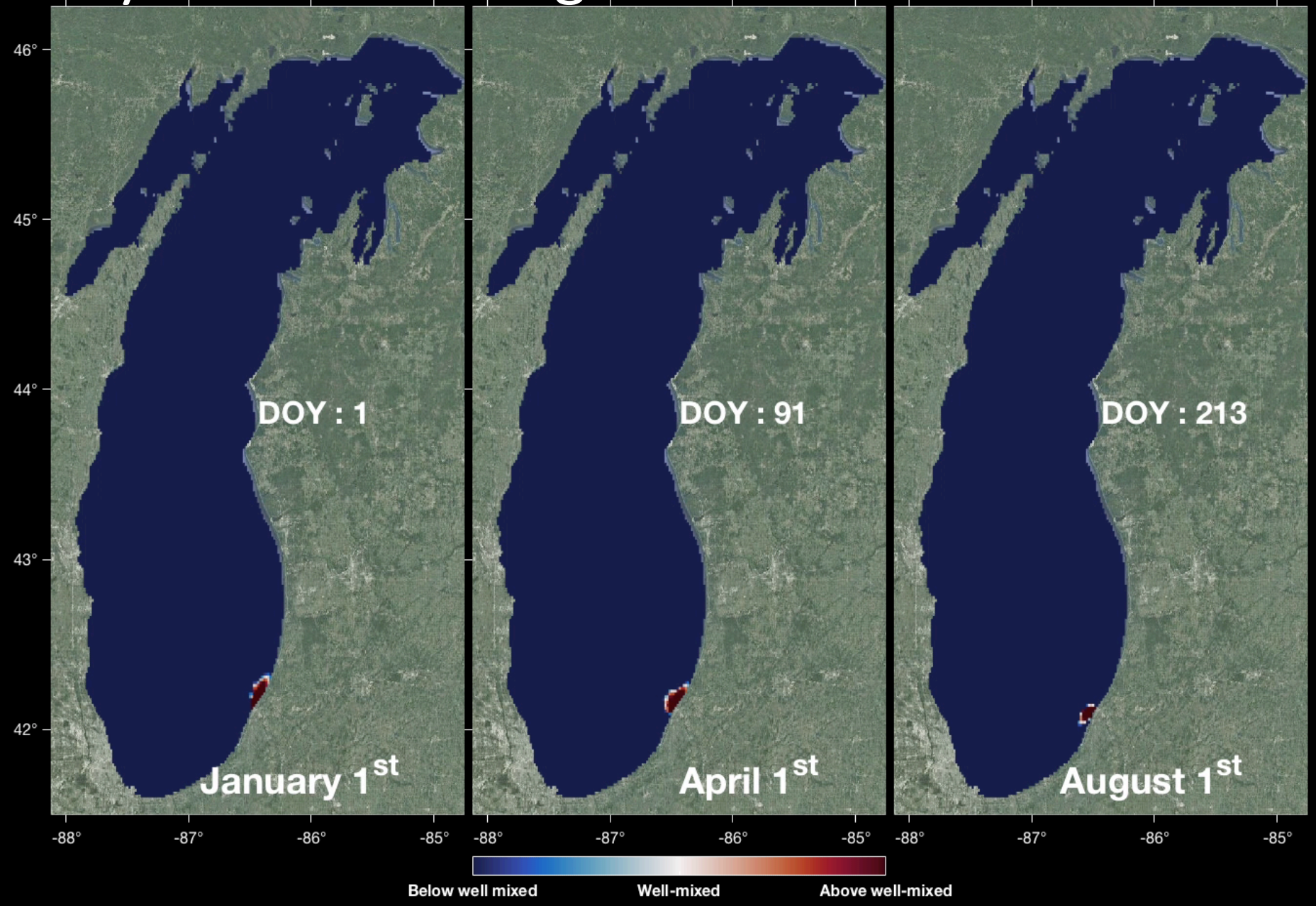
# Dye release during different months in 2007



# Potential impacts of tributary loads on coastal ecosystem services in Lake Michigan

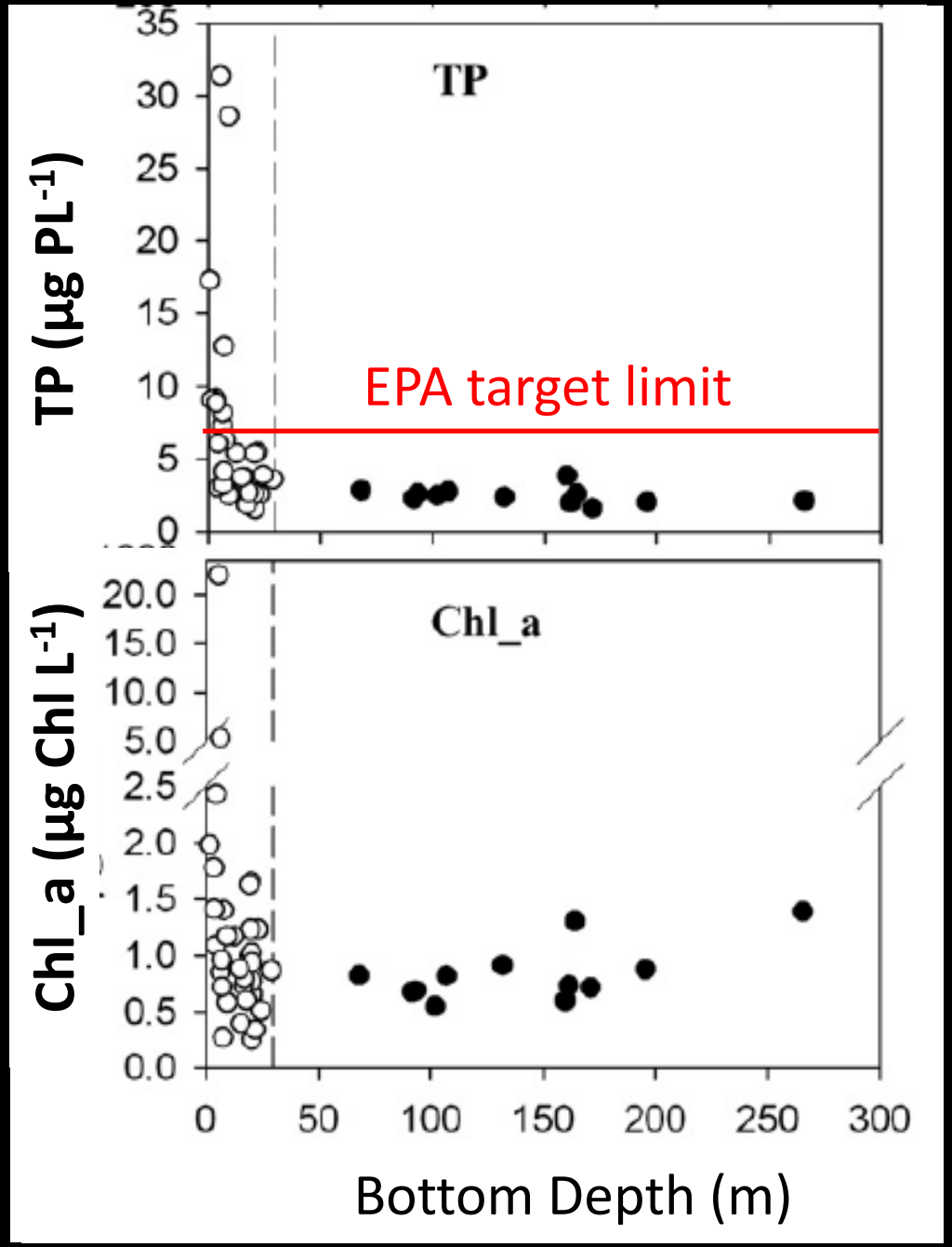
Luke Gloege

Galen McKinley, Peter McIntyre,

Robert Mooney, J. David Allan, Matthew Diebel

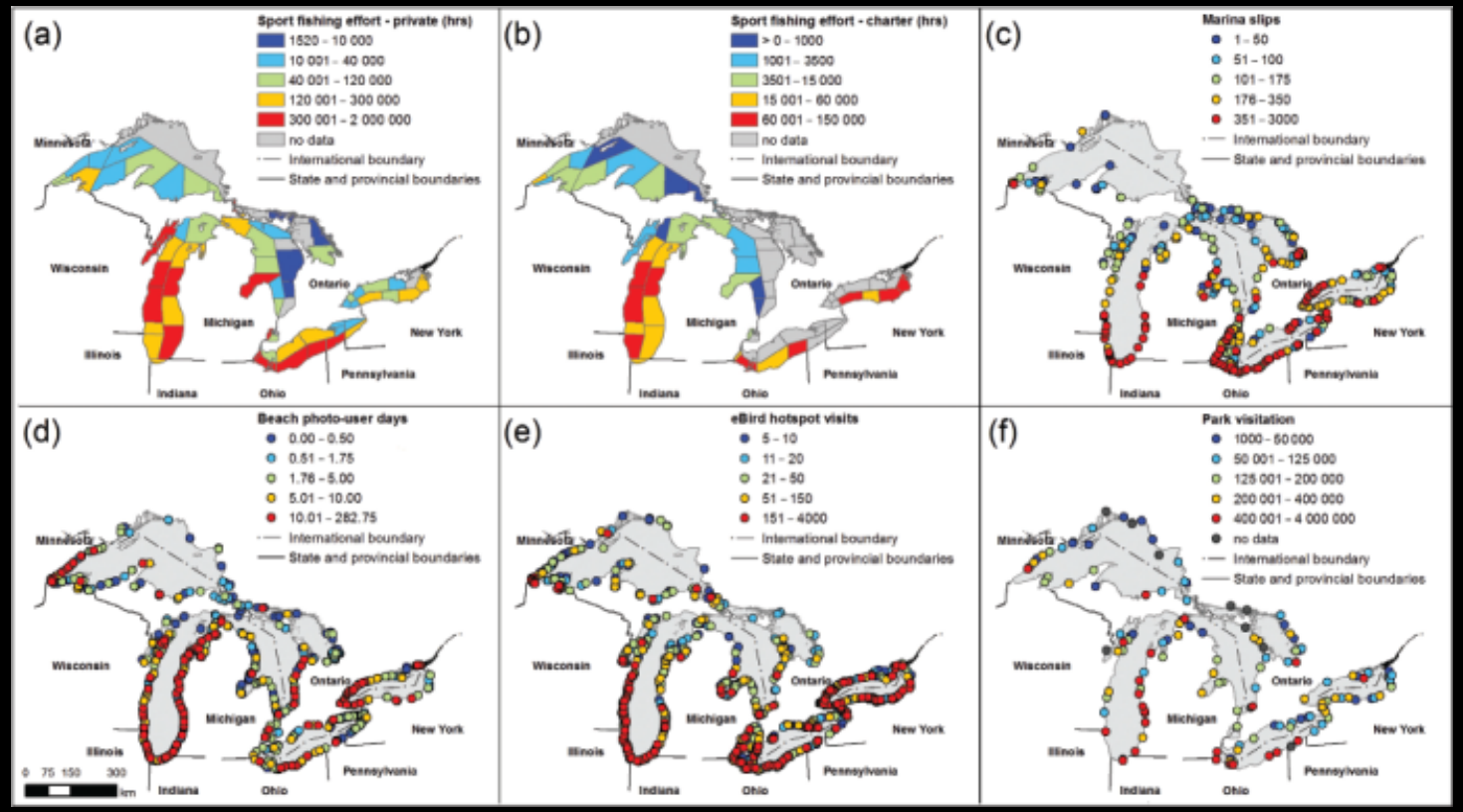
# Lake Michigan Phosphorous levels

- Phosphorous not well mixed
- Elevated phosphorous in nearshore (open circles)
- Phosphorous depletion offshore (closed circles)




Yurista et al. 2015 JGLR

# Great Lakes ecosystem services

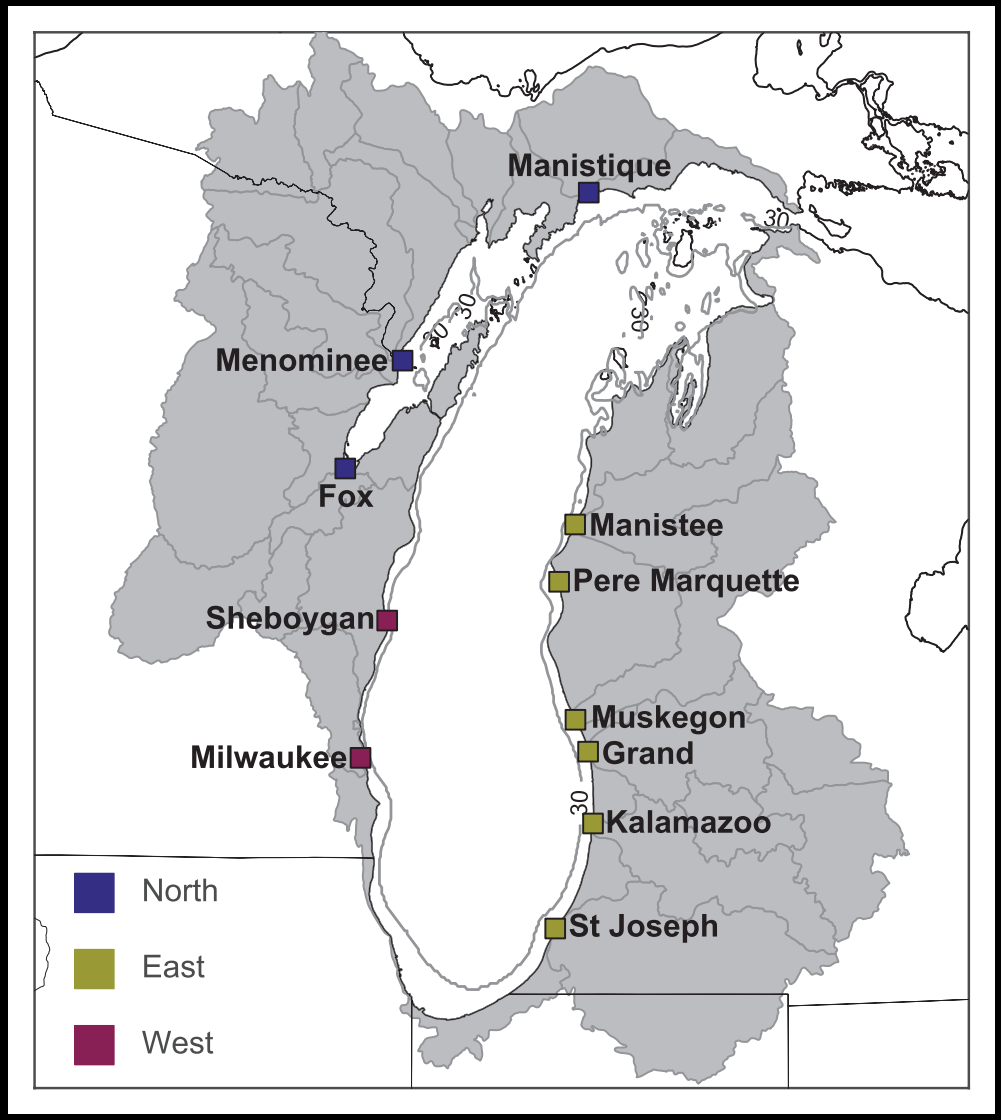



- Spatial distribution of ecosystem services
- Service use is quantified at each site
- Complement ecosystem stress assessment

Allan et al. 2015 Front. Ecol. Environ.

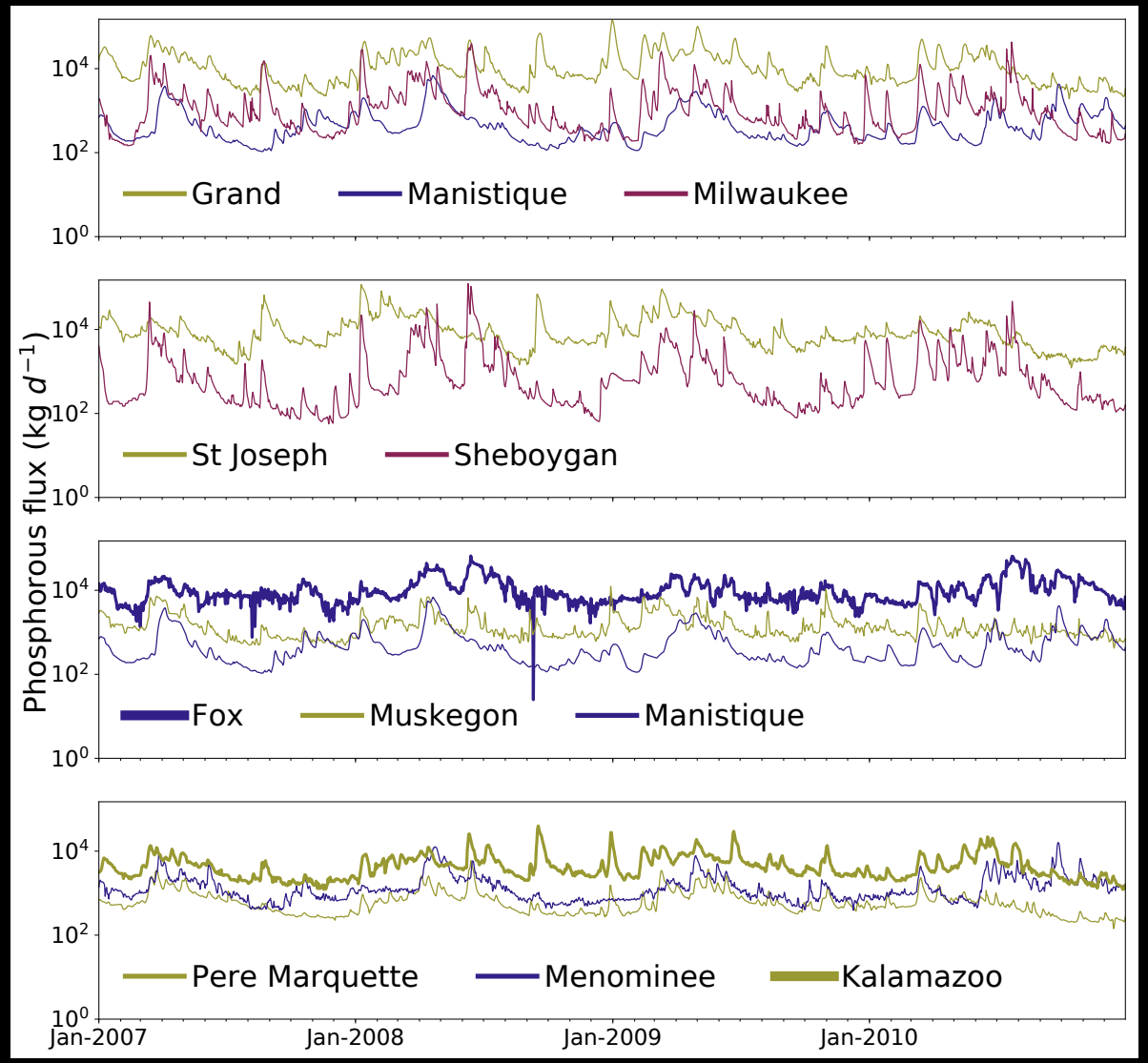
# Model Experiment

- MIT general circulation model
- 3D hydrodynamic model
- Closed basin
- 1/60 degree (~2km) horizontal res.
- 28 vertical layers (5 m – 31 m)
- Forced at surface with meteorological and radiative fields every 3 hours
- Simulated 2007 - 2010
- Phosphorous from 11 rivers



# Realistic Phosphorous fluxes

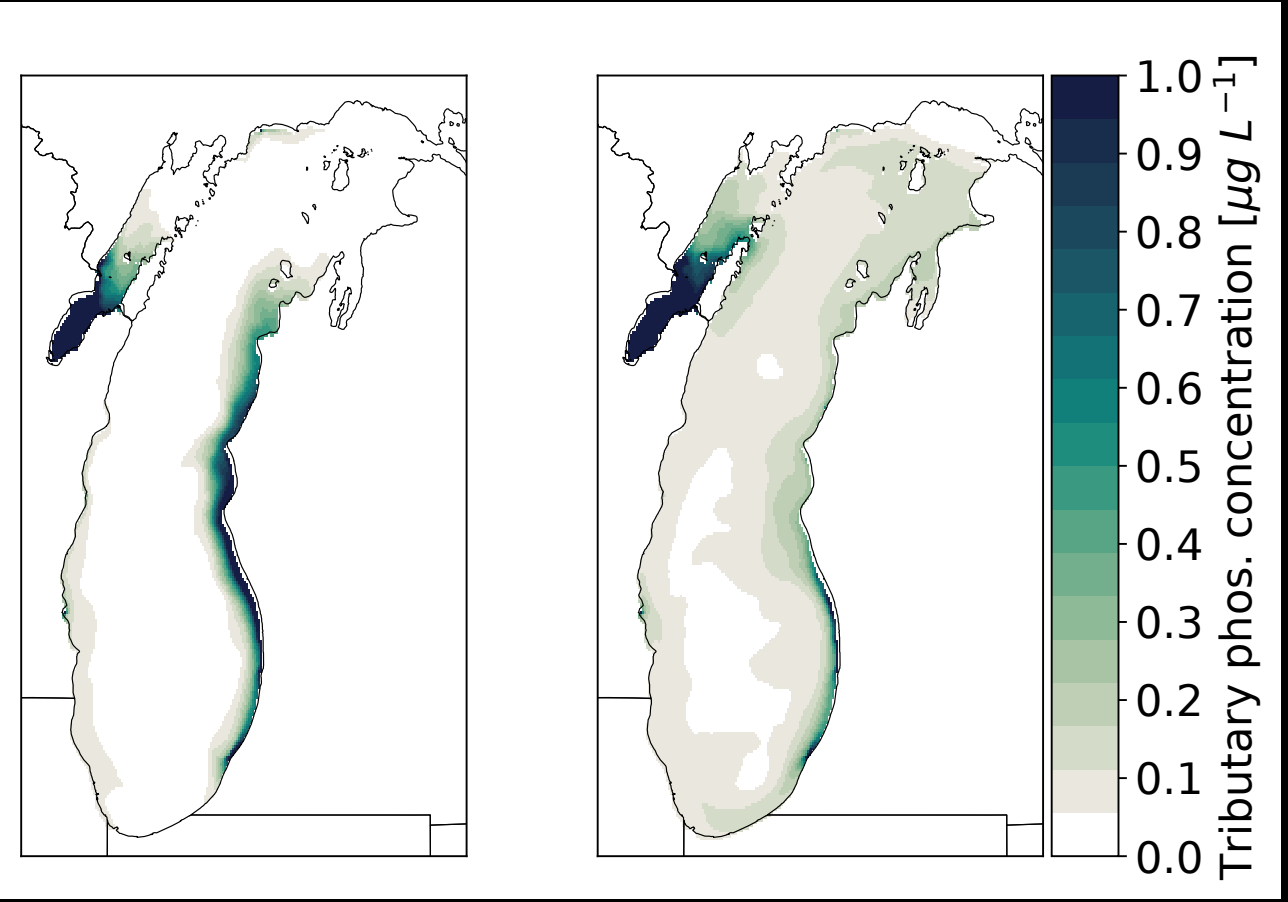
- Phosphorous flux calculated from discharge and phosphorous concentration [Hirsch et al 2010 JAWRA]
- These rivers capture 70% of the observed phosphorous load
- Annual loads compare well to estimates by [Dolan and Chapra 2012 JGLR]



# Phosphorous Concentration

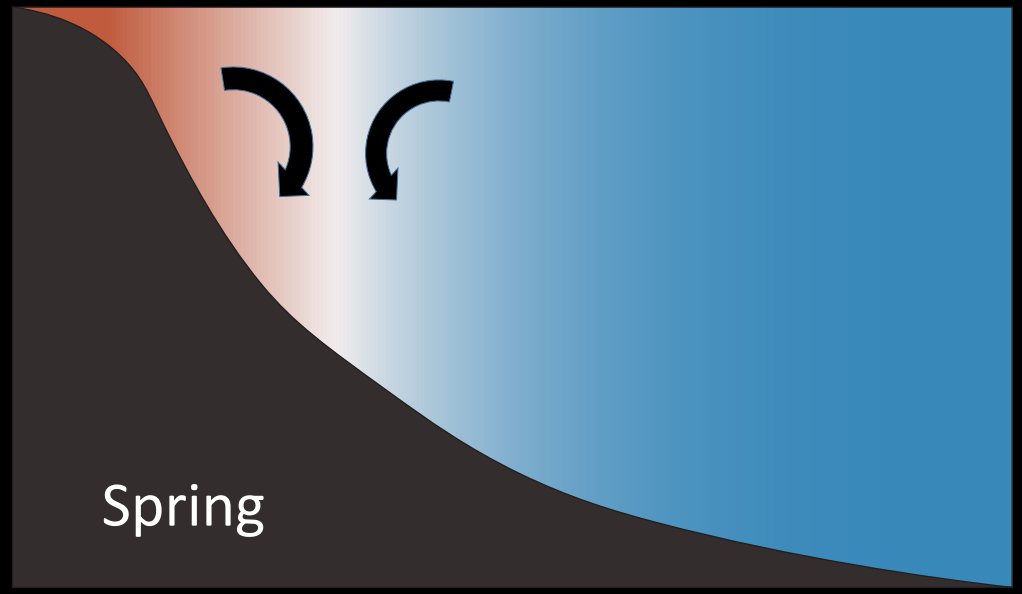
May

August

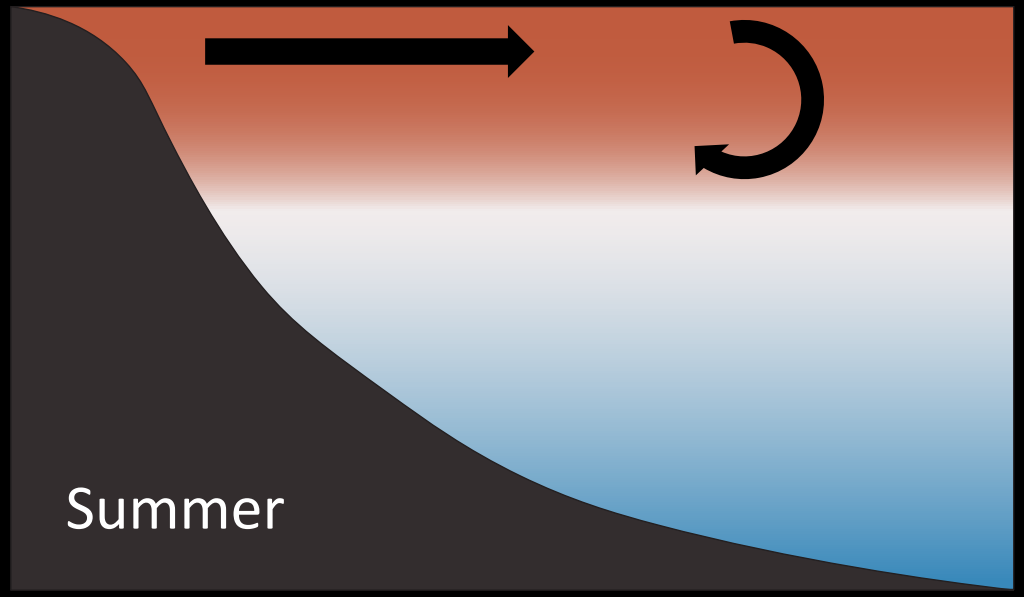



- Average concentration in May and August across all years
- Seasonal variation in concentration

# Temperature gradients are a barrier to mixing

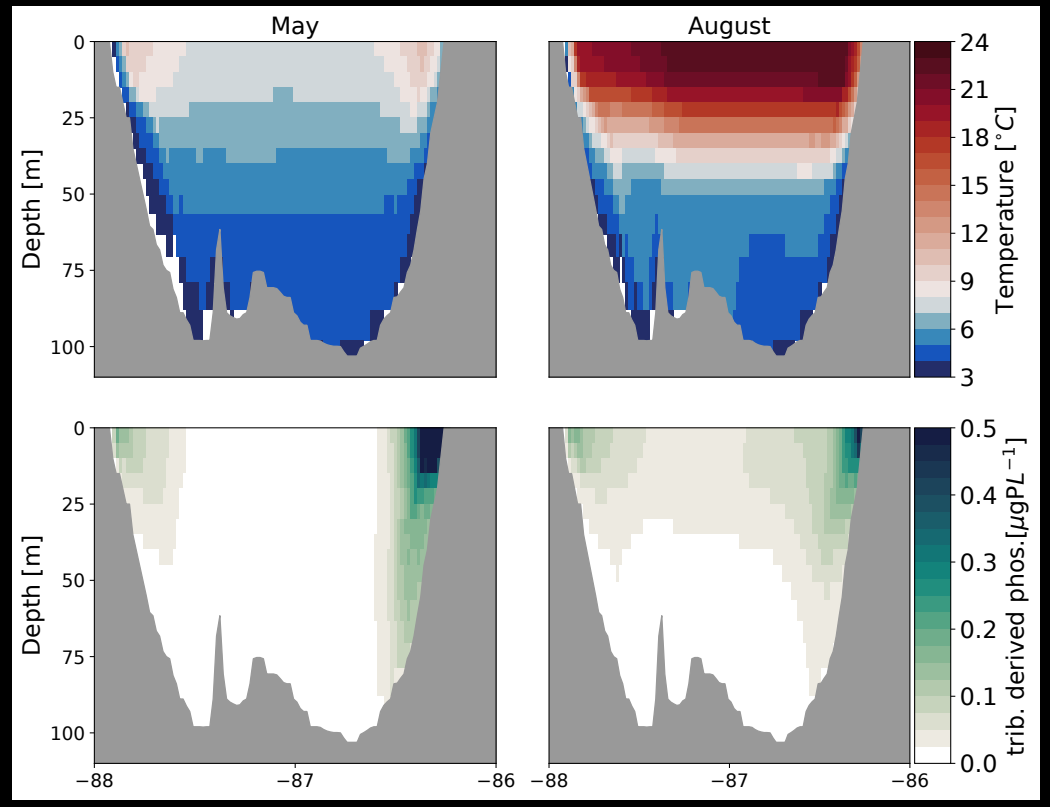


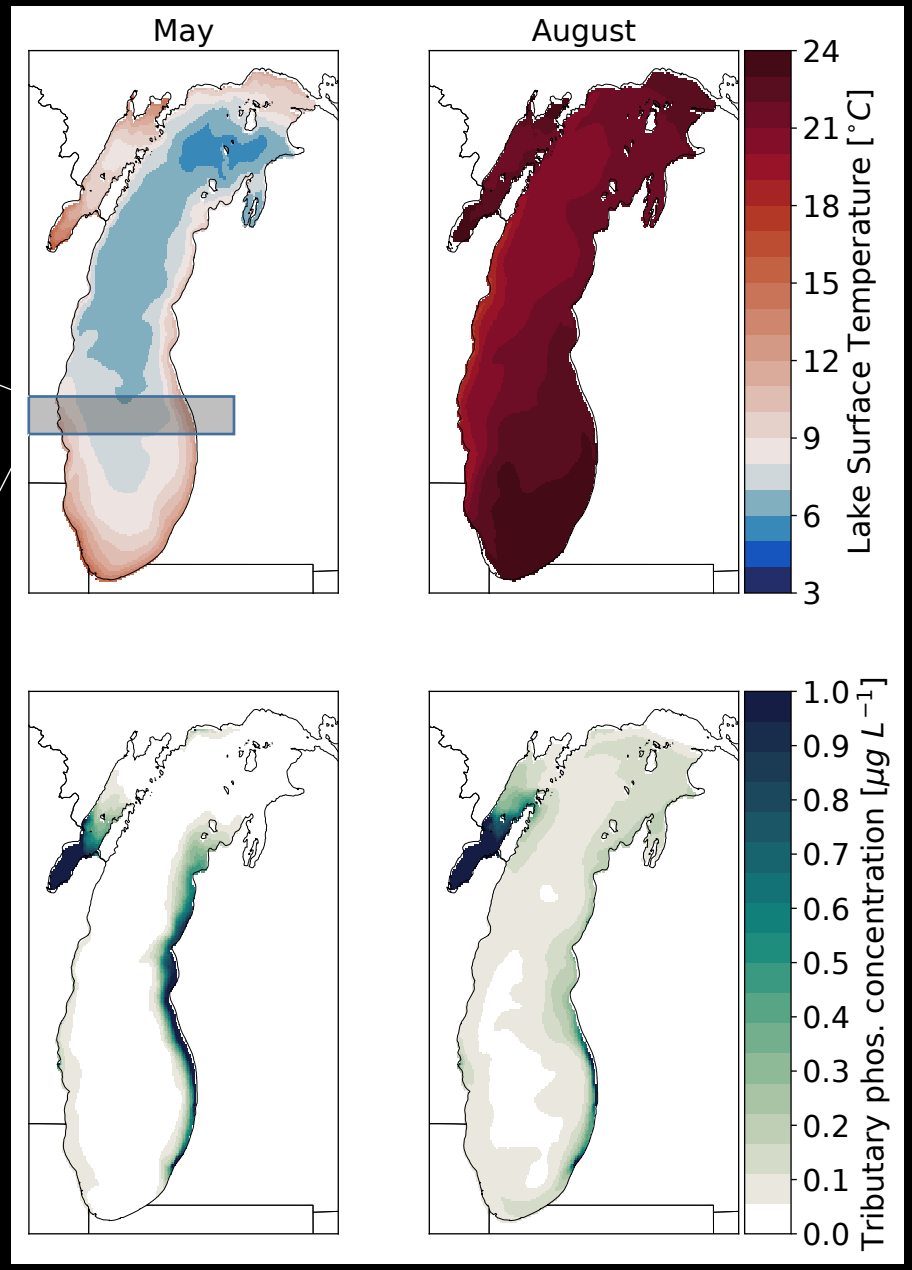

- Strong horizontal density gradient
- Inhibits offshore transport



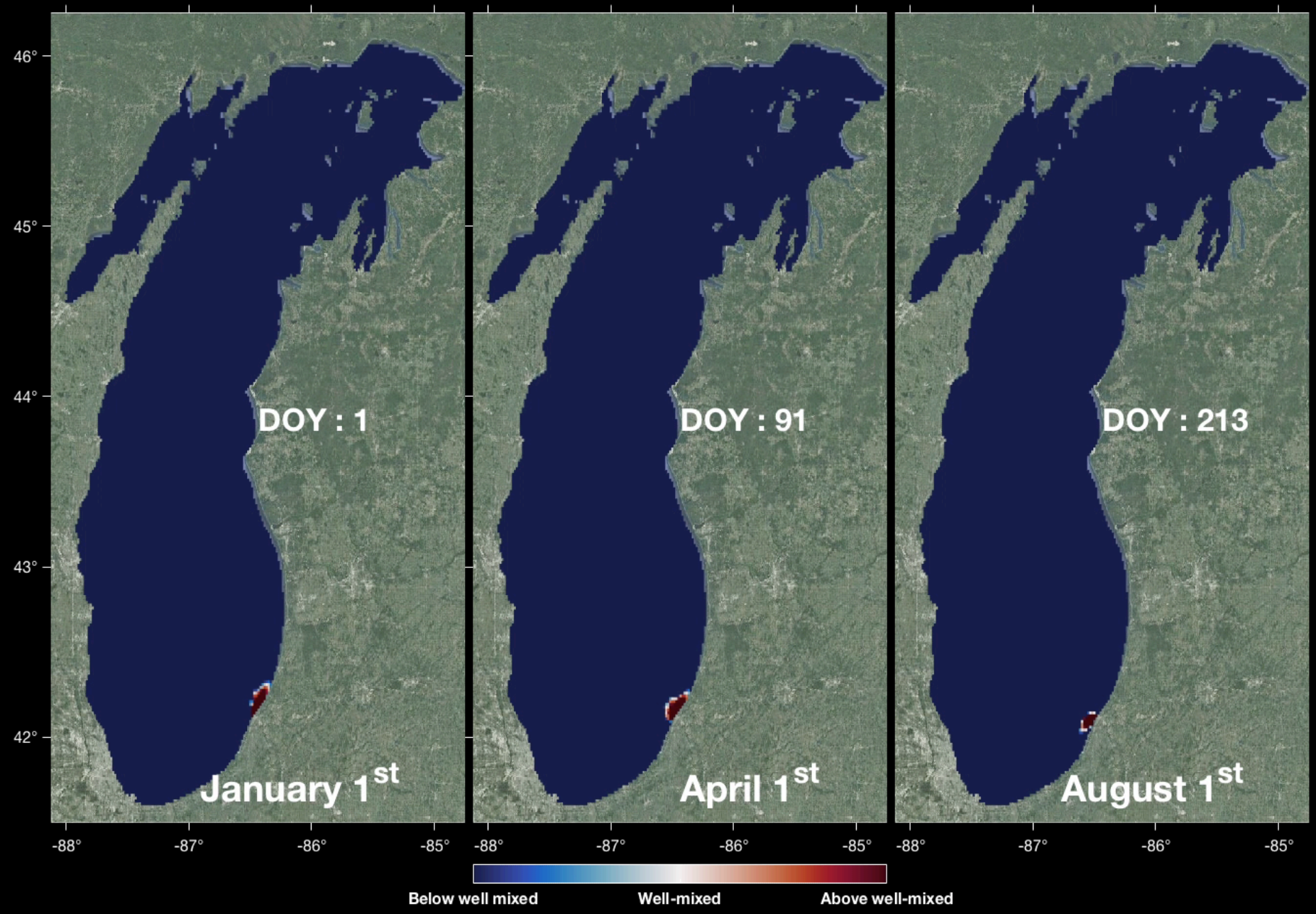

- Weak horizontal density gradient
- Thermocline act as barrier to mixing

# Model output

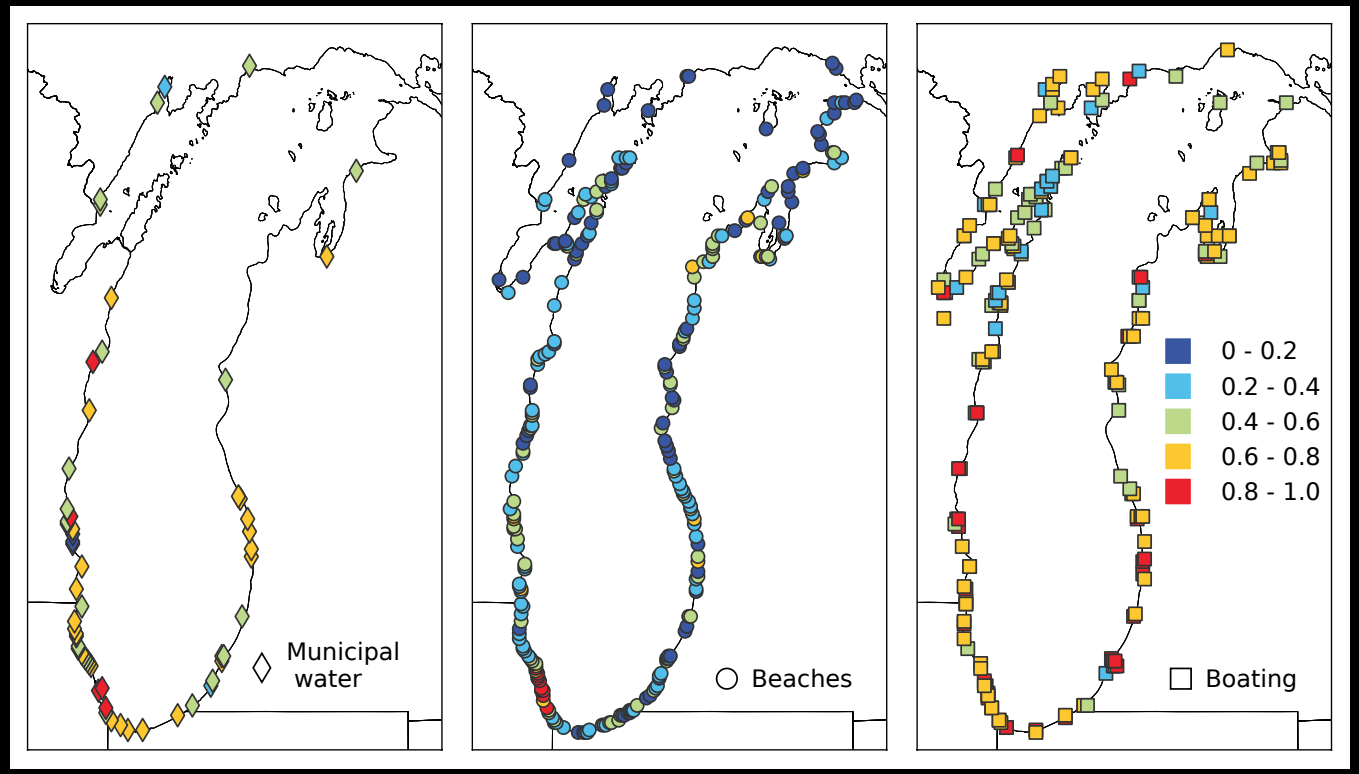



- Coastal trapping in May
- Offshore spreading in August


46°
45°
44°
43°
42°
DOY : 1
January 1st
DOY : 91
April 1st
DOY : 213
August 1st
-88°
-87°
-86°
-85°
Below well mixed
Well-mixed
Above well-mixed

# Ecosystem Service use around Lake Michigan




- Usage index for each service
- Normalized each index between [0, 1]

Annual water withdrawals

FLICKR photos at beaches

Number marina slips and boat launches

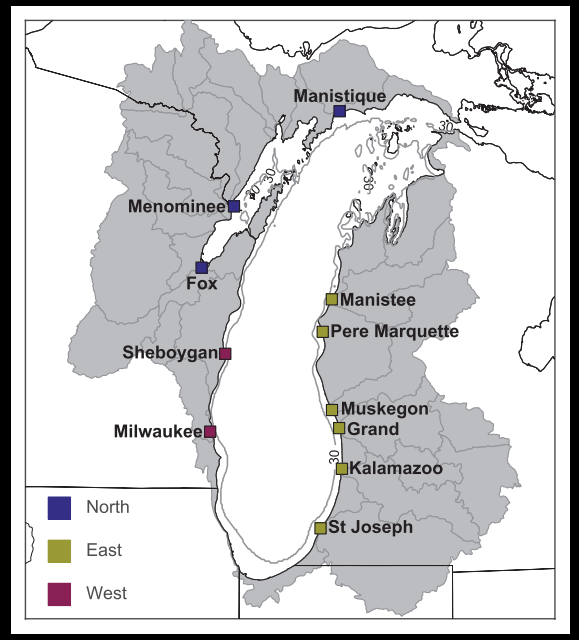


Allan et al. 2015 Front Ecol Environ

# Cumulative stress ecosystem service (CSES)

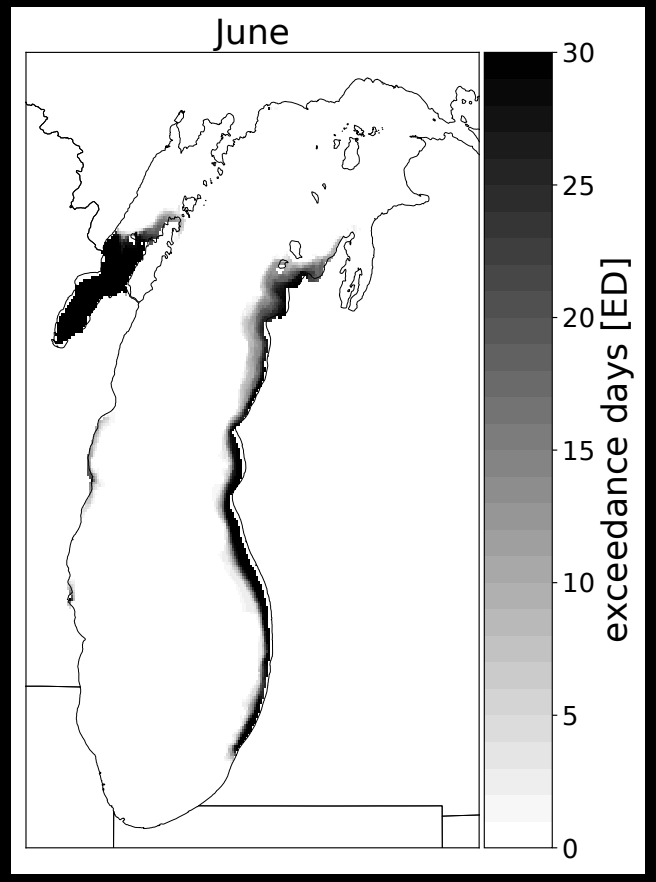
$$CSES = \sum_{\text{Plume in region}} [(ED * Muni.Water) + (ED * Beaches) + (ED * Boating)]$$

- ED quantifies severity of the phosphorous concentration
- Multiply ED by adjacent service cells
- Sum across plume in each region (North, East, West)



# Cumulative stress ecosystem service (CSES)

$$CSES = \sum_{\text{Plume in region}} [(ED * Muni.Water) + (ED * Beaches) + (ED * Boating)]$$

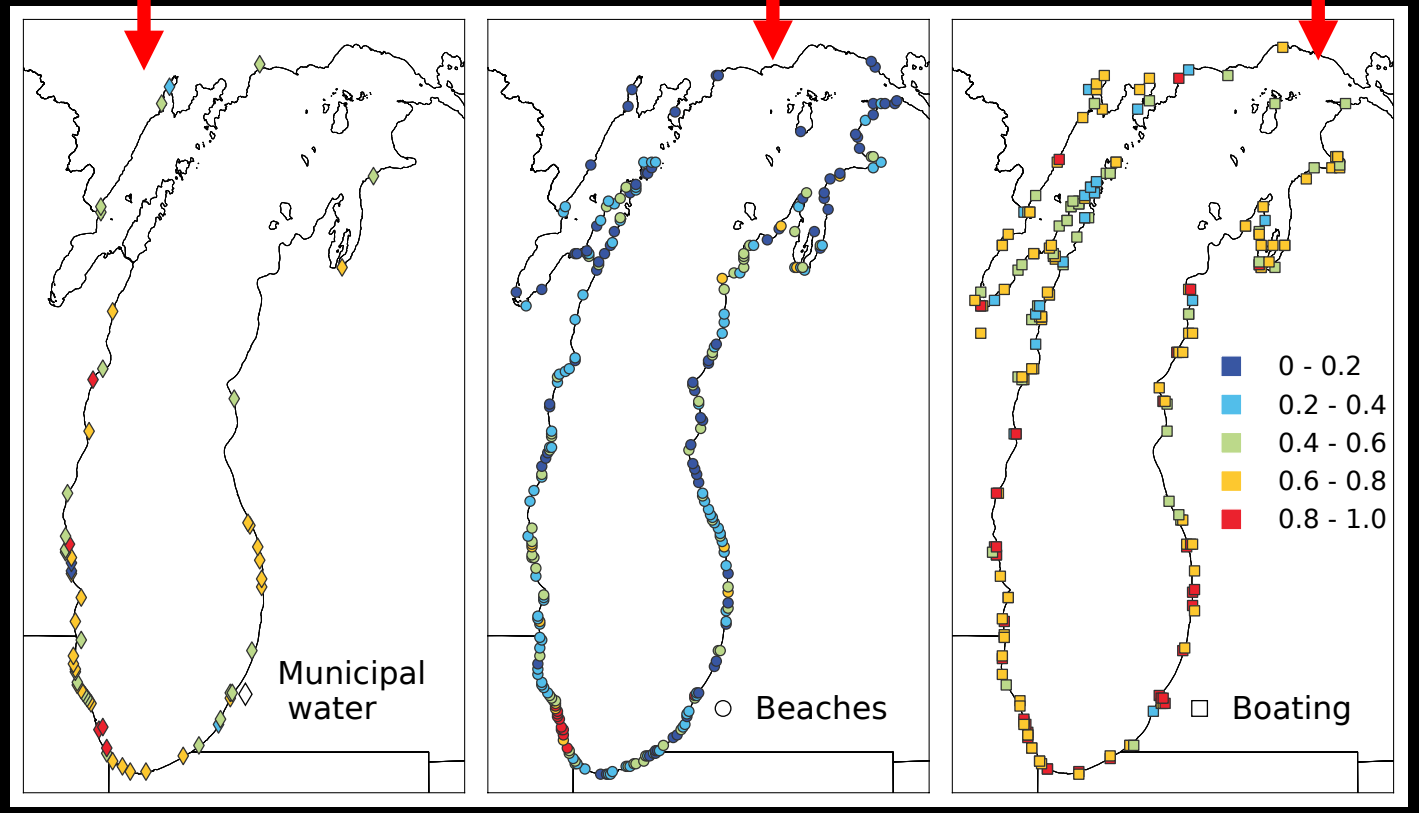



- Threshold of 0.4 µgPL$^{-1}$ above background concentration
- Exceedance Days (ED) - number days threshold concentration is exceeded at each grid cell

# Cumulative stress ecosystem service (CSES)

$$CSES = \sum_{\text{Plume in region}} [(ED * Muni.Water) + (ED * Beaches) + (ED * Boating)]$$

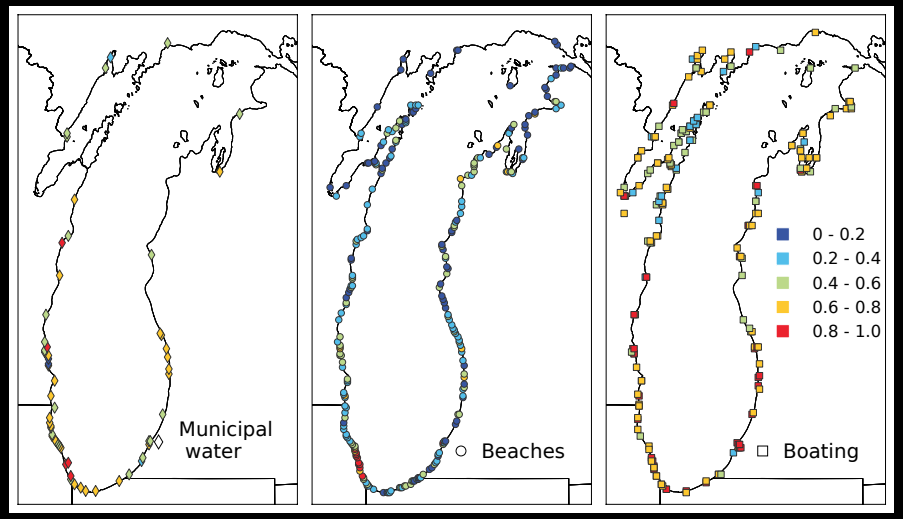
- Multiply ED by service use
- Sum across plume in each region

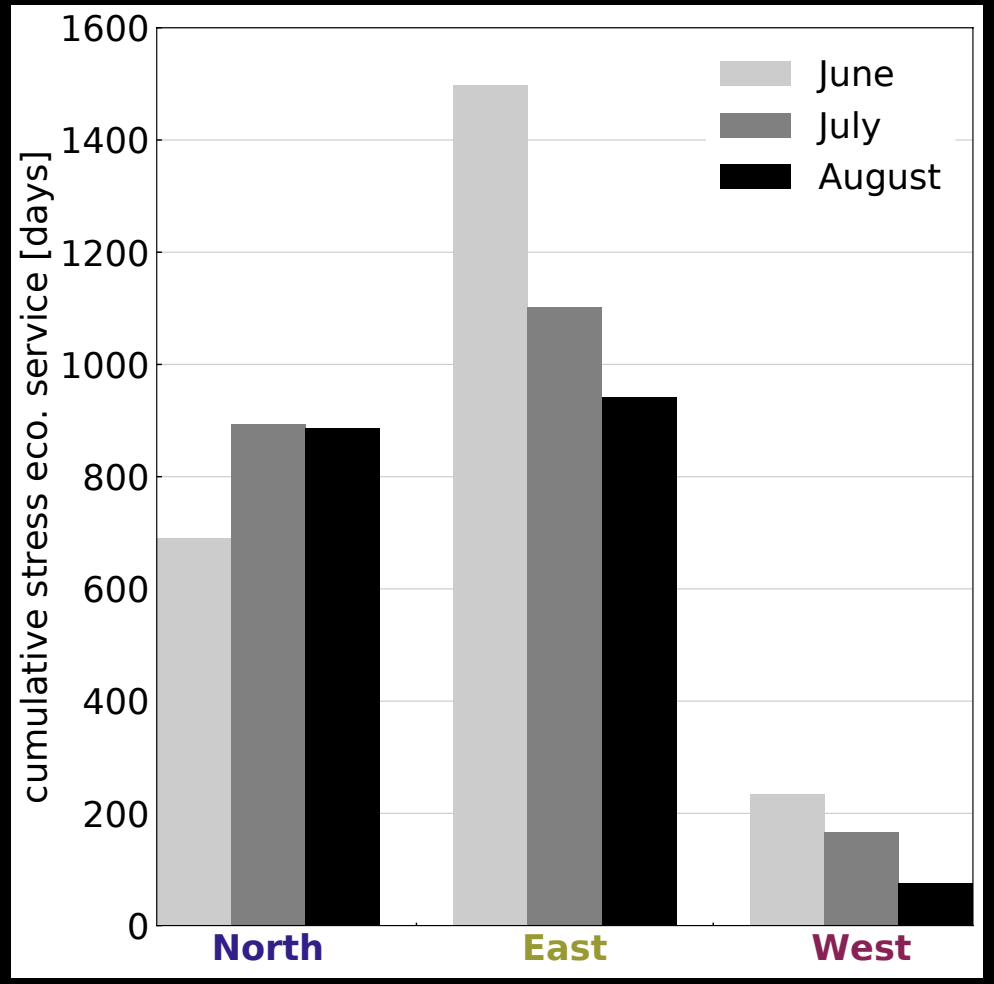


# Cumulative stress ecosystem service (CSES)

$$CSES = \sum_{\text{Plume in region}} [(ED * Muni.Water) + (ED * Beaches) + (ED * Boating)]$$

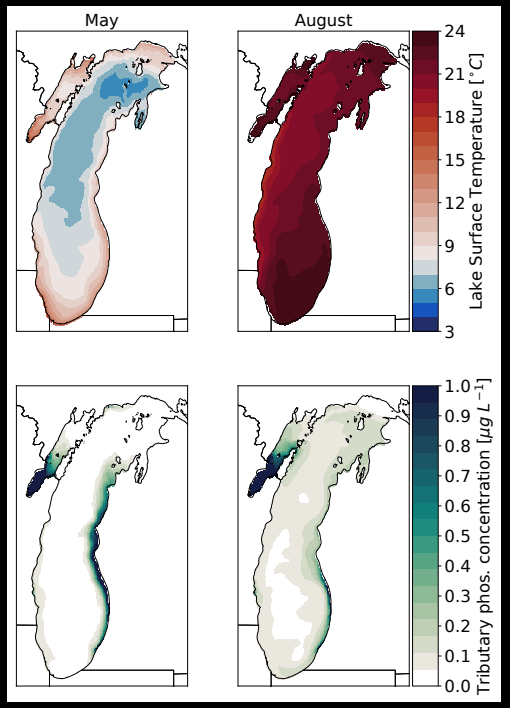
- Services in East and North have potential to be comprised

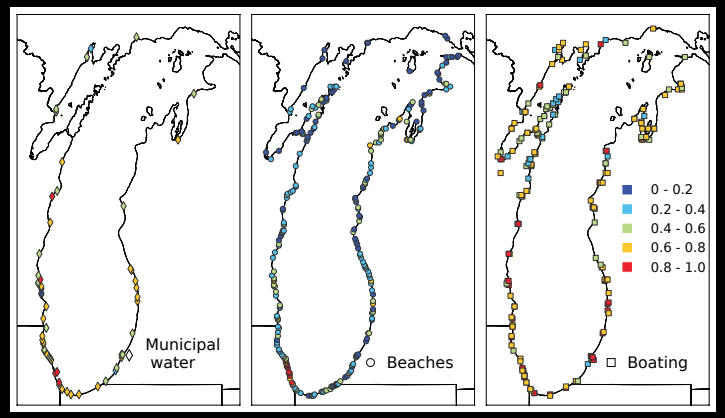


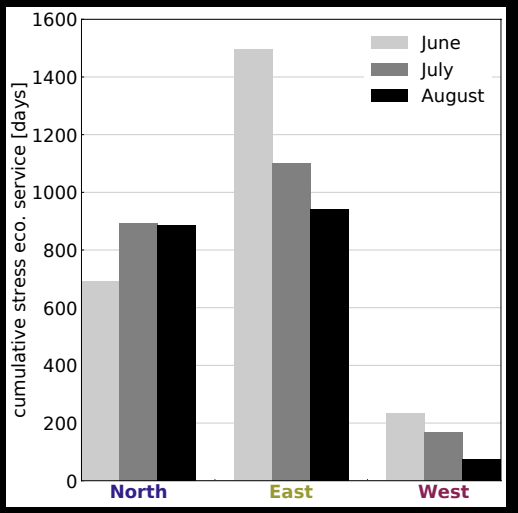



# Conclusions

- Lake Michigan is not well mixed
- In-lake physics influence redistribution
- Combination of non well-mixed lake, physics, and large loads have potential to regionally comprise ecosystem services



# Acknowledgements

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