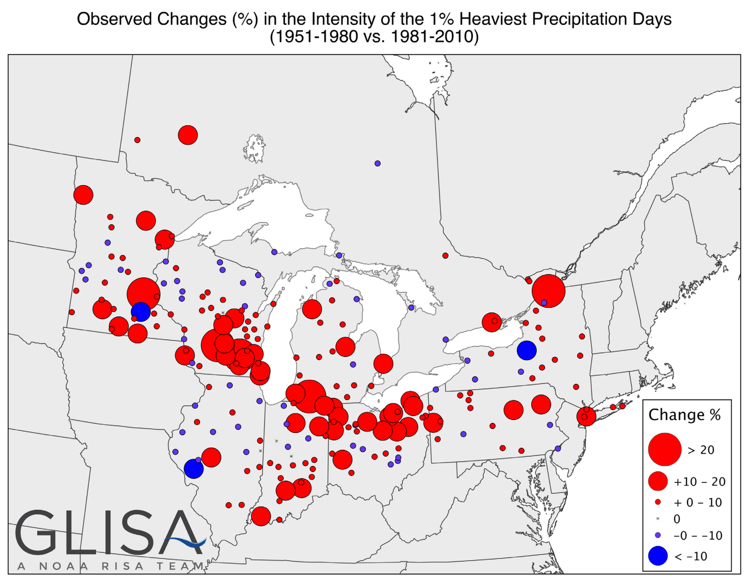
Fate of Tributary Loads to Lake Michigan

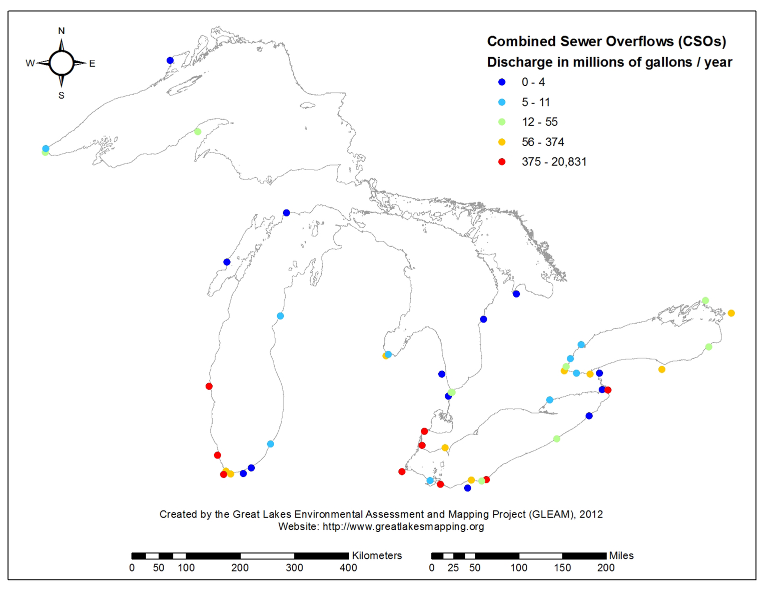
Luke Gloege[1*], Galen McKinley[1], Pete McIntyre[1], Rob Mooney[1]
[1]University of Wisconsin Madison
[*]gloege@wisc.edu

I. Introduction

- River pollution from runoff is a stressor to beneficial lake uses (Allan et al. 2013).
- River pollution impairs access to potable water and recreational uses (EPA 2016).
- Current management assume pollutants are well-mixed throughout the lake.
- Imminent increases in heavy precipitation (Kunkel et al. 2013) will exacerbate runoff, contributing to stormwater management problems (Changnon and Westcott 2002).
- A 3D hydrodynamic model of Lake Michigan simulates the redistribution of river discharge at the mouth of the Milwaukee River during three thermal regimes (Figure 1): i) winter thermal front ii) spring thermal front iii) strong summer stratification.



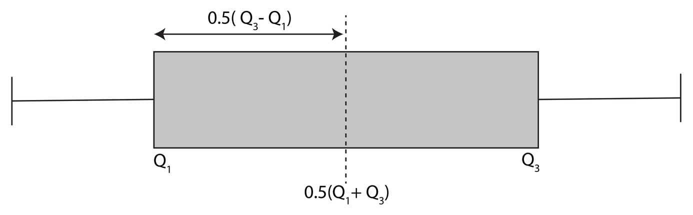
Change in intensity of the heaviest 1% of daily precipitation events at Great Lakes Integrated Science + Assessments (GLISA) climatology stations.



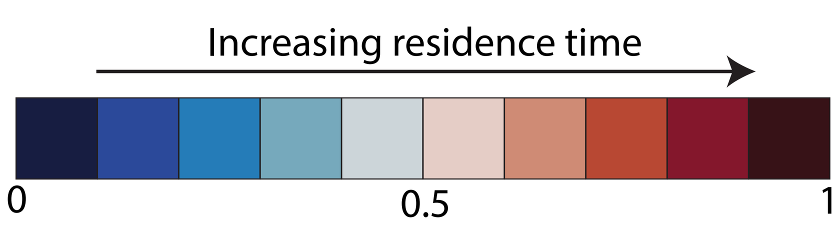
Estimated combined sewer overflow (CSO) discharge volume for 49 cities within the Great Lakes watershed over the period 2005-2008.

II. Methods

- MITgcm is configured to bathymetry of Lake Michigan with 28 vertical levels.
- The model has a spatial resolution of 1/60 of a degree (~2 km).
- Forced at the surface with meteorological and radiative fields (3 hr. temporal resolution).
- Passive tracer is released at the mouth of Milwaukee River.
- Release either instantaneous or annual profile followed the observed hydrograph.
- Hydrograph is normalized such that the "well mixed" concentration will be unity.
- CQV* quantifies plume residence time $CQV* = 1 - \frac{[0.5(Q_3 - Q_1)]}{[0.5(Q_3 + Q_1)]}$
- CQV* calculated using 1st (Q1) and 3rd (Q3) quartiles within a 10 day window.



Graphical representation of CQV* terms



Physical interpretation of CQV* value

III. Results

- Winter and spring are characterized by coastal thermal fronts (Figure 1).
- Horizontal thermal structure has potential to trap plumes in the coastal zone (Figure 2).
- Tracer release is coastally trapped in spring and winter (Figure 2, Figure 3, Figure 4).
- Plume resides near the coast during winter/spring and offshore in summer (Figure 4).
- Future work will consider biologically active tracers.

IV. Conclusion

- Lake Michigan does not act as a well mixed reactor.
- Coastal trapping has the potential to exacerbate ecological impacts.
- Strategic management efforts should be framed around coastal impacts.
- Anticipated increase in precipitation intensity call for infrastructure updates to mitigate the impact of runoff into Lake Michigan.

Thermal Structure

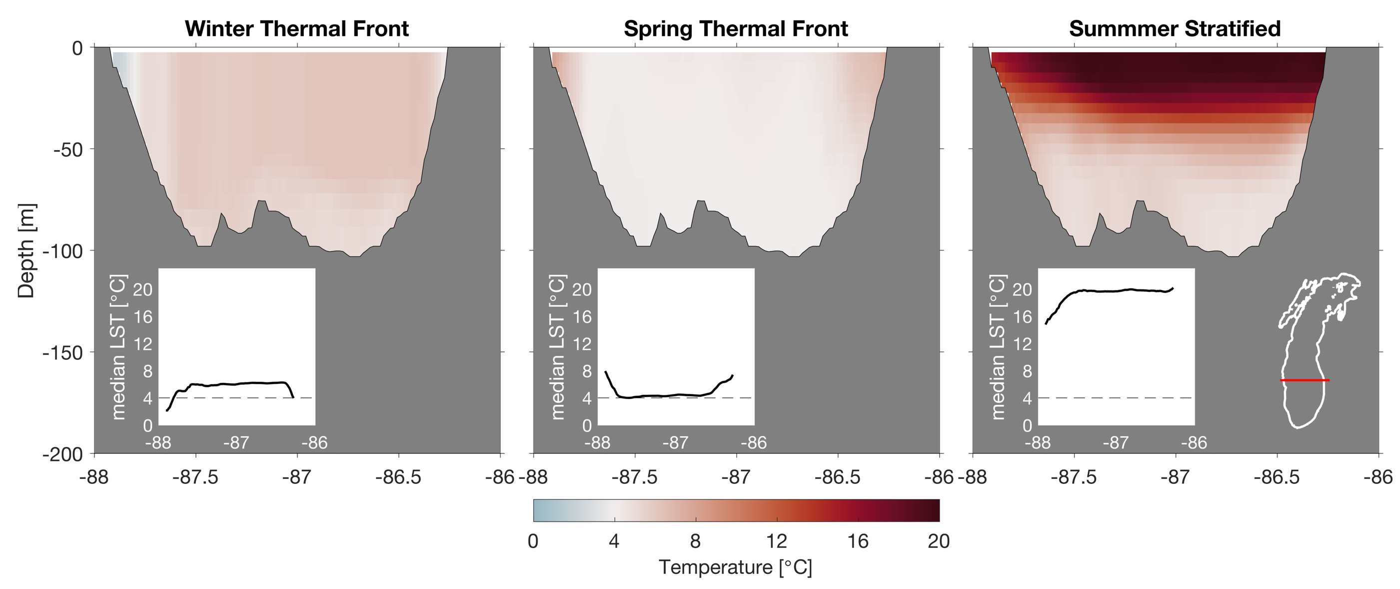


Figure 1: Median temperature across Lake Michigan at 43N during winter (left), spring (middle), and summer (right) for 2007. Winter is defined as days of year 1-78 and 309-365. Spring is defined as days of year 79-150. Summer is defined as days of year 151-308. The median temperature over each period is plotted. Inset figure shows median lake surface temperature (LST) over each period.

Instantaneous Tracer Release

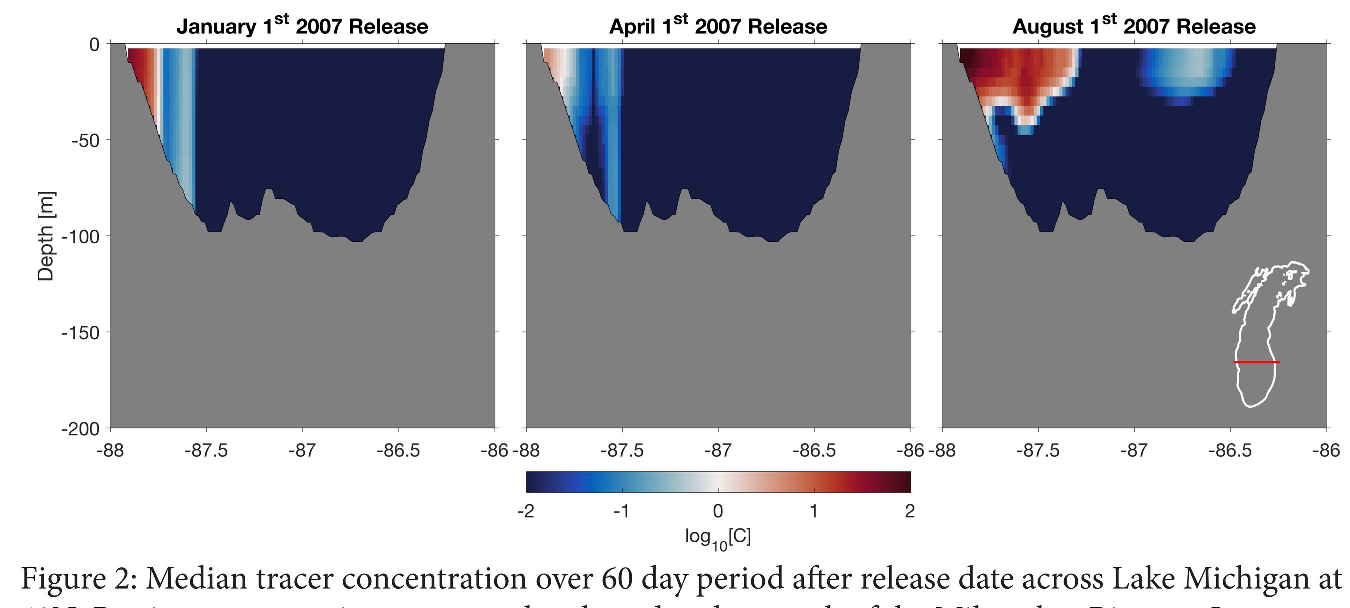


Figure 2: Median tracer concentration over 60 day period after release date across Lake Michigan at 43N. Passive tracer was instantaneously released at the mouth of the Milwaukee River on January 1st (left), April 1st (middle), or August 1st (right) of 2007.

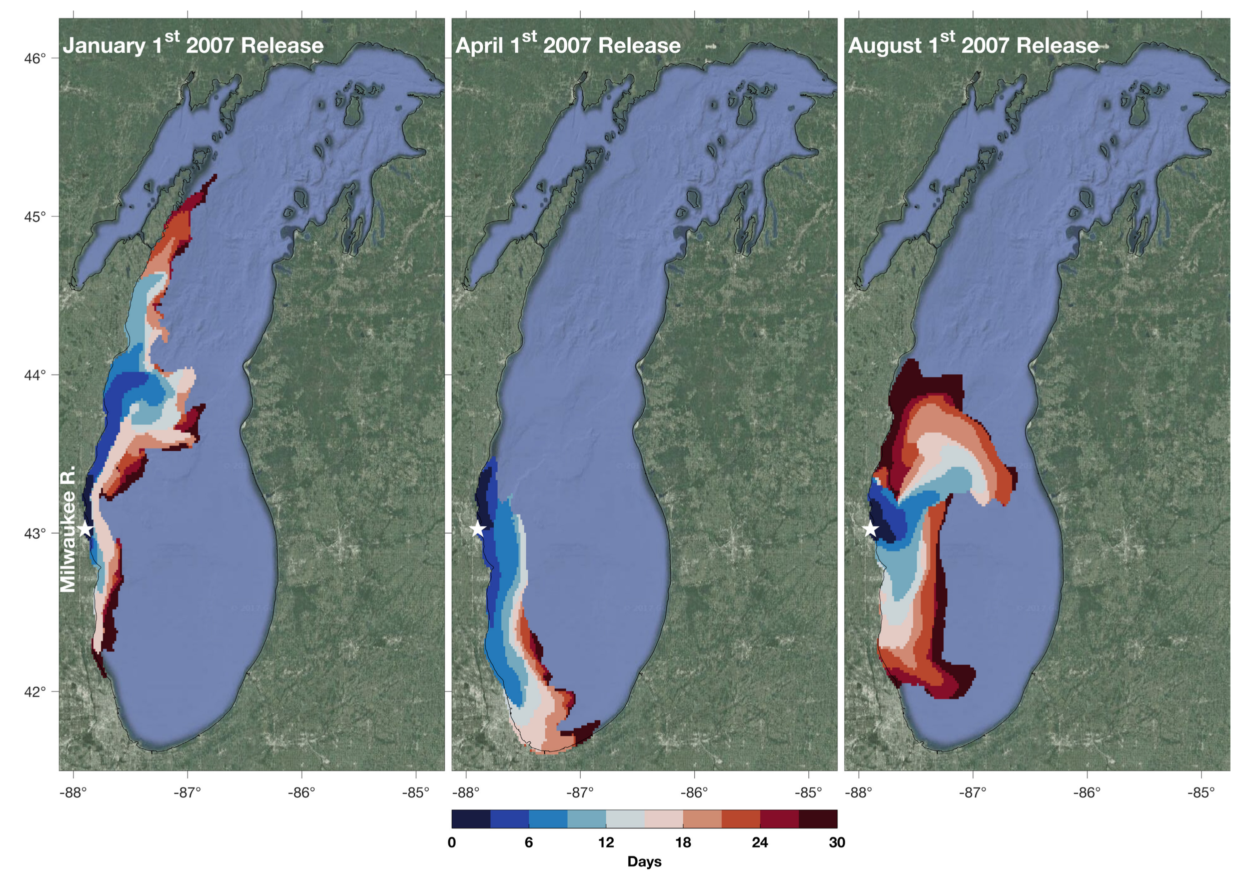


Figure 3: Number of days after instantaneous tracer release until "well-mixed threshold" is observed at each grid cell. Passive tracer was instantaneously released at the mouth of the Milwaukee River (indicated by a star) on January 1st (left), April 1st (middle), or August 1st (right) of 2007.

Time Varying Tracer Release

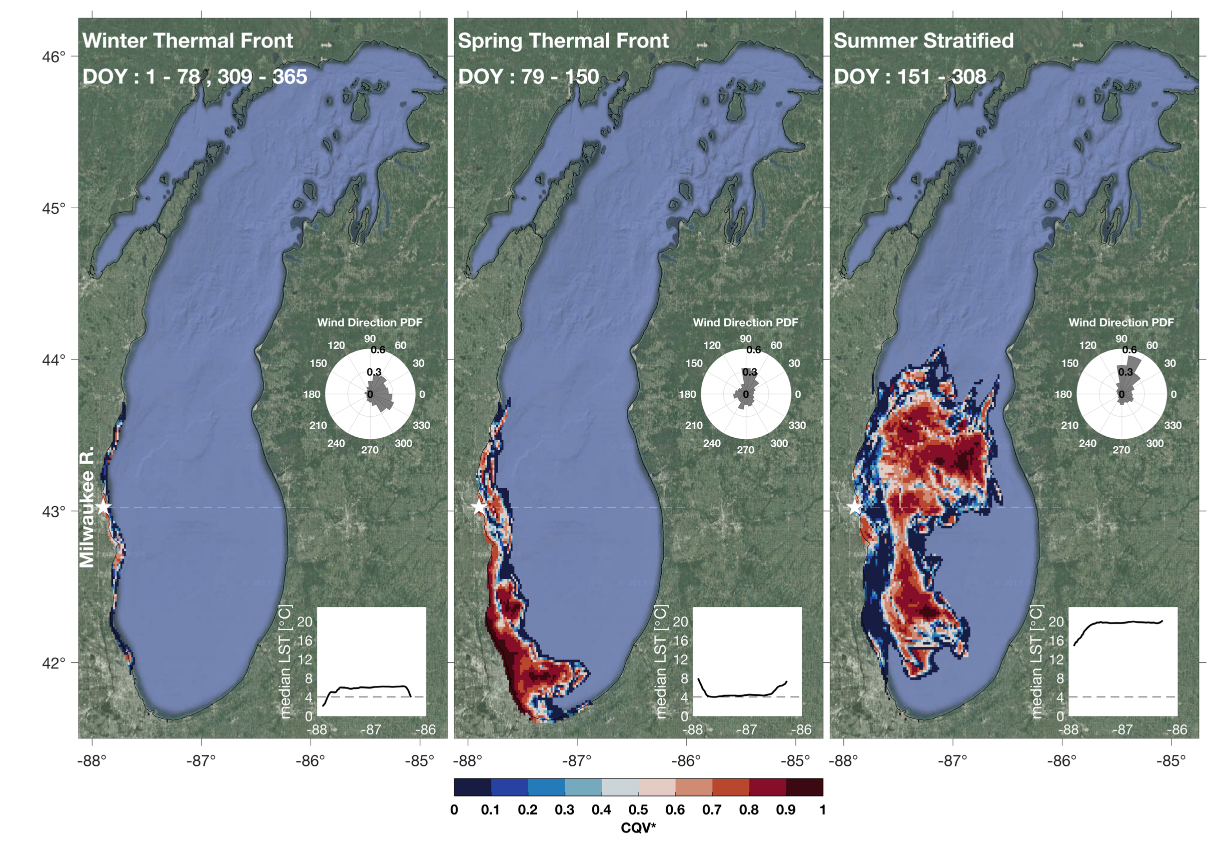


Figure 4: Median CQV* value during winter thermal front, spring thermal front, and summer stratified season for 2007. Winter is defined as days of year 1-78 and 309-365. Spring is defined as days of year 79-150. Summer is defined as days of year 151-308. CQV* is calculated within a 10 day moving window with 5 days of overlap. The median value across each season is plotted. Inset figures show the distribution of wind directions over the entire basin and the median lake surface temperature (LST) across 43N for each season.

References
Allan, J. D., et al. 2013. Joint analysis of stressors and ecosystem services to enhance restoration effectiveness. Proceedings of the National Academy of Sciences. 110(1). 372-377.
Changnon S.A. and Westcott N.E. 2002. Heavy rainstorms in Chicago: increasing frequency, altered impacts and future implications. Journal of the American Water Resources Association. 38:1467–1475.
EPA (U.S. Environmental Protection Agency). 2016. Report to congress - Combined Sewer Overflows into Great Lakes basin. EPA 833-R-16-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC.
Kunkel, K.E., et al. 2013. Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 3. Climate of the Midwest U.S. NOAA Technical Report NESDIS 142-3, 95 pp.

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Scan the QR on the right to view an animation of a tracer dispersing throughout Lake Michigan.