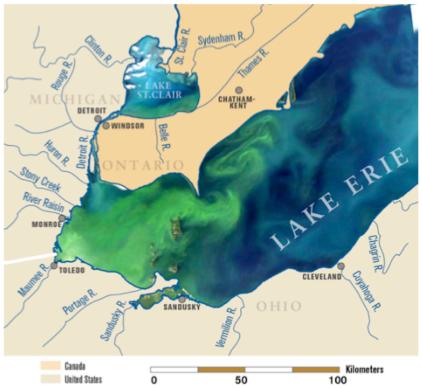
Physical-Biological Coupling in the Great Lakes

Dmitry Beletsky
Integrated Physical & Ecological Modeling & Forecasting
Research Scientist, CILER

From Beletsky et al., *Journal of Great Lakes Research* 25(1):78-93 (1999)

Linking HABs with Lake Hydrodynamics in Current and Future Climates



MODIS image of Lake Erie
on September 3, 2011

- In 2011, Lake Erie experienced its largest recorded harmful algal bloom due to record-breaking nutrient loads in spring.
- In addition to nutrient load, physical factors played important role.
- Weak lake circulation led to abnormally long residence times that incubated the bloom.
- Warm and quiescent conditions stimulated growth and prevented flushing of nutrients.
- These factors are consistent with expected future conditions.

Michalak, A.M., E.J. Anderson, D. Beletsky, et al., (2013). *PNAS.*
ISI Web of Science highly cited paper (top 1% in its field)

This material is based upon work supported by the National Science Foundation Water Sustainability and Climate program under Grant No. 1039043 & 1313897, Extreme events impacts on water quality in the Great Lakes: Prediction and management of nutrient loading in a changing climate

Michalak, A.M., E.J. Anderson, D. Beletsky, et al. (2013) “Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions”, Proceedings of the National Academy of Sciences, 110:16, 6448-6452, 10.1073/pnas.1216006110.
- ISI Web of Science highly cited paper (top 1% in its field)

Tracking Detroit and Maumee River Waters in Western Basin of Lake Erie

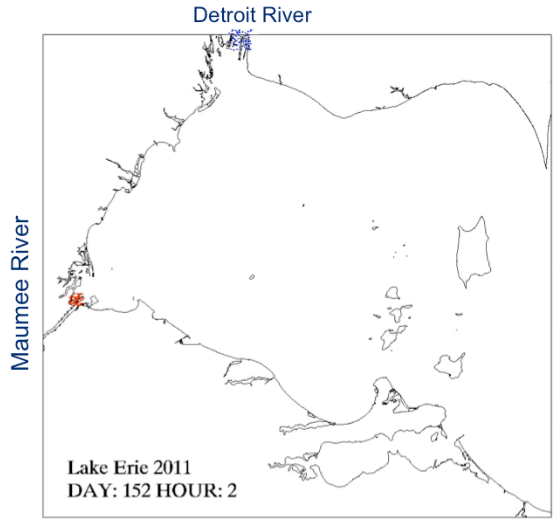
Virtual particles released daily in Detroit River (blue) and Maumee River (red) mouths.

Hydrodynamics is based on Princeton Ocean Model (POM).

Particles tracked during 30 days.

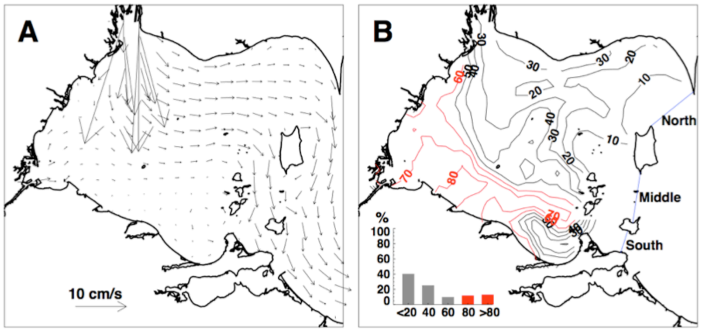
Spread from Maumee was slow contrary to fast spread from Detroit.

Interaction between plumes was weak, preventing quick dilution of nutrient rich Maumee waters.



IPEMF | Physical-Biological Coupling in the Great Lakes

Understanding Circulation and Residence Time in Western Basin of Lake Erie



Spring circulation in 2011

Residence time (days). Red color indicates long residence time for Maumee waters, conducive to bloom development

Hydraulic residence time of the Western Basin is 53 days.

Detroit River water residence time is 30 days.

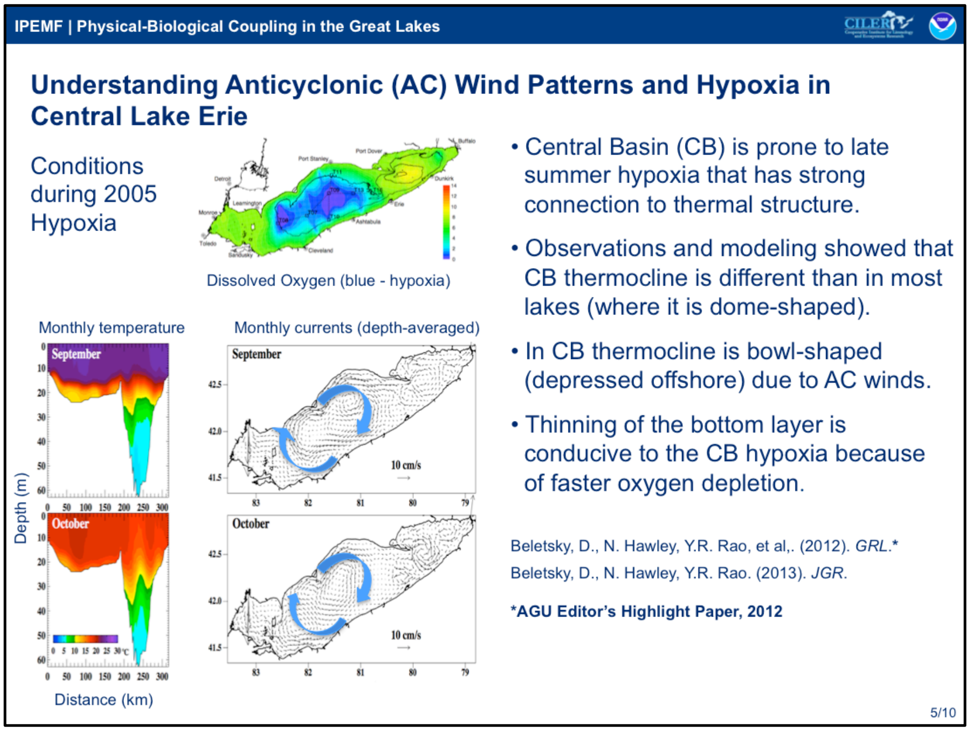
Maumee River water residence time is 70 days.

Future Research:

Compare hydrodynamics and residence time in Western Basin in current and future climates driving POM with regional climate model predictions

4/10

Residence Time: The average amount of time that a particle spends in a particular system.



Central Basin (CB) is prone to late summer hypoxia.
Most large lakes have a dome-shaped summer thermocline (deep nearshore, shallow offshore) accompanied by cyclonic circulation.
Observations and modeling showed that CB thermocline is atypical: it is bowl-shaped (depressed offshore) and circulation is anticyclonic due to anticyclonic wind vorticity.
Thinning of the bottom layer is conducive to the CB hypoxia because of faster oxygen depletion

This material is based upon work supported by the NOAA grant NA07OAR4320006: Forecasting the Causes, Consequences and Remedies for Hypoxia in Lake Erie and NSF Water Sustainability and Climate program under Grant No. 1039043 & 1313897, Extreme events impacts on water quality in the Great Lakes: Prediction and management of nutrient loading in a changing climate

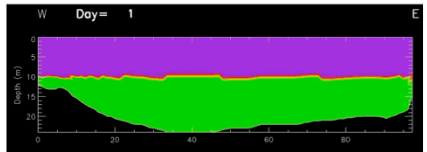
Beletsky, D., N. Hawley, Y.R. Rao, H. A. Vanderploeg, R. Beletsky, D. J. Schwab and S.A. Ruberg. 2012. Summer thermal structure and anticyclonic circulation of Lake Erie, Geophys. Res. Lett., 39, L06605, doi: 10.1029/2012GL051002
- AGU Editor's Highlight paper, 2012

Beletsky, D., N. Hawley, Y.R. Rao. 2013. Modeling summer circulation and thermal structure in Lake Erie. J. Geophys. Res. 118, doi: 10:1002/jgrc.20419

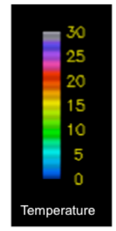
Scavia, D., J. D. Allan, K. K. Arend, S. Bartell, D. Beletsky, N. S. Bosch, S. B. Brandt, R.D. Briland, I. Daloglu, J. V. DePinto, D. M. Dolan, M. Anne Evans, D. Goto, H. Han, T. O. Hook, R. Knight, S. A. Ludsin, D. Mason, A. M. Michalak, P. R. Richards, J. J. Roberts, D. K. Rucinski, E. Rutherford, D. J. Schwab, T. Sesterhenn, H. Zhang, Y. Zhou. 2014. Assessing and addressing the re-eutrophication of Lake Erie. J. Great Lakes Res. 40, 226-246
- ISI Web of Science highly cited paper (top 1% in its field)
- 2014 Chandler-Misener Award (for most notable paper), International Association for Great Lakes Research

Thermocline Response to Anticyclonic (AC) Wind over Lake Erie

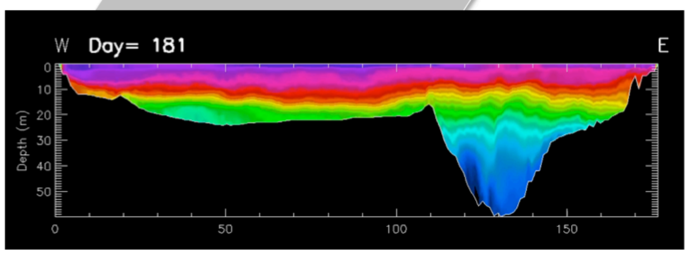
Idealized 10-day AC wind leading to mid-lake downwelling; 2-layer initial thermal structure



Temperature (West-East transect, central basin)



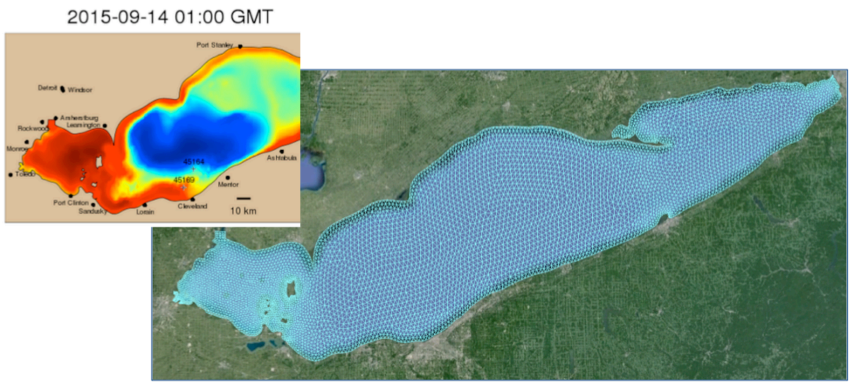
Full year POM run with 2005 meteorology. Bowl shaped thermocline forms in CB



Temperature, West-East transect

Future Research: Continue researching wind-hypoxia connection

Co-Principle Investigator in the NOAA Coastal Hypoxia Research Program **(**CHRP) proposal "Operational Lake Erie Hypoxia Forecasting for Public Water Systems Decision Support" (submitted)



FVCOM grid used by hydrodynamic and ecological models

IPEMF | Physical-Biological Coupling in the Great Lakes

Predicting Spread of Aquatic Invasive Species (AIS) by Lake Currents

Lake circulation causing AIS spread

D. Beletsky, R. Beletsky, E. S. Rutherford, et al., (in review). *J. Great Lakes Res.*

- A great number of species invaded the Great Lakes region in recent decades due to shipping and other vectors of spread.
- Important AIS introduction points are deballasting locations (e.g. ports and mid-lake exchange locations).
- Knowledge of dispersal by lake currents is required for understanding and prevention of secondary spread of AIS in the Great Lakes.
- We use particle transport model to predict larval dispersal of several target species (fish, mussel, plant) from a variety of introduction points.
- Predictions were made for both existing species and potential invaders.

8/10

This material is based upon work supported by the EPA GLRI via NOAA Center for Sponsored Coastal Ocean Research, grant NA10NOS4780218 Forecasting spread and bioeconomic impacts of aquatic invasive species from multiple pathways to improve management and policy in the Great Lakes.

D. Beletsky, R. Beletsky, E. S. Rutherford , J.L. Sieracki, J. M. Bossenbroek, W. L. Chadderton, M. E. Wittmann, and D. Lodge. 2016. Spread of aquatic invasive species by lake currents. J. Great Lakes Res. (in review)

Predicting Spread of Invasive Larval Eurasian Ruffe to Determine Safe Ballast Exchange Locations in Lake Michigan

Particles released daily at several known mid-lake ballast water exchange locations

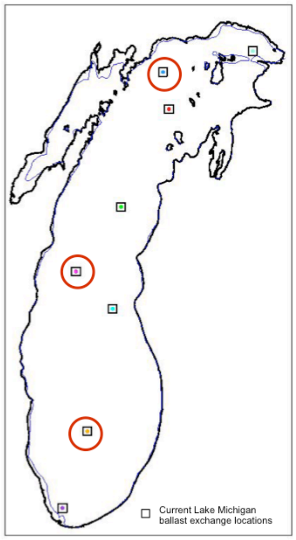
Hydrodynamics is based on POM

Release period: Days 102-224
(Ruffe spawns between 5 and 18 C)

Maximum larval drift - 14 days

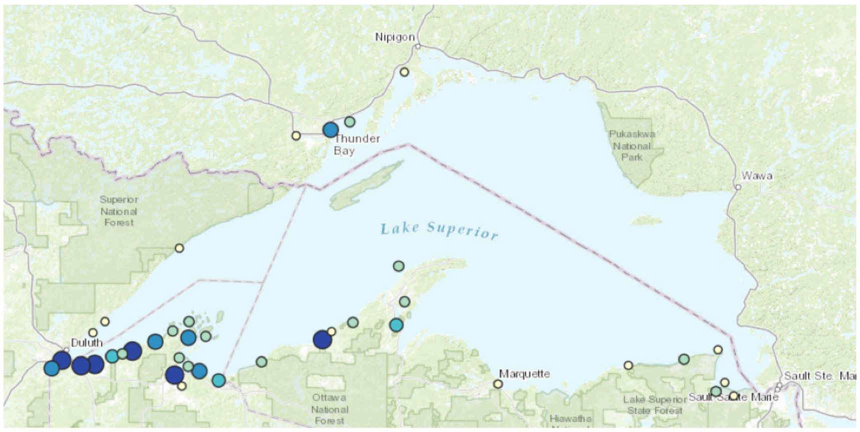
Settlement zone: 0-10 m (substrate not considered yet)

Several safe locations identified (particles didn't reach settlement zone)



Future Research: Predicting the spread of Aquatic Invasive Species

Developing predictive models for Lake Superior (GLFC proposal submitted)



Spread of Invasive Eurasian Ruffe in Lake Superior from introduction point in Duluth, MN (source: USGS).
Circle size indicates frequency of occurrence.

Questions?

From Beletsky et al., (1999). *J. Great Lakes Res.*