UNCW UNIVERSITY of NORTH CAROLINA WILMINGTON

Modelling A Feshwater Estuary Under the Stresses of Anthropogenic Activities and Climate Change

For NOAA SCHISM Boot camp and workshop on Feb 17, 2021

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Outline

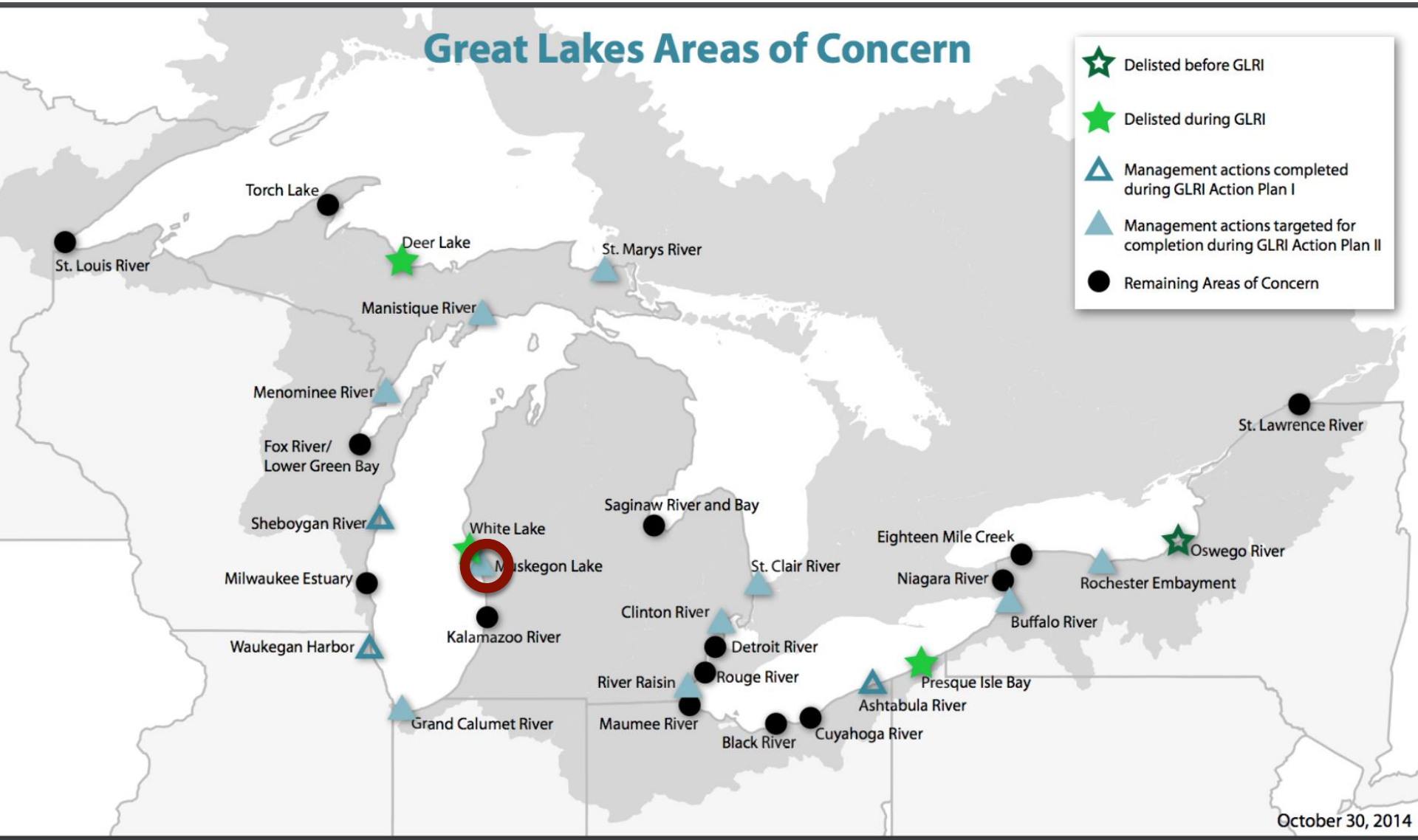
- **Background**
- Model Configuration
- Model Set-up
- Model Assessment
- Model Results

  Bottom Cold Water Intrusion from Lake Michigan
  Groundwater effects to Muskegon Lake
  Process Oriented Experiments
- Conclusion

Background

31 EPA Areas of Concern

An AOC is a location that has experienced environmental degradation.



Background

31 EPA Areas of Concern

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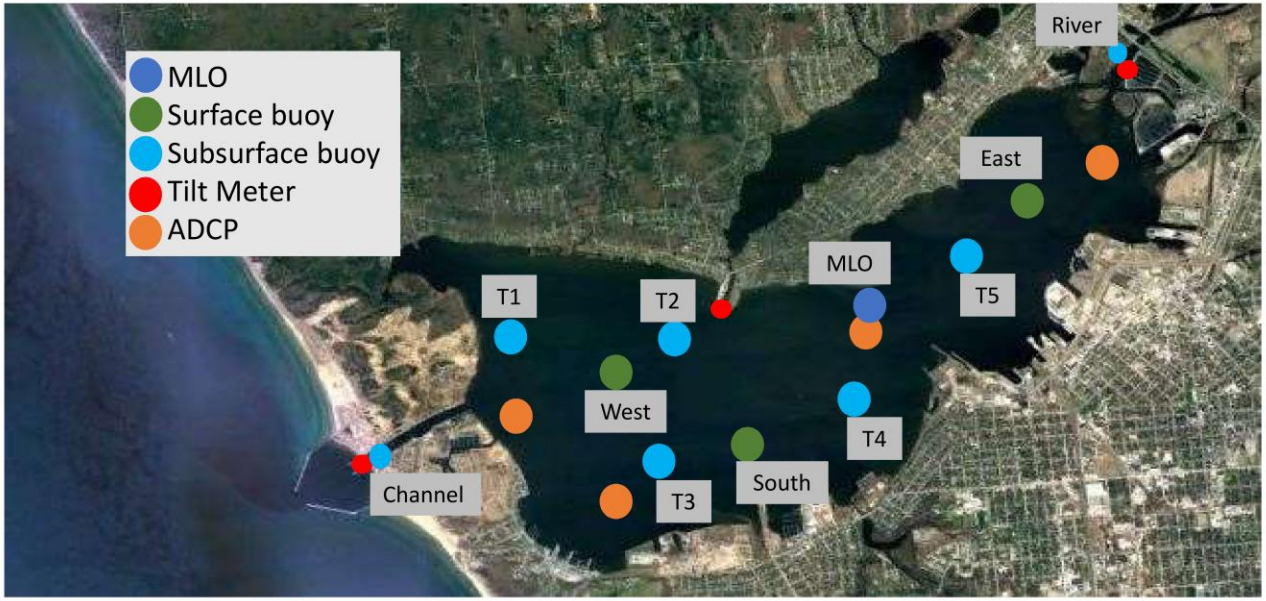
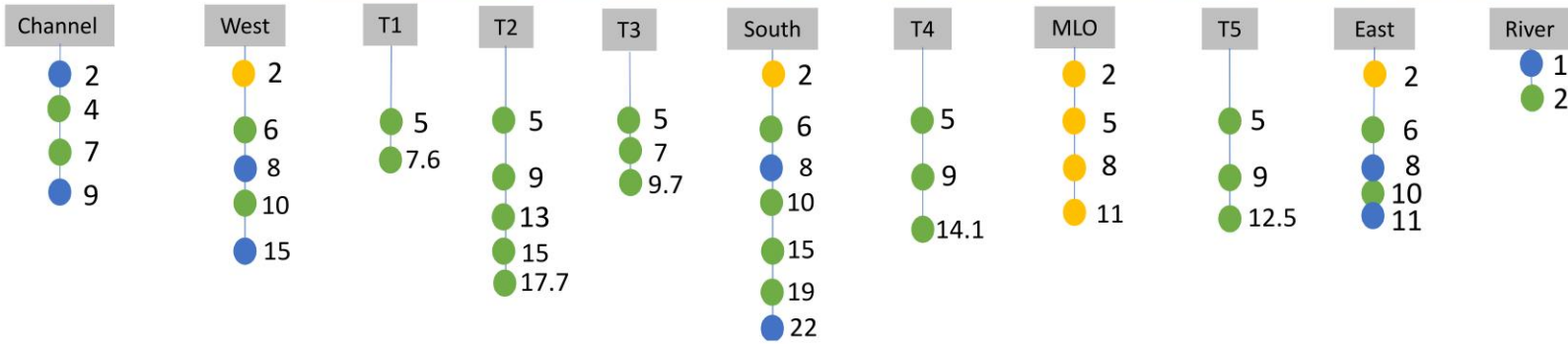
Muskegon Lake Instrumentation Map





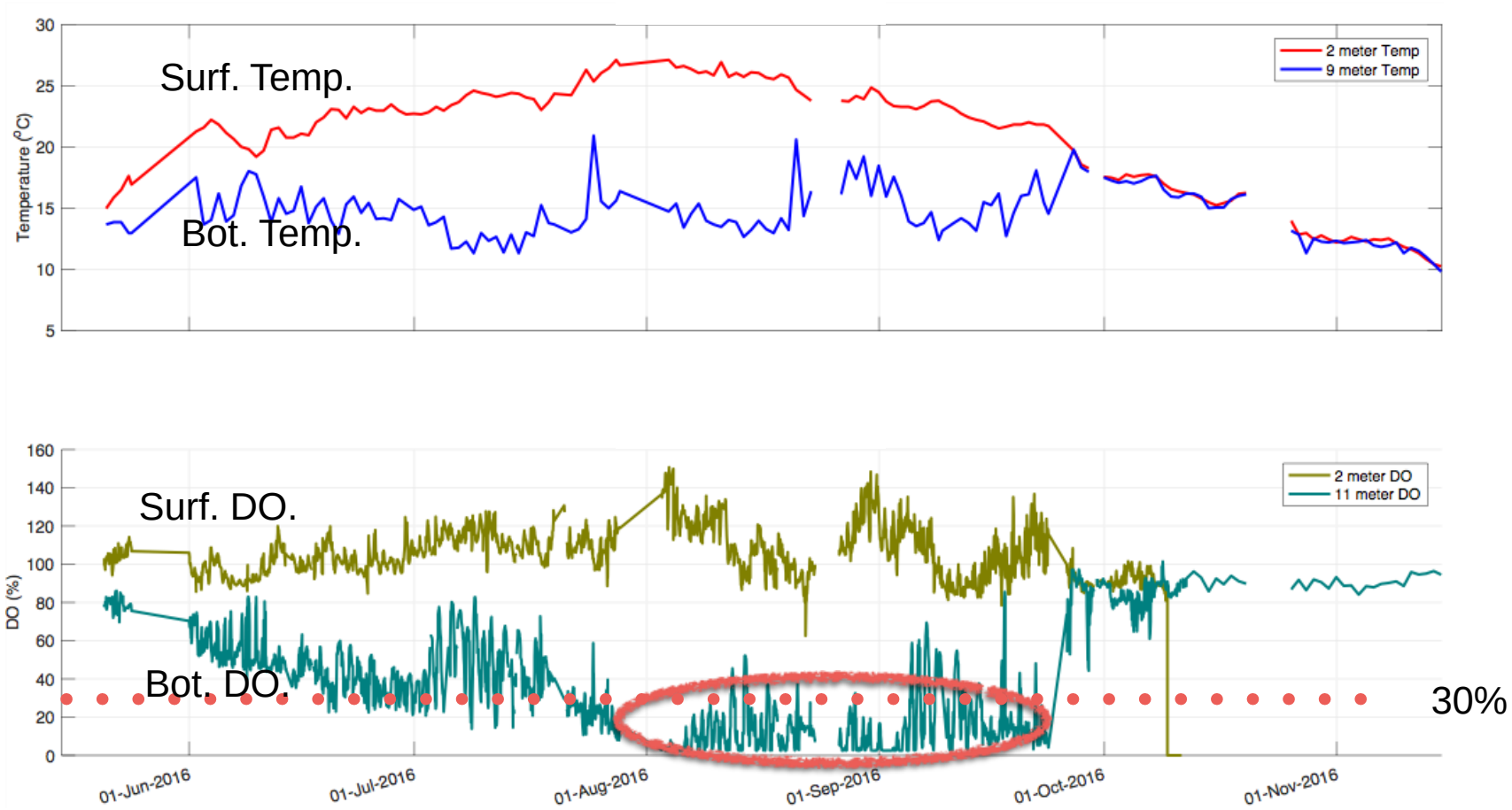
Muskegon Lake New Observations in 2017

Biddanda et al., AWRI-GVSU and CIGLR-UM Muskegon Lake Observatory Program

Background

Eutrophication, HABs and Hypoxia

Observations at the Buoy Site of the Muskegon Lake Observatory Program



hypoxia in 2016 summer

Such event is infrequent in Lake Michigan → Exchange Process is important

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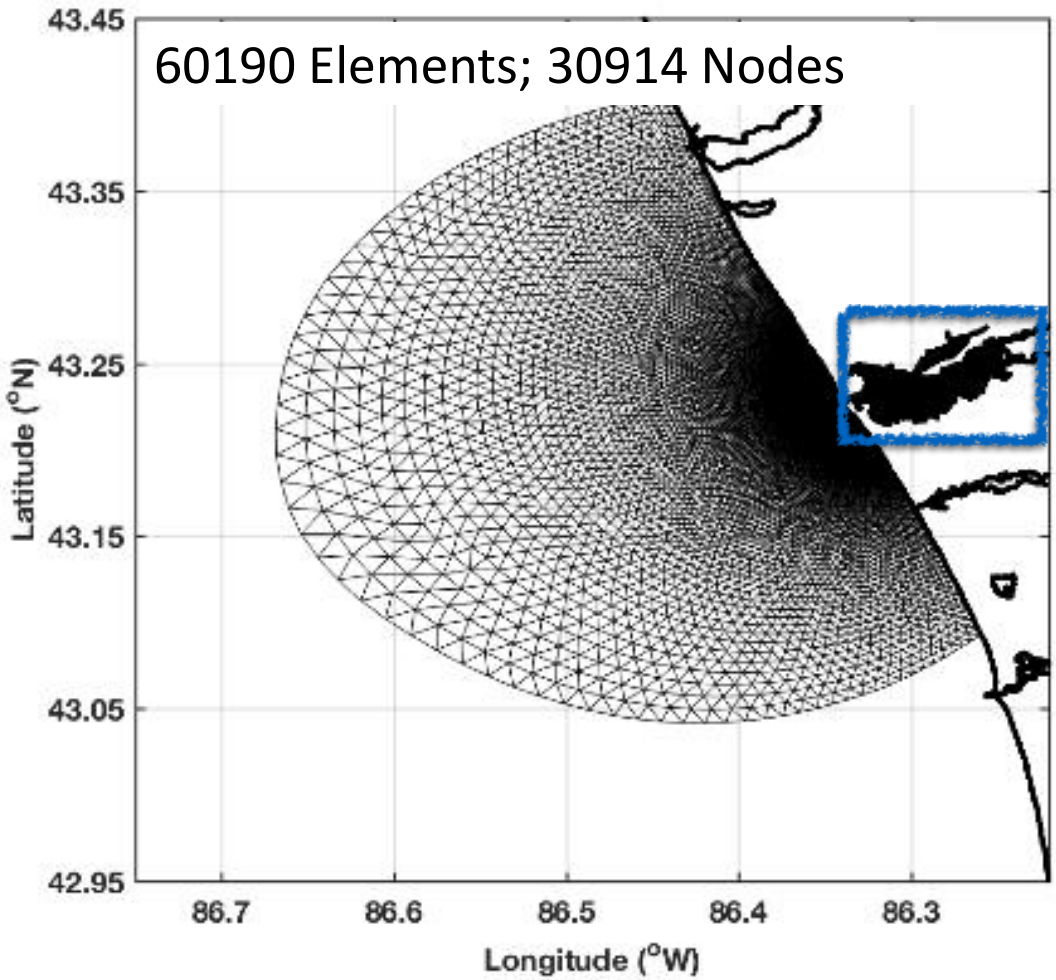
Model Configuration: SCHISM

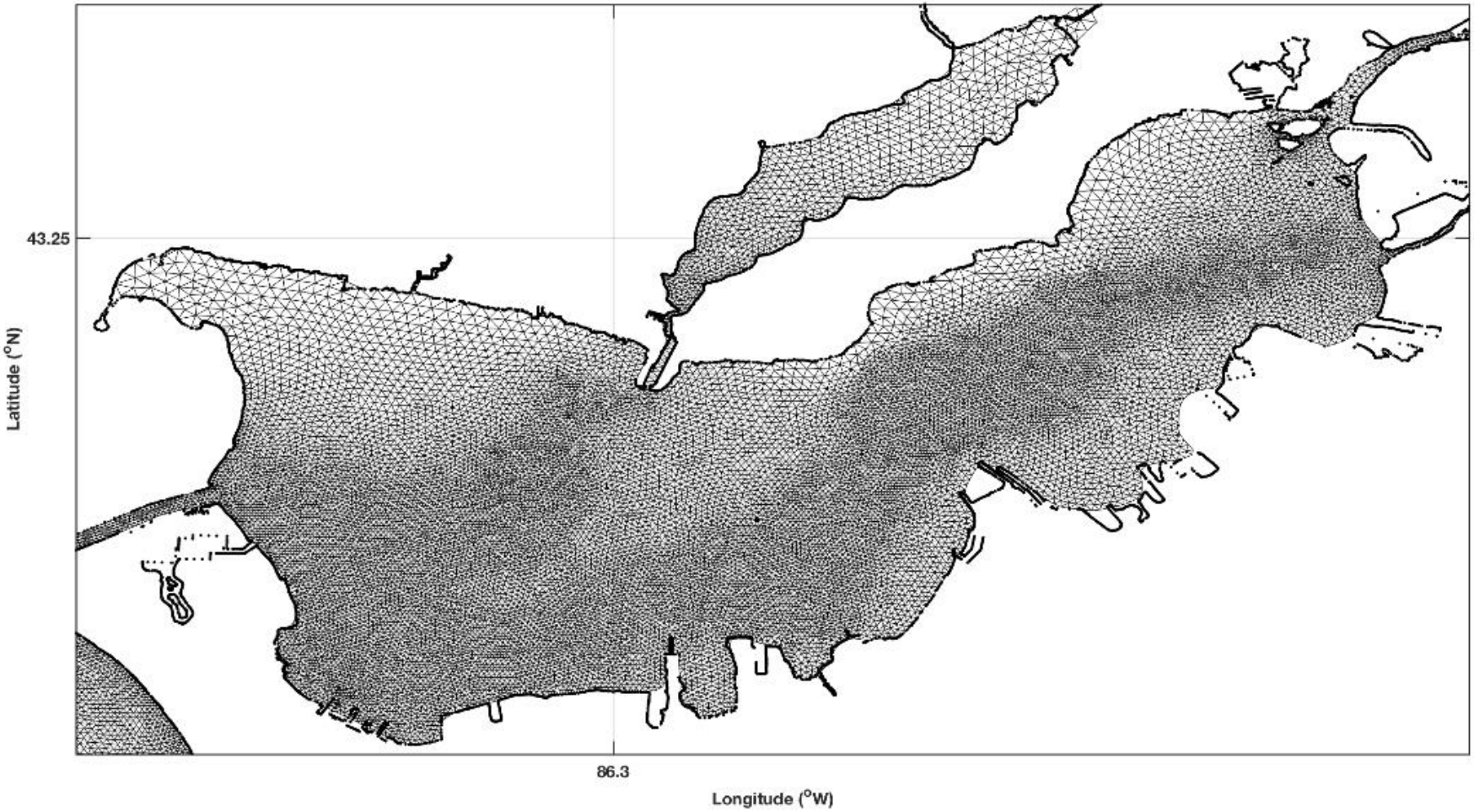
SCHISM (Semi-Implicit Cross-scale Hydroscience Integrated System Model): **Unstructured** grids; **3D Seamless Cross-scale;** Joseph Zhang et al. at VIMS)



SCHISM (Semi-implicit Cross-scale Hydroscience Integrated System Model) Configuration for the study of Muskegon Lake

Model Configuration: SCHISM

60190 Elements; 30914 Nodes



SCHISM Configuration for the study of Muskegon Lake

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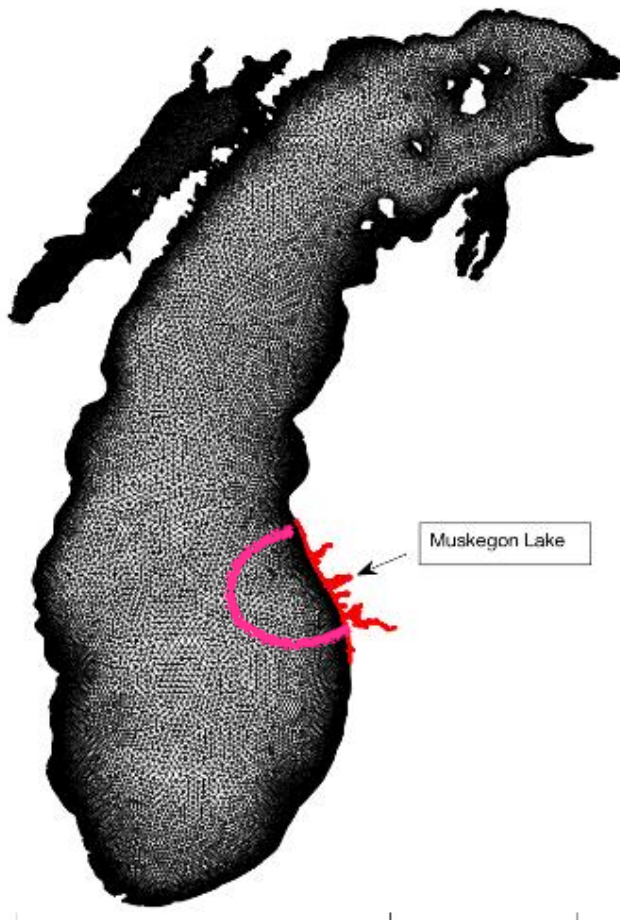
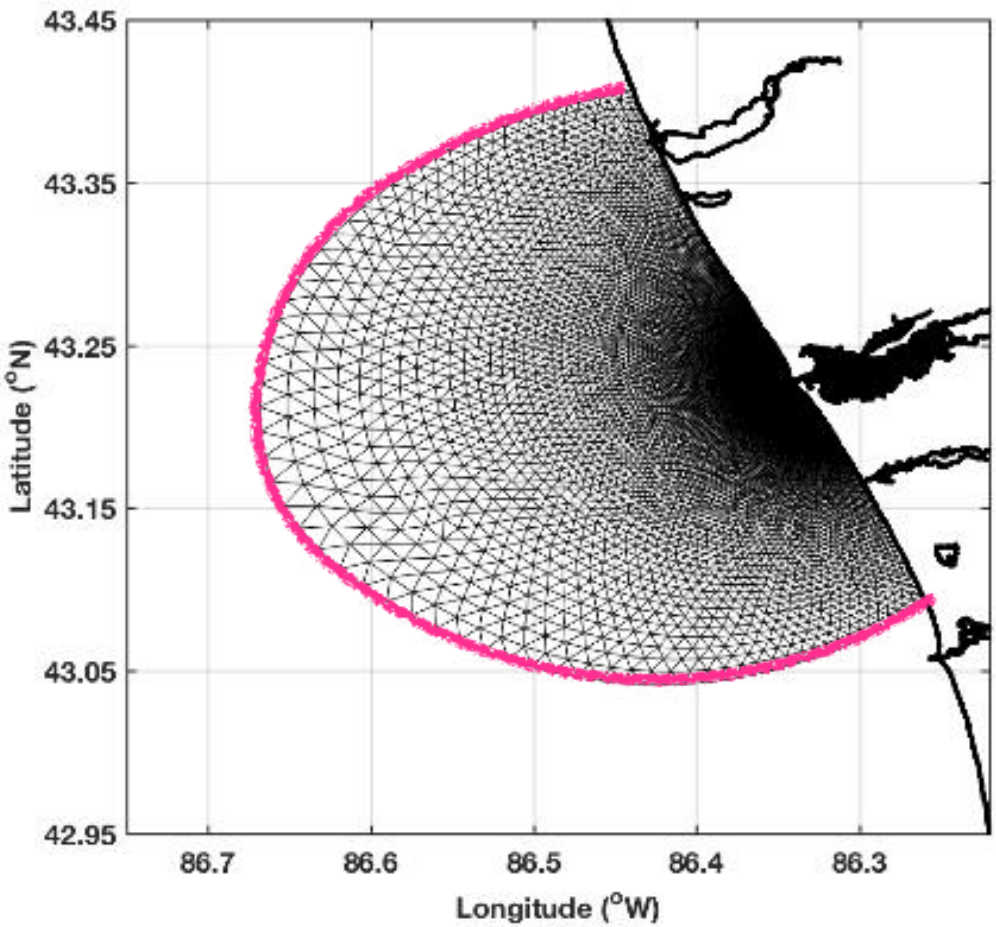
Model Set-up

One-way nested in the Lake Michigan-Huron Operational Forecasting System (**LMHOFS; NOAA**)



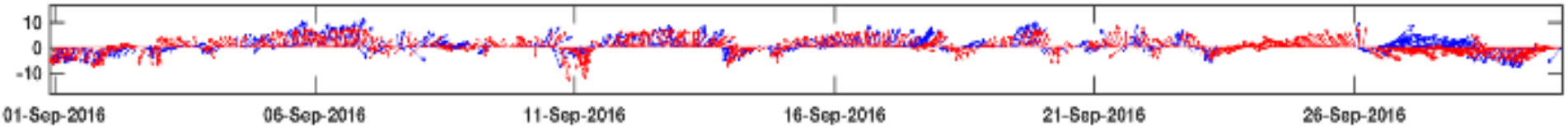


FVCOM Model Configuration of Lake Michigan-Huron Operational Forecasting System

Model Set-up

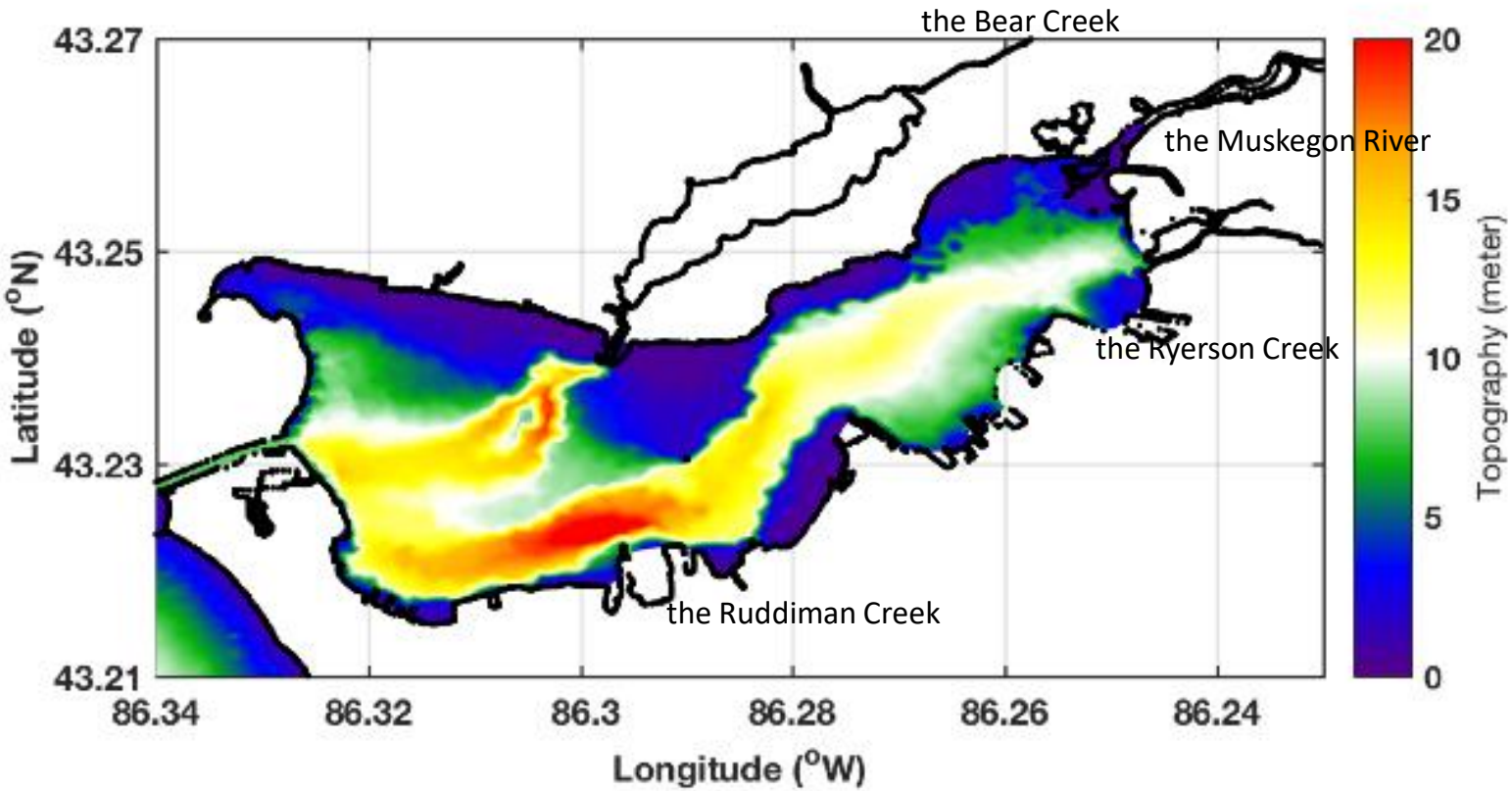
Atmospheric Forcing from Interpolated Observations

Wind in September (Blue: Wind from GVSU Buoy; Red: Interpolated Forcing from NOAA GLCFS)



Model Set-up

Rivers Included: The Muskegon River and Bear Creek



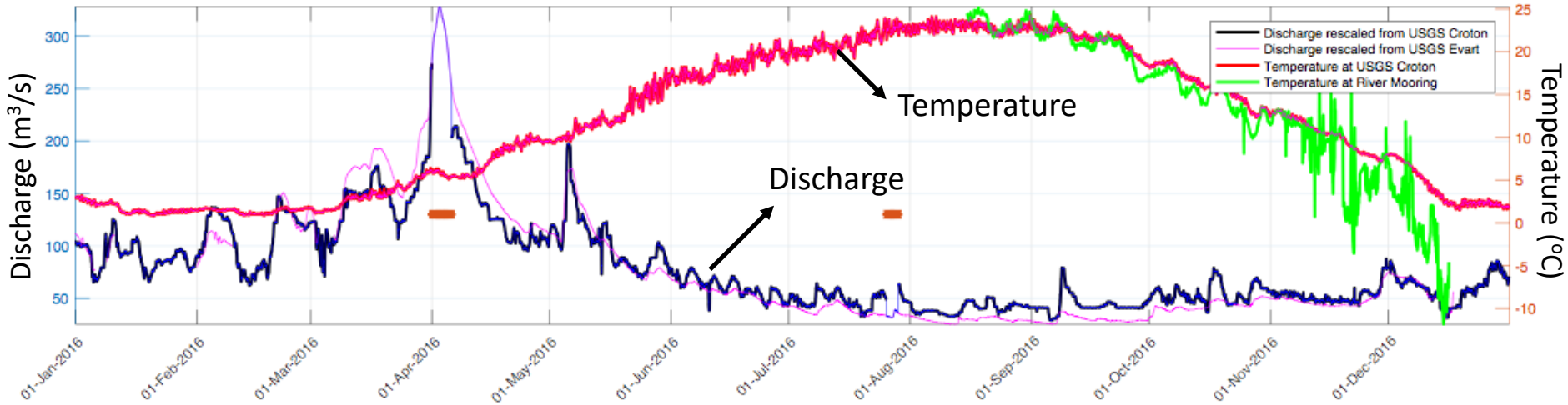
Bathymetry of Muskegon Lake

Model Set-up

Rivers Included:

The Muskegon River and Bear Creek

Discharge and temperature for the Muskegon River



The USGS river discharge at the Croton Dam is rescaled:

$$\frac{\text{USGS discharge at Croton Dam}}{\text{watershed at Croton Dam}} \times \text{Muskegon River Watershed}$$

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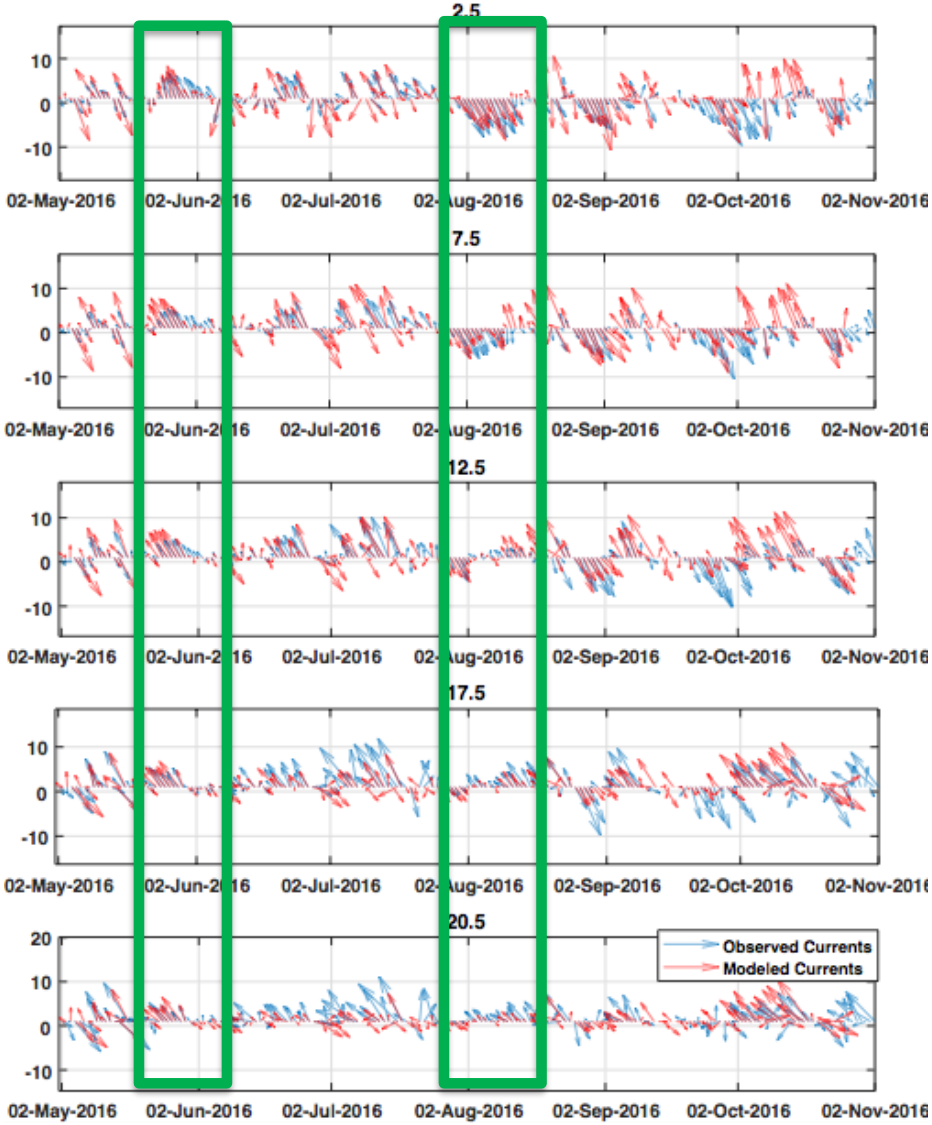
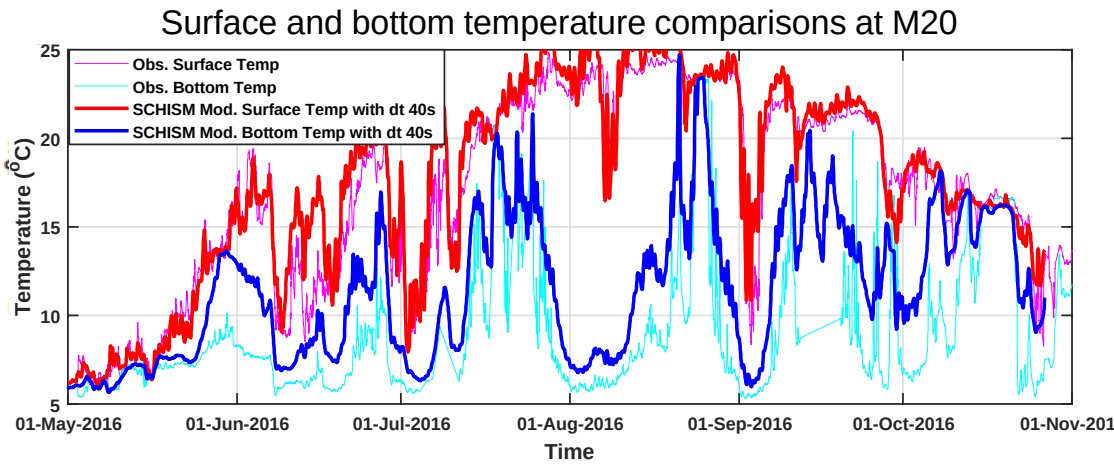
Model Assessment

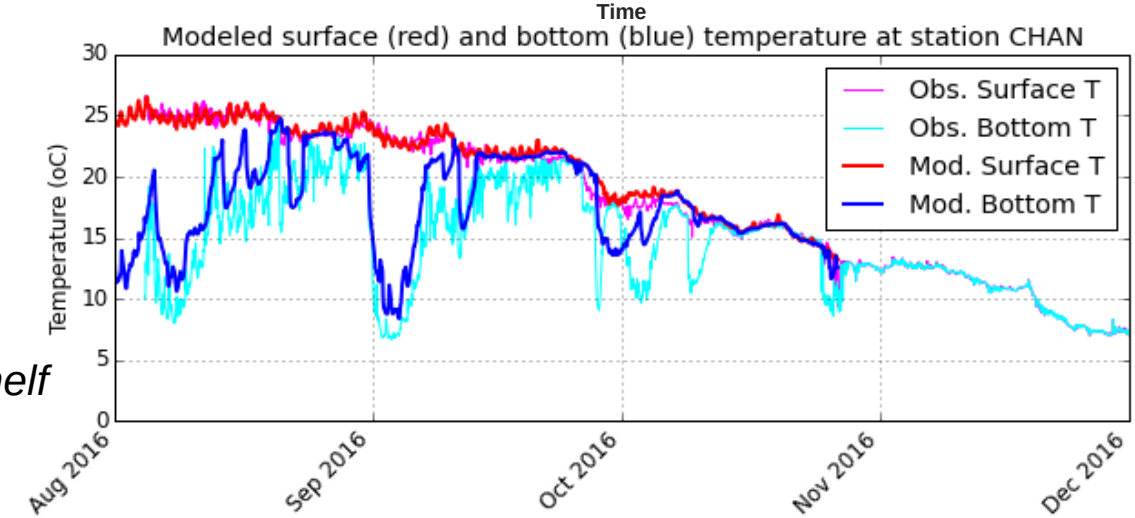
SCHISM simulates nearshore currents in Lake Michigan on par with previous studies

Model-Observation Comparisons of Currents at M20



Model Assessment



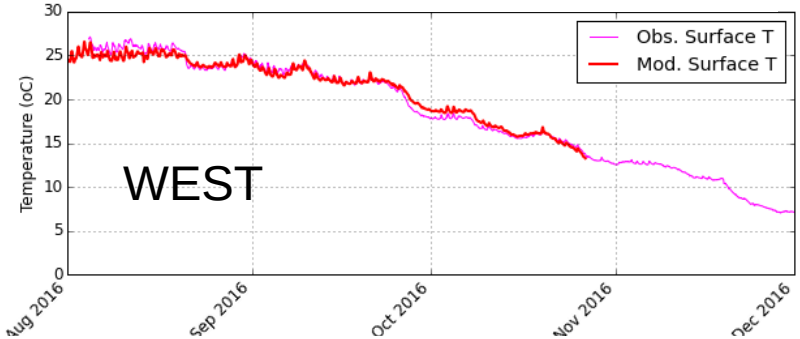


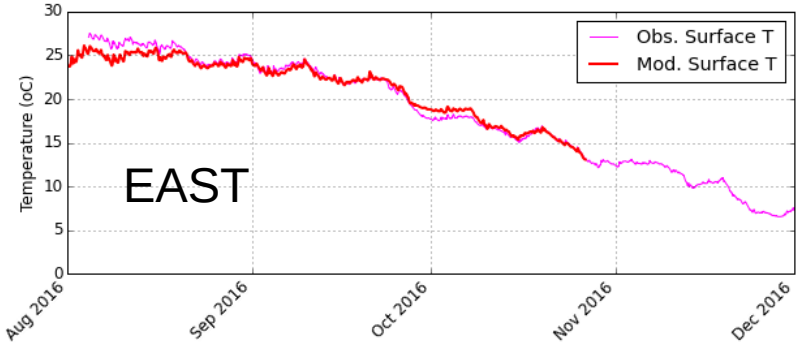
SCHISM well simulates the major exchange events between Lake Michigan and Muskegon Lake

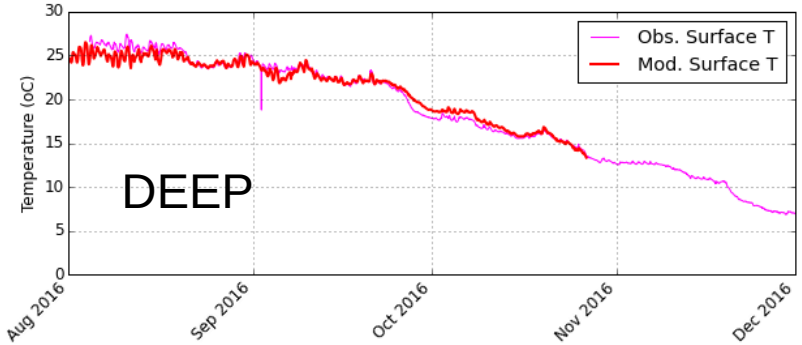
Liu et al., Estuarine, Coastal and Shelf Science, 2018

Model Assessment

Comparisons of Mod. and Obs. Surface Temperature







SCHISM well simulates the surface temperature throughout the lake

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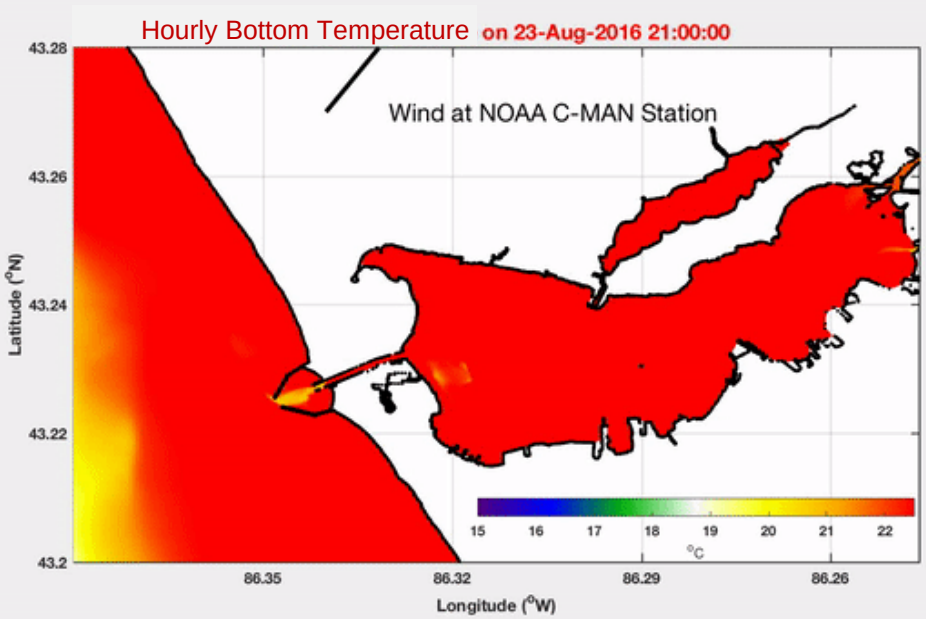
Model Results

Hourly-averaged bottom temperature and dissolved oxygen in 2016



2016 retrospective animation in August and September showing bottom cold water intrusion from Lake Michigan to Muskegon Lake (Upwelling wind: southeastward; Downwelling wind: northwestward)

How to respond anthropogenic activities and climate change?

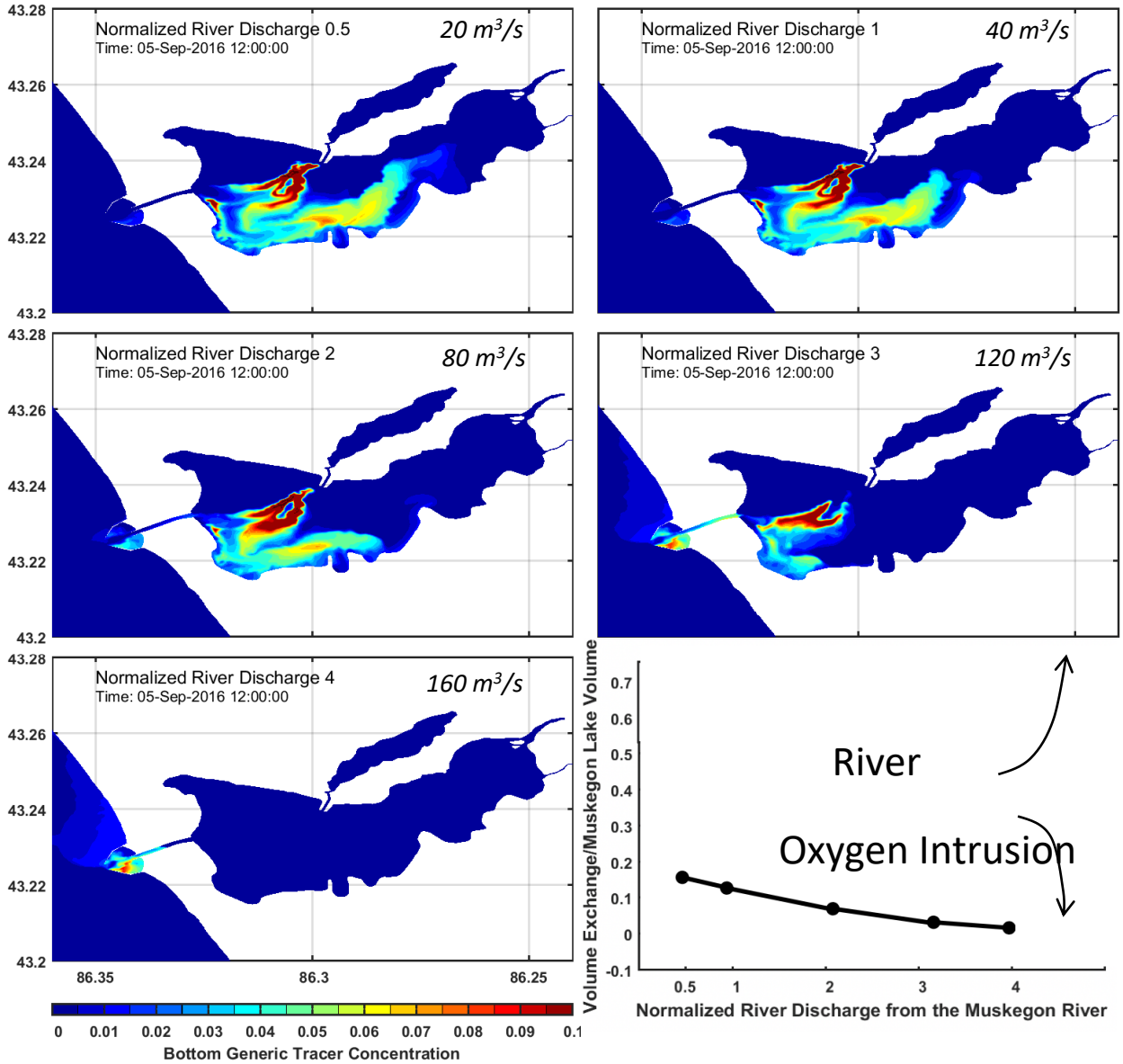
Model Results: Process-oriented experiments

To study the intrusion's response to **Hydrologic Input Shift** and **Navigation Channel Width,** we carried out Process-oriented experiments:

Name	Normalized River Discharge	Normalized Navigation Channel Width
R1	0.5	1
Ctrl Case	1	1
R2	2	1
R3	3	1
R4	4	1
N1	1	2
N2	1	3

List of process-oriented experiments

Model Results: Hydrological Input Shift



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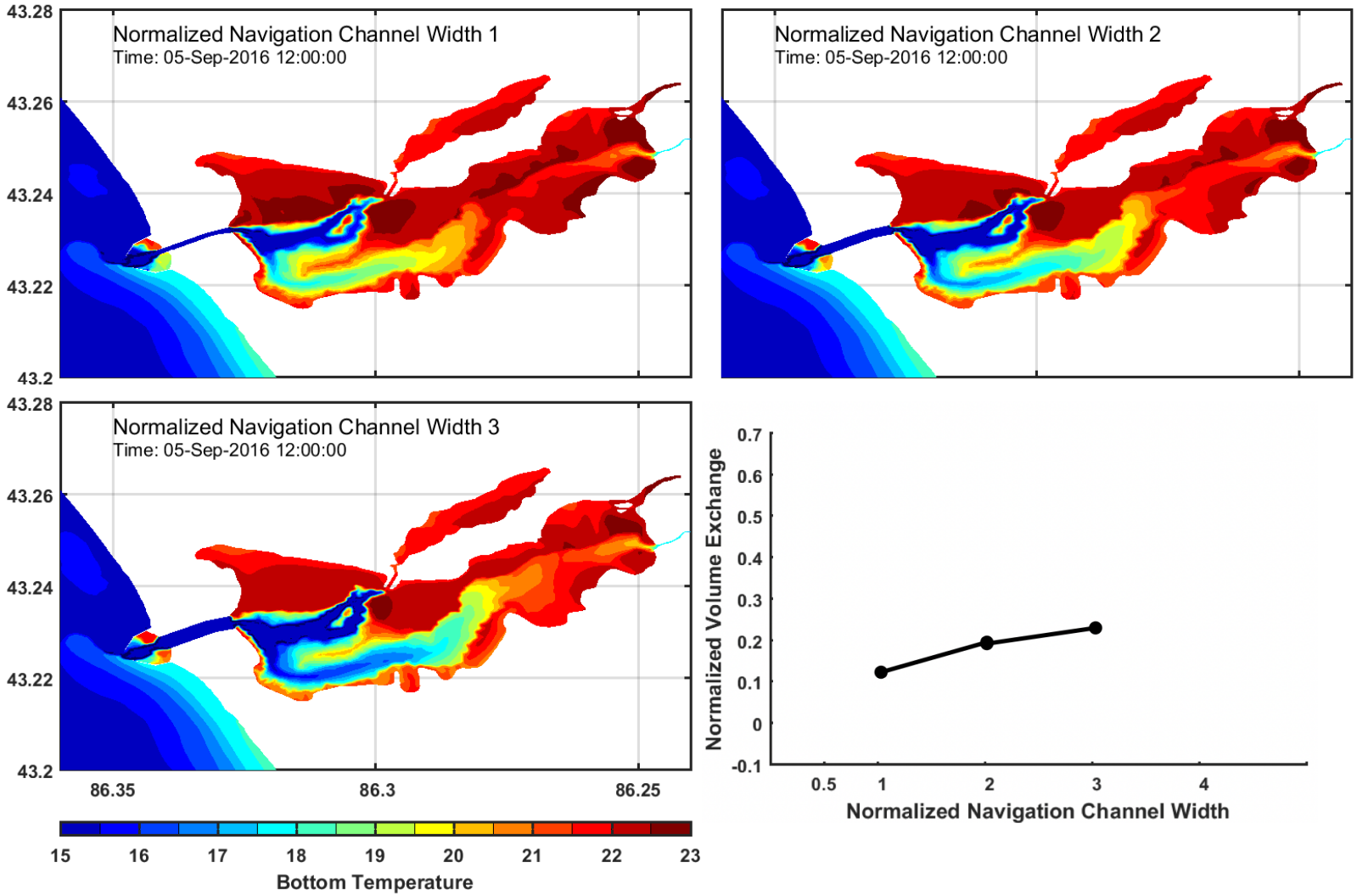
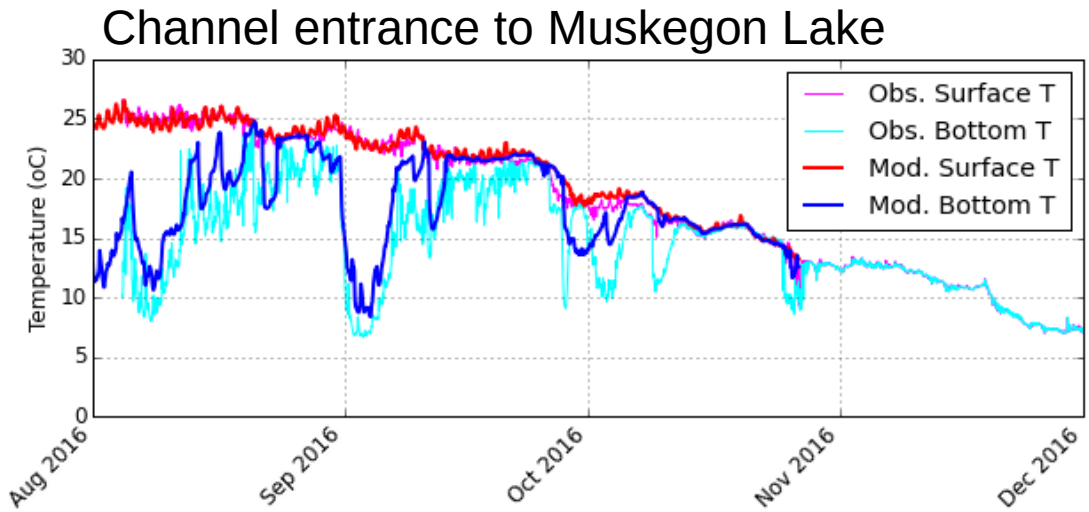
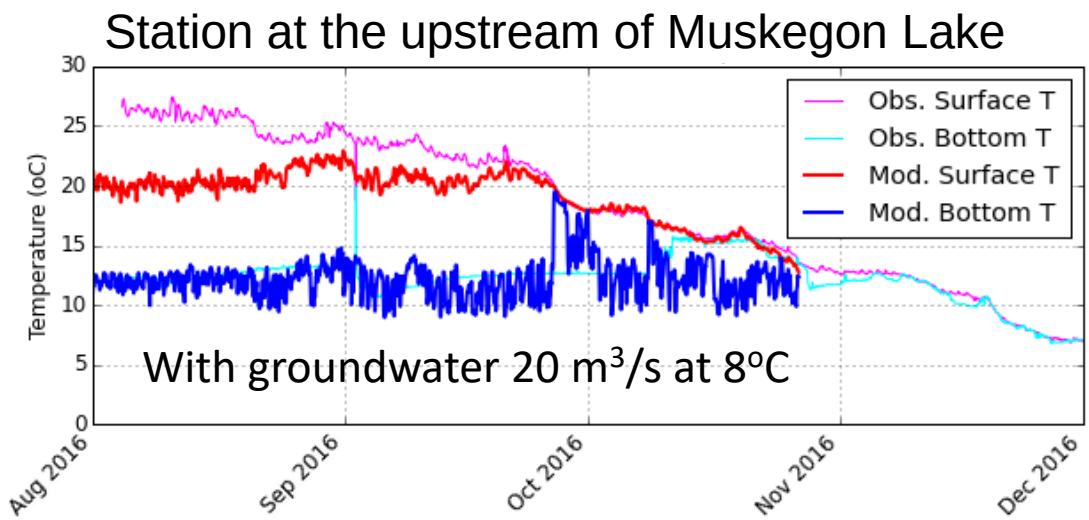
Model Results: Navigation Channel Width



Coastal engineering projects have the potential to mitigate climate impact's on coastal ecosystem

Model Results: Groundwater Effects?





Conclusion

- Our model reproduces the cold water intrusion;
- The increase of hydrologic input suppresses the intrusion (climate change implication);
- Navigation channel width can modulate the water intrusion;
- Groundwater input is important for the Muskegon Lake stratification.

Acknowledgment

- CIGLR Postdoctoral Fellowship
- GVSU Long-term Monitoring Program
- Katie Knapp and Anthony Weinke at GVSU for data collection
- Joseph Zhang at VIMS