Modeling Muskegon Lake – A Freshwater Estuary under Stress

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Introduction

Muskegon Lake, a freshwater estuary located on the eastern shore of Lake Michigan,

- Experiences water qualify degradation caused by extensive shoreline filling and sediment contamination;
- Is impacted by Harmful Algal Blooms (HABs) and hypoxia;
- Is designated as EPA Area of Concern (AOC) and a NOAA Habitat Blueprint Focus Area.

The Muskegon Lake can serve as a microcosm of the water quality issues found in other larger lakes and coastal estuaries.

GOALS:

- Understand the physical dynamics of Muskegon Lake including cold water intrusion from Lake Michigan;
- Understand the ecological drivers of Muskegon Lake.

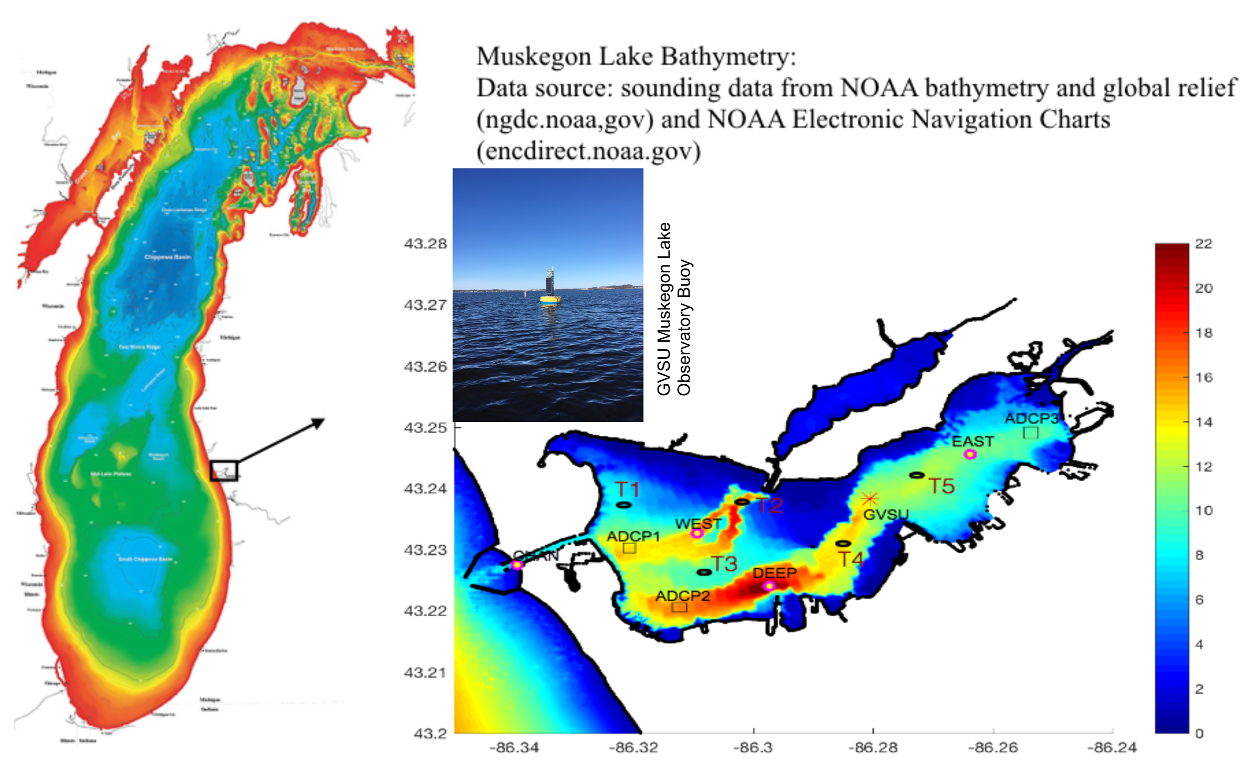


Figure 1. Location and Bathymetry of Muskegon Lake with the observational sites marked in Muskegon Lake.

Data and Methods: Observations

Muskegon Lake Observatory Buoy (www.gvsu.edu/buoy) has delivered high-frequency meteorological and water quality data throughout the water column from Apr/May to Nov/Dec since 2011 (Biddanda et al., in review).

Historical observations in Muskegon Lake (as marked in Figure 1), including seasonal shipboard monitoring since 2003 (Steinman et al., 2008), lake-wide test profiles (magenta circles) since 2011, ADCP (squares) and Temperature (ellipses) moorings deployed in 2017, provide valuable information for investigating the ecosystem and hydrodynamics of Muskegon Lake..

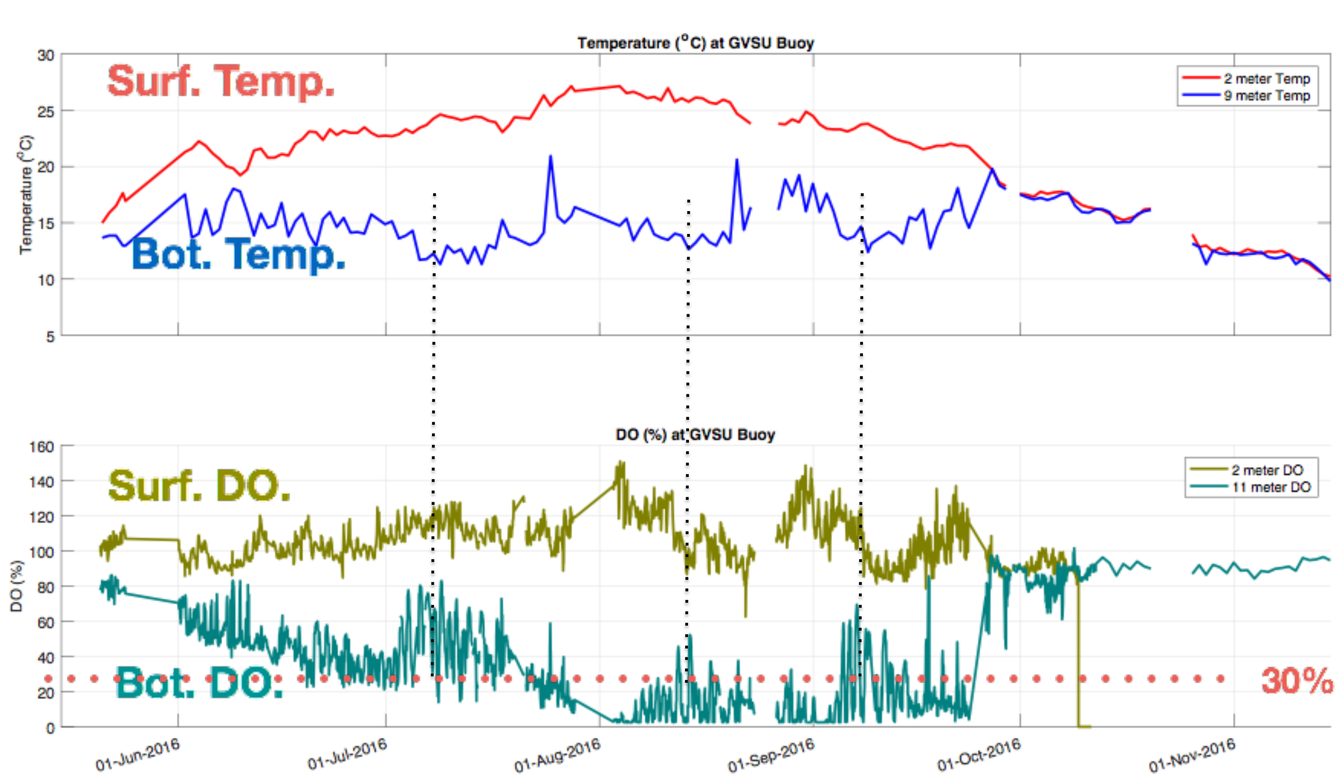


Figure 2. Temperature and dissolved oxygen (DO) observations from the GVSU Muskegon Lake Observatory Buoy.

For example, the episodic occurrence of bottom cold water at GVSU Buoy is highly correlated with the increase of DO concentration (Weinke et al., 2017). The further study requires a high-resolution numerical model.

Data and Methods: High-Resolution Numerical Model

SCHISM: Semi-implicit Cross-scale Hydroscience Integrated System Model developed by Joseph Zhang in VIMS (Zhang et al., 2011)

Simulate the year of 2016 driven by *the Muskegon River and Bear Creek* (USGS), *Atmospheric Forcings* (NOAA GLCFS), and *Offshore Conditions* from Lake Michigan (NOAA LMHOFS).

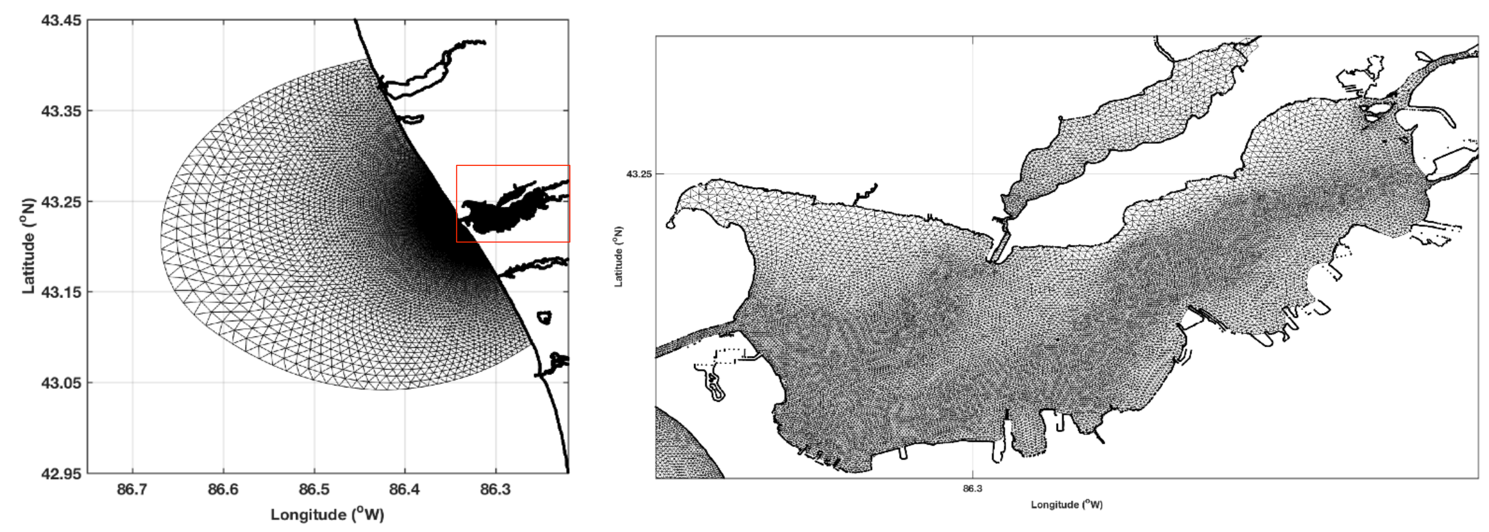
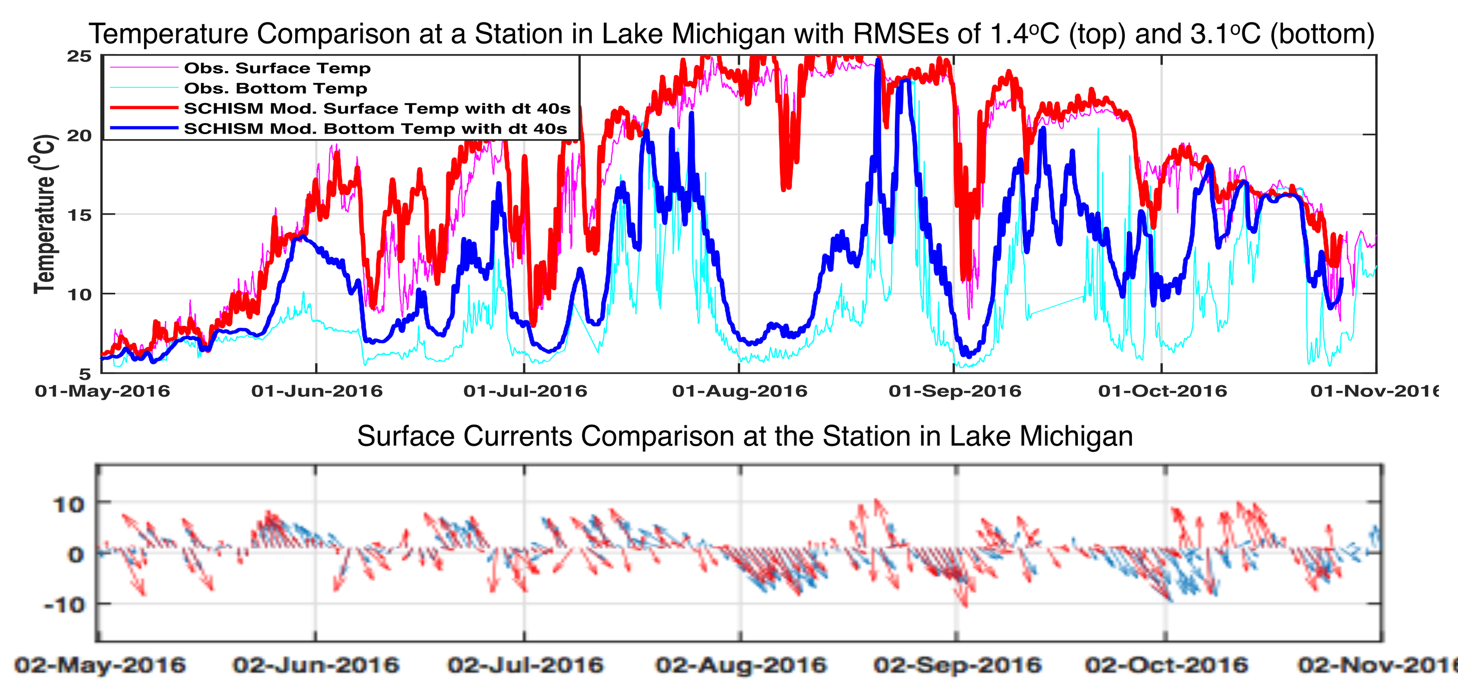


Figure 3. SCHSIM Model Configuration for the study of Muskegon Lake with Horizontal Resolutions of 25 m to 3 km, 20 Vertical Layers, 30914 Nodes and 60193 Elements.

Model Evaluation



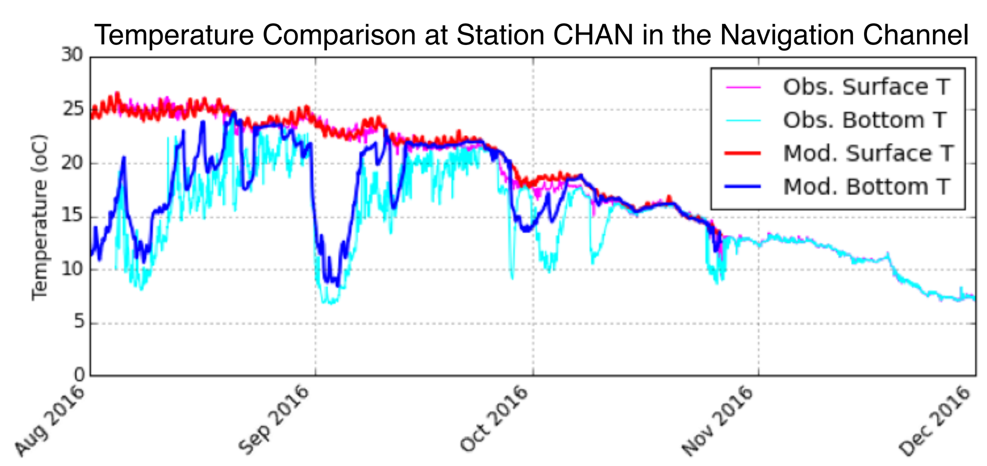


Figure 4. Model validation through comparisons with observations at the stations in Lake Michigan and Muskegon Lake.

Model Results: Cold Water Intrusion from Lake Michigan

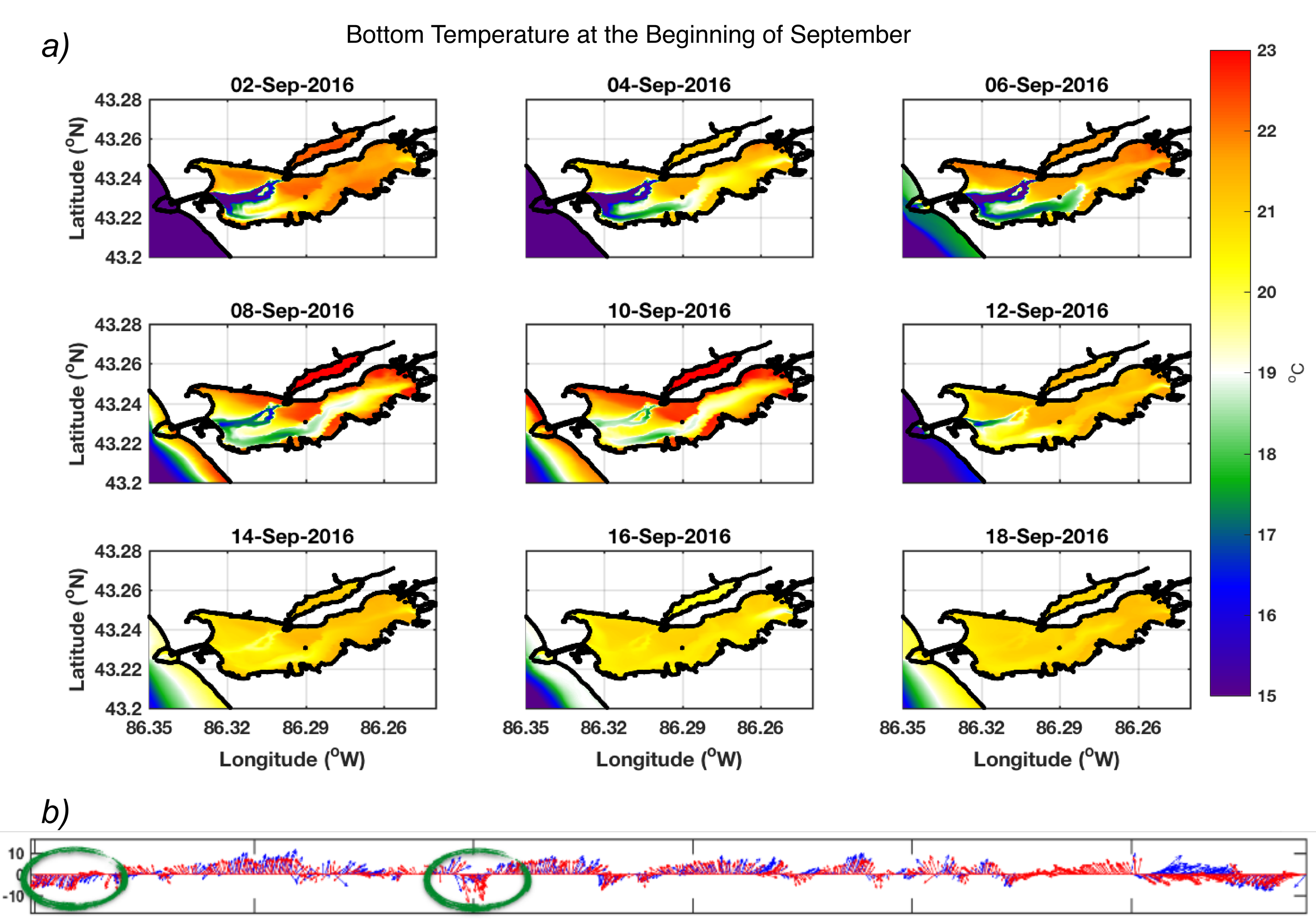


Figure 5. a) Bottom temperature at the beginning of September showing the cold water intrusion during upwelling-favorable winds; b) Winds in September 2016.

Process-Oriented Experiments

To test cold water intrusion's response to river discharge, width of navigation channel, and winds with different directions and amplitudes, we carried out:

•Experiments with normalized river discharges of 0.5, 1, 2, 3 and 4 for the intrusion event at the beginning of Sep.;

•Experiments with normalized navigation channel widths of 1, 2 and 3;

•Experiments with different winds' directions and strengths (not shown).

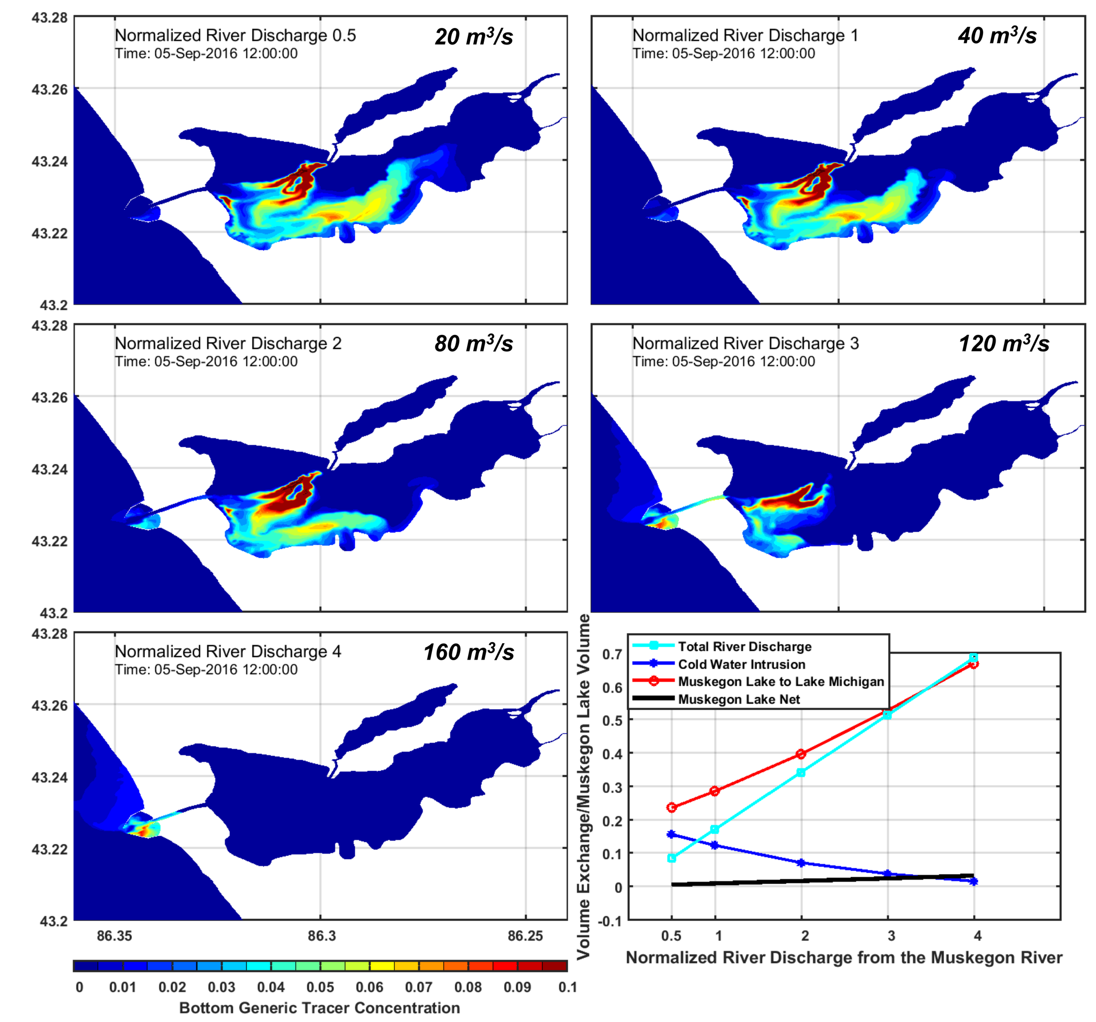


Figure 6. Passive tracer distributions for the experiments with normalized river discharges of 0.5, 1, 2, 3 and 4, and the corresponding changes in water exchange.

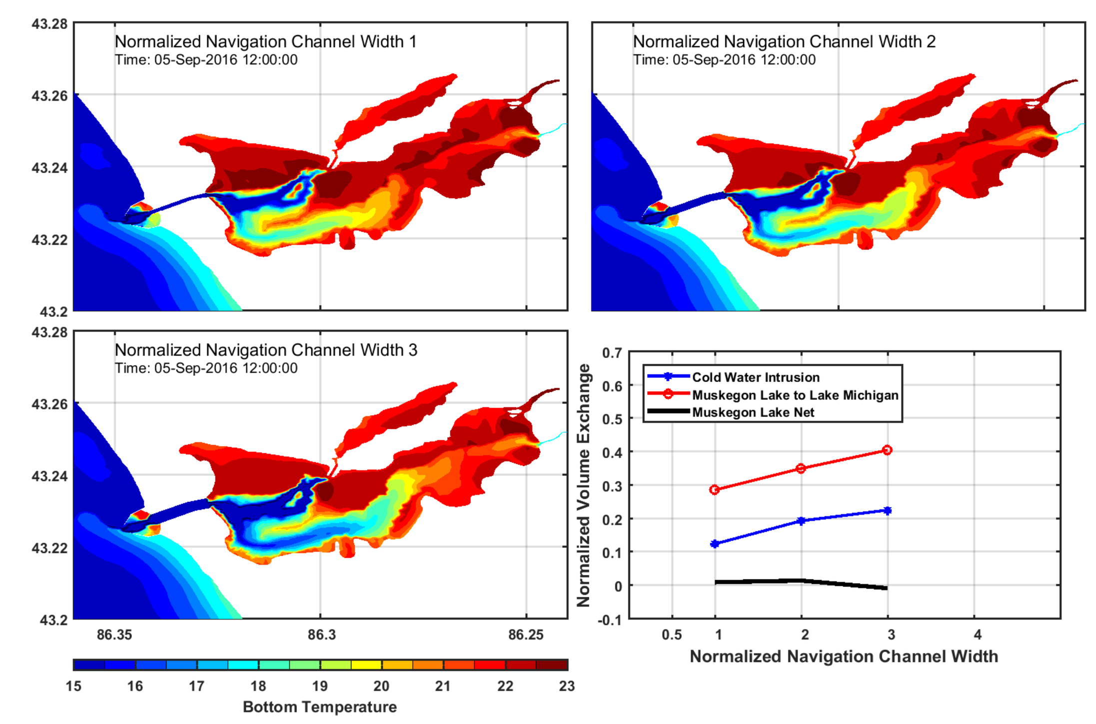


Figure 7. Bottom temperature for the experiments with normalized navigation channel widths of 1, 2 and 3, and the corresponding changes in water exchange.

Conclusions

- ❖ Cold water intrusion has a control of DO-enrichment of the estuary;
- ❖ Intrusion length of offshore waters and frequency of flushing events can be reduced as a result of increased precipitation, signaling a key feature of possible future water quality conditions under a changing climate;
- ❖ Cold water intrusion is regulated by the navigation channel width, winds and stratification, which allows us to extend the study to other coastal systems.

Future Plan

•Implement more realistic groundwater sources;

•Couple ecological model (CoSiNE; Chai et al., 2002) with the hydrodynamic model to study HABs and hypoxia in Muskegon Lake.

Acknowledgements

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