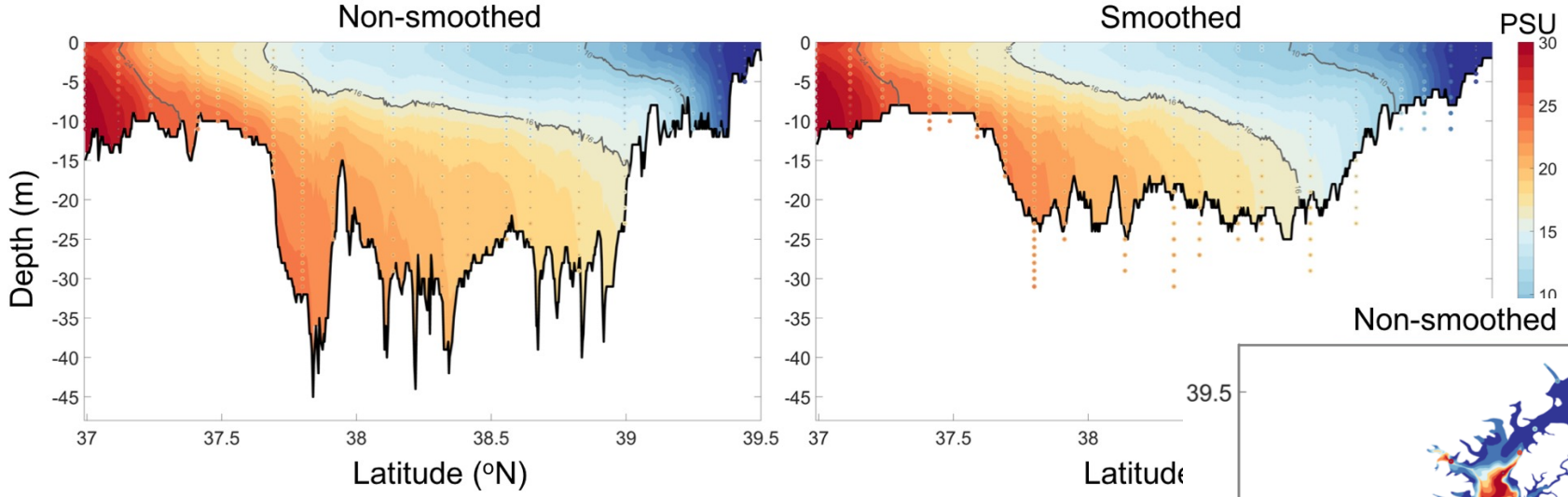
Bay Model

Past work from the main Bay towards tributaries



Importance of an accurate representation of bathymetry

Salinity



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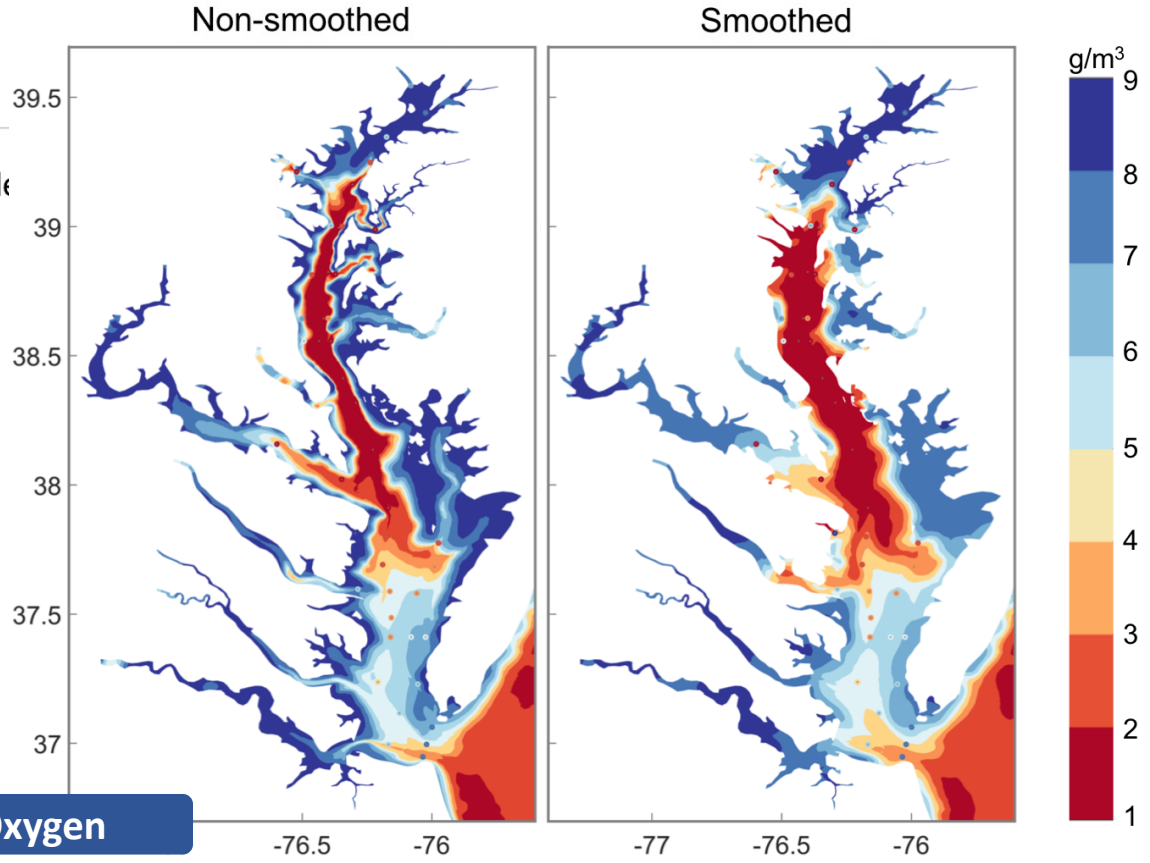
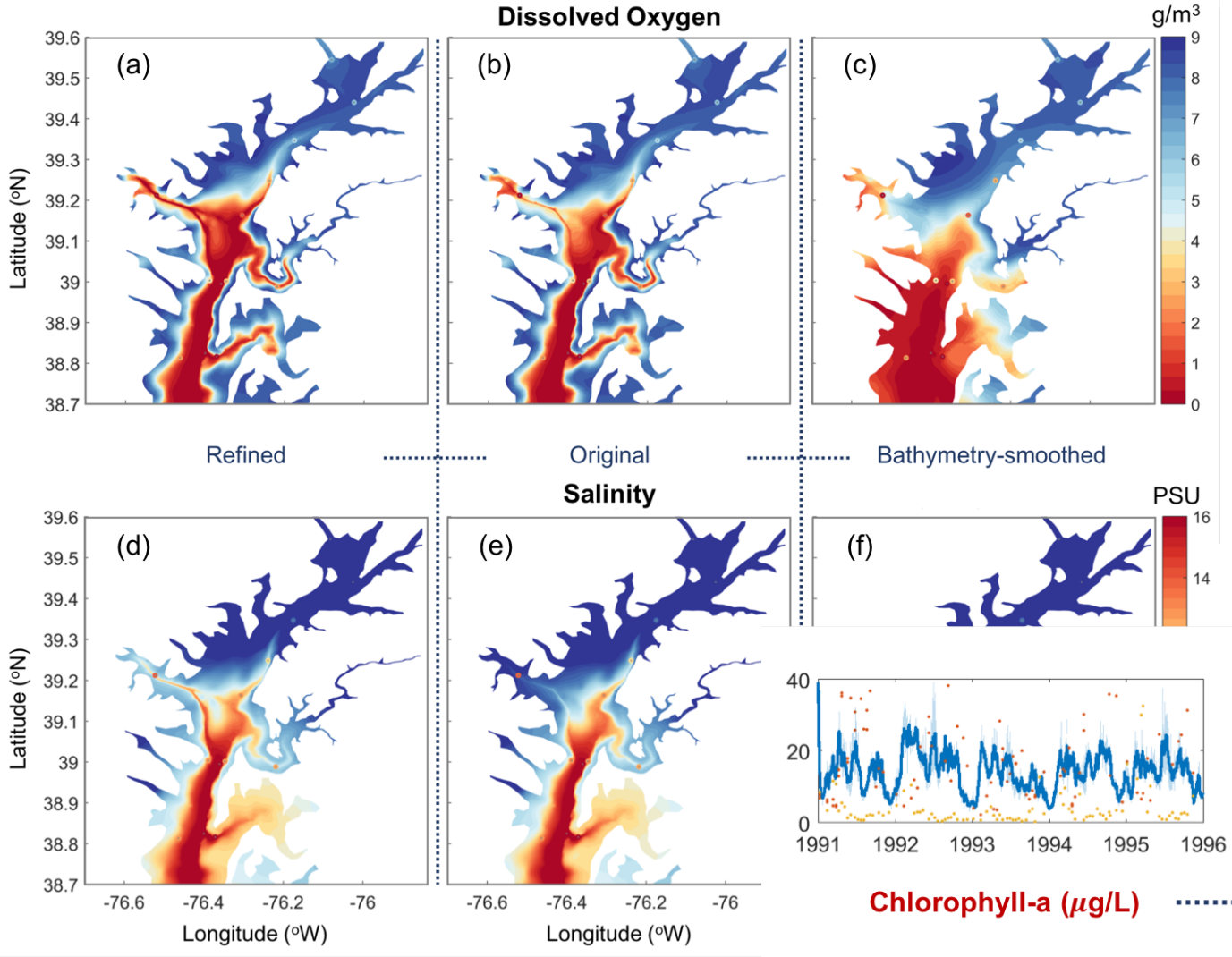
A Numerical Study of Hypoxia in Chesapeake Bay Using an Unstructured Grid Model: Validation and Sensitivity to Bathymetry Representation

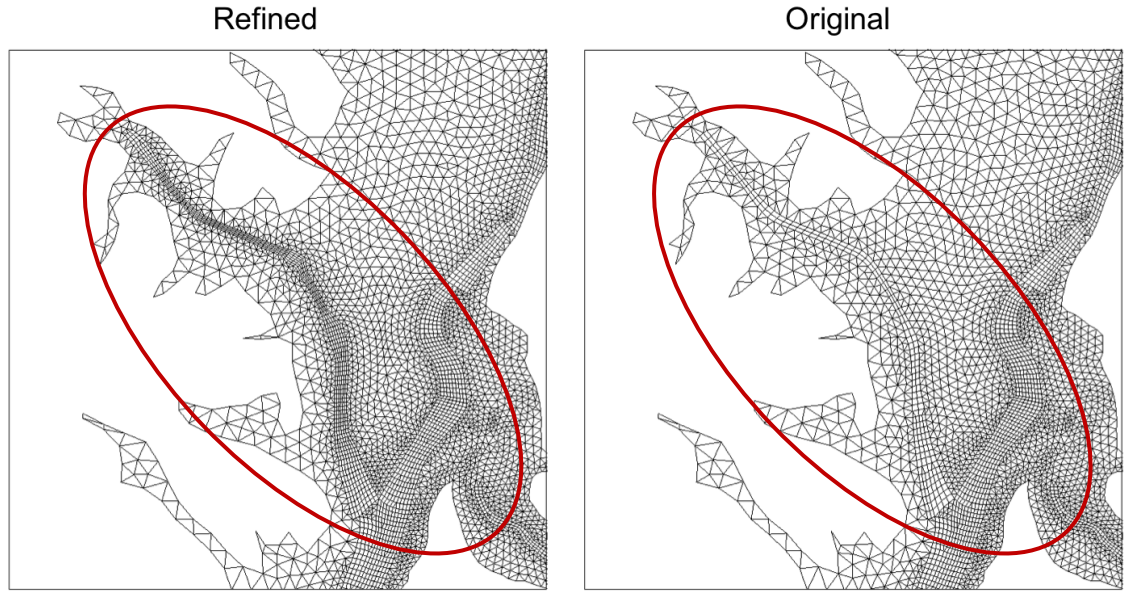
Xun Cai, Yinglong J. Zhang, Jian Shen, Harry Wang, Zhengui Wang, Qubin Qin, and Fei Ye

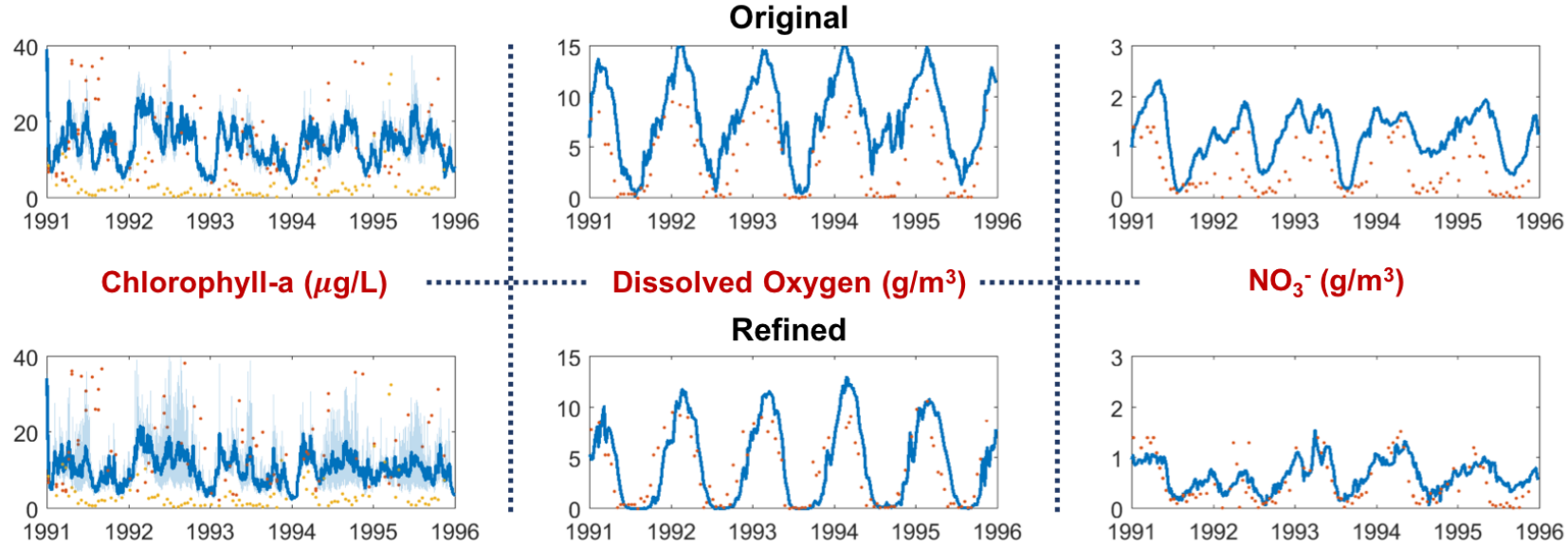


Dissolved Oxygen

Importance of high-resolution grid for the tributaries -- Baltimore Harbor



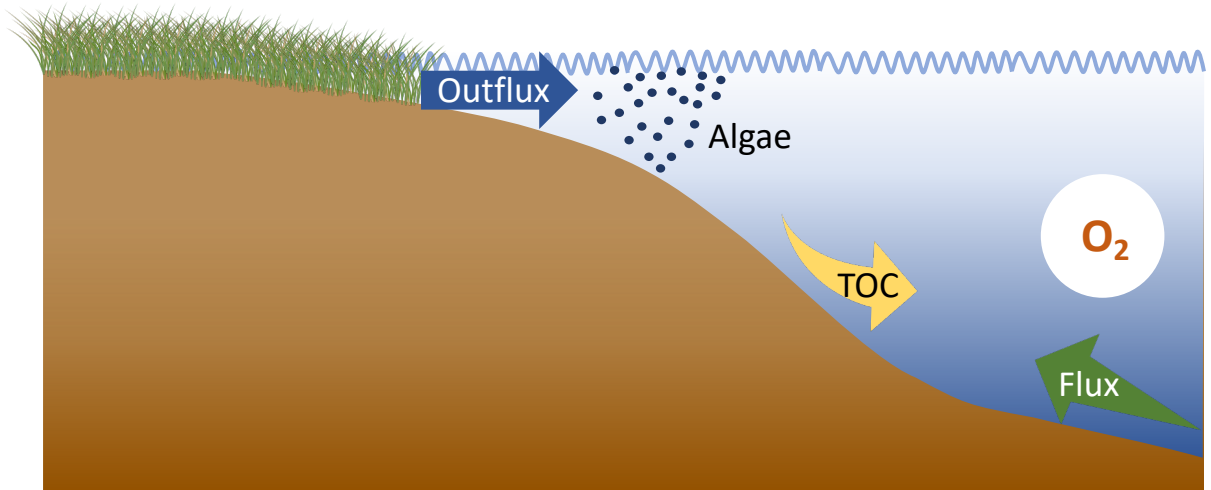




Motivations towards the shallow waters using unstructured grids

Shallow waters

- Over 24% area is less than 2 m in depth
- More degradation of water quality
- Early responses to management actions
- Larger impacts from climate change
  - Relative larger change on local bathymetry
  - Evolution of coastal lines



Unstructured grids

Complex linkages between land and shoreline, shallows regions, and open Bay waters

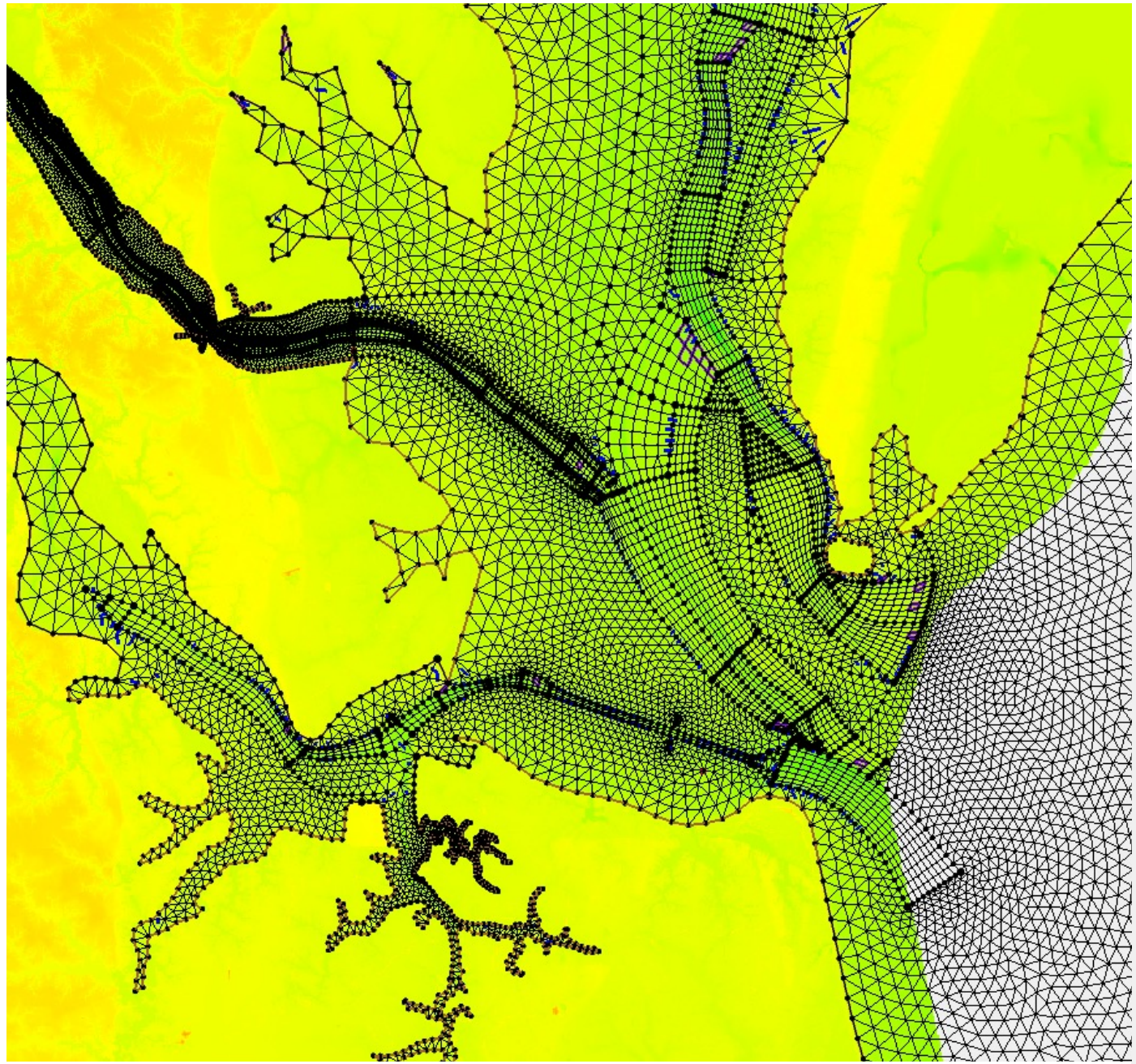
Chickahominy River

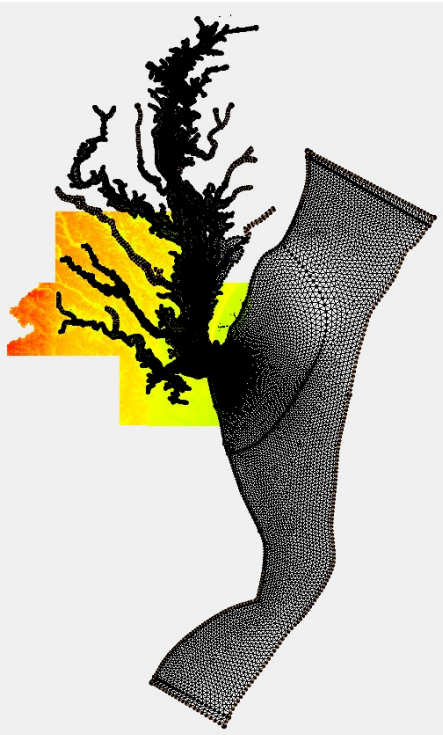
Initiation in the James River

Chesapeake Bay grid (hydro base; no wetlands)

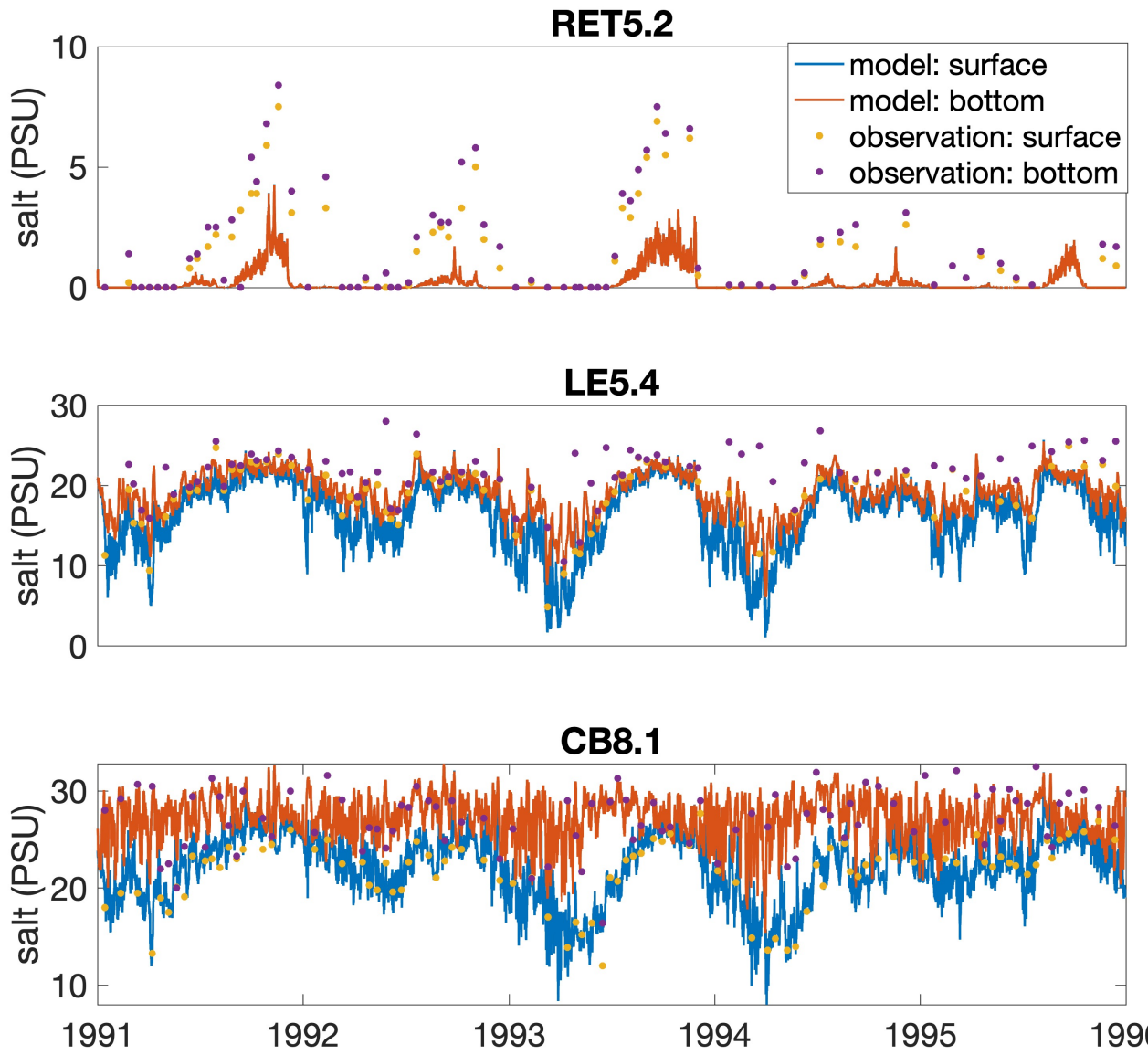
- # of elements: 73k; # of nodes: 50k
- Channel-based grid to capture major physical processes.
- Based on Ye et al., (2018), Cai et al., (2020), and Cai el al. (submitted)
- Refined York River Estuary including meanders but excluding tidal marshes.
- This hydro base was chosen for a future full linkage between the main Bay and the tributaries.

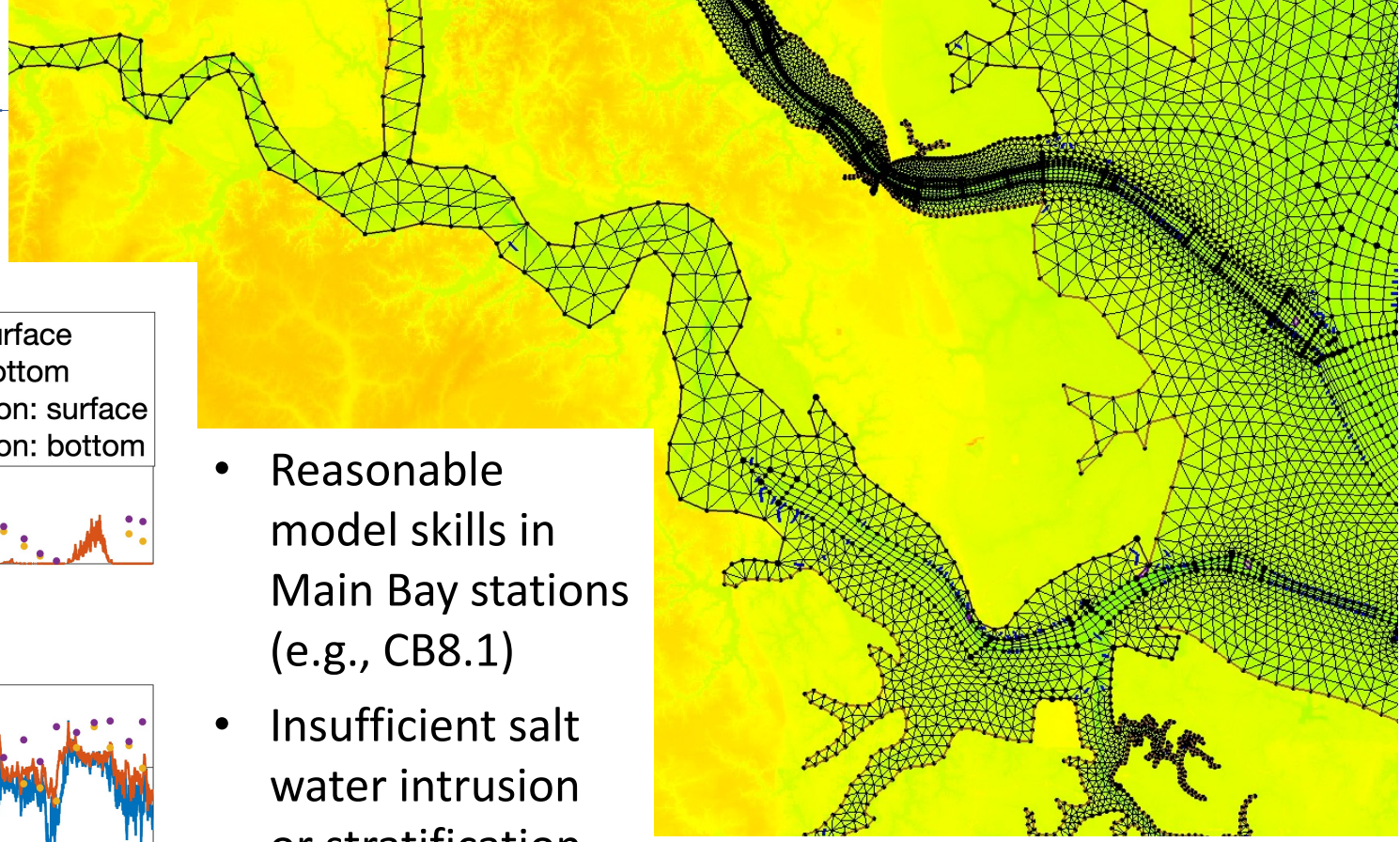
A process of learning and trying!!





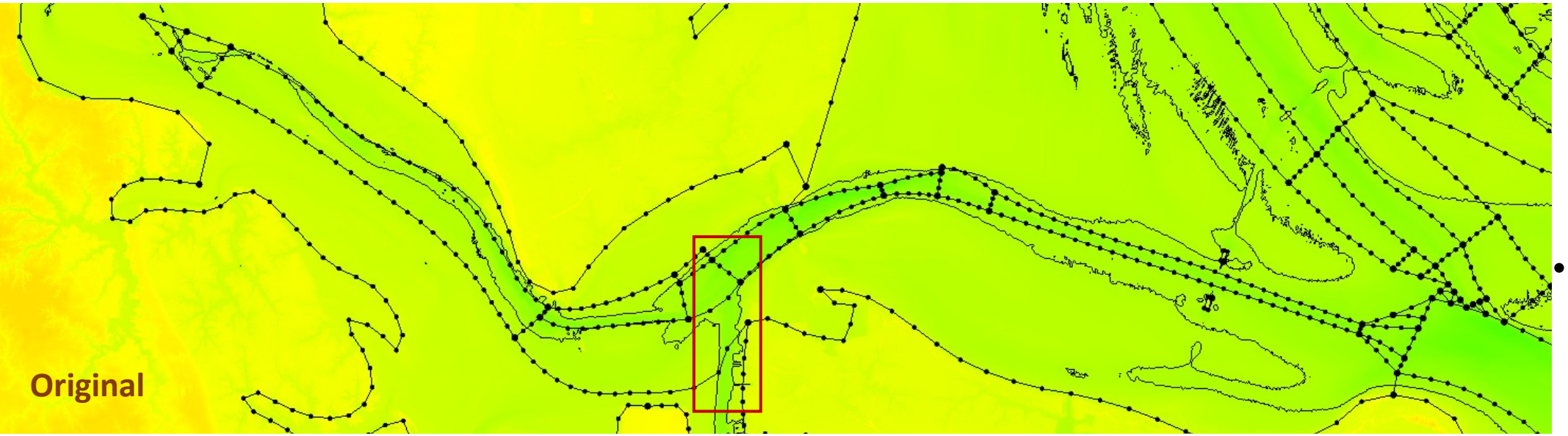
Original James grid





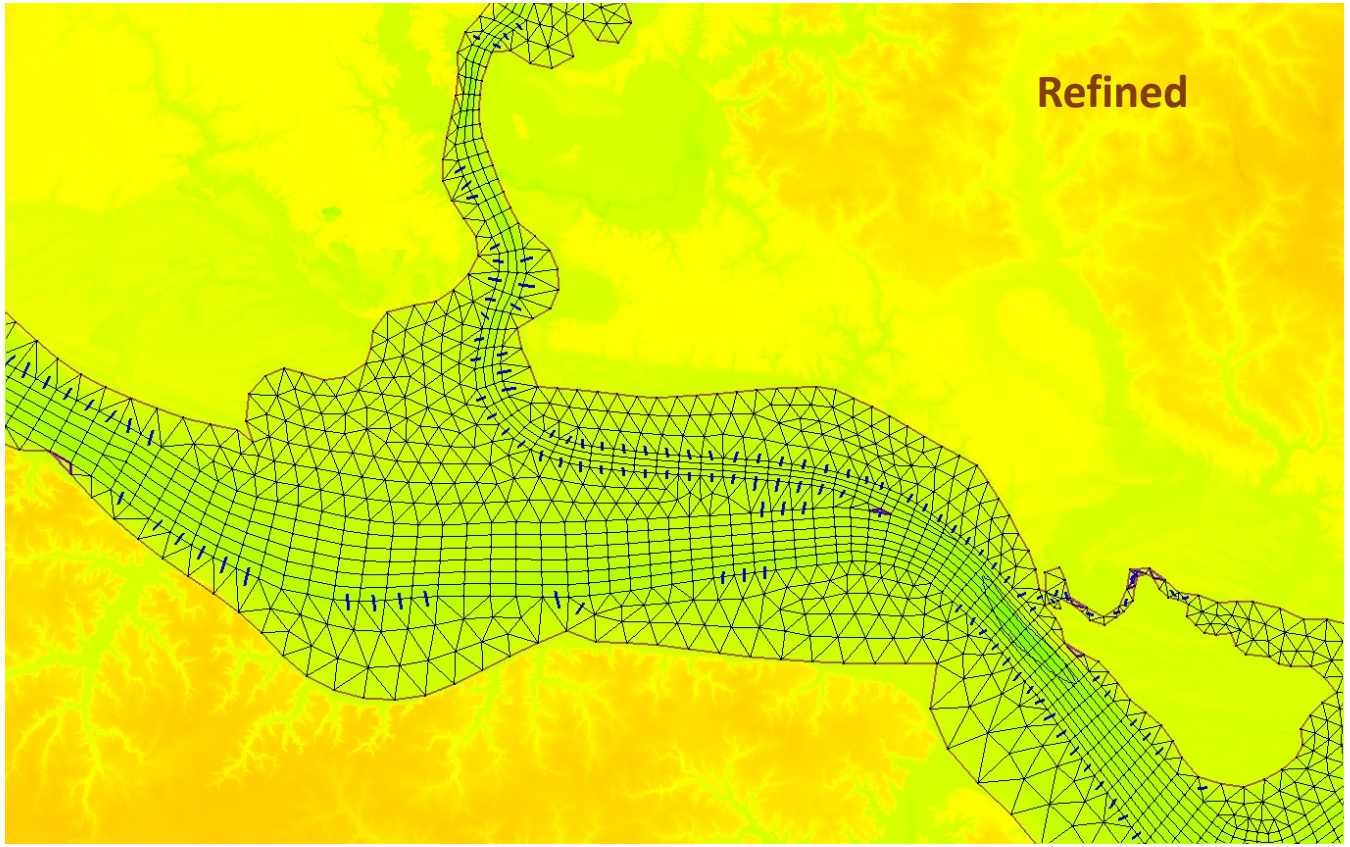
- Reasonable model skills in Main Bay stations (e.g., CB8.1)
- Insufficient salt water intrusion or stratification from James mouth to the head of James River and inner sub-tributaries (e.g., Chickahominy R.)

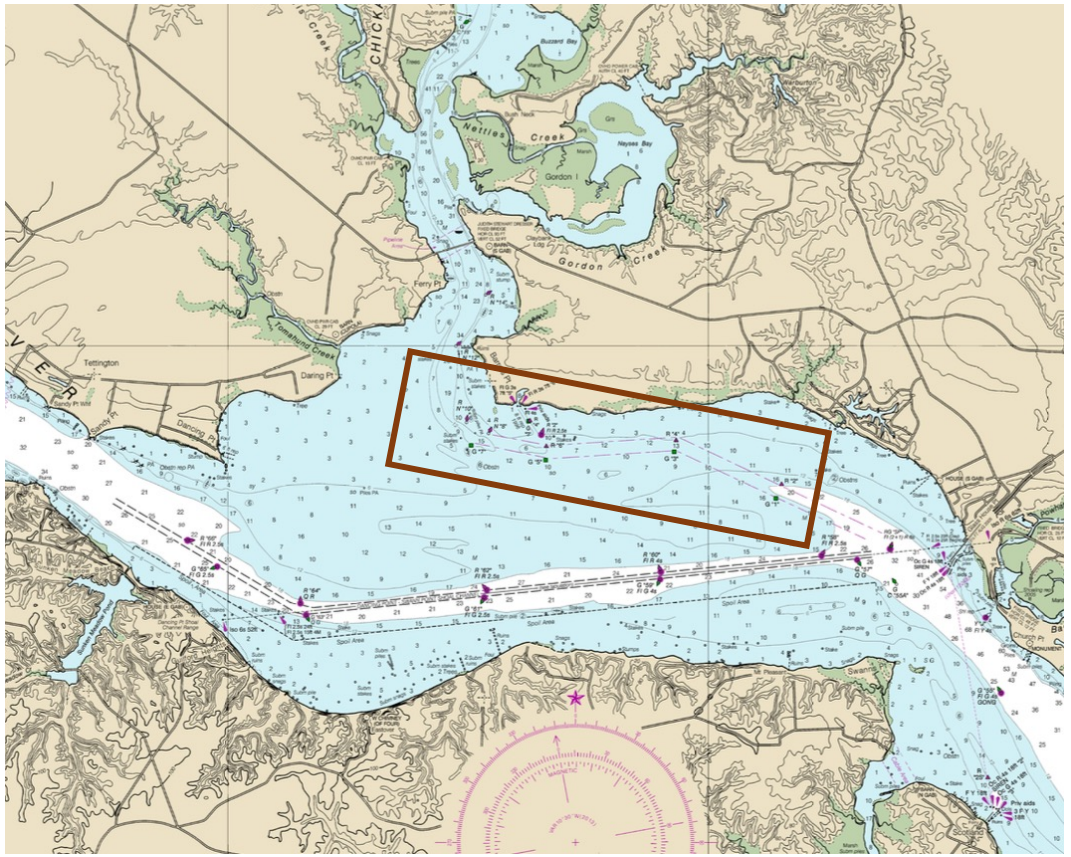
Local refinements in the James River



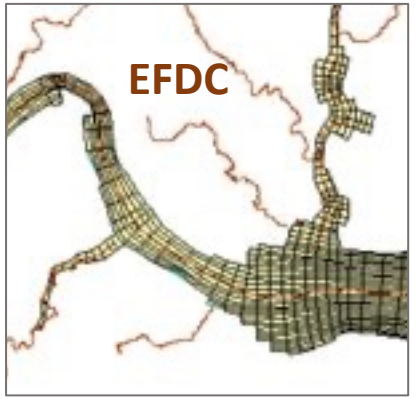
- Along counters (e.g., 9 m and 6 m) to have arcs capture the major channels all the way from the shipping channel to the fall line.
- Construct sufficient quals to capture major sub-tributaries (e.g., Elizabeth R.)
- Refine **cross-channel** and along-channel resolutions

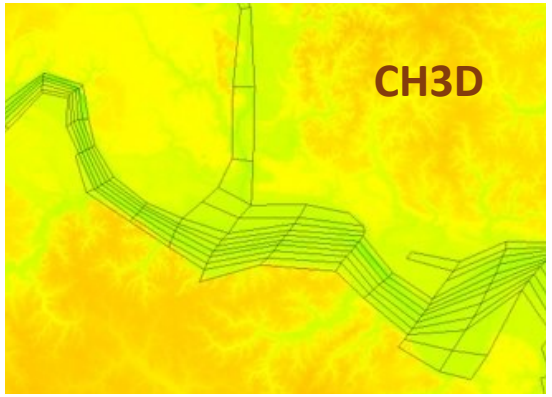
Local refinements



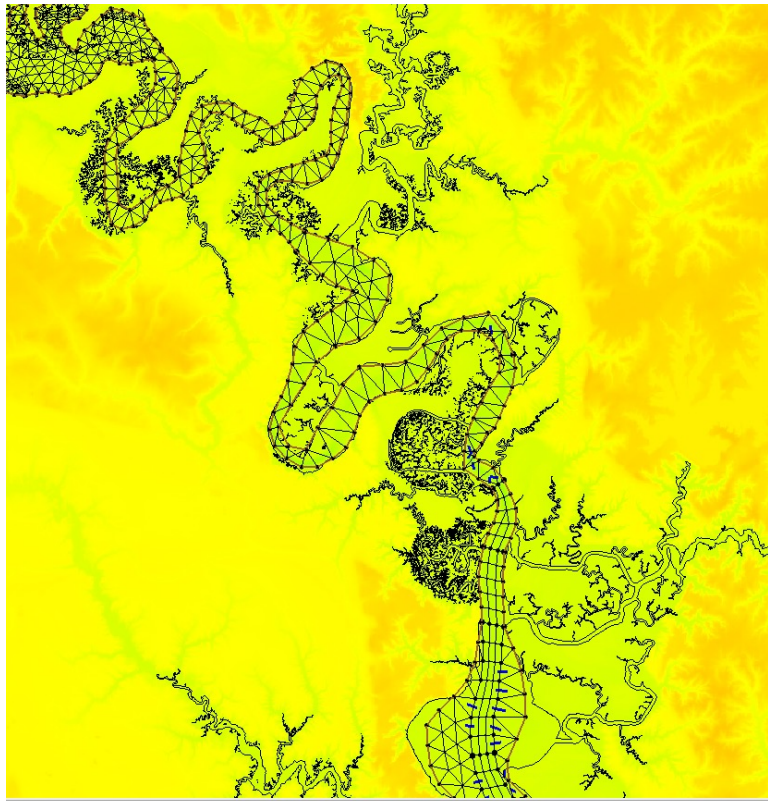


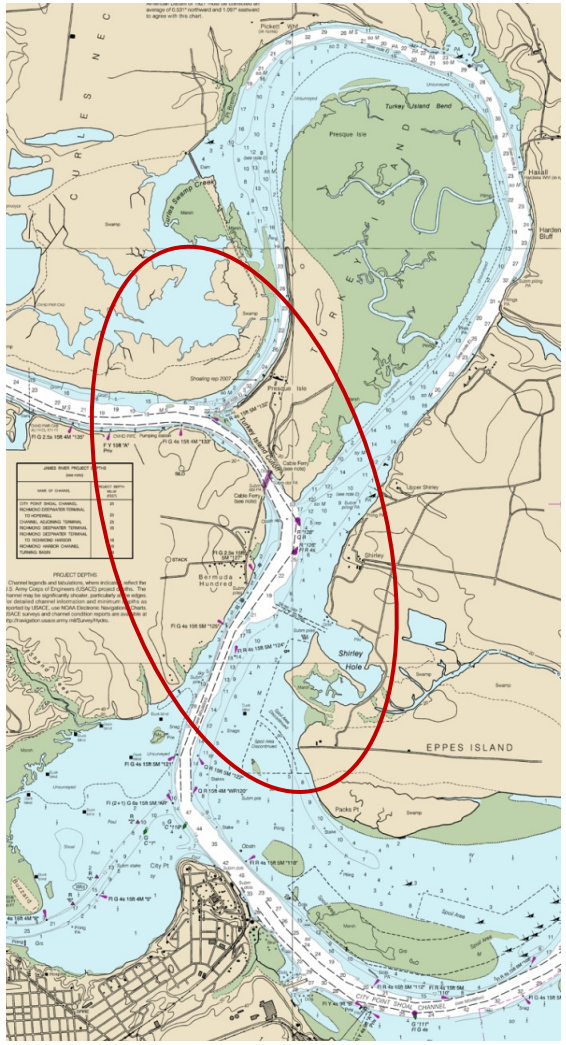
Construct sufficient quals to link the James and Chickahominy R. based on both DEM and nautical charts



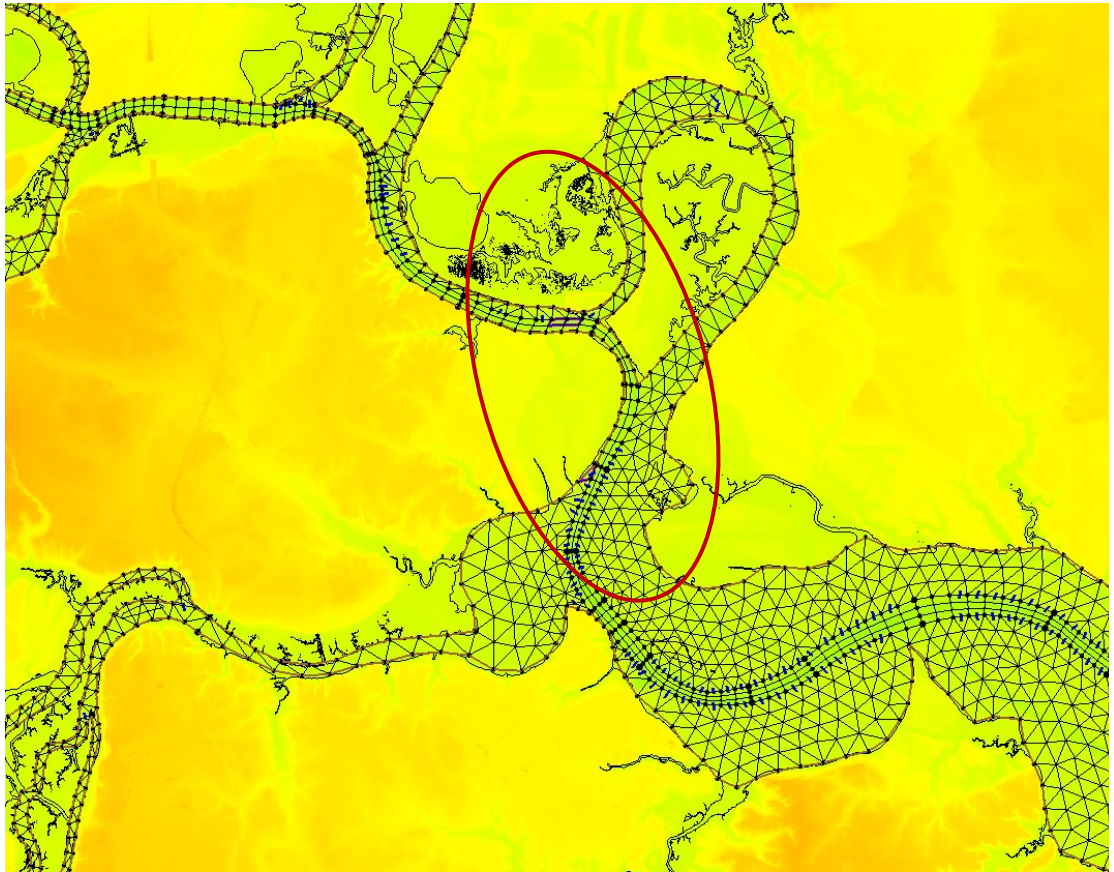


Local refinements -- excluding wetlands for current phase



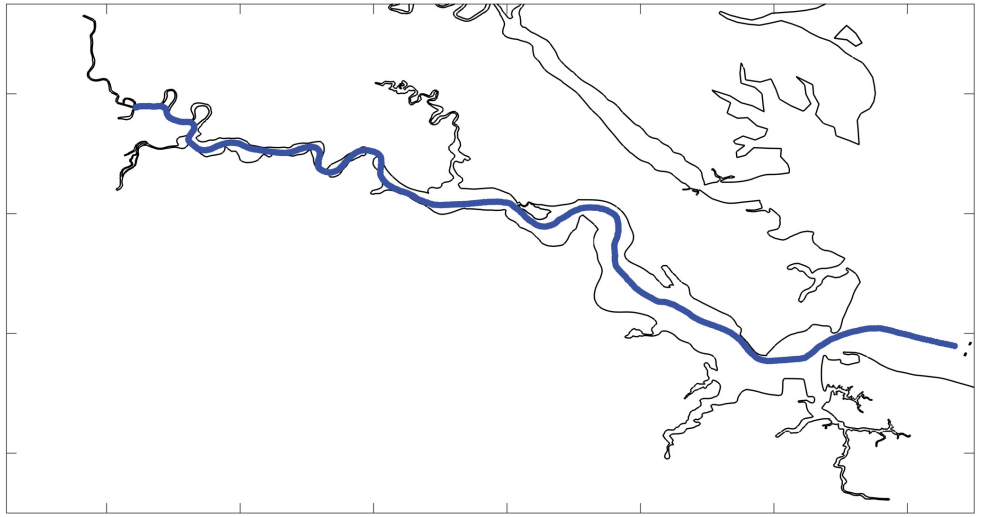


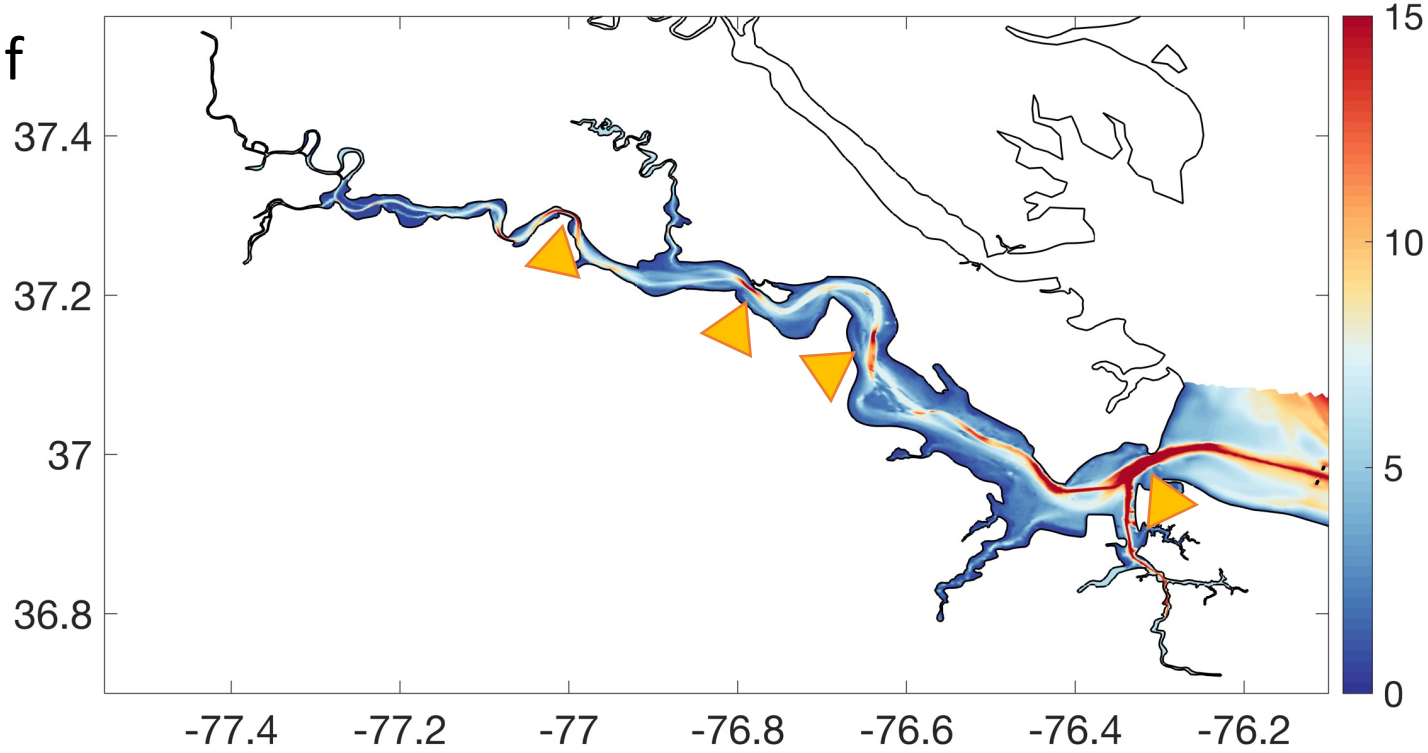
- The grid covers shoals and major channels within the 0 m contour
- Tidal wetlands are not included so far.
- This version of grid will serve as a base for the next level of developments.



Hybrid shaved vertical grid system

- Maximum 52 layers for continental shelf
- Minimum 2 layers for shallow shoals

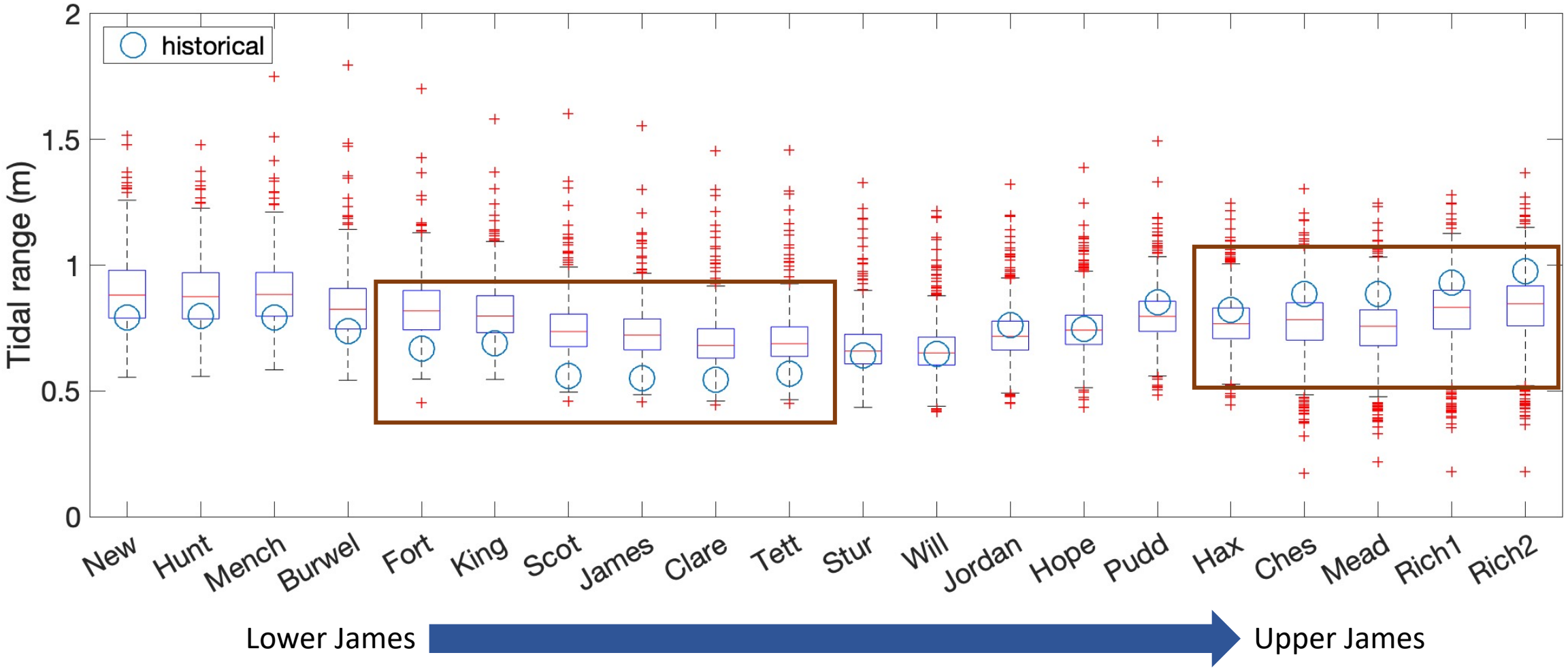




Vertical grid along the James channel

Preliminary results – tidal range

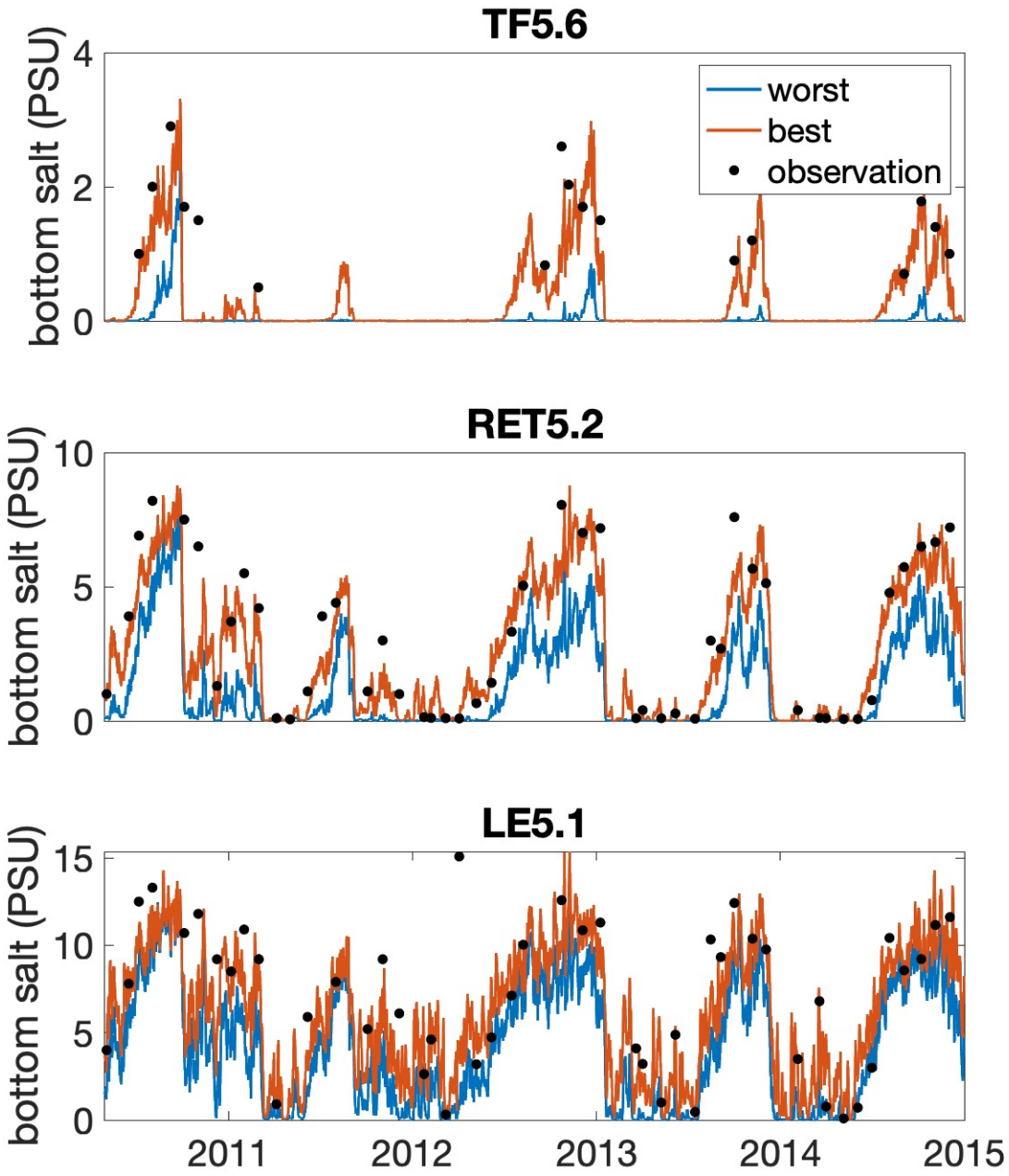
- Good capture of the increasing trend of tidal range towards upper streams
- Overestimation of mid-James tidal range



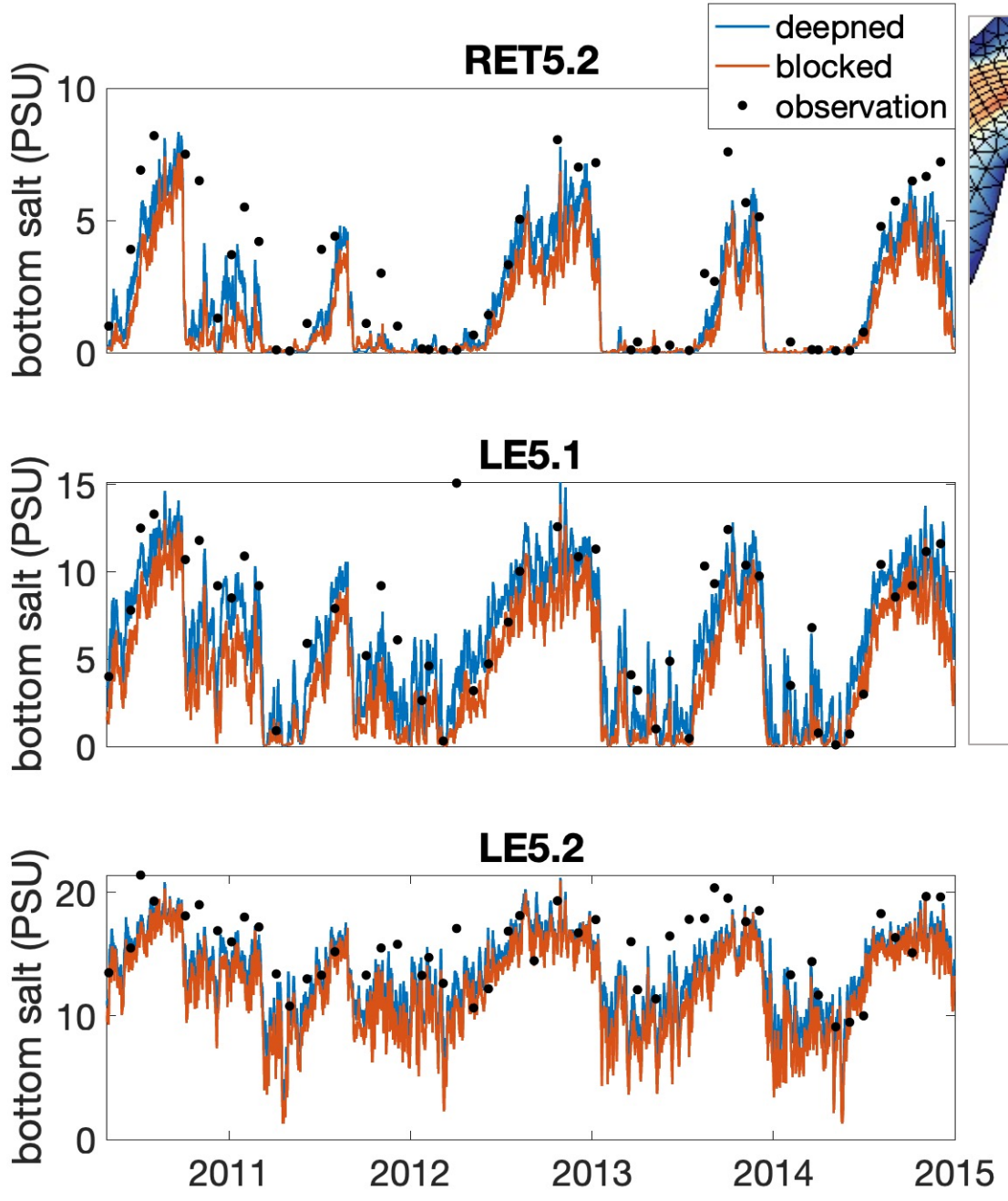
Preliminary results – salinity

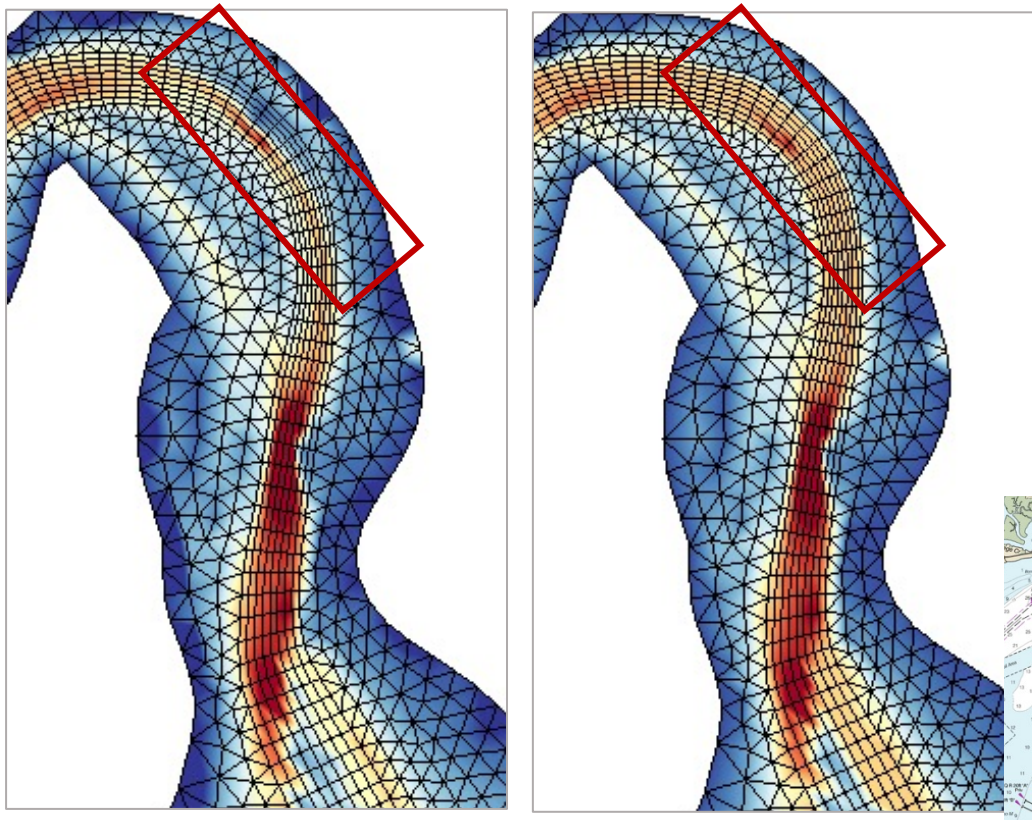
- Overall reasonable salt water intrusion distance and stratification level
- Reasonable skills along the river cross the polyhaline, mesohaline, oligohaline, and tidal fresh zones.

Station	Layer	RMSE	CC	RE_(%)
TF5.5A	S	0.3345	1	94.611
TF5.5A	B	0.33422	1	94.53
TF5.6	S	0.81566	0.42552	47.838
TF5.6	B	0.97632	0.4437	48.45
RET5.1A	S	1.2481	0.67847	42.454
RET5.1A	B	1.2461	0.68741	42.394
RET5.2	S	1.1834	0.89696	19.47
RET5.2	B	1.4235	0.90868	23.544
LE5.1	S	1.6696	0.90863	13.155
LE5.1	B	2.3974	0.8541	13.001
LE5.2	S	2.3533	0.86042	8.0531
LE5.2	B	3.1089	0.6974	13.382
LE5.3	S	1.9726	0.88233	3.955
LE5.3	B	2.1961	0.66994	0.32117
LE5.4	S	1.5982	0.88799	3.4387
LE5.4	B	1.9268	0.70842	2.7381



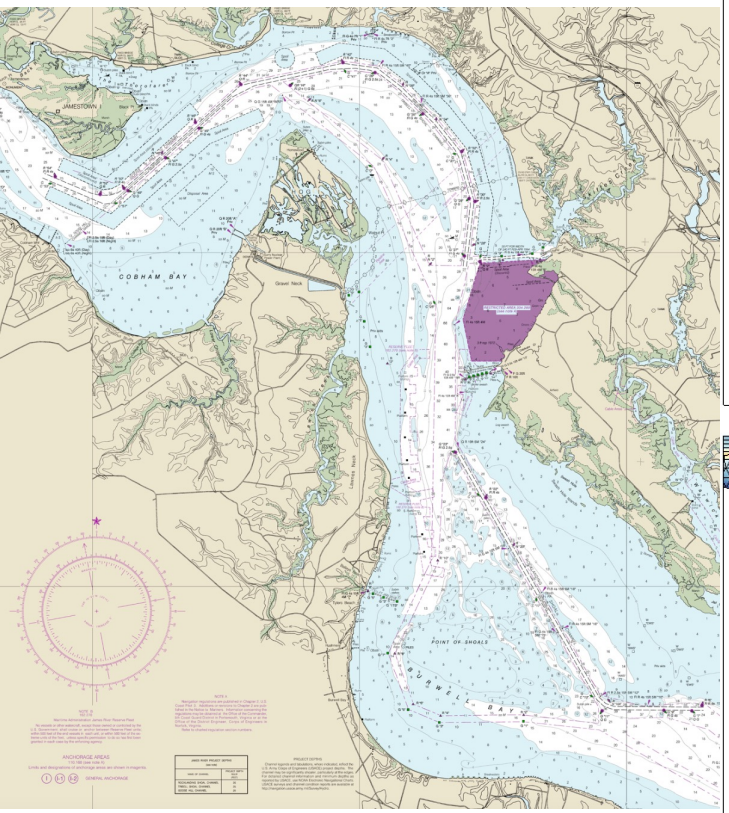
Sensitivity tests: w/ vs. w/o maintaining shipping channel depths

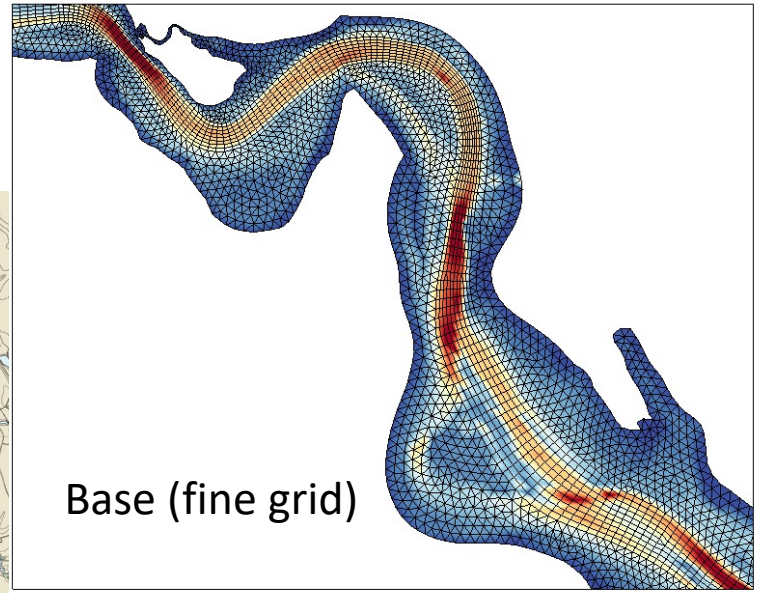


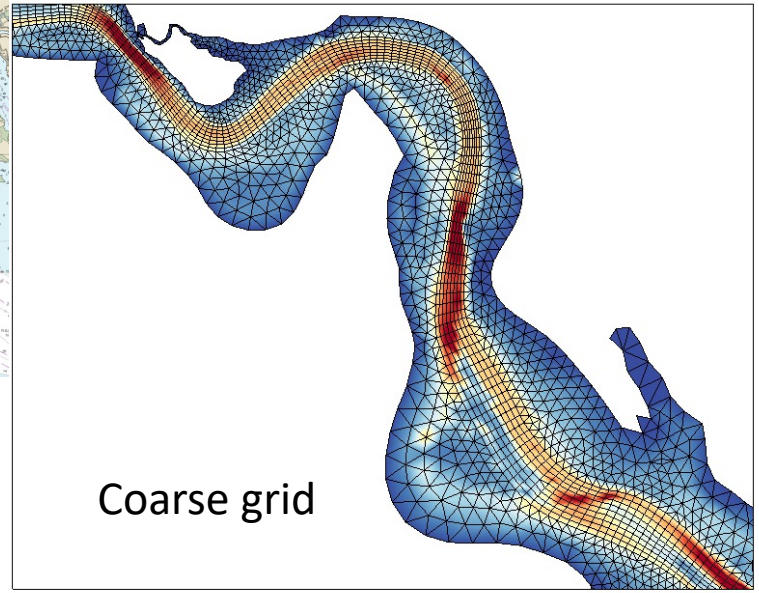


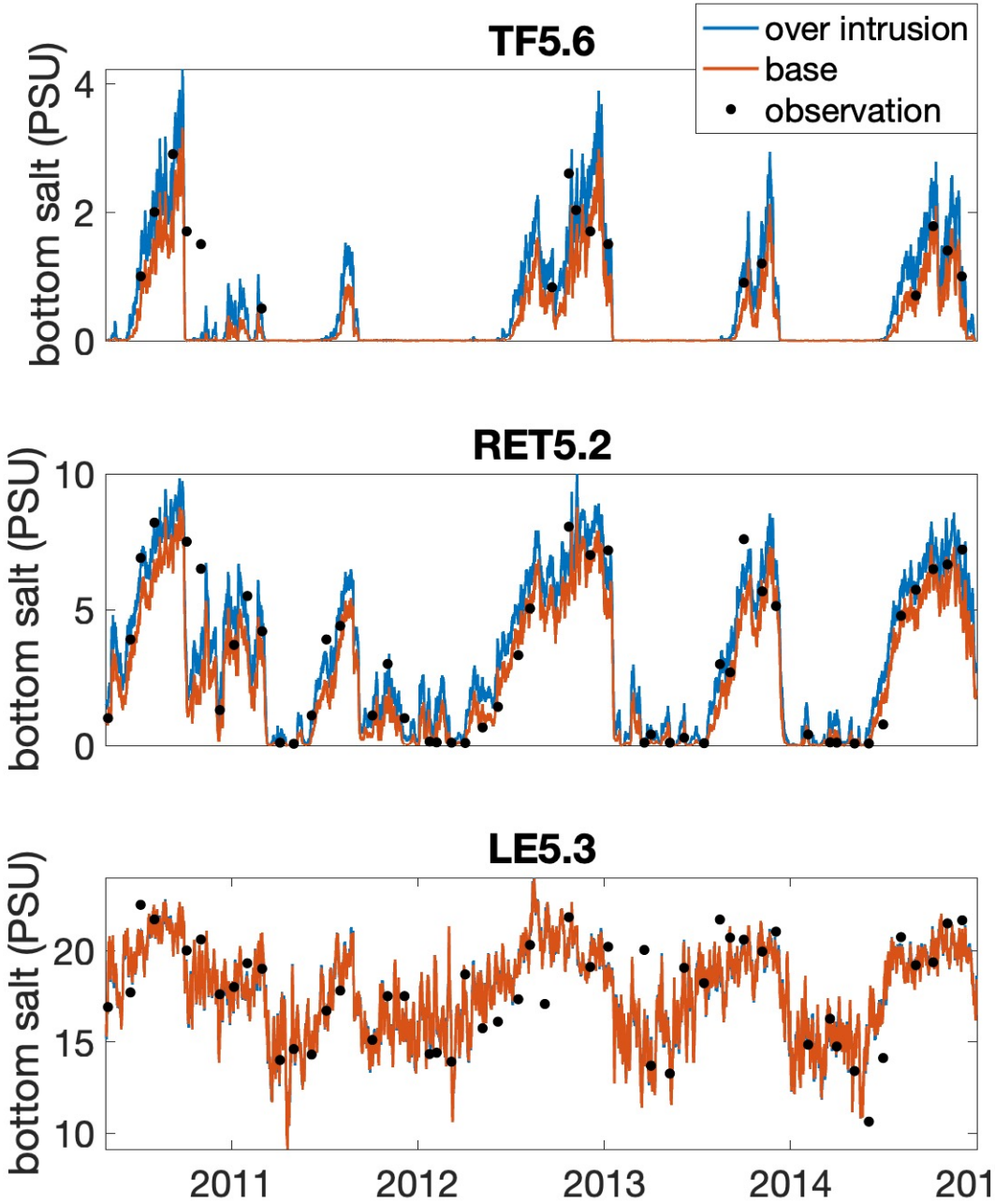
Deepened channel with standard minimum depth helps to get the intrusion upwards.

Sensitivity tests: impacts of resolution at Mid James River

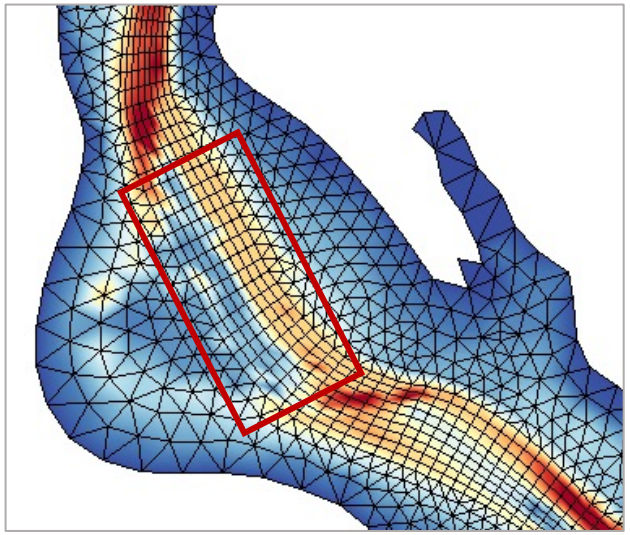


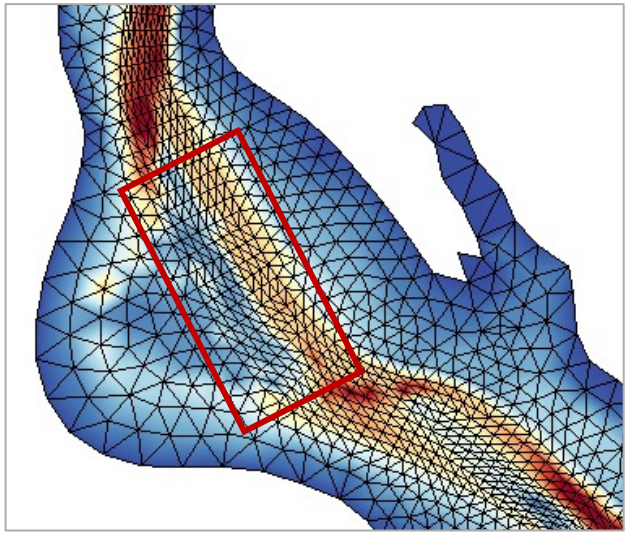


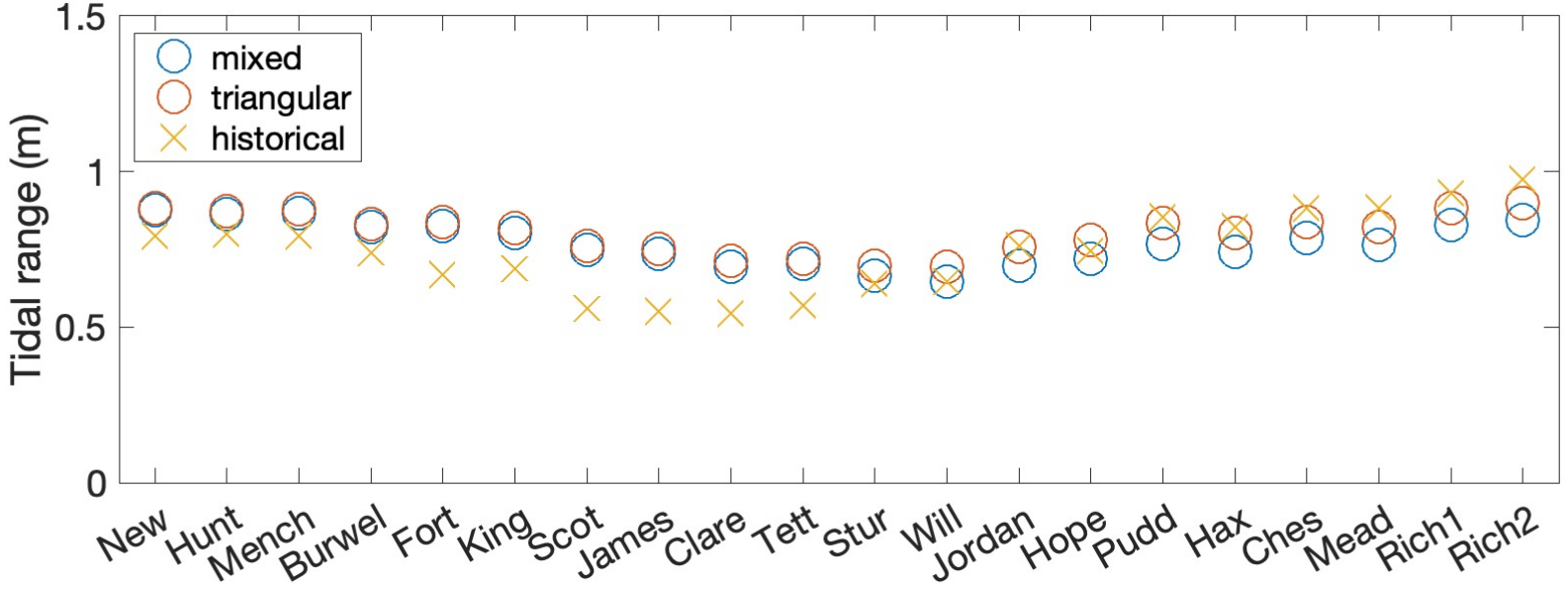


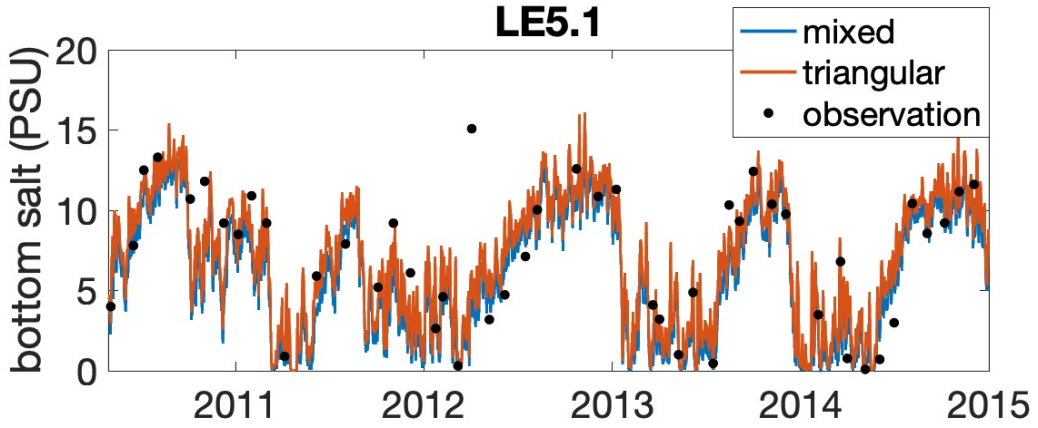


Sensitivity tests: triangular vs. mixed hybrid grids with orthogonal channel meshes







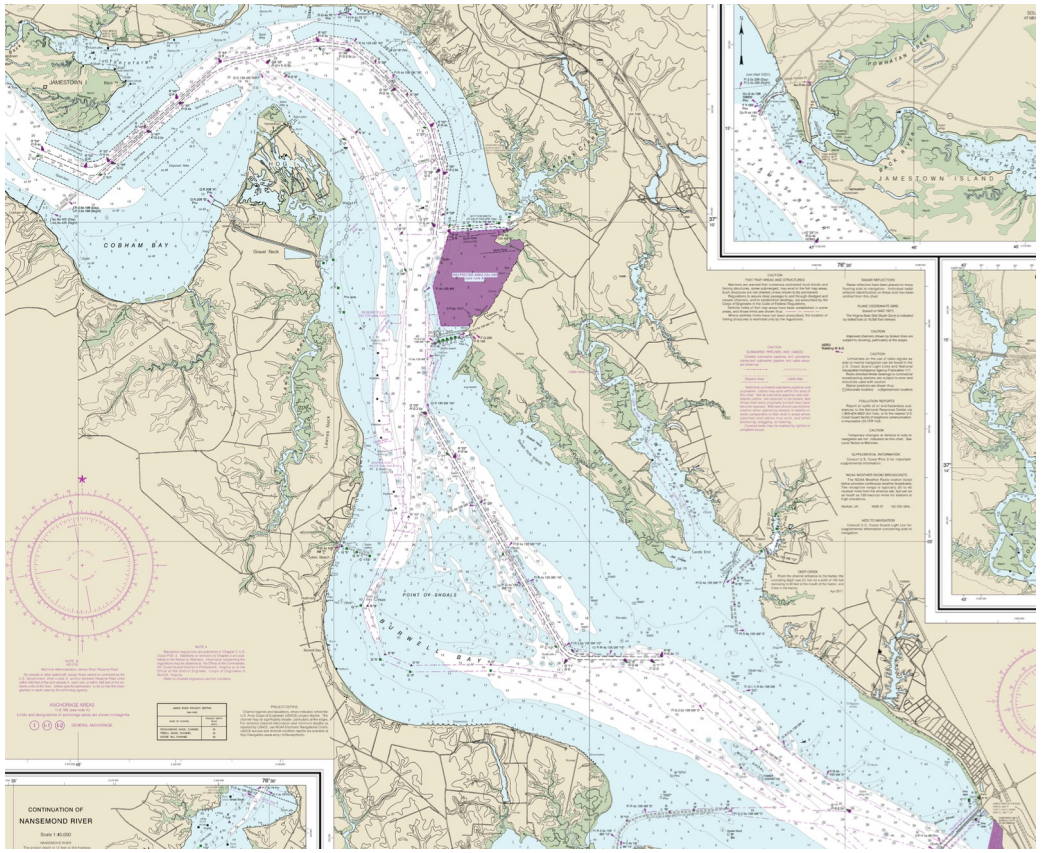


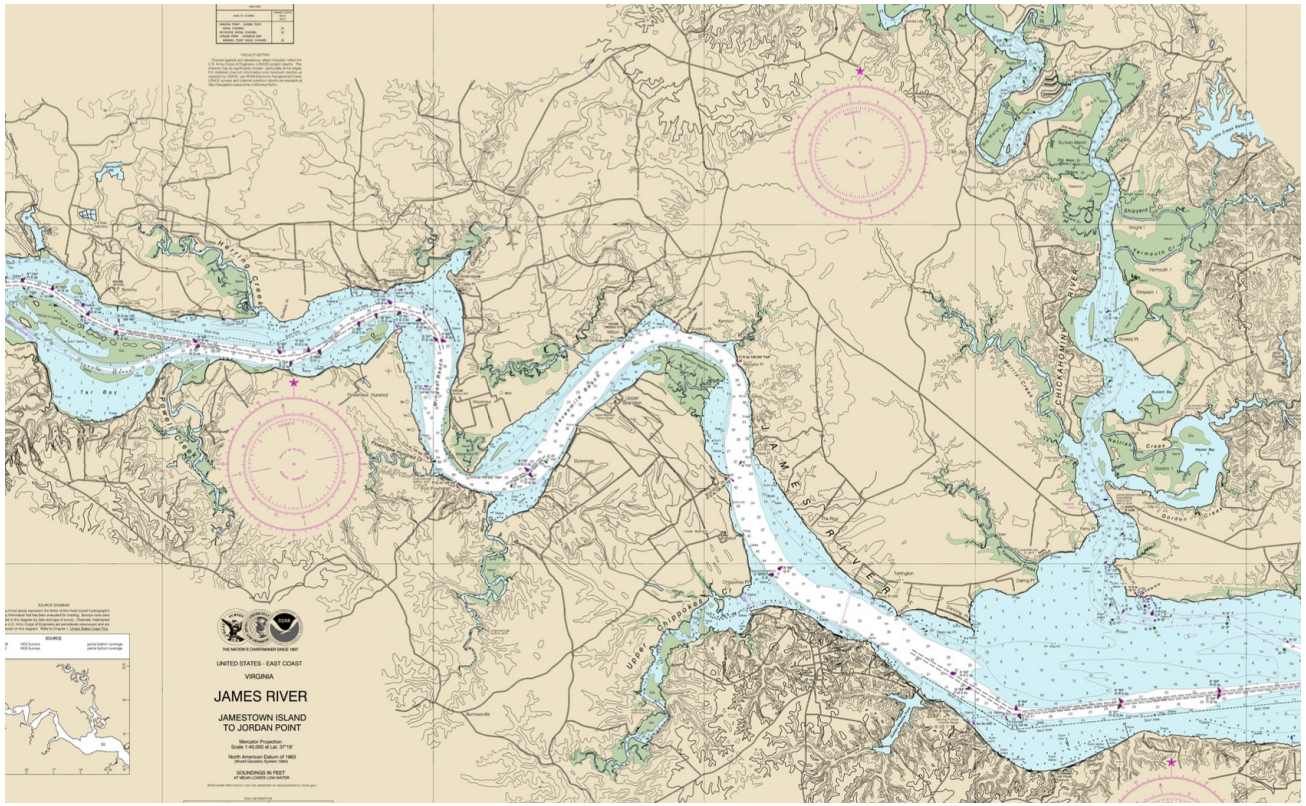
Minor increase of salt water intrusion with spitted triangular grids

- Using triangular grids has larger computational costs
- Splitting the quadrangular elements is a simple way of testing with finer resolutions guaranteed in the channels. One more possible way to test is to pave the channels with lower resolution.

Next steps

- Next phase of grid generation
  - Add resolution to shallow shoals and areas of interests
  - Include tidal wetlands
- Apply tests of water quality simulations

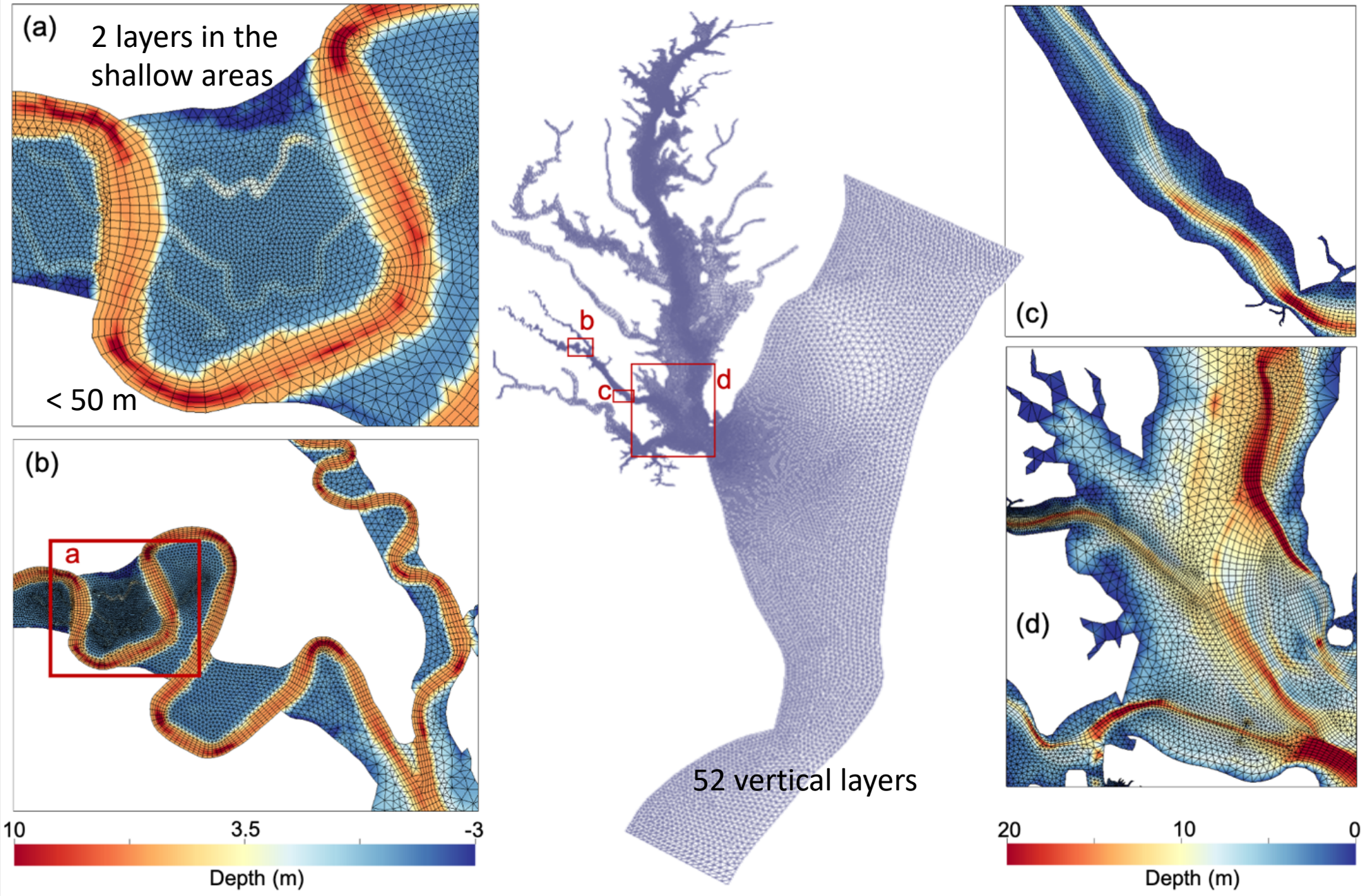




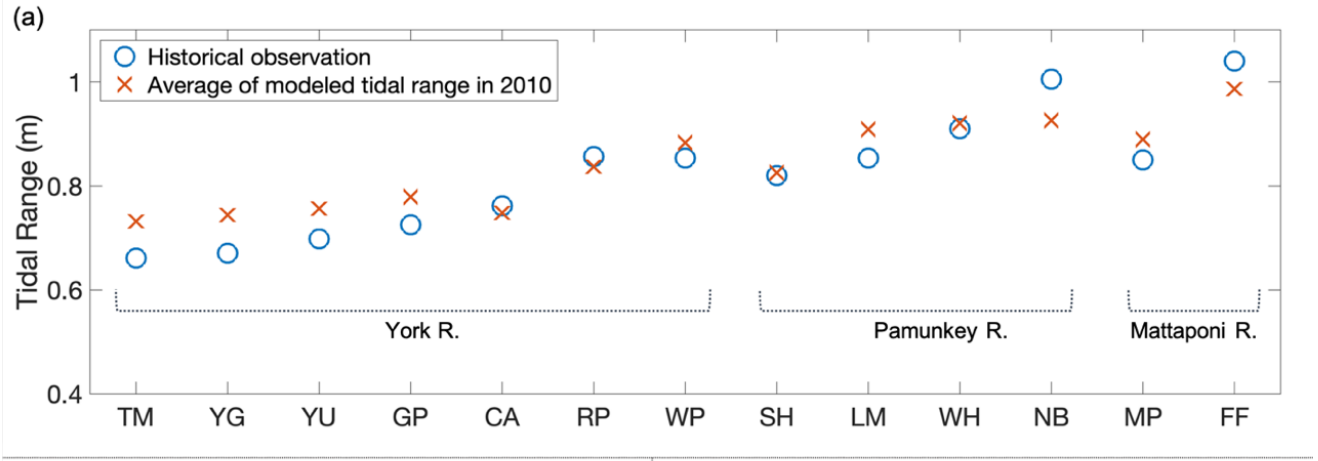
Suggestions on locations of interest?

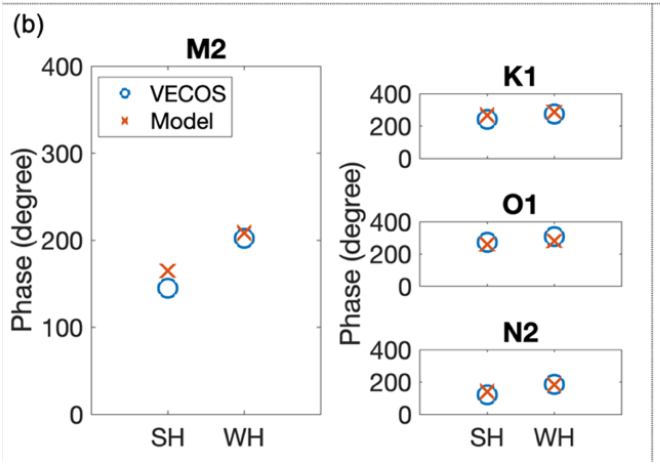
Pilot work in the York River

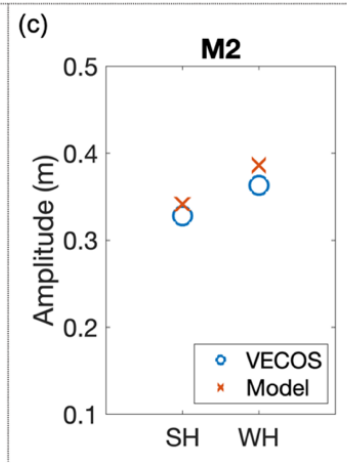
Model implementation in the York River including marshes

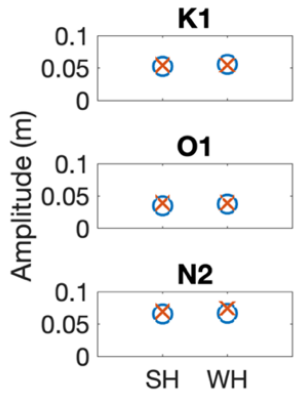


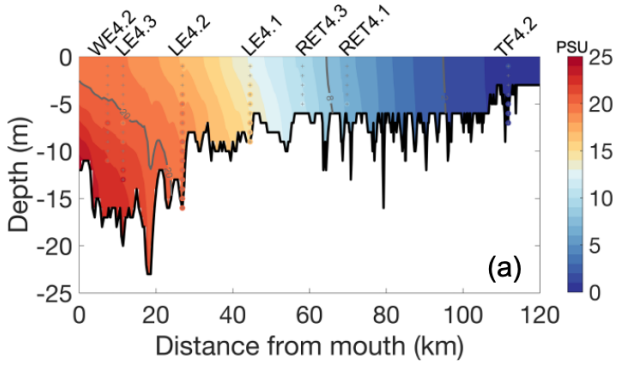
Model assessment – hydrodynamics

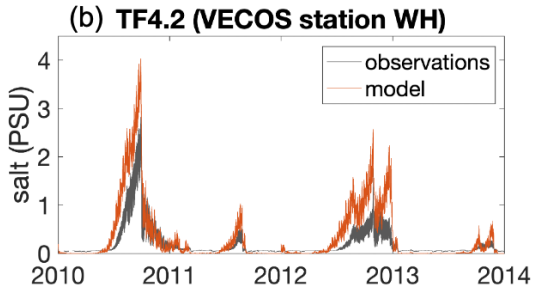


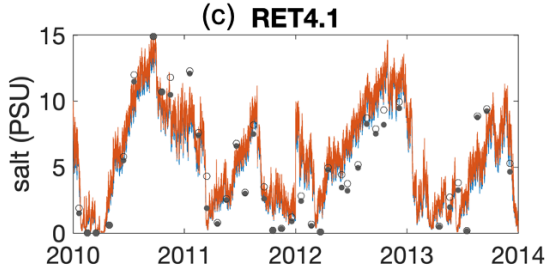


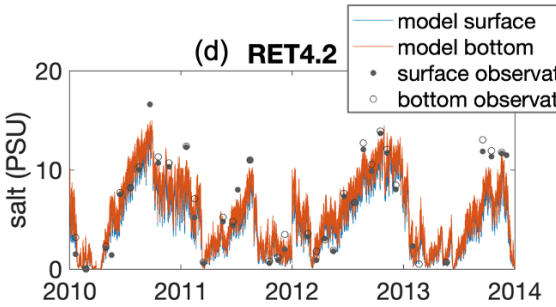


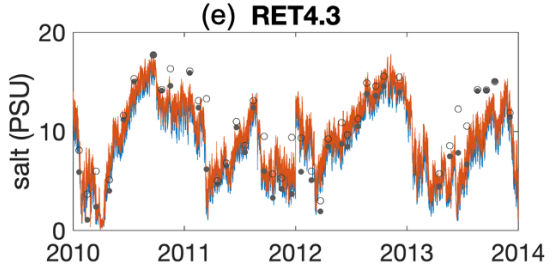


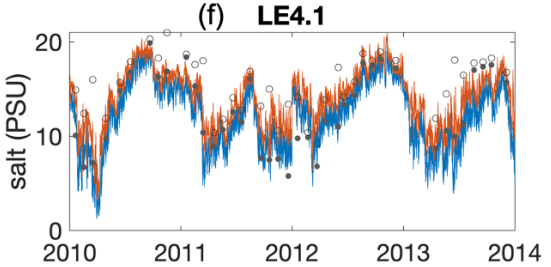


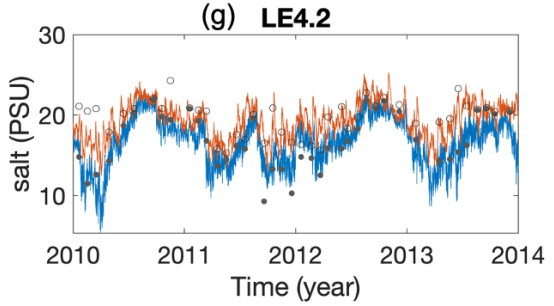


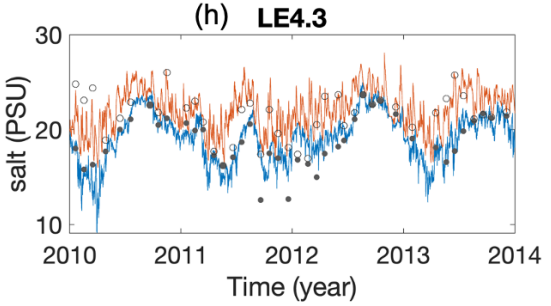




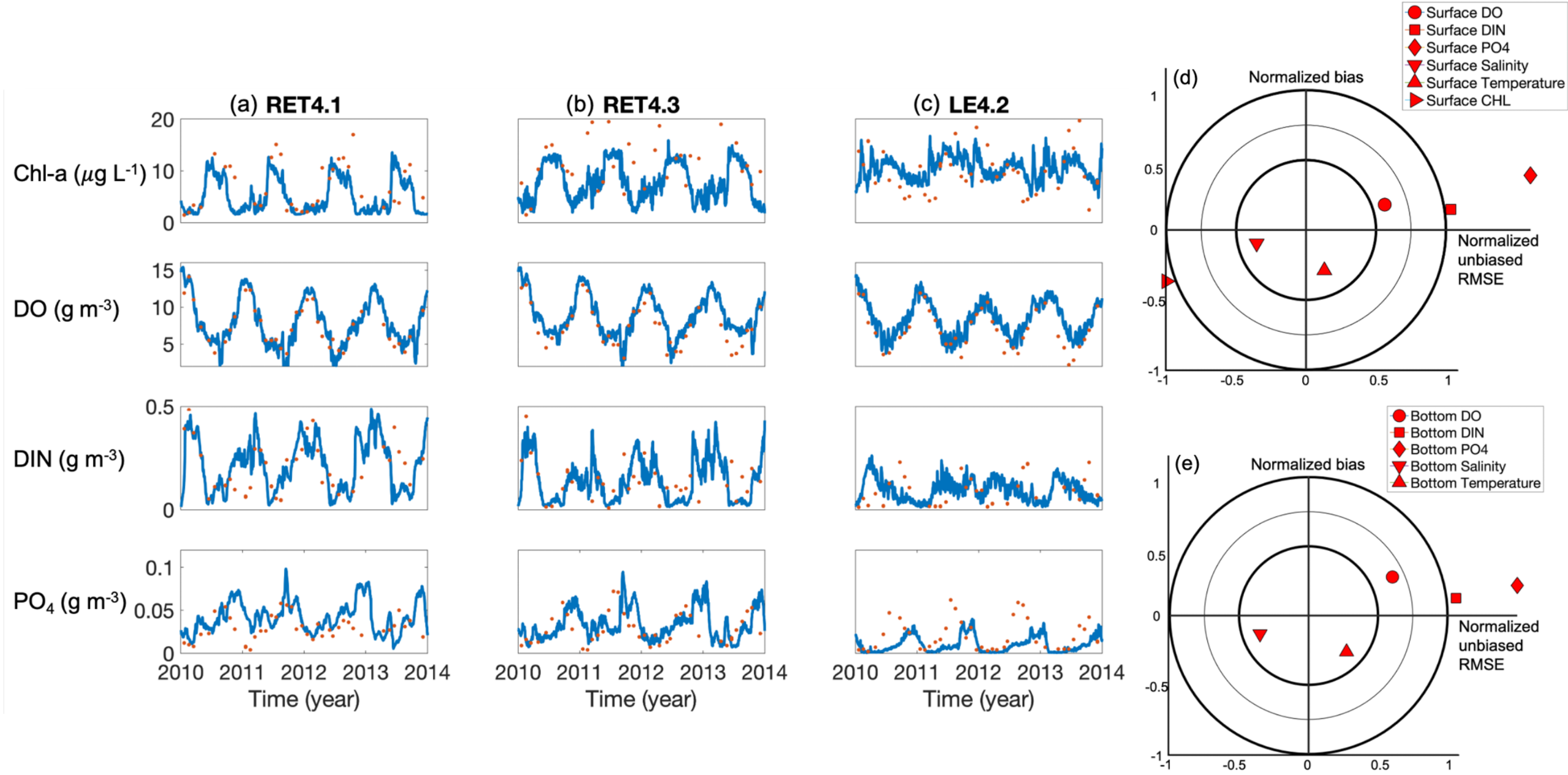




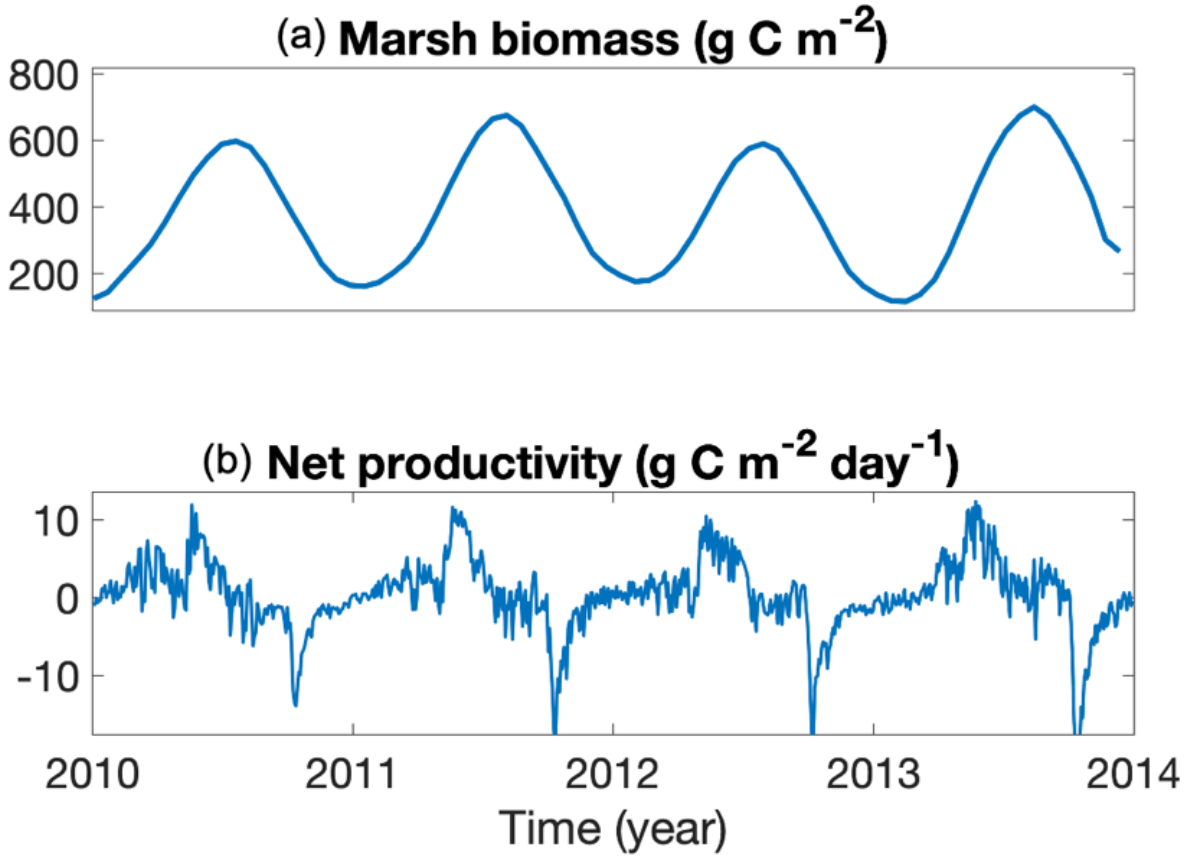


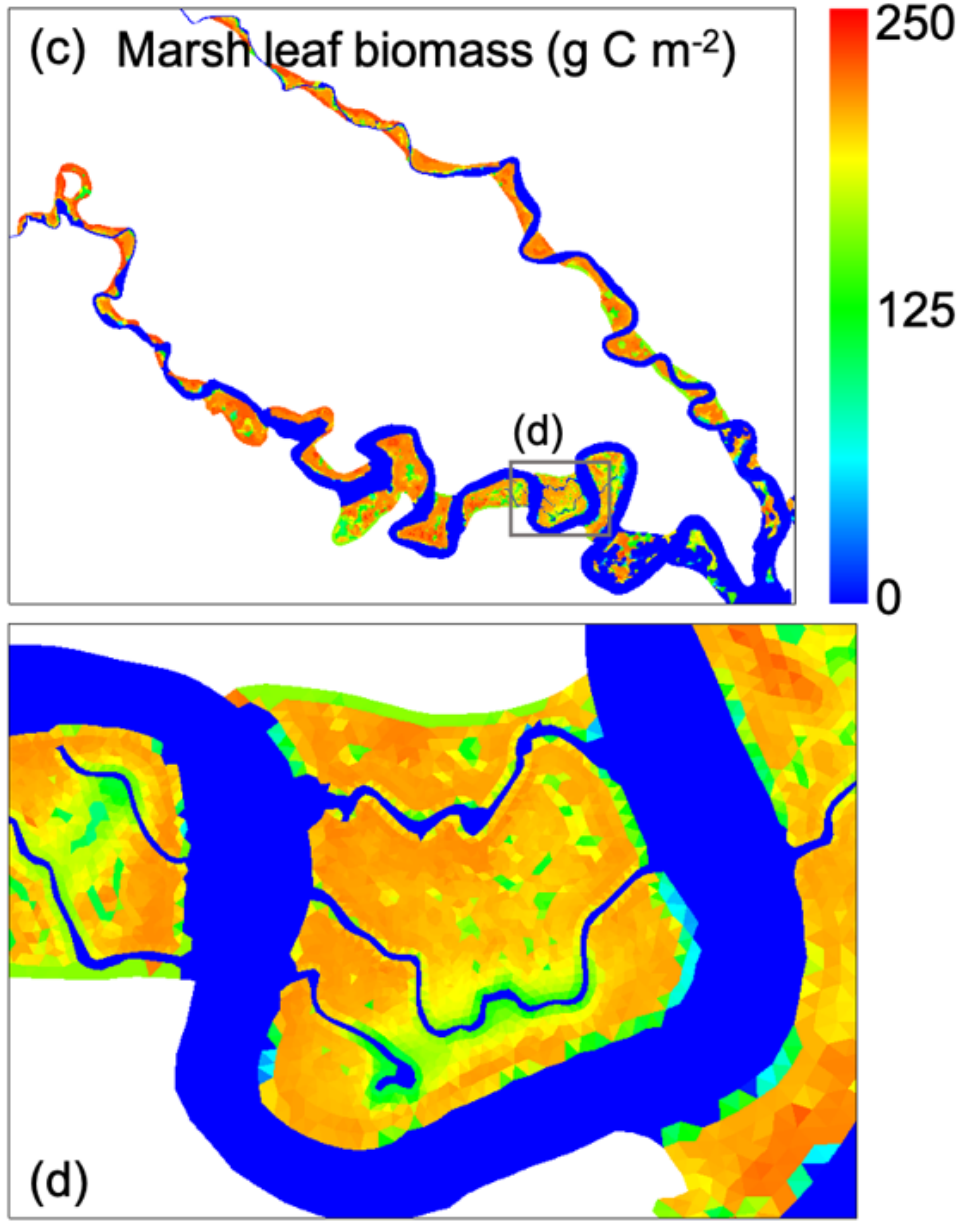


Model assessment – water quality



Model assessment – marsh

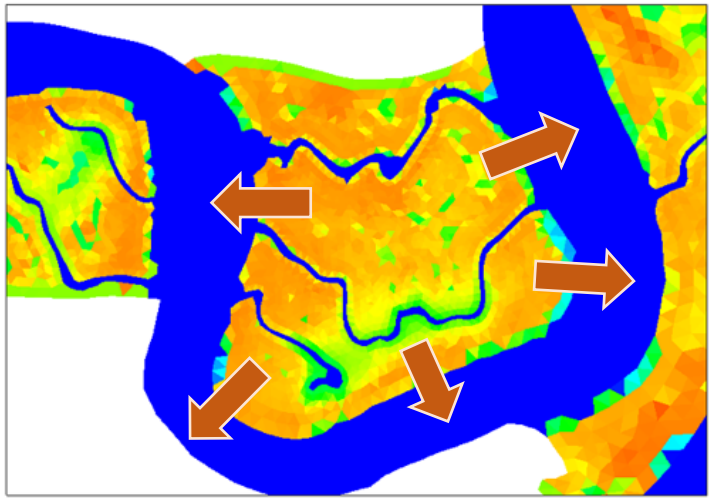




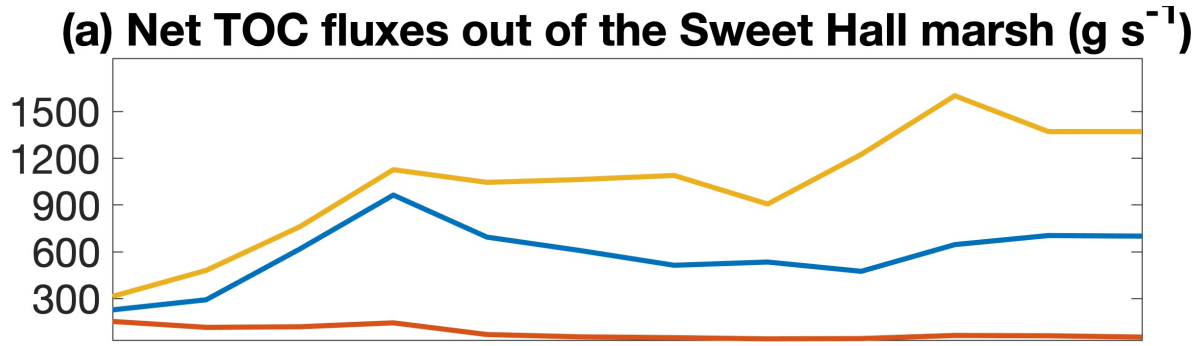
- Reasonable magnitudes of biomass and productivity
- Sensible seasonal pattern of biomass and productivity

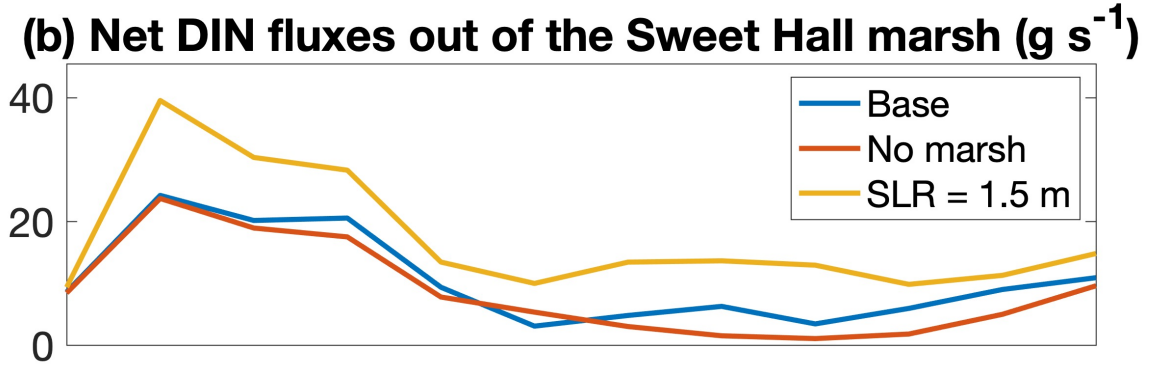
Materials out from the marshes

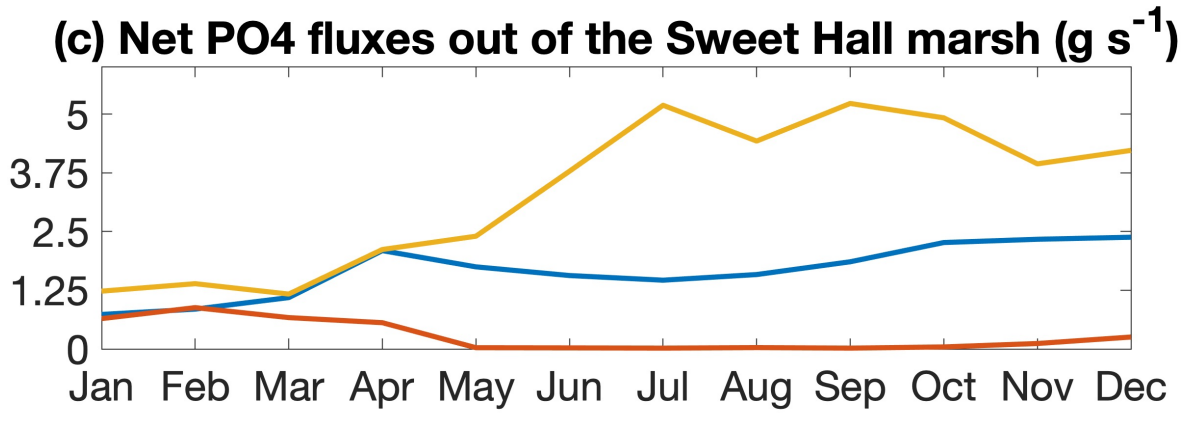
- Base Case
- Sensitivity test of “No marsh” without changing the hydrodynamics
- Sea-level rise of SLR with assumptions of “Keep-up”



- Marsh is a significant source of organic matter and nutrients
- SLR causes more outfluxes of materials from the marshes.

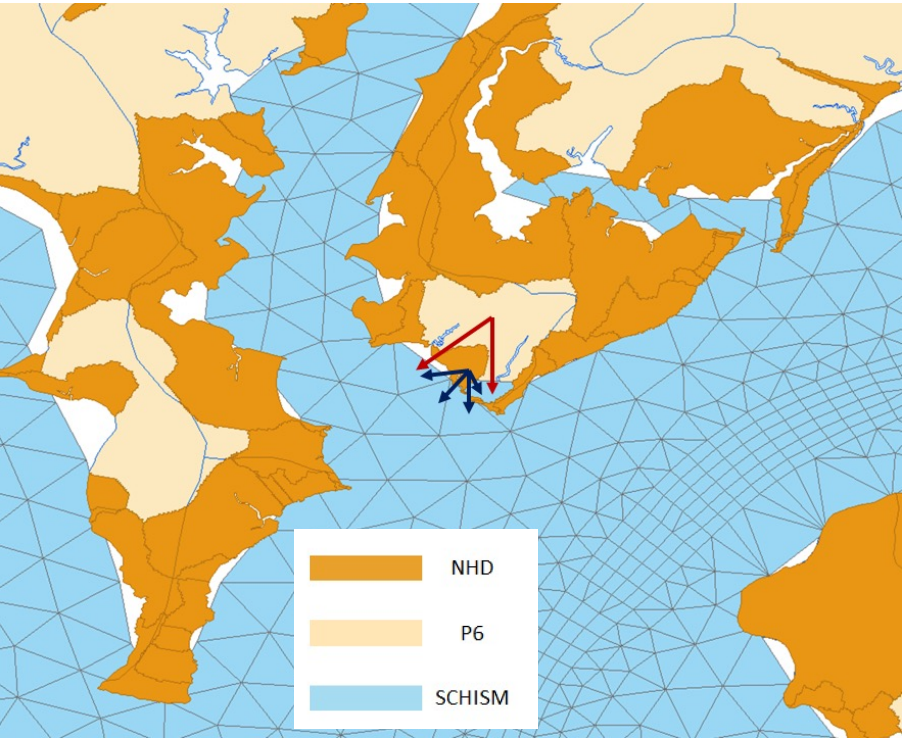






Pilot work on linking the NHD segments to estuarine model

The linkage to prototype NHD segments



Application of an unstructured-grid model in the Chesapeake prototype

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1. Virginia Institute of Marine Science
2. U.S. EPA Chesapeake Bay Program Office

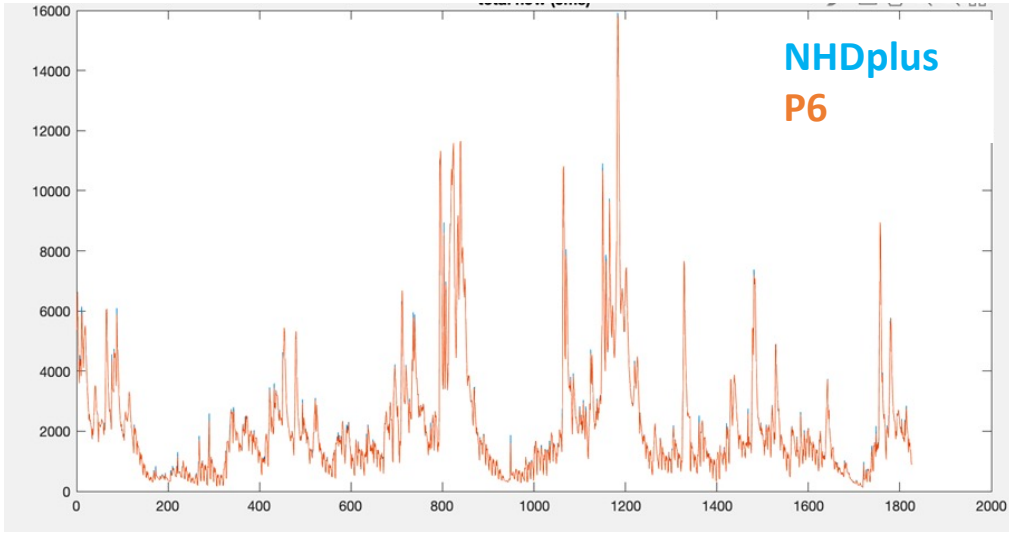
Chesapeake Community Research Symposium 2020

- Does the NHD segment touch the land boundary?
  - Yes: split the loading evenly to number of boundary elements adjacent to the segment
  - No: find the nearest land boundary element and assign the flow
- The final flow is the sum from NPS/PS and NHDplus segments, using the interpolation procedure in 1-2
- There is no nutrient loading data from NHDplus segments yet
  - use P6 loadings and try to reconcile the flow and nutrient
  - Brings uncertainty

Cross check against P6

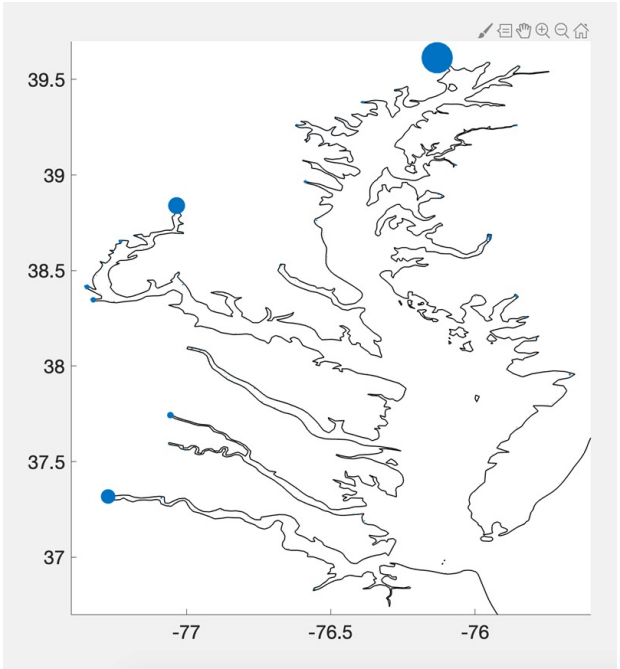
- Total flow from all rivers is consistent between P6 and NHDplus
- Nutrient conversion is trickier: notice that there are some discrepancies between the old and new as we tried to reconcile the old nutrient loadings with new flow inputs
  - The approach used has implications for WQ results

Total flow

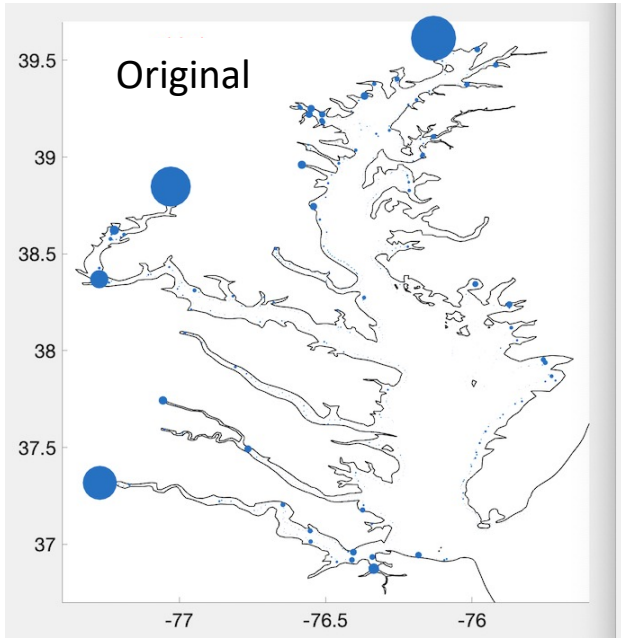


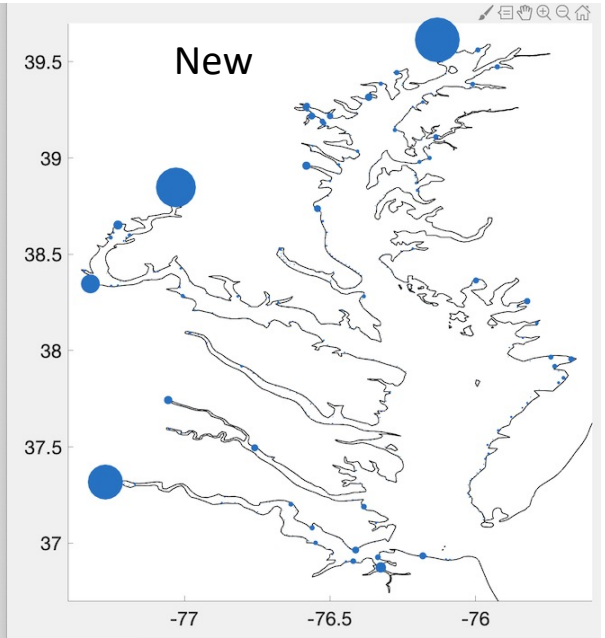
Days from Jan 1, 1991

Averaged flow



Averaged PO4

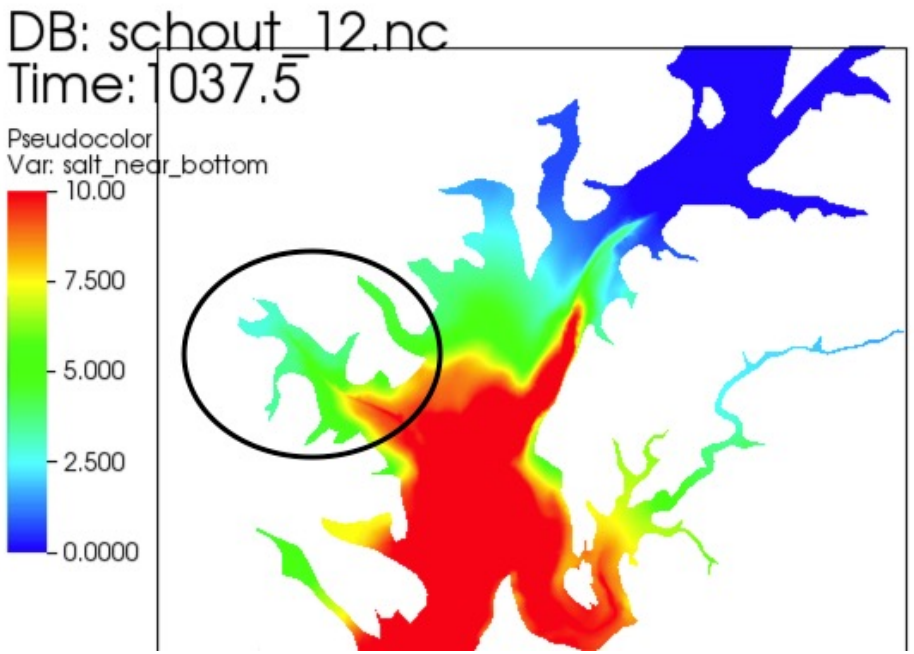




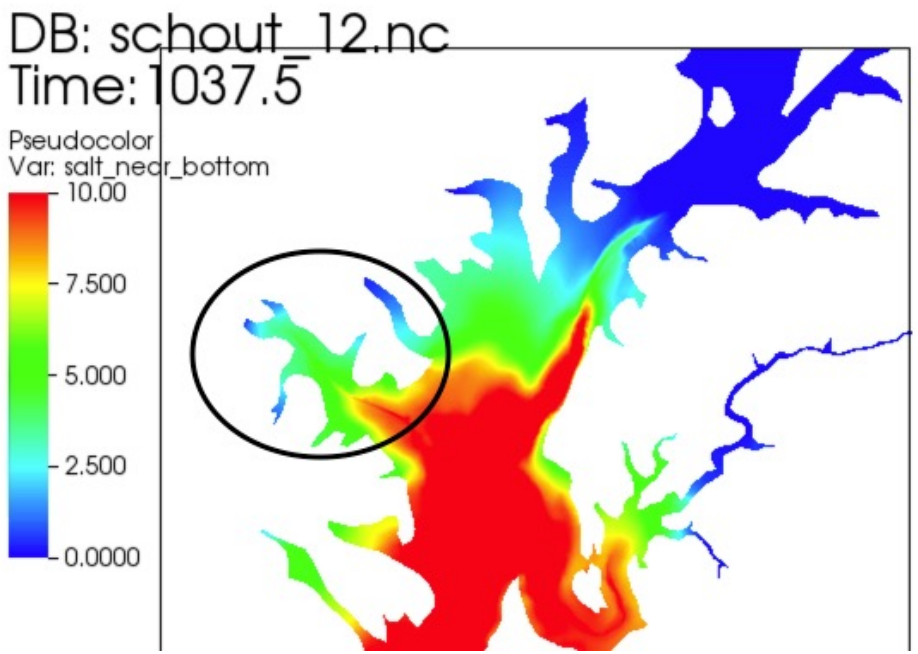
Impact of NHDplus flow on tributaries

* Did not significantly affect the dynamics in main stem of the Bay
* The finer resolution in NHDplus flow allows us to better capture salinity gradients in tributaries and sub-tributaries
* Needs to further validate the model in those systems

P6

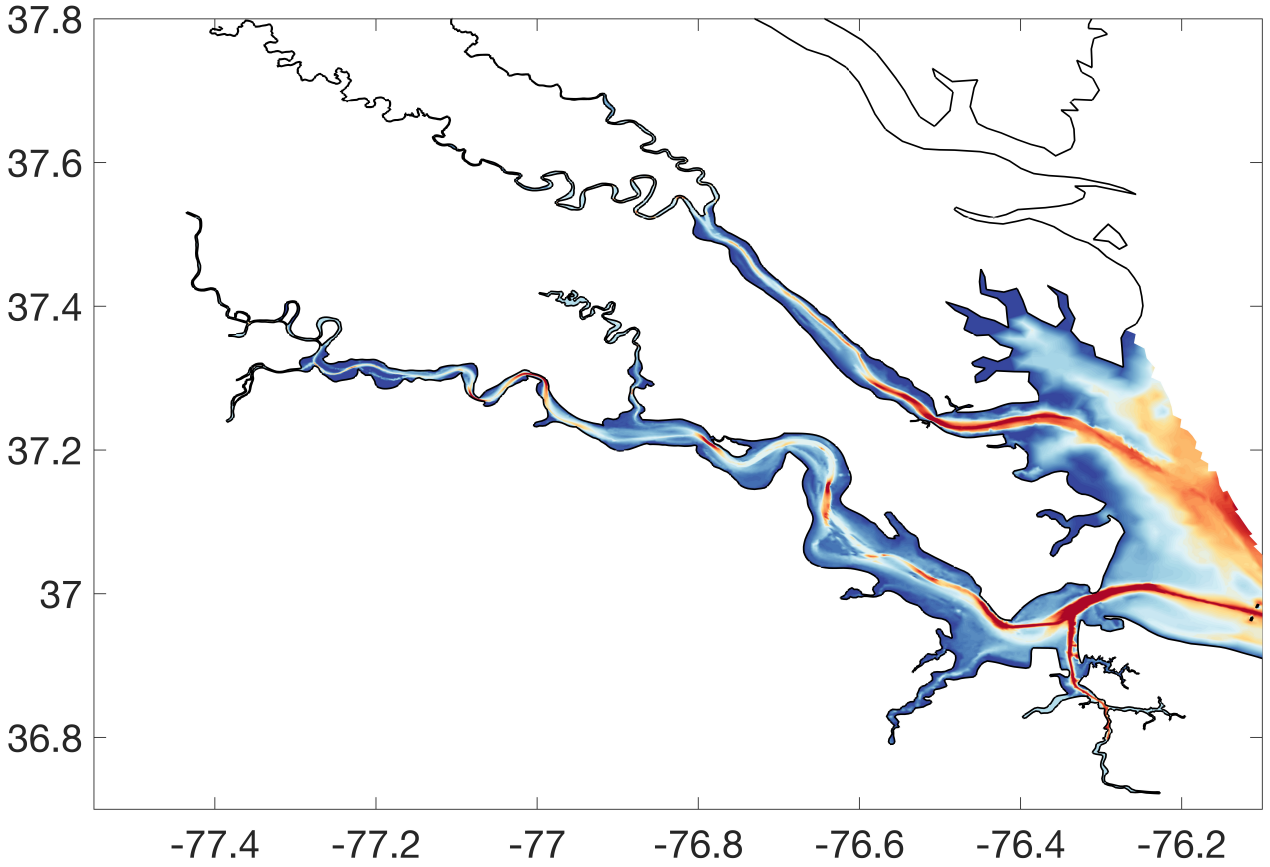


NHDplus

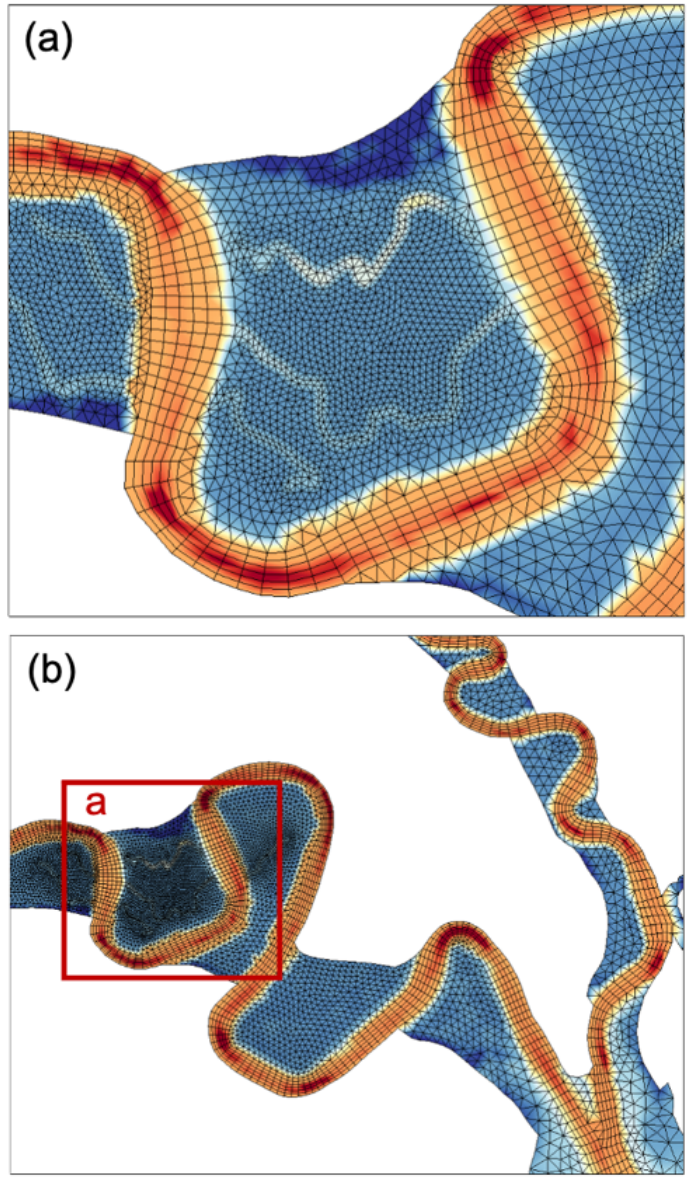


Bottom salinity

Summary



Initiation of James River model development



Coverage of tidal marshes in the York River Estuary

Questions?

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ORISE

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