Expanding the Great Lakes Operational Forecast System to Simulate Coastal Flooding

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Presented by Brooke Odstrchel

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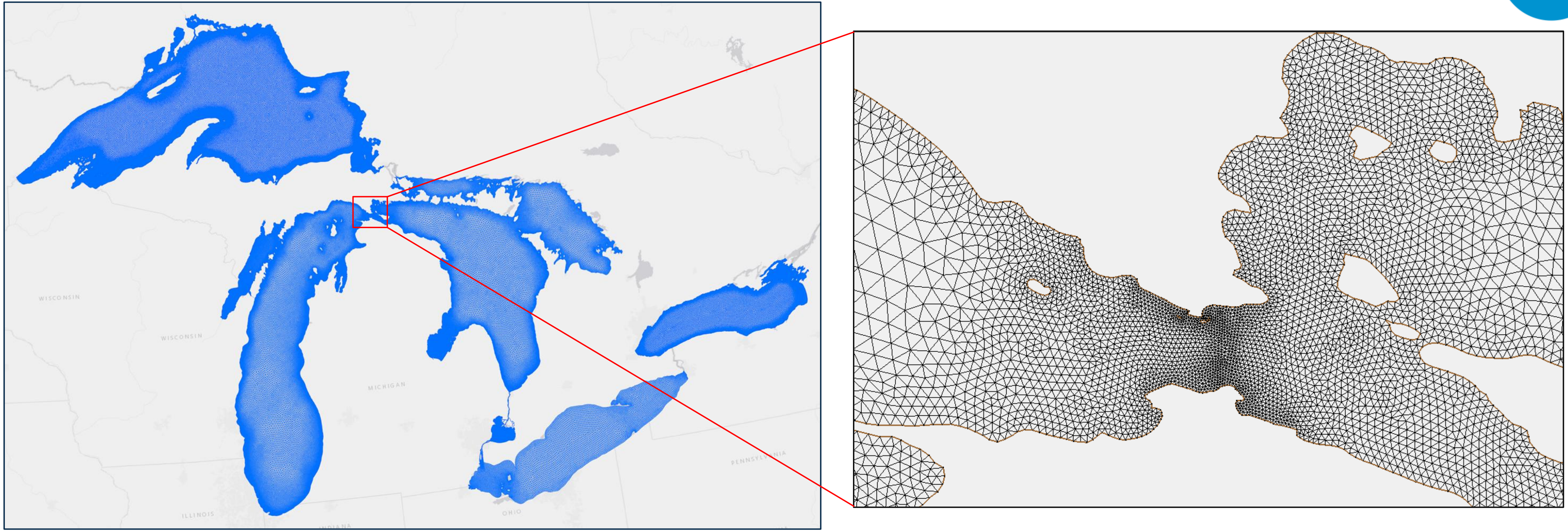
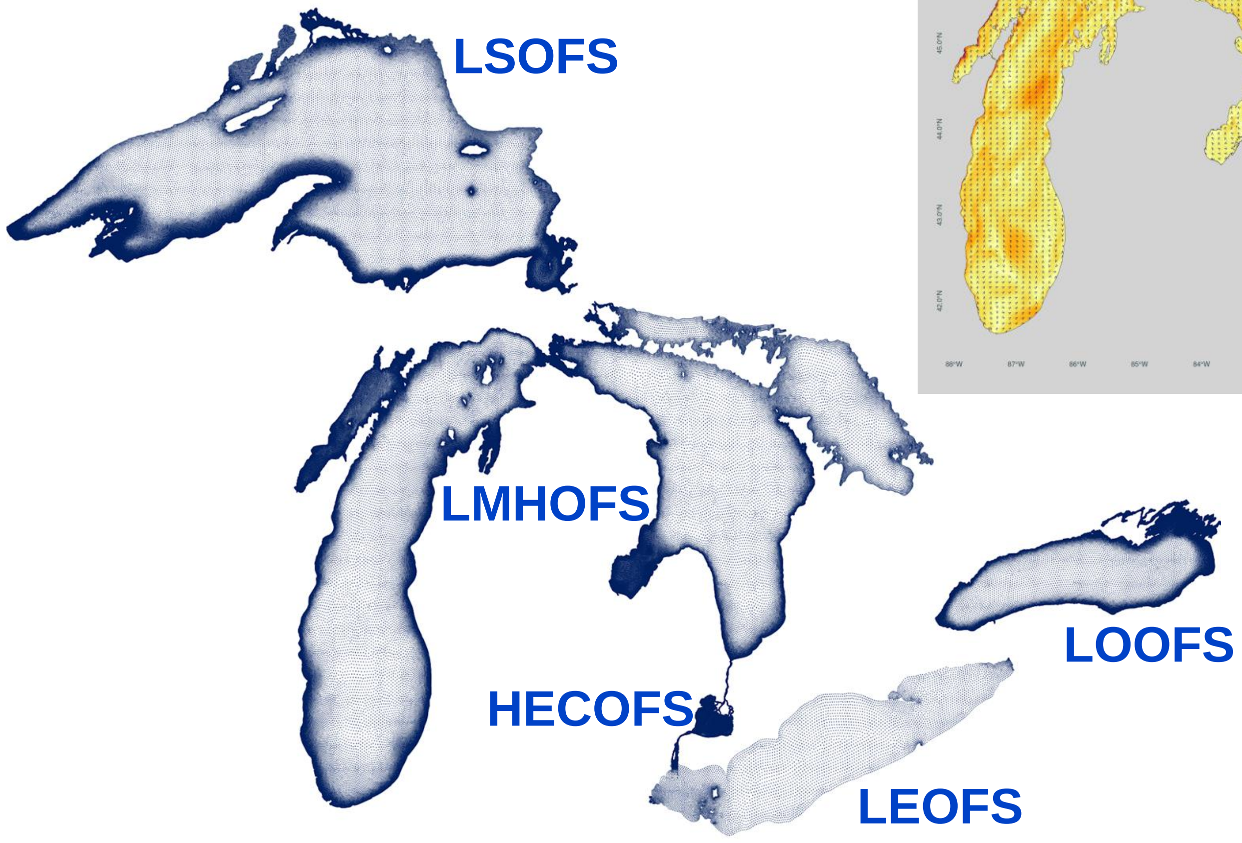
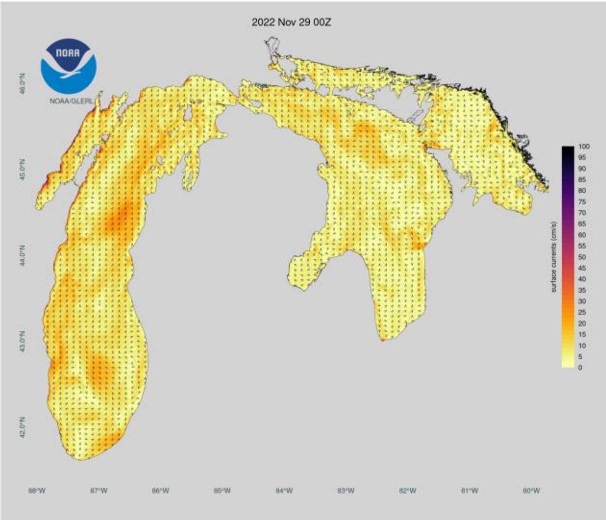
Background and Introduction



- The Great Lakes Operational Forecast System (GLOFS) is a set of 3D hydrodynamic models that simulates physical processes within the Great Lakes.
- Provide near-real time guidance on currents, water temperatures, short-term water level fluctuations (e.g. seiche, storm surge), and ice out 120 hours into the future.
- Built on the Finite Volume Community Ocean Model (FVCOM)
- Resolution is approximately 2.5 km offshore, 200-500m along coastlines



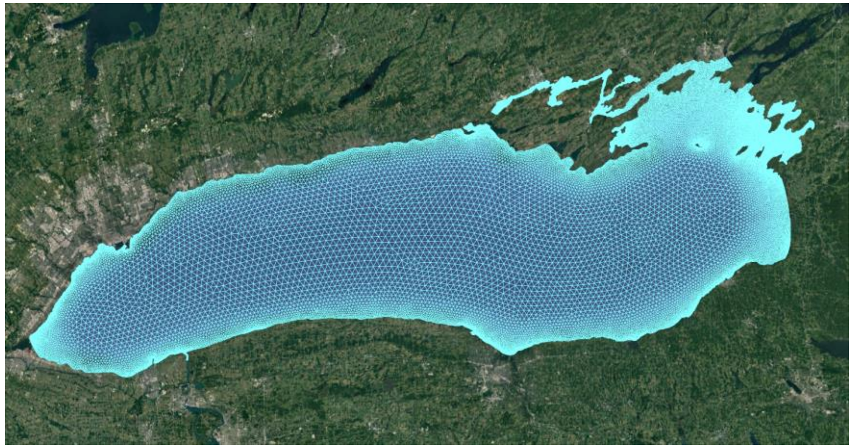


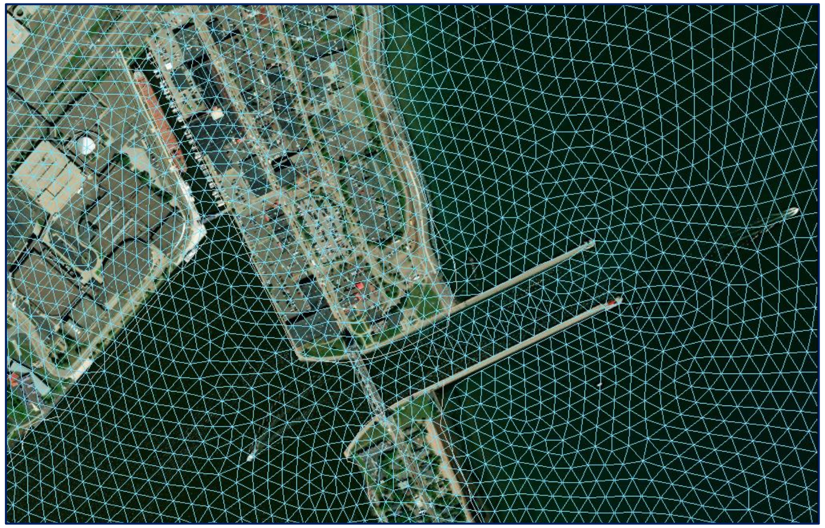
- GLOFS supports commercial navigation, flood preparedness and coastal resiliency, recreation, and more
- Many coastal ports, harbors, and estuaries are not resolved in the domain, and floodplains are excluded

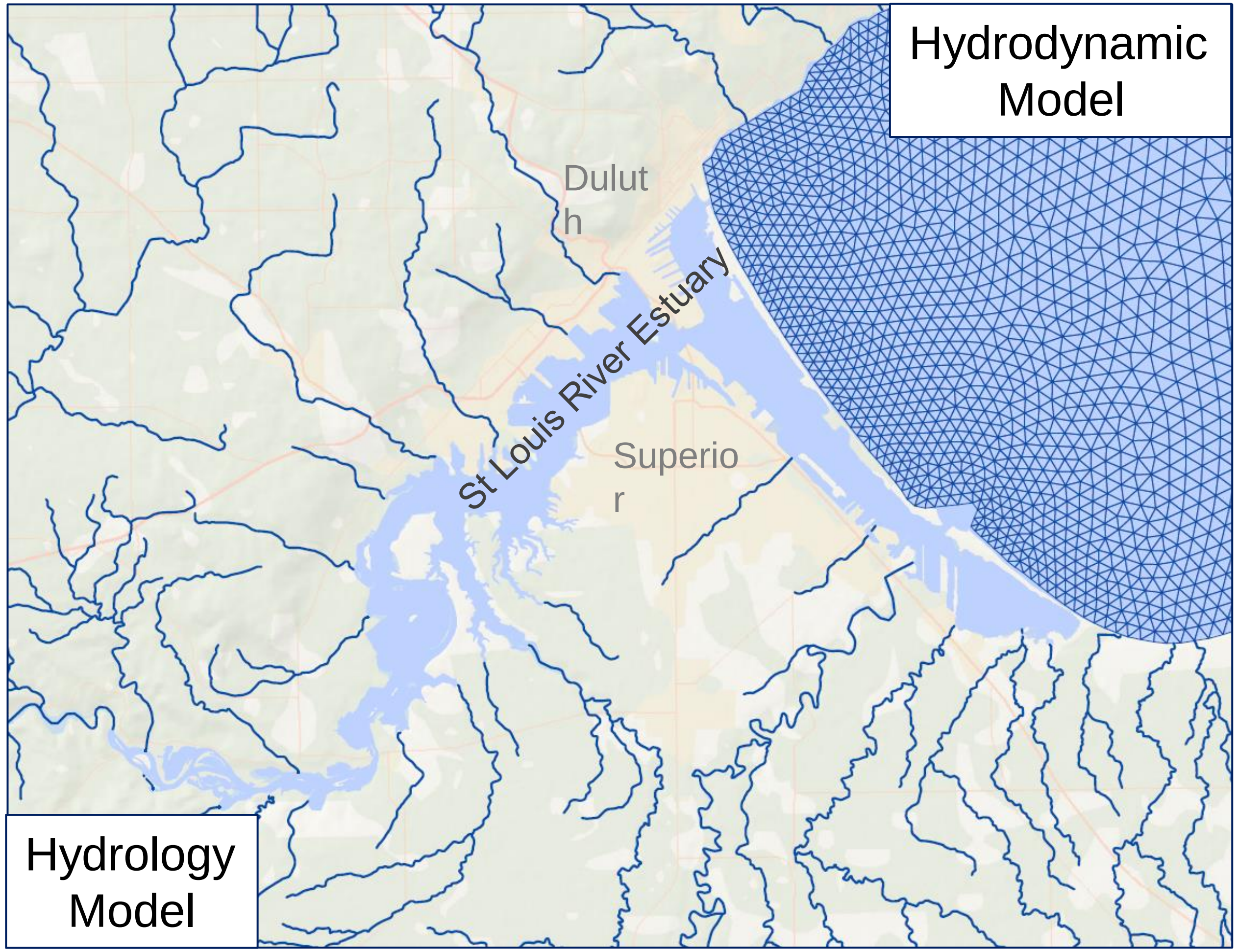
Bipartisan Infrastructure Law (BIL) Coastal and Inland Flood Inundation Mapping (CIFIM)

Improving understanding and prediction of compound flooding along coasts

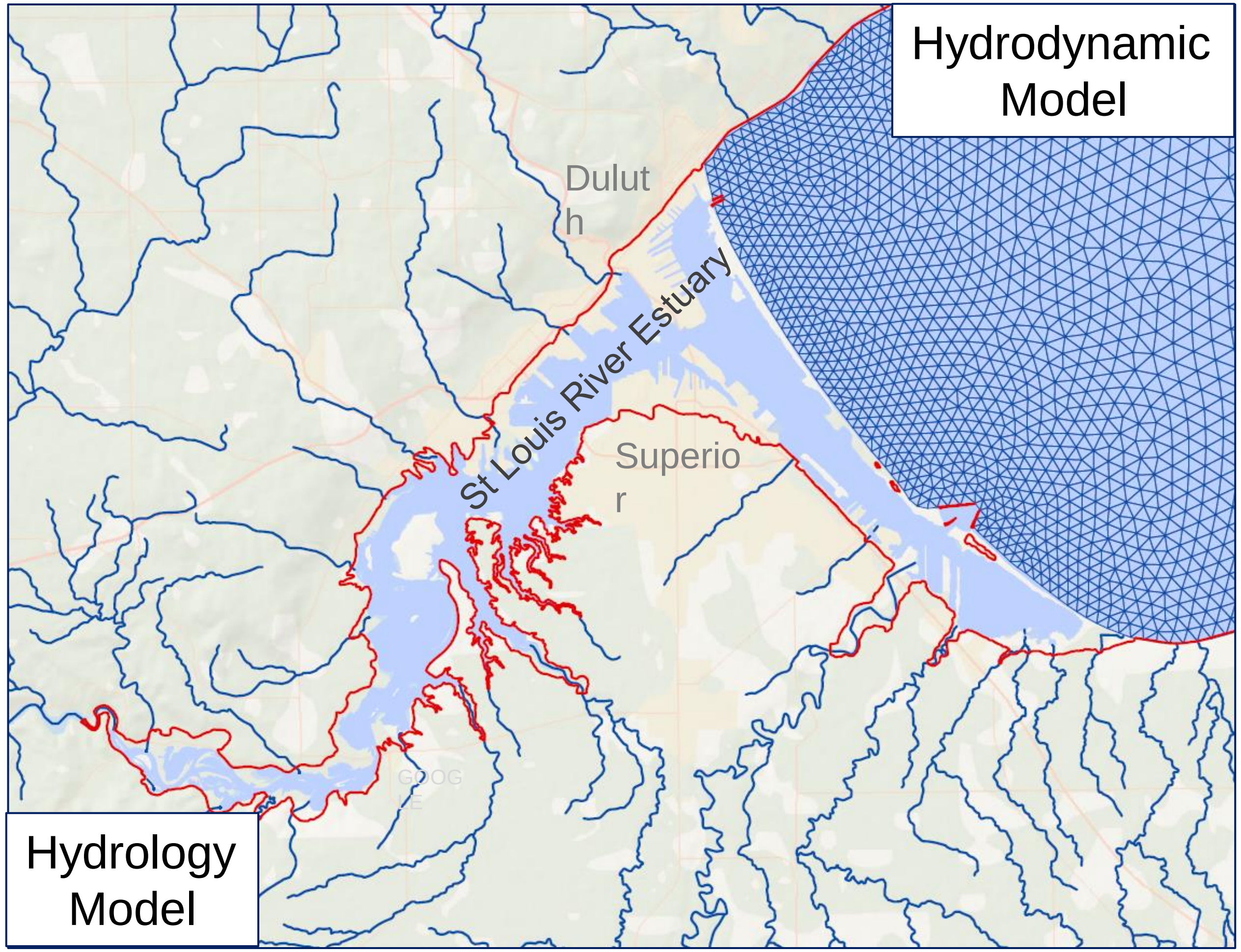
- Initial focus on the Great Lakes will be on the development of a next-generation coupled system for Lake Ontario
  - Expanding hydrodynamic domain into the floodplain
  - Improved guidance for lake surge and coastal flooding out to at least 5 days
  - Methods and infrastructure developed for Lake Ontario expected to be readily expanded to other Great Lakes
- Development of coupling architecture to enable advanced 3D coupling between the National Water Model and hydrodynamic models
- Envisioned to serve as the next generation GLOFS
- Project builds on recent coastal coupling work conducted in St Louis River Estuary of western Lake Superior, conducted by GLERL/CIGLR as part of the NOAA NOS Water Initiative



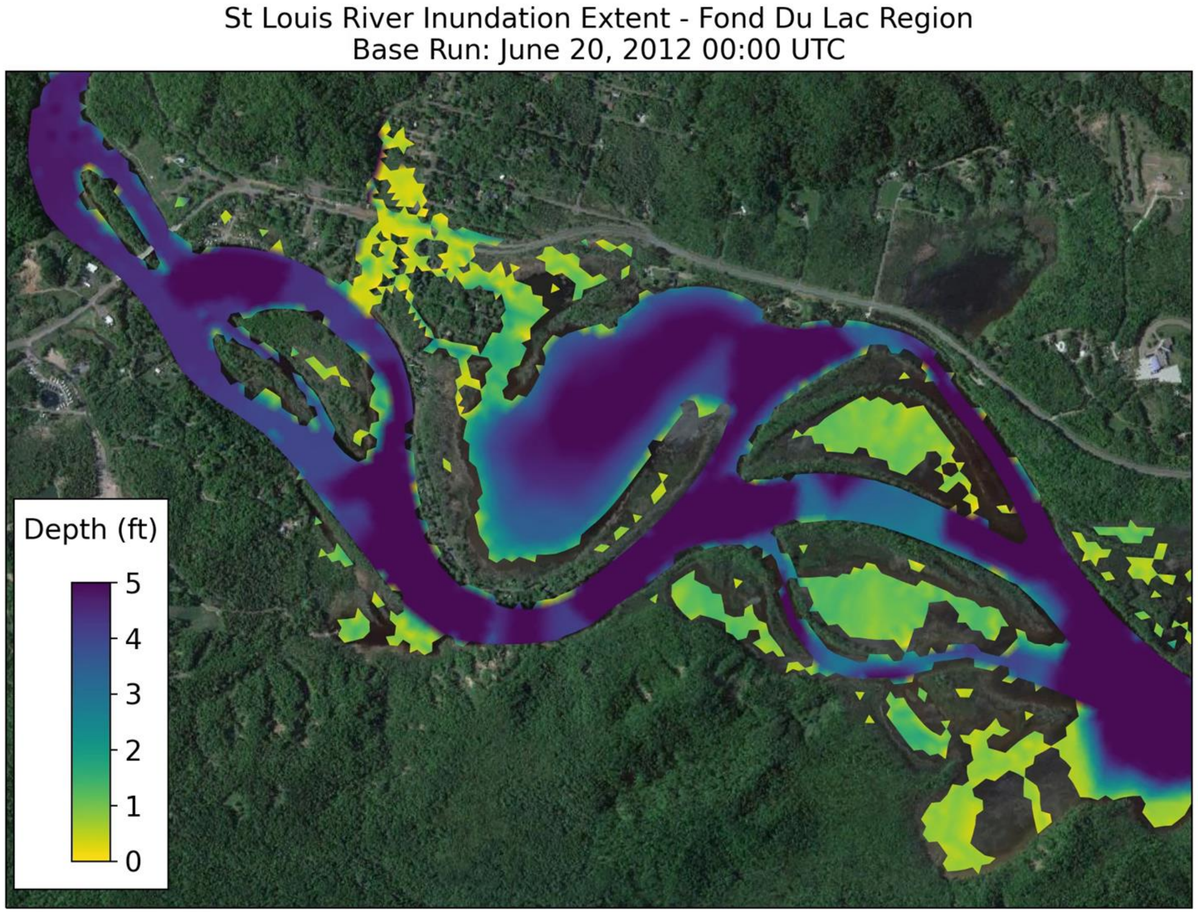


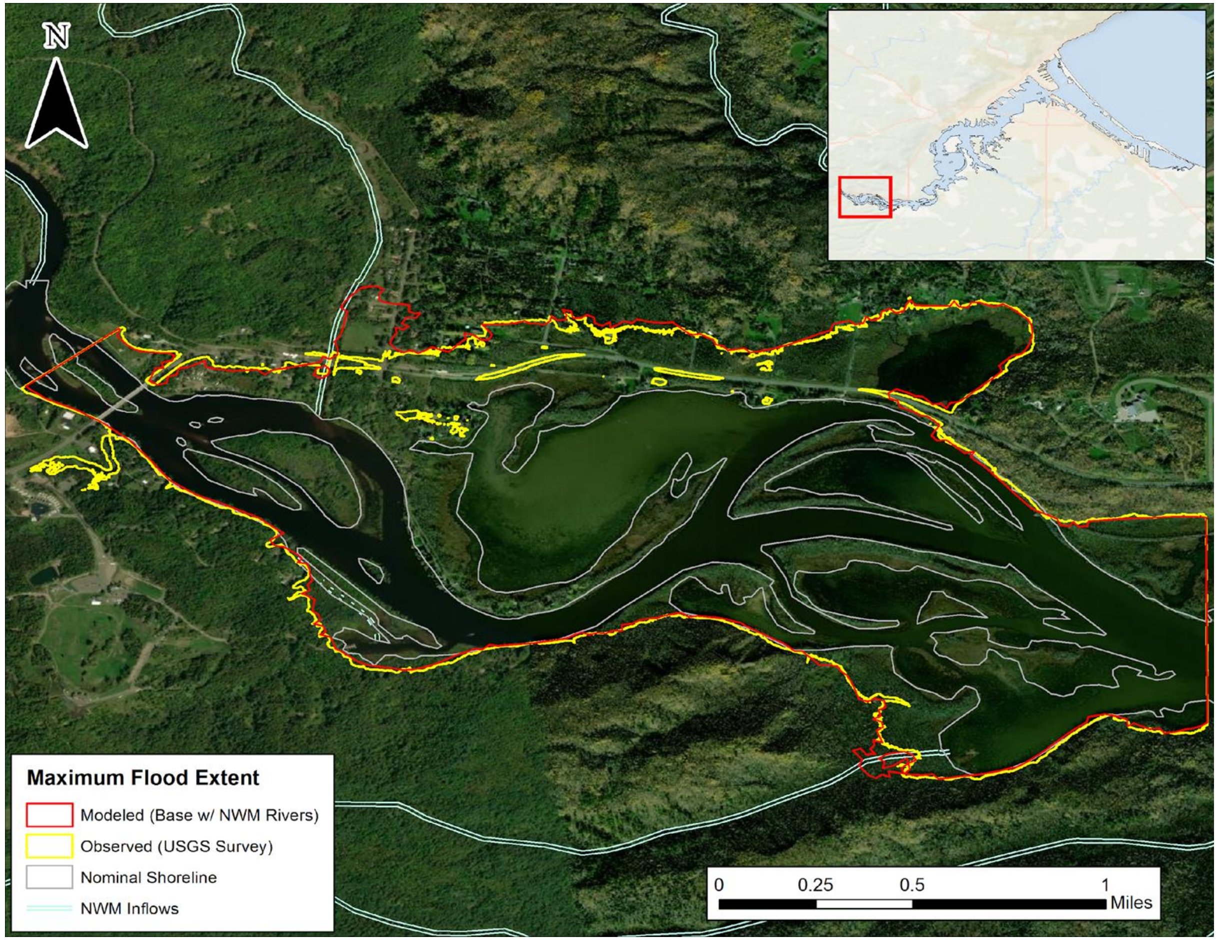


- There is a gap between hydrodynamic and hydrologic models in current forecasting systems
- In case of St Louis River Estuary: hydrology model (National Water Model) is treating it as a lake; hydrodynamic model (GLOFS) is treating it as a river – not being resolved in either domain



- Through the NOS Water Initiative, expanded Lake Superior domain to include the St Louis River Estuary and surrounding floodplain
- Link with National Water Model through one-way coupling to incorporate all inflows into the hydrodynamic model

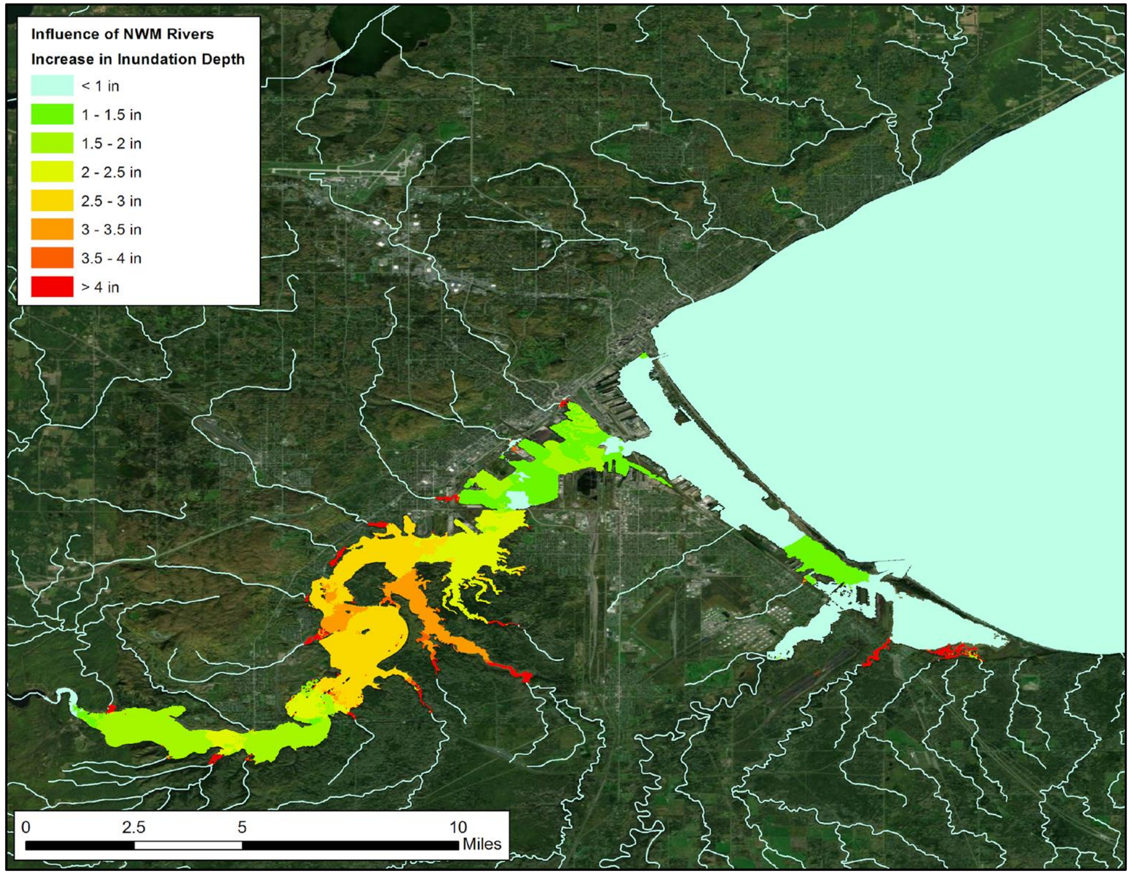




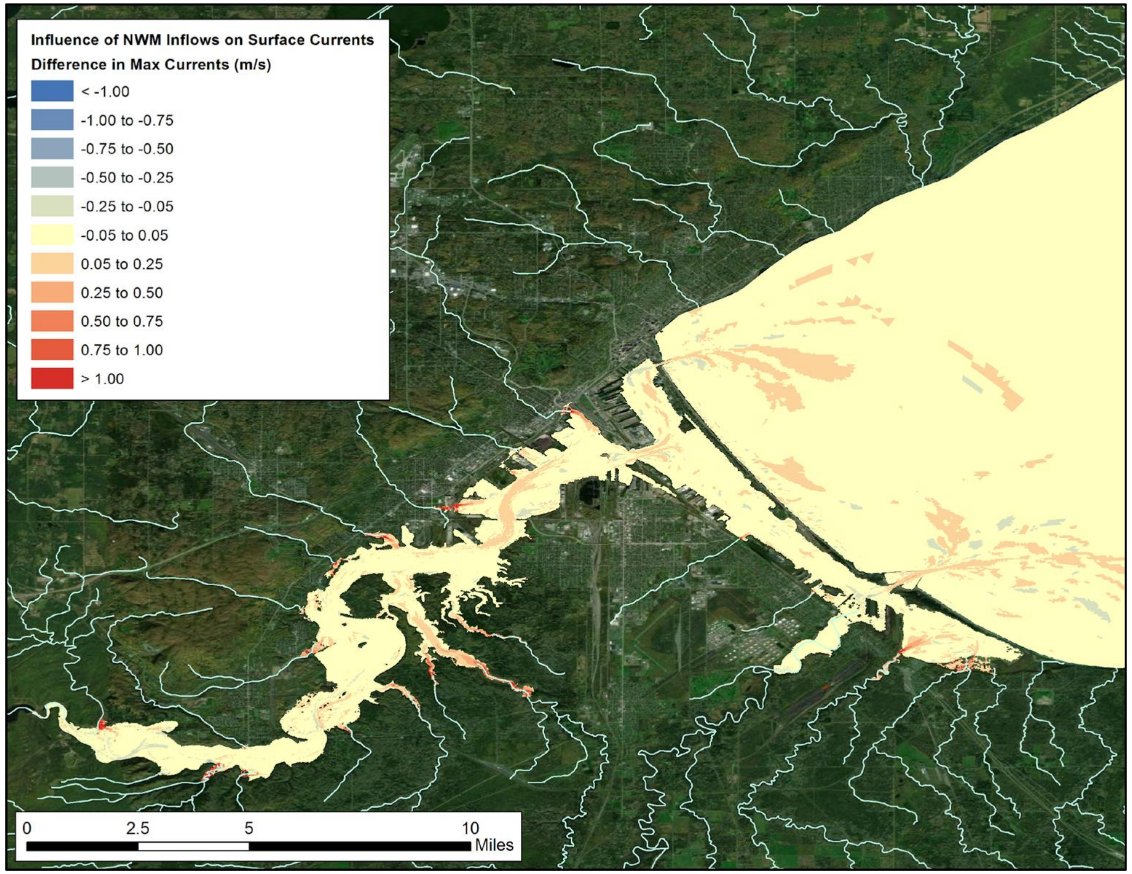
- Expanded domain accurately simulated inundation extent for a record flood event that occurred in June 2012
  - Modeled flood extent showed strong agreement with USGS flood surveys conducted during the event

Localized Influence of NWM Tributaries

- Inclusion of ungauged inflows through National Water Model had noticeable impact on estuary dynamics, compared to runs conducted with only gauged rivers



Localized differences in water levels of 2-4 in (5-10 cm)



Surface currents up to 40 cm/s higher in harbor entrances

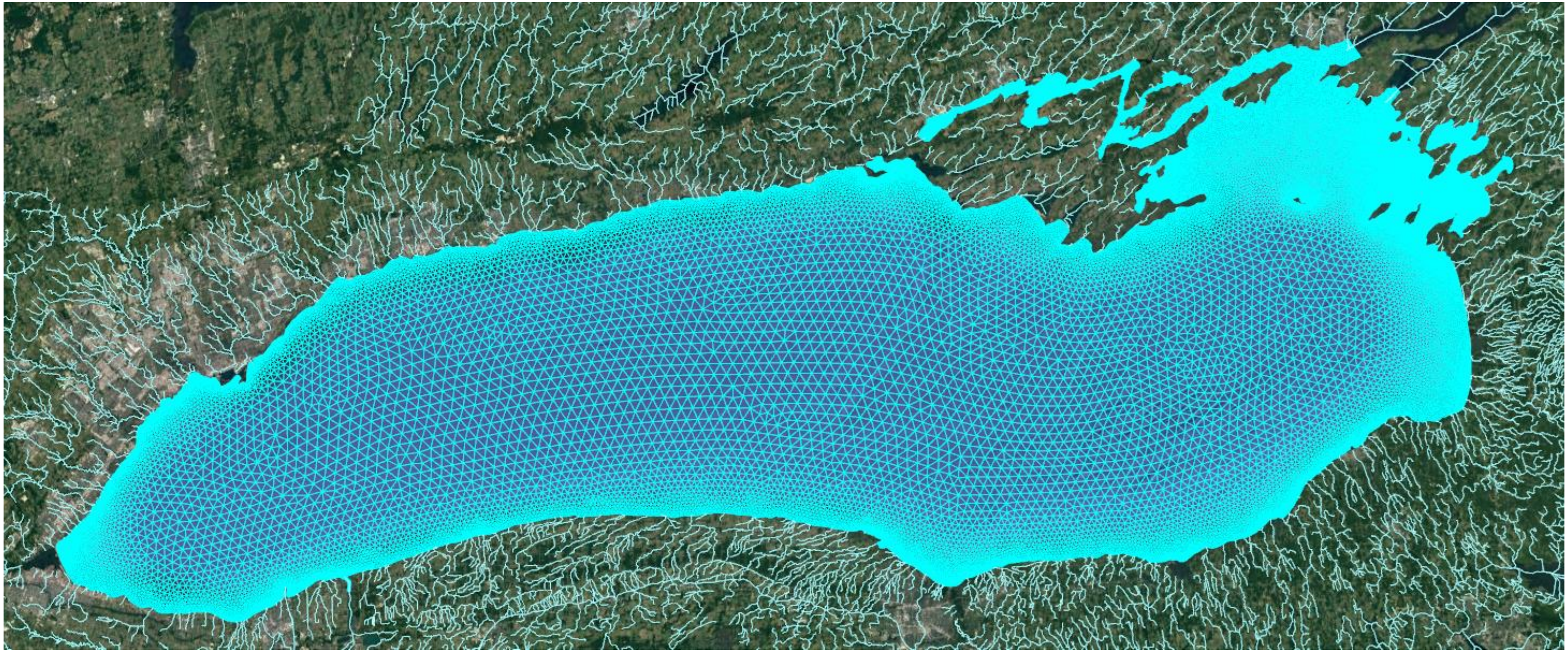
Ocean Dynamics (2023) 73:433–447
https://doi.org/10.1007/s10236-023-01559-7

Simulating flood events at the Twin Ports of Duluth-Superior using a linked hydrologic-hydrodynamic framework

Lindsay Fitzpatrick[1] · Daniel Titze[2] · Eric J. Anderson[3] · Dmitry Beletsky[1] · John G. W. Kelley[4]

Received: 14 November 2022 / Accepted: 25 May 2023 / Published online: 22 June 2023

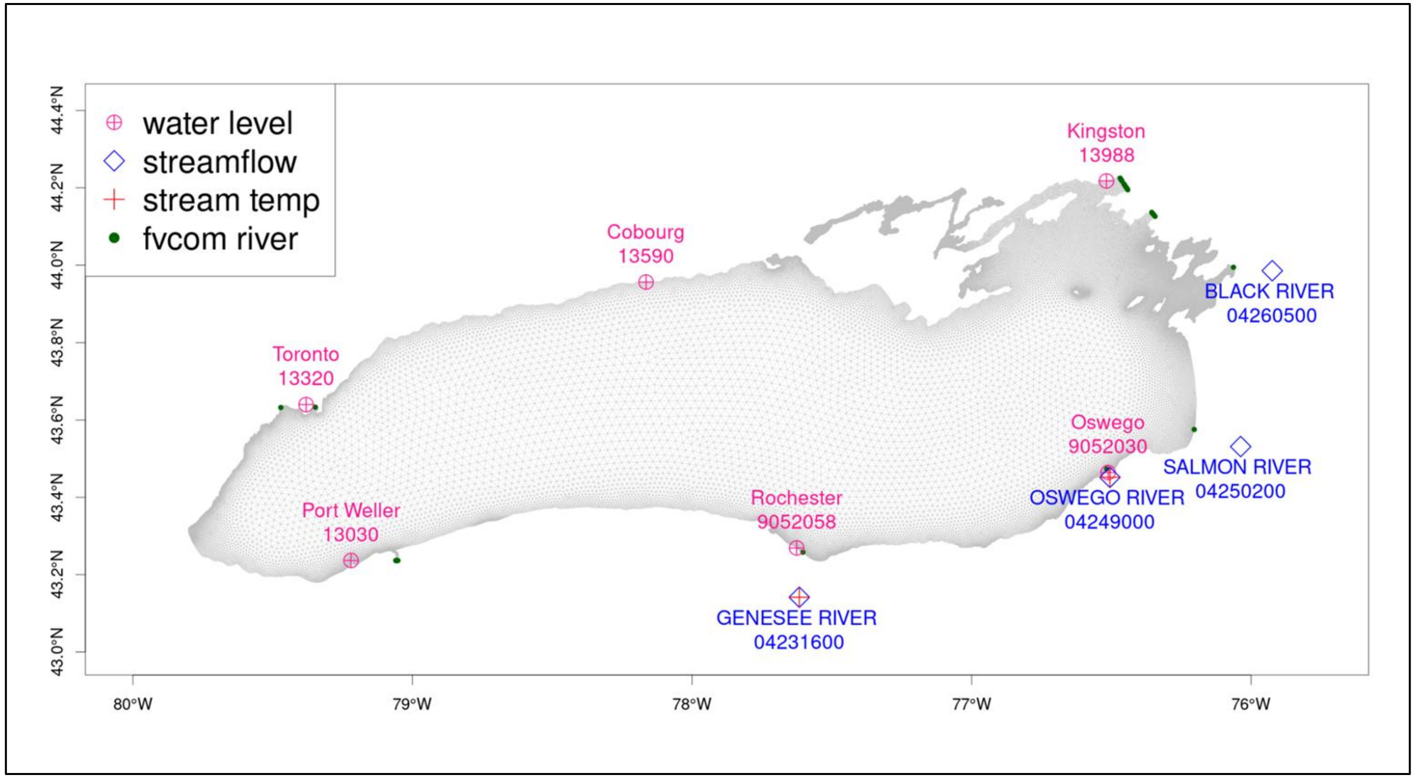
- Results published in Fitzpatrick et al. 2023



- Through BIL CIFIM, plan to apply a similar approach to the Lake Ontario basin
- Currently early in the 5-year project:
  - Doing baseline testing during a flood year, and working on mesh development for floodplain

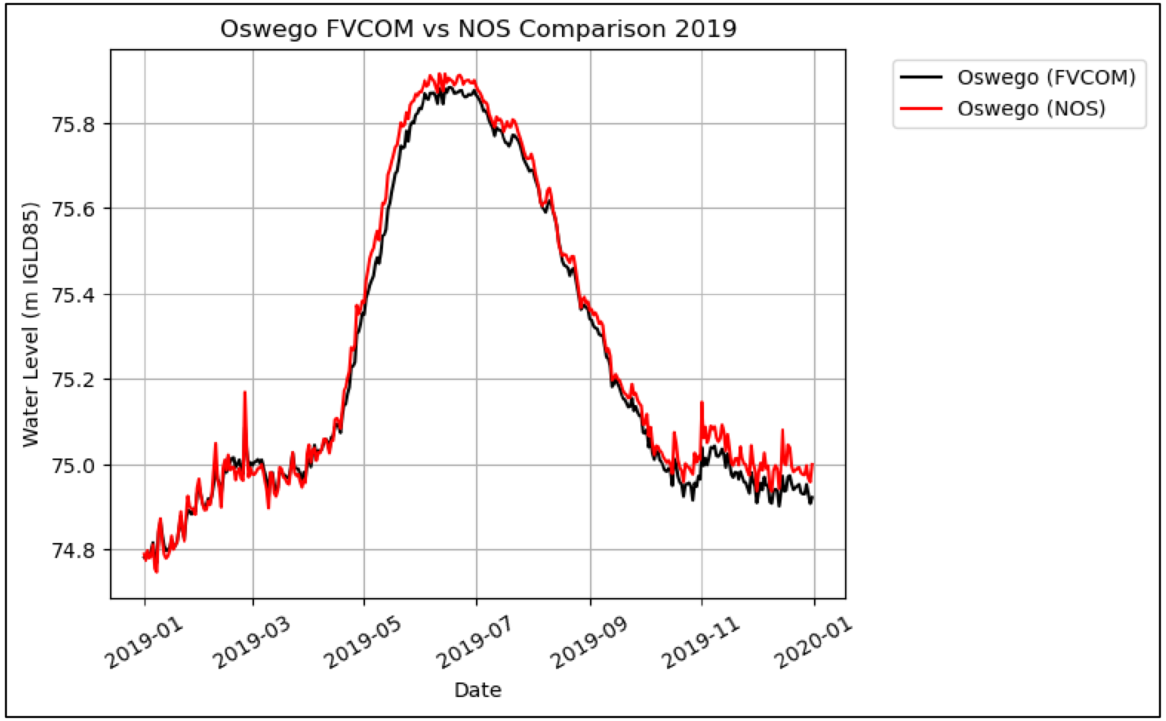
Baseline Model Testing

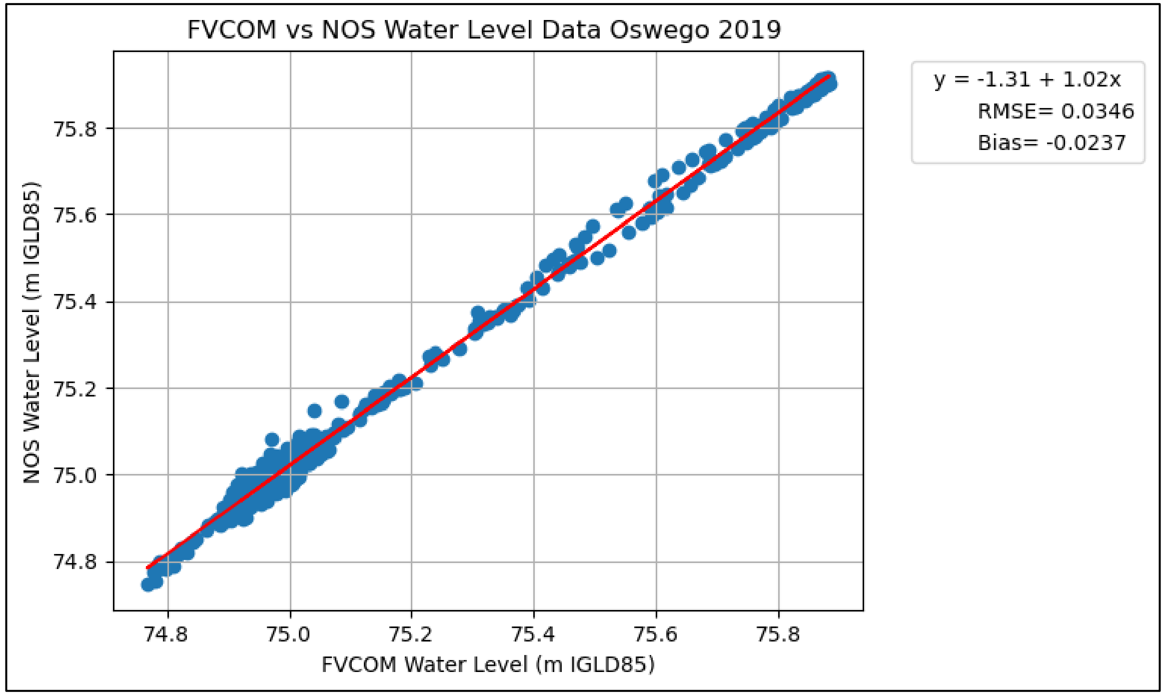
- Starting with GLOFS Lake Ontario configuration (LOOFS) as a baseline
  - Establish skill statistics against which future iterations of the model can be evaluated
  - Simulations using FVCOM for hydrodynamics
- Using 2019 flood year for testing
  - Compared 2017 and 2019
  - 2019 has:
    - Modern HRRR forcing
    - Consistently high water levels
    - More storm surges
  - Weather Forecast Office Buffalo confirmed it was a good flood year to model
  - End of May (28th-31st) saw significant flooding on Lake Ontario
  - Historical high water level event



- Observations available for validation from 10 water level stations, 5 surface temperature stations, 3 thermal structure stations (all very near shore)

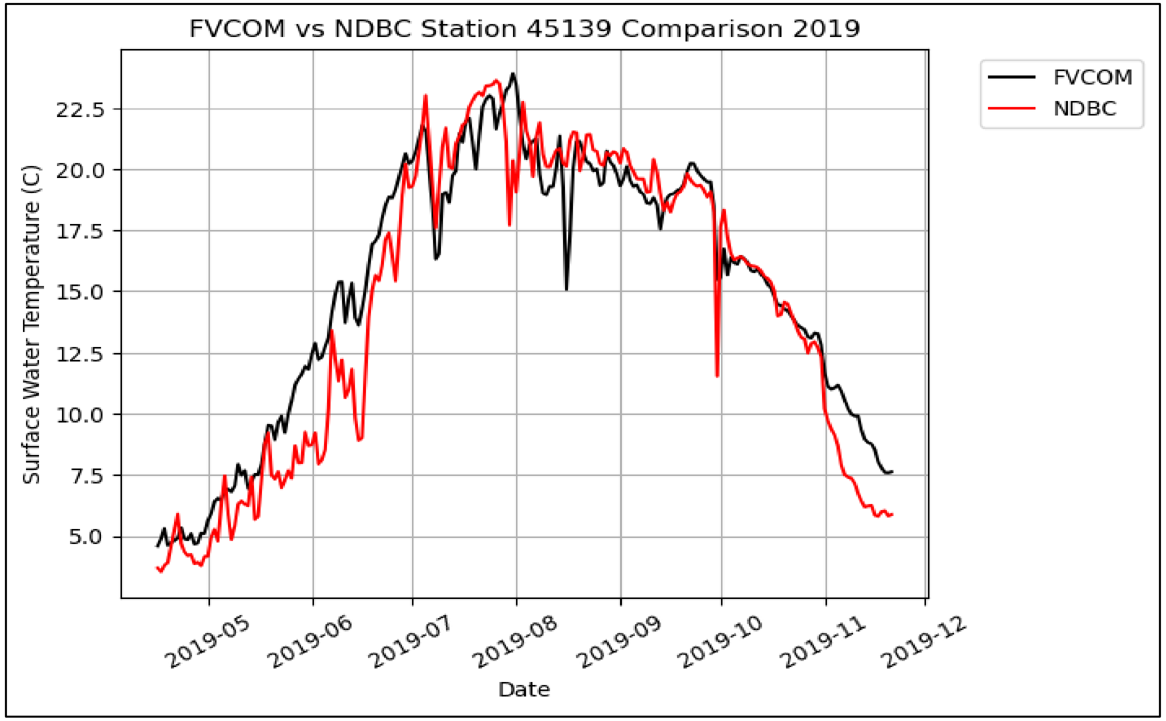
Example Water Level Comparison (Oswego)

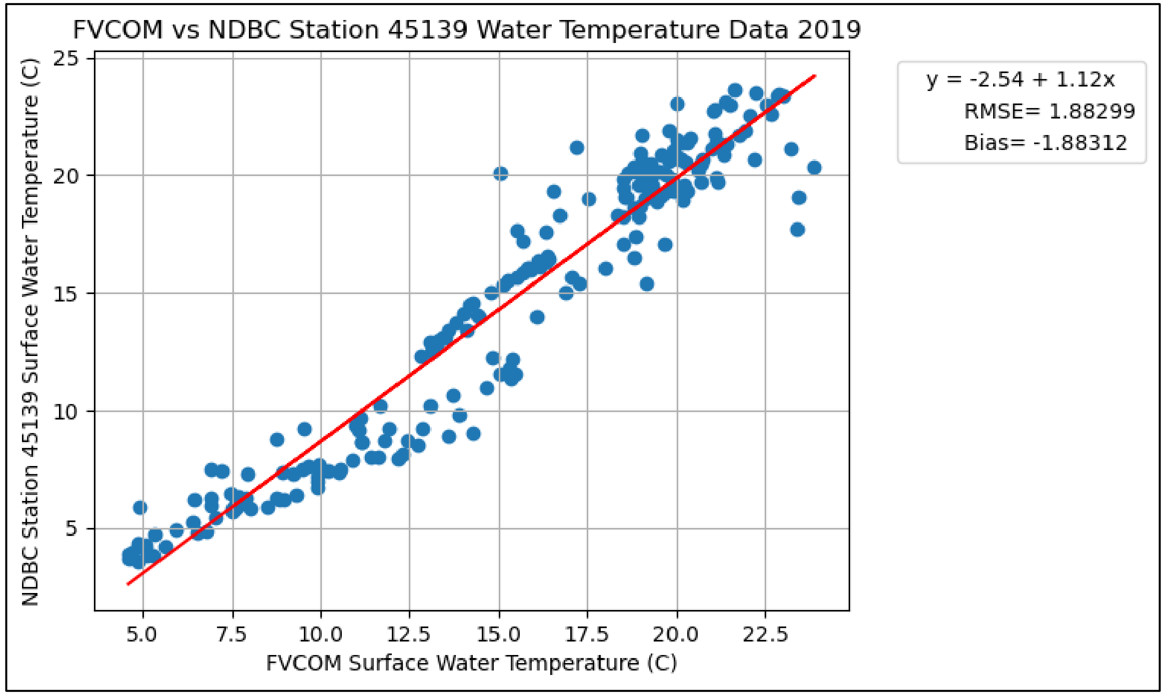




- Water level skill assessment for baseline run consistent with past skill assessments of GLOFS models
- Biases in lakewide water level could be reduced with more aggressive water level nudging method, which has been tested in Lake Champlain Flood Forecasting System developed by GLERL/CIGLR

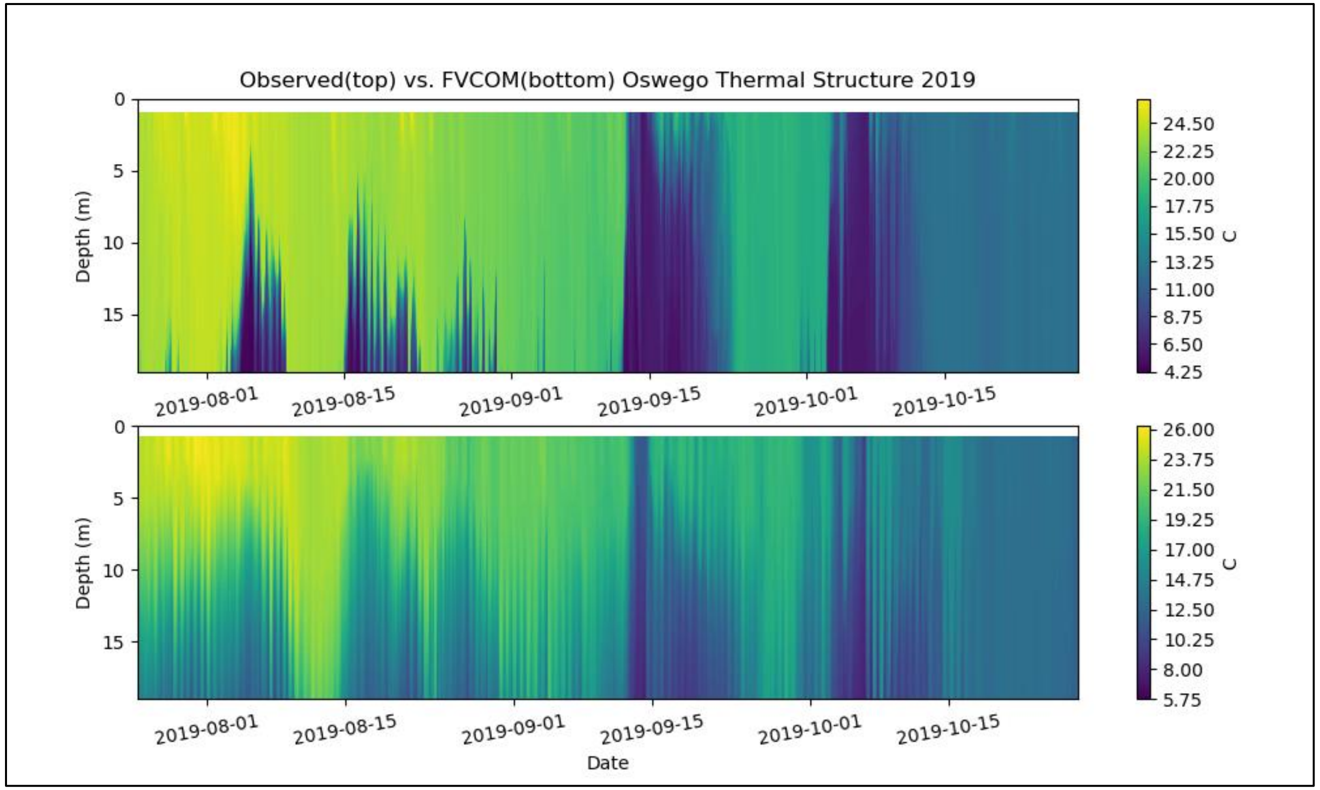
Example Surface Temperature Comparison (Nearshore Location 45139)





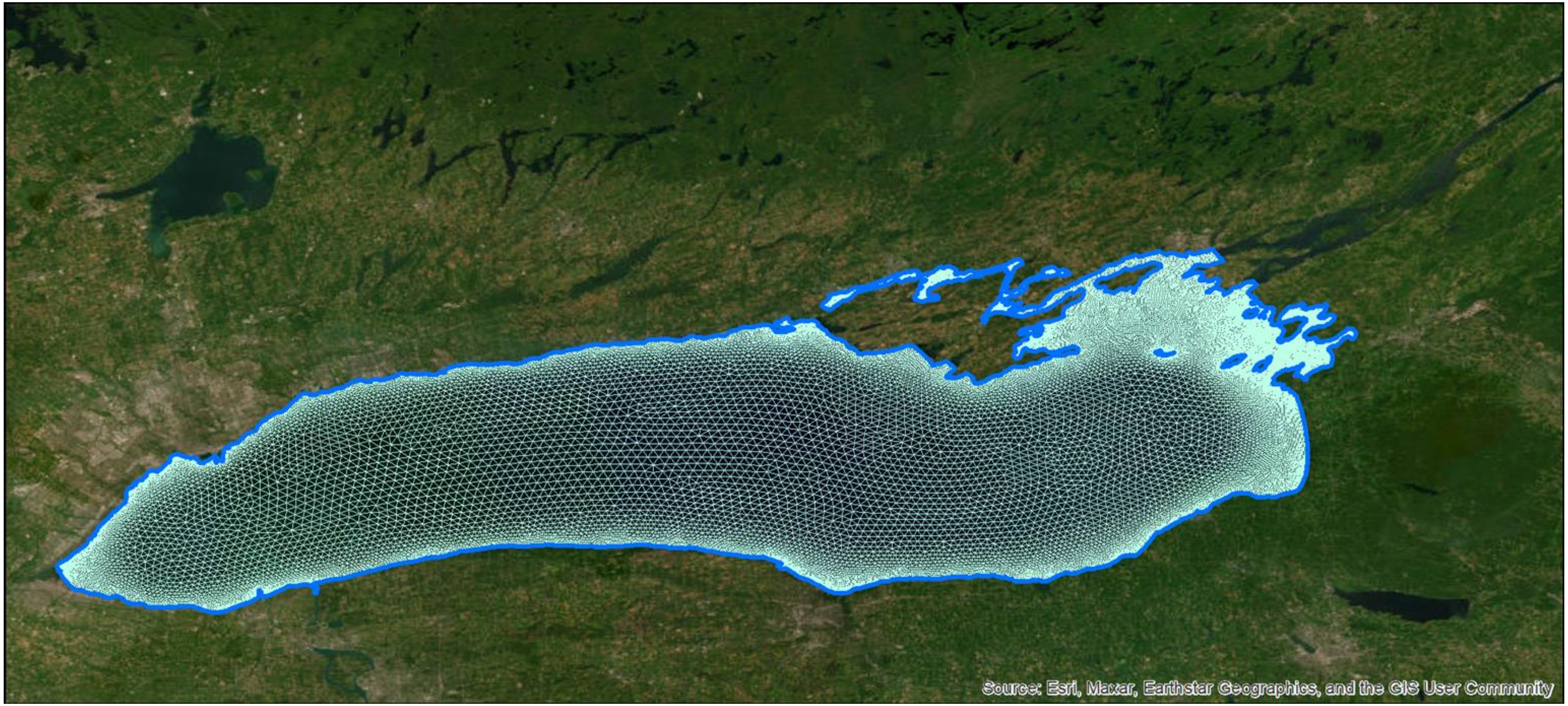
- Noticeable cold bias in the spring, consistent with operational FVCOM models
- Some upwelling events are well-captured by the model

Example Thermal Structure Comparison (Oswego)

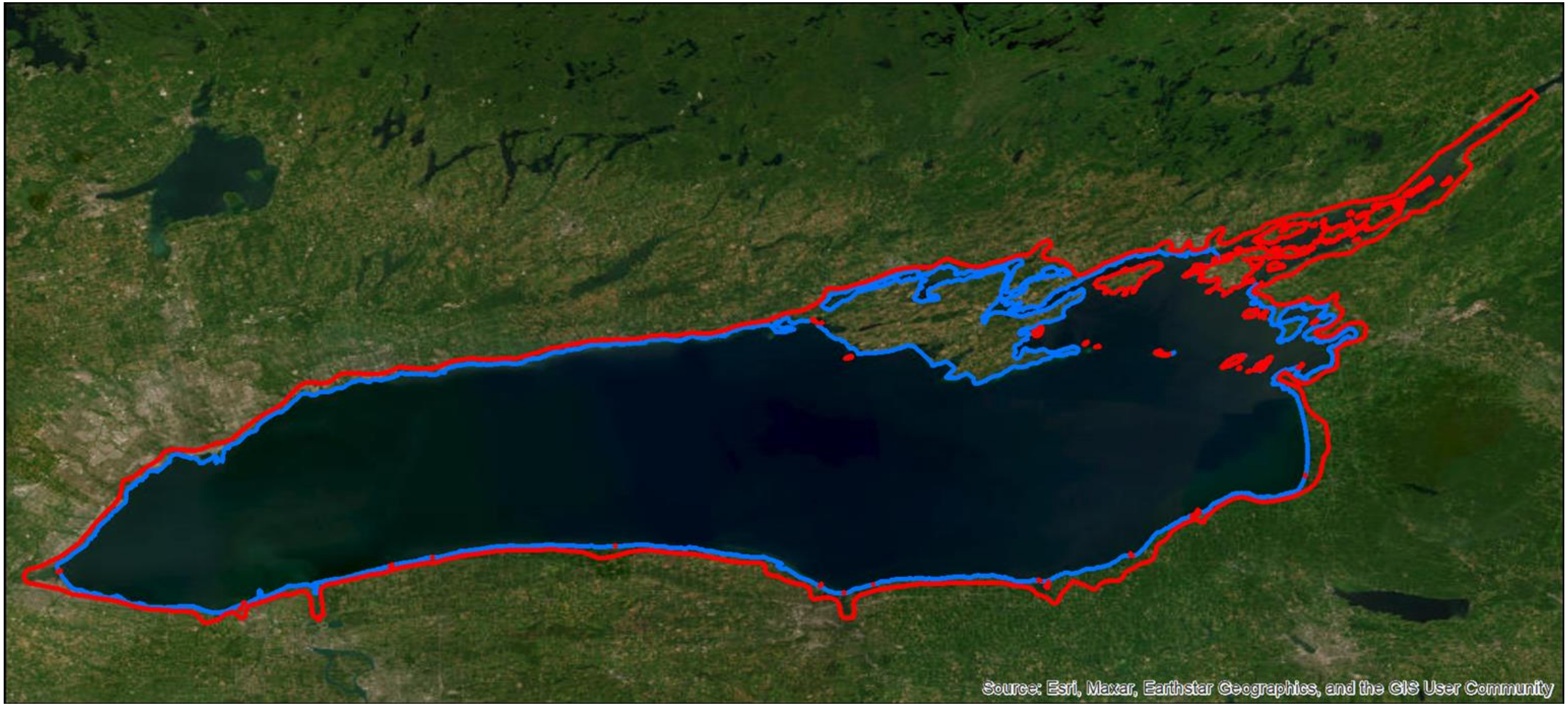


- Timing of upwelling/downwelling events well-captured in the model
- Thermal structure is more diffuse in model than observations

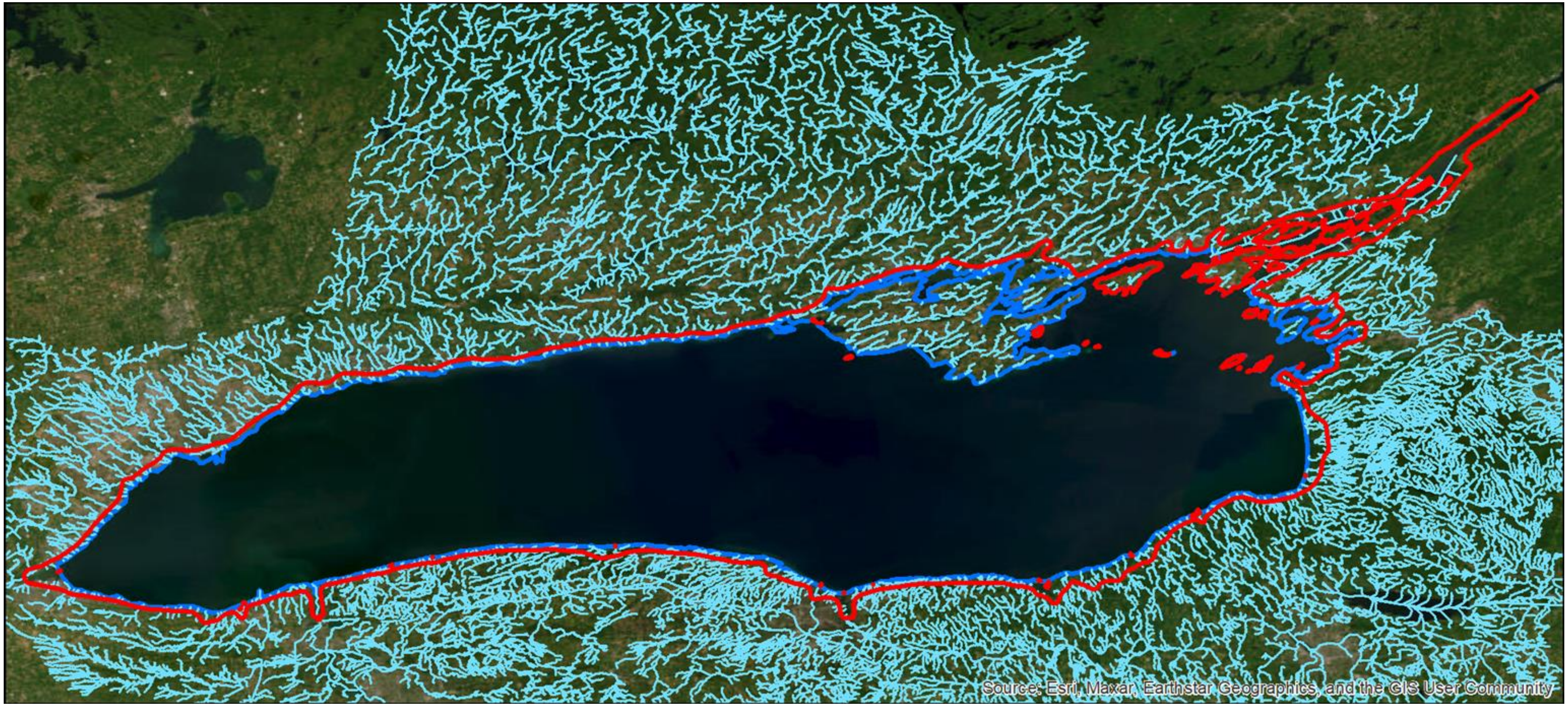
Mesh Expansion and Next Steps



- Baseline mesh is lake only
- Many bays and harbors are not included in the model domain, and does not include the floodplain



- Expanded mesh to include floodplain, starting with an ADCIRC mesh provided by the US Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC)
- Includes floodplain up to approximately 6m contour, and includes more of St Lawrence River



- Overlap with National Water Model streams allows for spatial coupling with that model

- Similarly to Duluth Harbor, there are gaps between the NWM and GLOFS in Lake Ontario
  - (ex. Sodus Bay in southeastern Lake Ontario)

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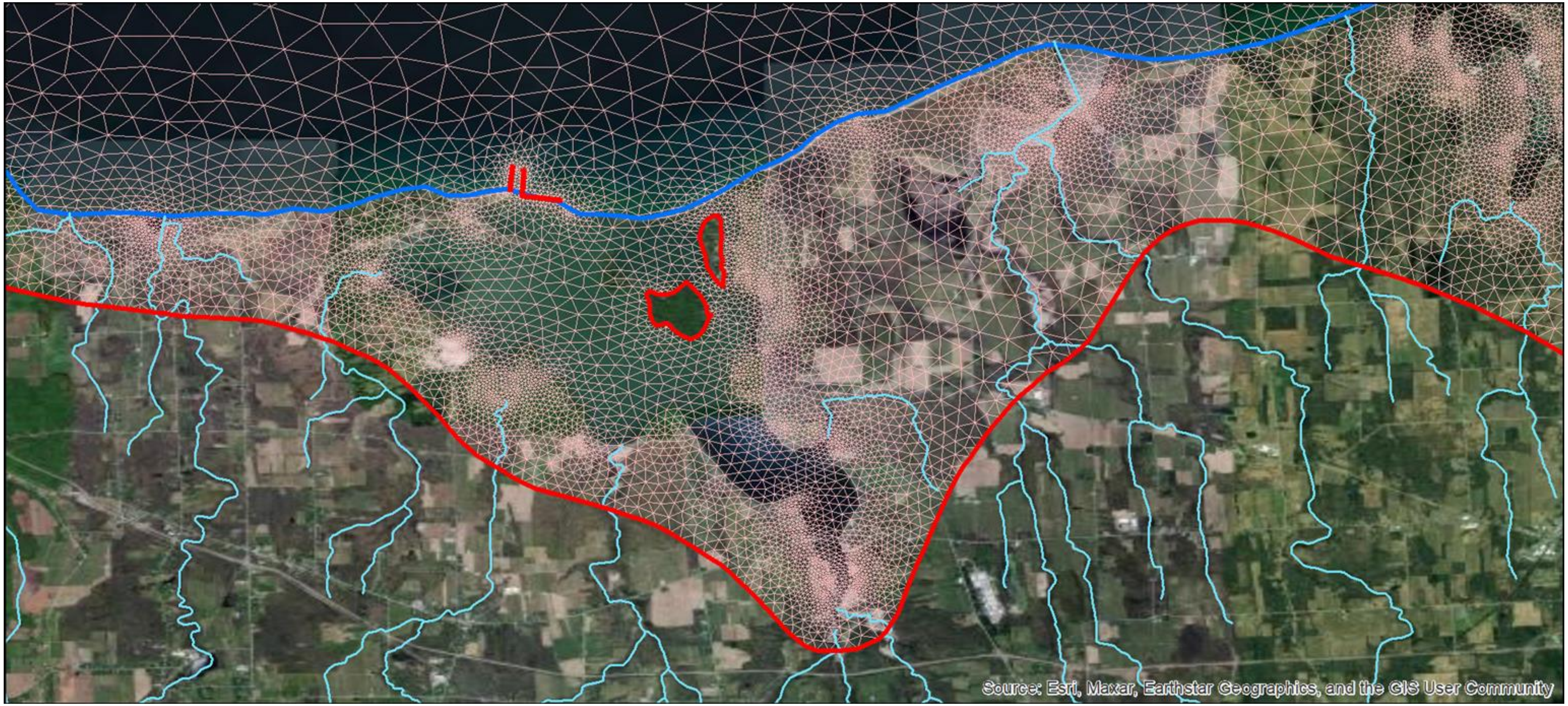
- Expanding model domain will allow for spatial coupling with NWM and simulation of inundation



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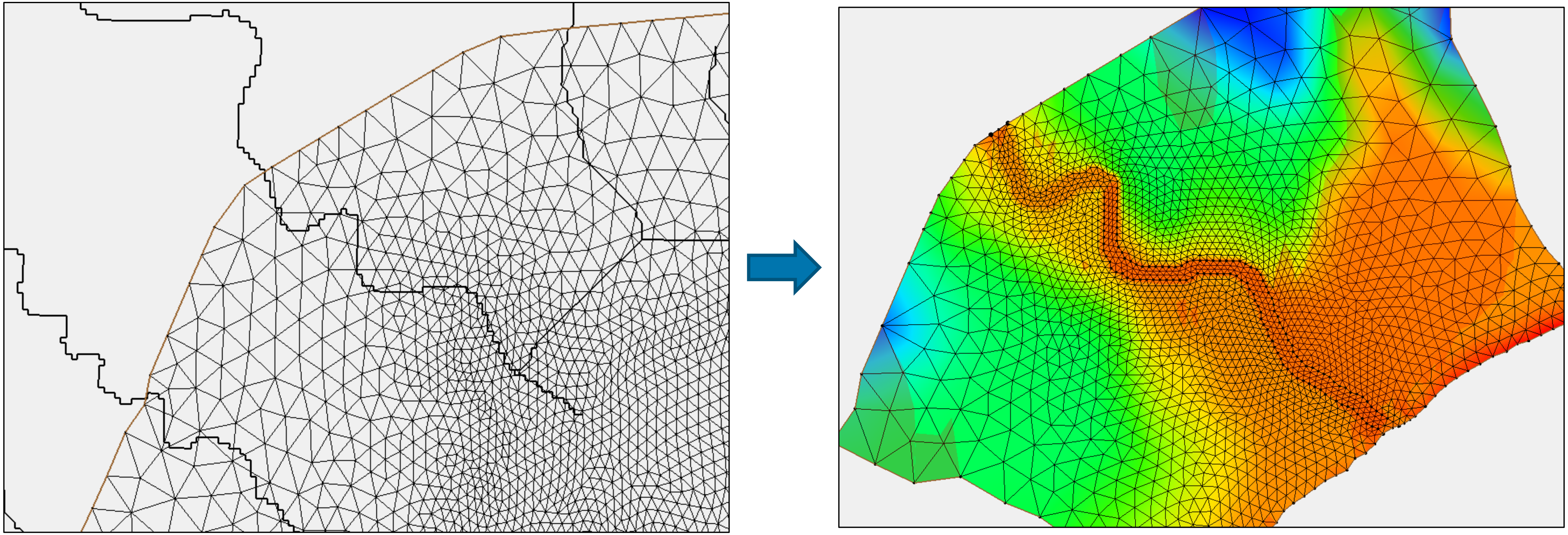

- Currently refining the mesh in areas to produce a stable FVCOM run for 2019, to compare to baseline run on lake-only grid
  - High currents in poorly-resolved river channels are leading to instabilities in the model

<u>Next Steps</u>

- Revise grid until stable for FVCOM
  - Current focus is on better resolving key river channels
- Evaluate SCHISM model as an alternative to FVCOM
  - Supports mixed mesh models (i.e. quads in river channels, triangles elsewhere), with the potential to greatly improve model efficiency while resolving critical features
- Develop NWM coupling strategy
  - What is the minimum size of stream that can reasonably be resolved while maintaining suitable efficiency (to be determined in collaboration with operations teams)?
  - Determine how to incorporate flow from smaller tributaries to close the water budget (e.g. aggregate and apply to nearest fully resolved river)
- Transition from research (GLERL) to operations (NOS CO-OPS)
- Methods and infrastructure developed for Lake Ontario expected to be readily expanded to other Great Lakes

Acknowledgements

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