Vermont EPSCoR

Experimental Program to Stimulate Competitive Research

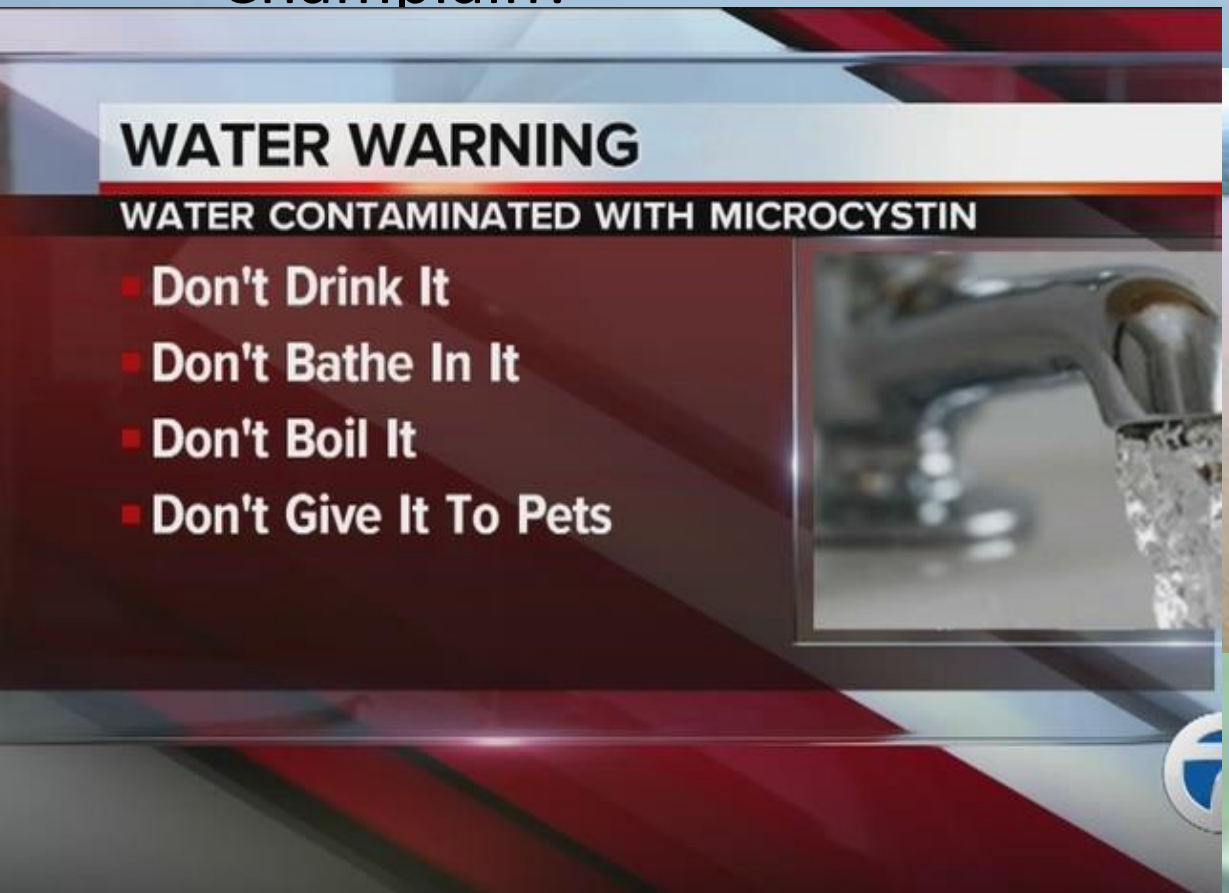
Lake Processes Group Update

Research on **A**daptation to **C**limate **C**hange

Andrew Schroth

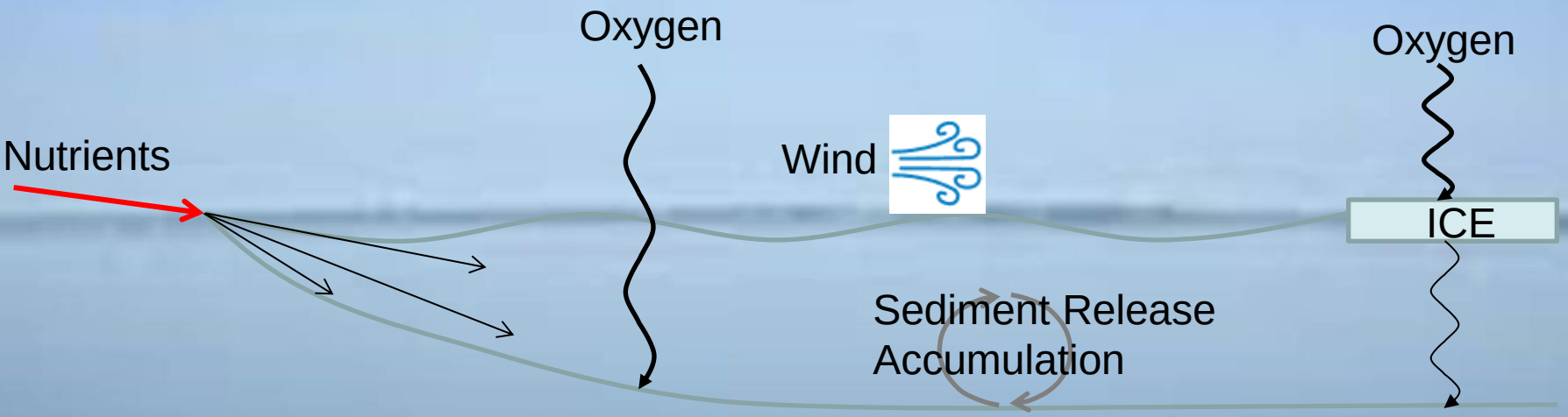
Fundamental Lake Process Research Question (Formerly Q1)

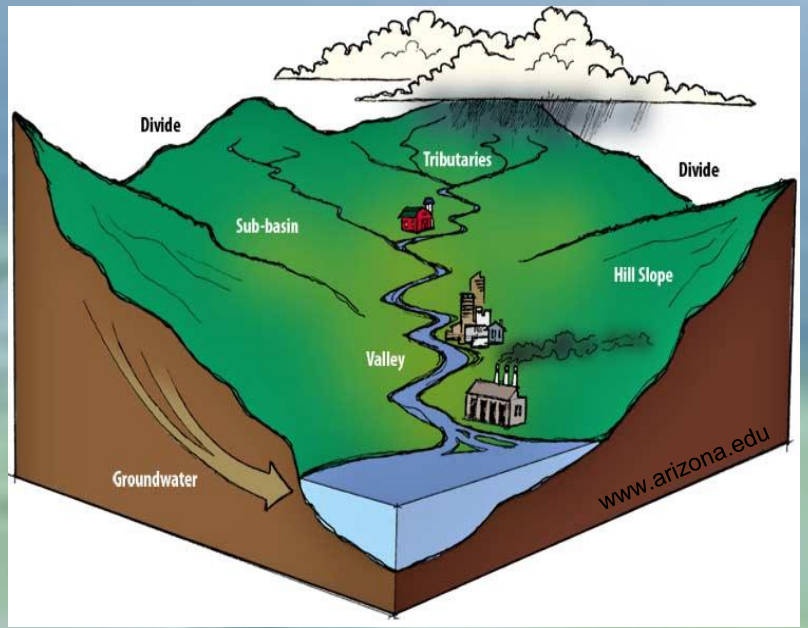
- What is the relative importance of **endogenous** (in-lake) processes versus **exogenous** (to-lake) processes to eutrophication and harmful algal blooms in Lake Champlain?



External

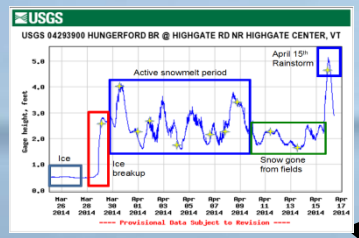
Approach to Question 1

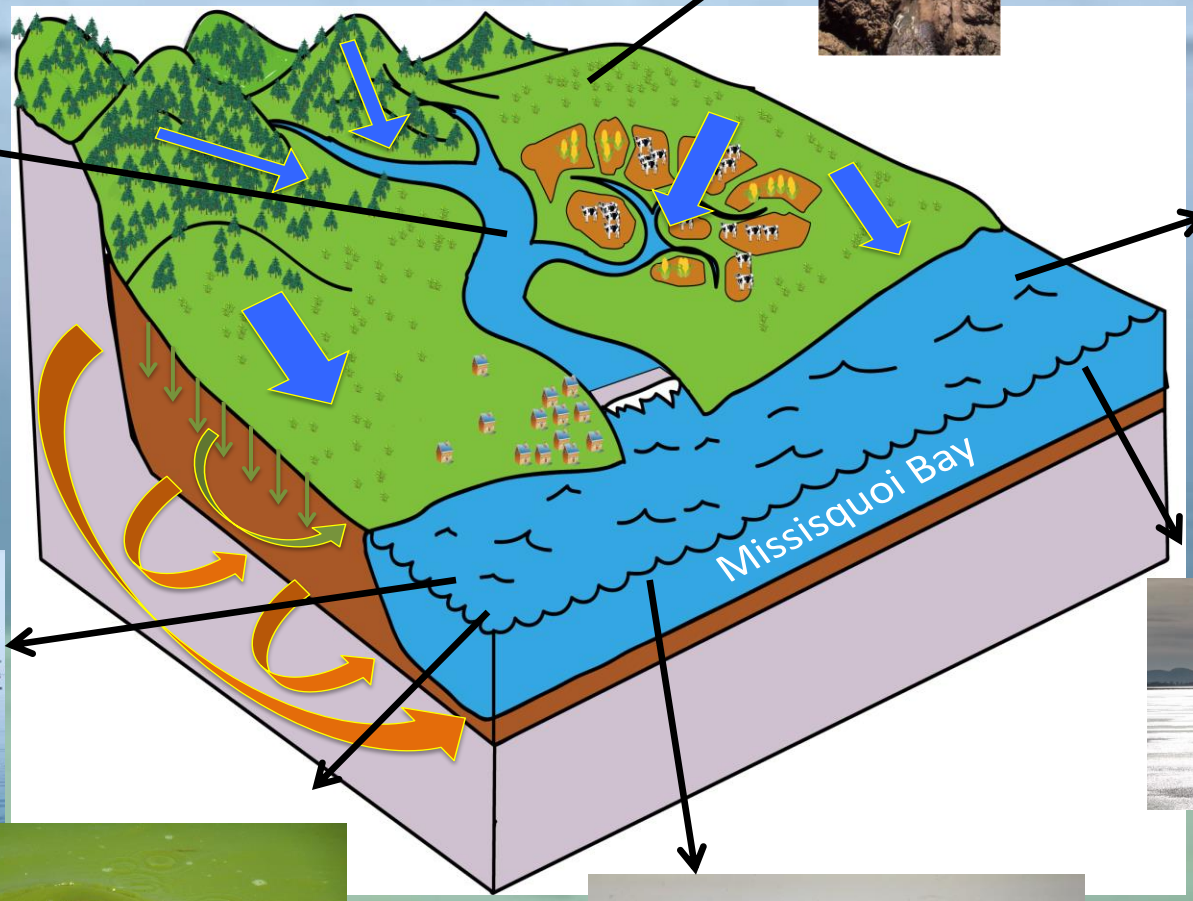


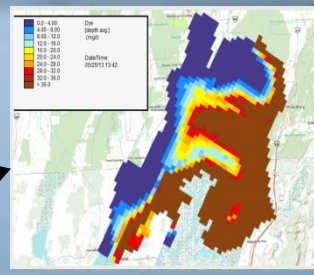


- What are the important sources of nutrients & sediment to the lake?
- How do land use and climate affect the nature and strength of these sources?
- How are nutrients and sediments transformed and cycled within the lake?
- How do the loadings of these materials and hydrodynamics affect lake processes and ecosystems?

Presentation Structure







Focus Watersheds

Agriculture: runoff, groundwater, soils, stream bank erosion

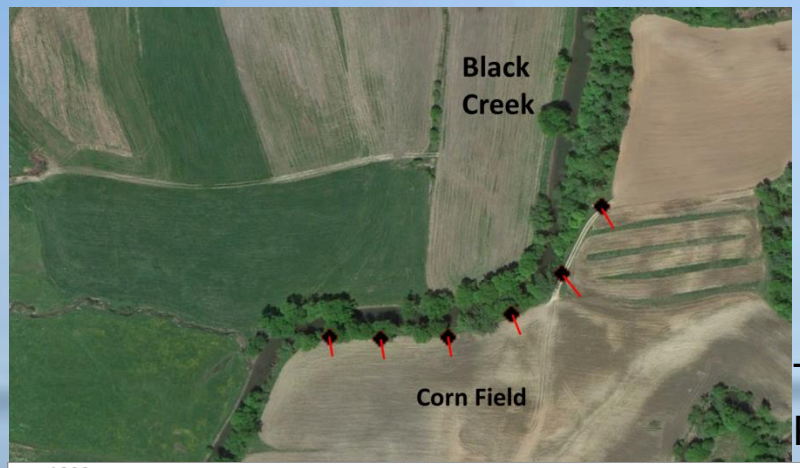
Forested: soils, groundwater, roads, channel migration, erosion

Urban: stormwater runoff, wastewater, stream erosion

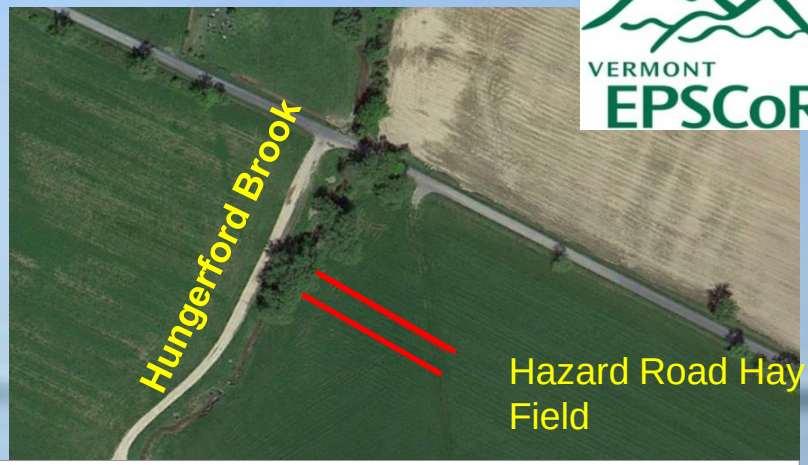
What we have accomplished?

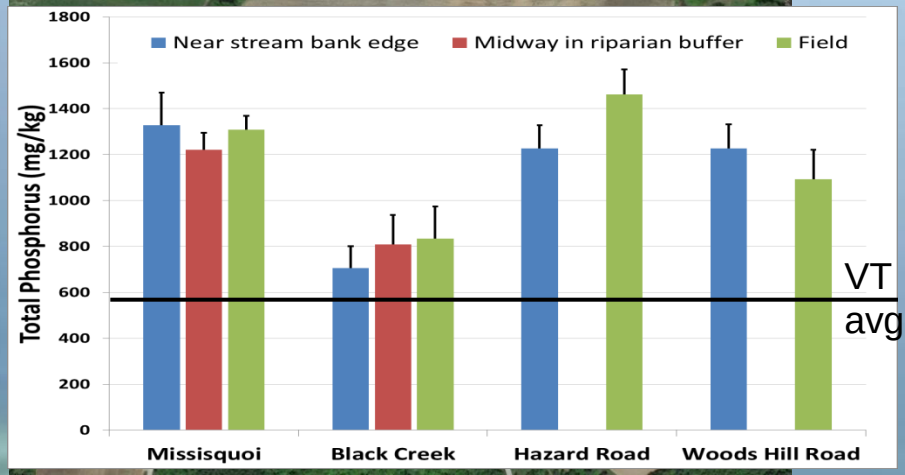
Source area characteristics: Soil Chemistry

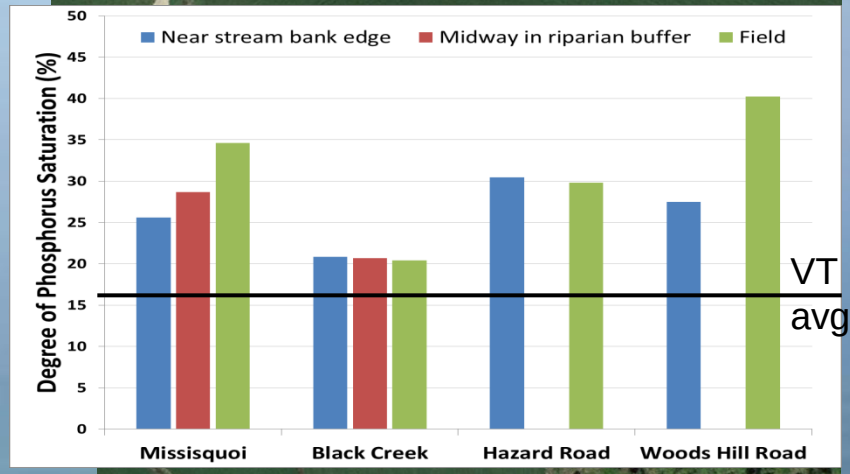
P Distribution: Agricultural Field (corn/hay) through riparian zones/stream bank

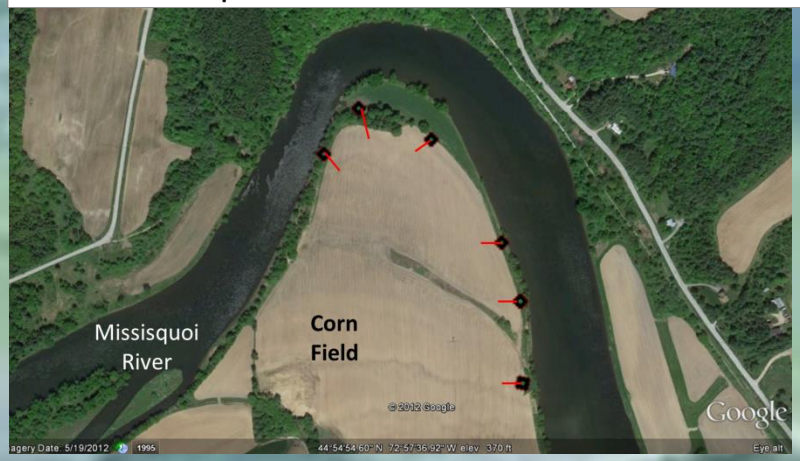


Total Phosphorus

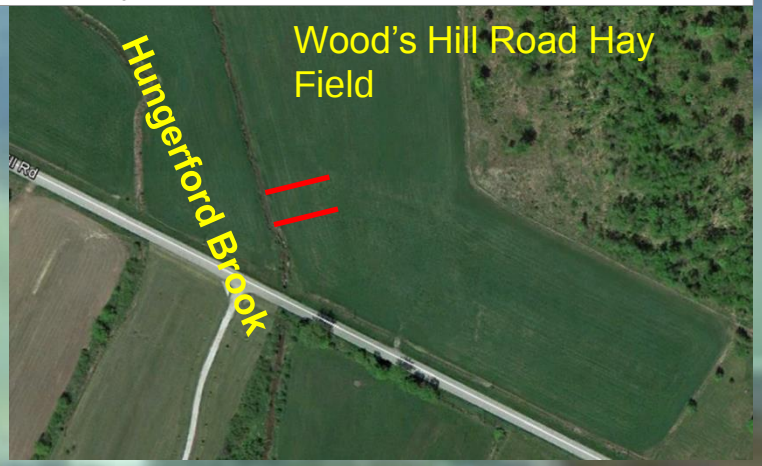




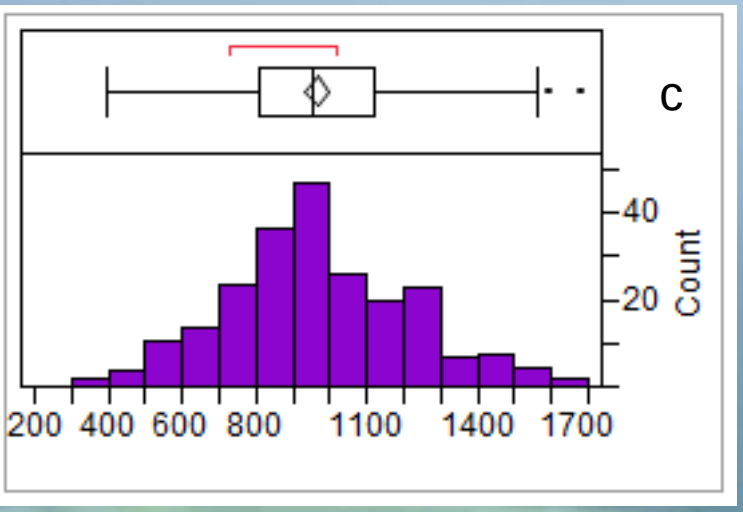




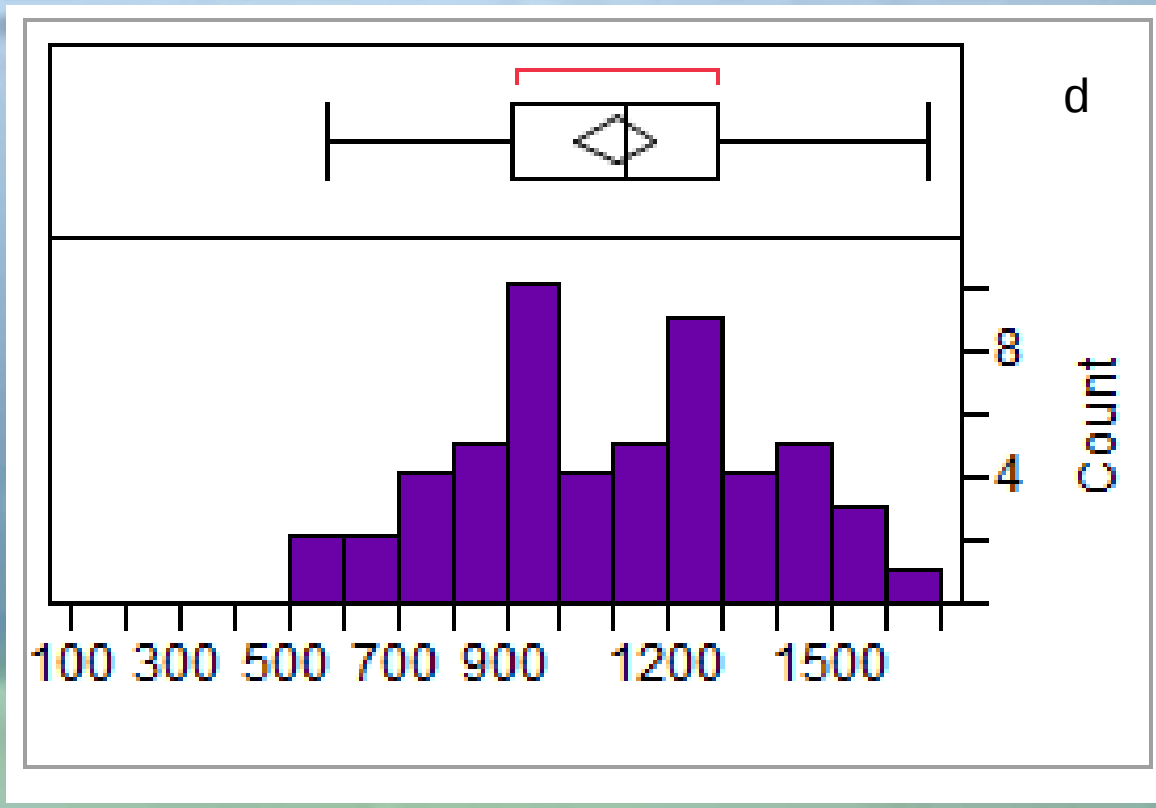
Degree of Phosphorus Saturation



Total phosphorus in Vermont stream corridor soils



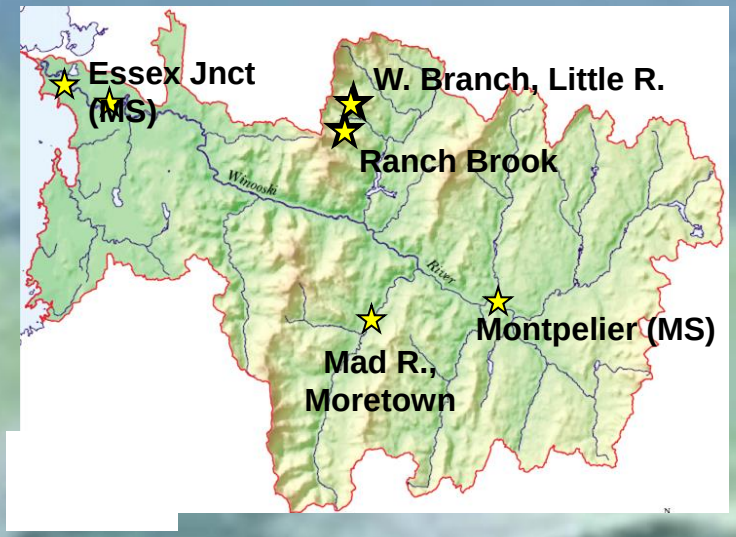
216 soil samples from Missisquoi corn field transects. Median =**950** mg/kg



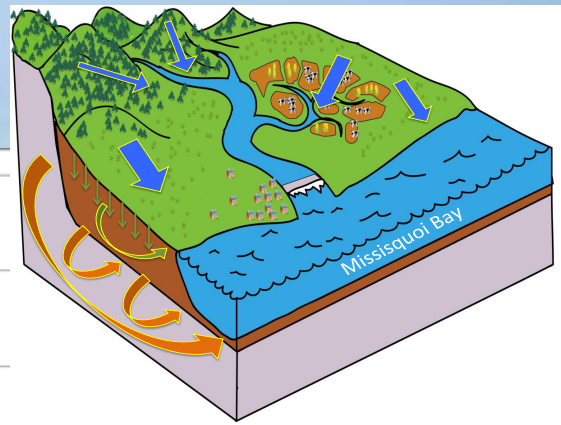
54 surface soil samples from Missisquoi corn fields transects. Median =**1122** mg/kg

What we have accomplished?

Instrumented key sub-watersheds



Capture Storm Event Biogeochemical Evolution with Automated Sampling

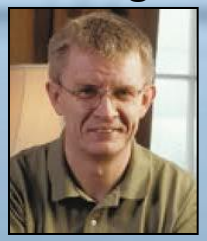


Watershed and Lake Sampling
What we have accomplished?

Integrated water sampling & analysis network

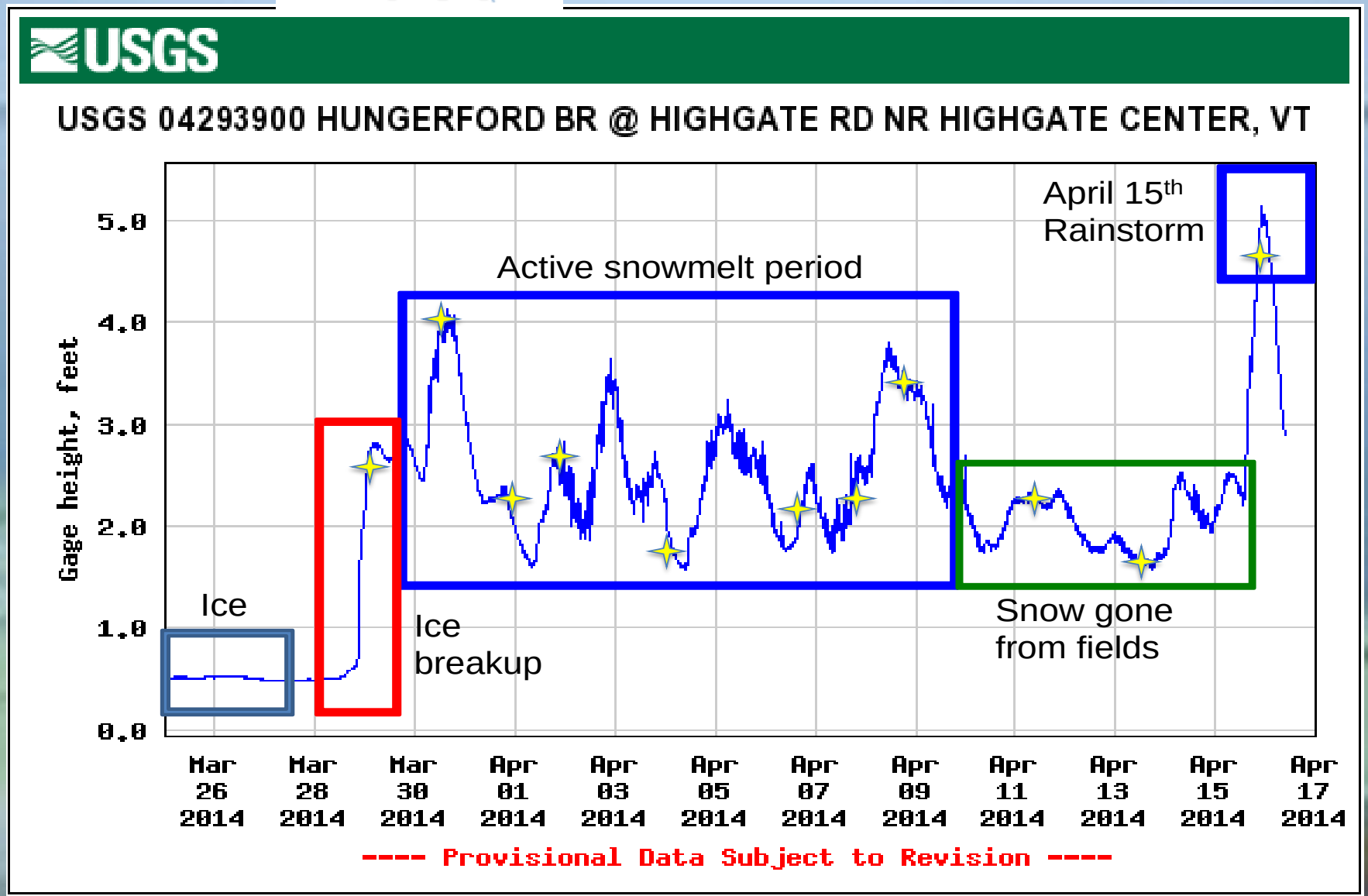
Johnson State College

St. Michael's College

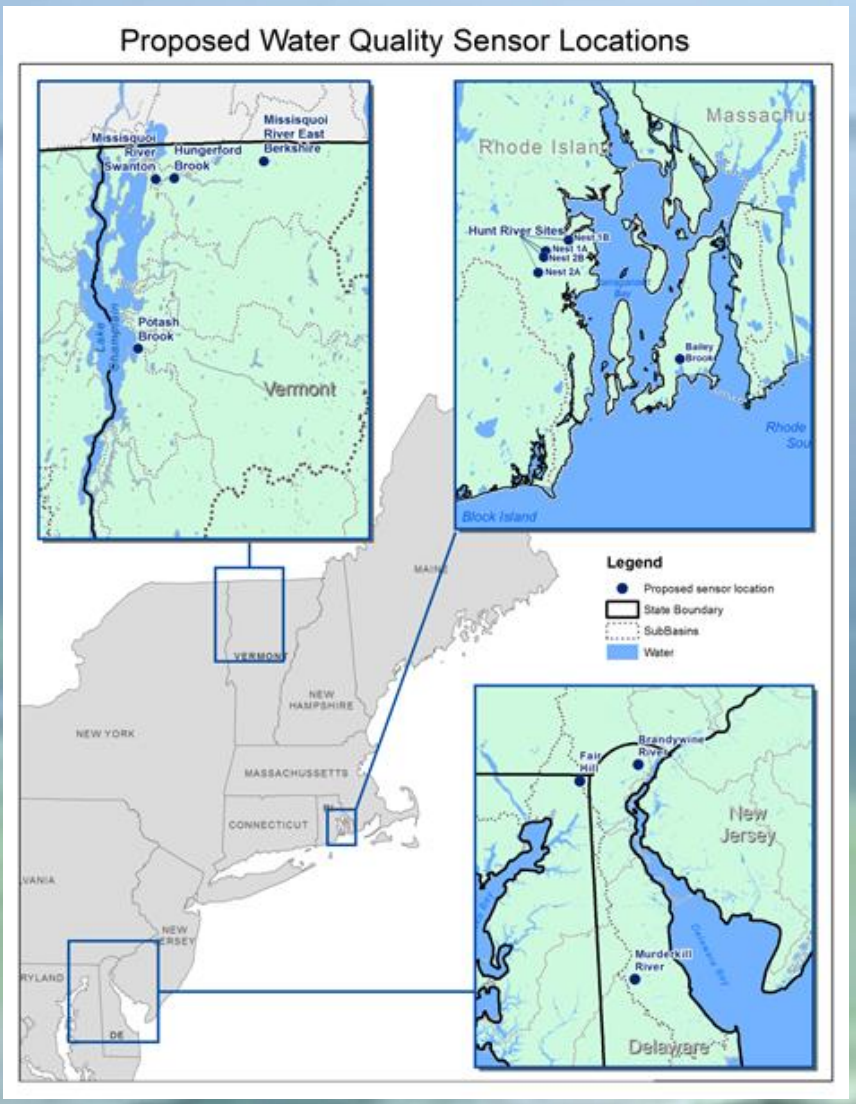


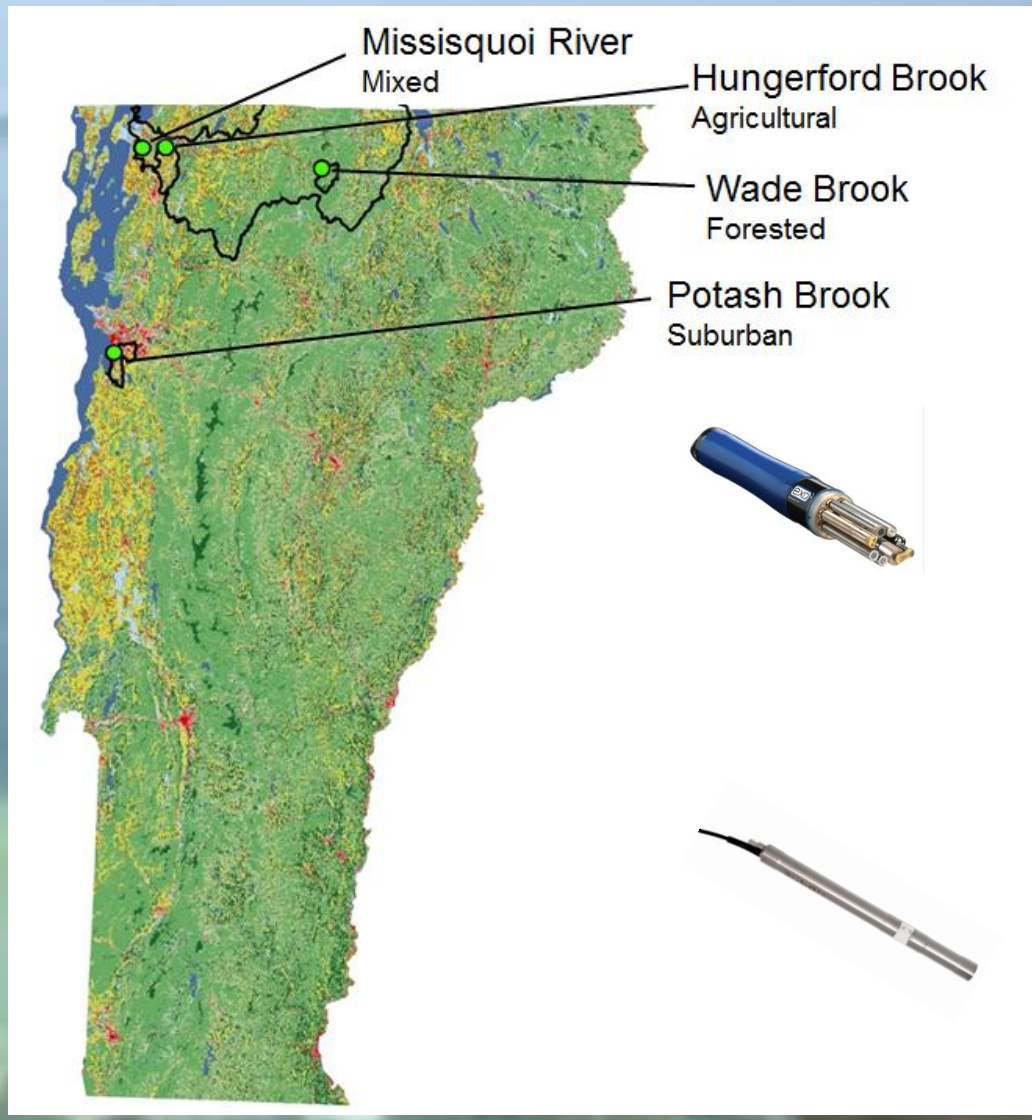
Undergraduate and graduate students have been directly involved in installation, maintenance, sampling, analysis, and data management.

High-Frequency Targeted Snowmelt Sampling



NEWRnet Sensor Network: Schroth, Bowden, Vaughan, Jerram (UVM), Shanley (USGS), Vermilyea (Castleton)



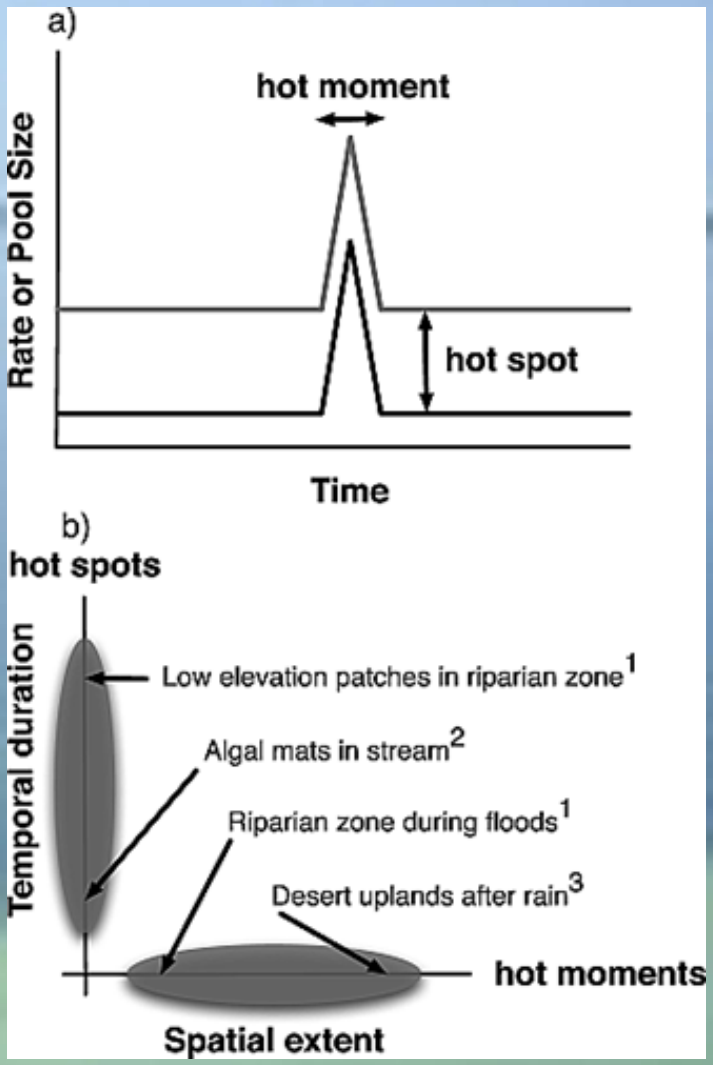


Research Questions

- Can we detect and describe regional hot moments? **Examples:** late summer storms, snowmelt, rain on snow, autumn leaf fall, large regional storms or droughts

- How does local watershed water quality respond to extreme events across variable landcover?

- Anthropogenic hot moments in agricultural systems? BMP effects?

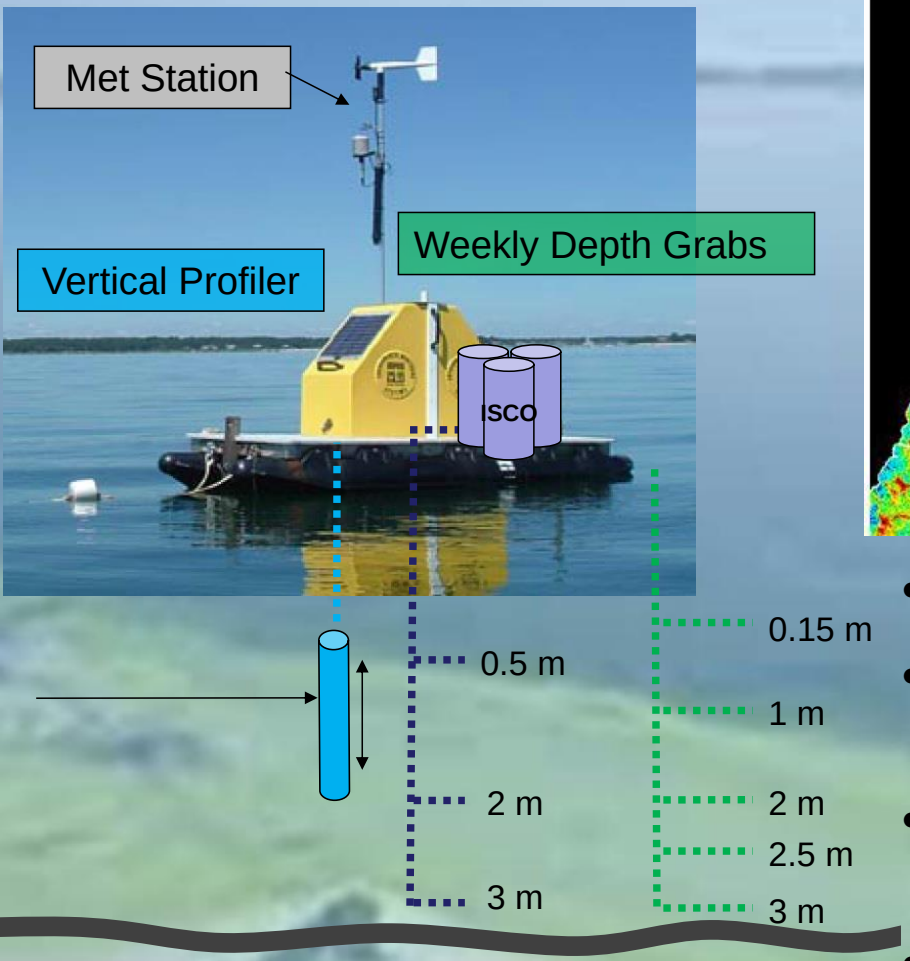


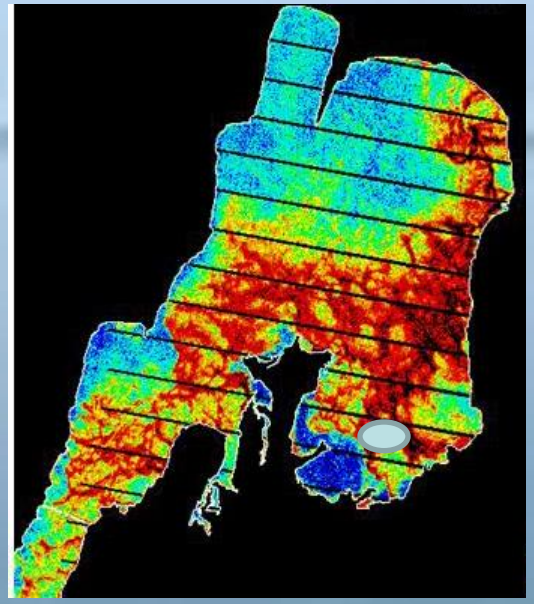
Harms and Grimm, 2008

What we have accomplished?

Missisquoi Bay Advanced Environmental Monitoring Sensor Array

UVM Biogeochemical Station





- Water depth ~ 3-4 m
- SE portion of bay insulated from S, E, W winds
- Site of the most intense BGA blooms
- 2012-present continuous data (Spring-Fall)

Middlebury Hydrodynamics

UVM Biogeochemical Sampling Strategy

- **Hourly**:

❑ Sonde measurements (DO, pH, turbidity, temp, phycocyanin, chlorophyll *a*) (5 depths)

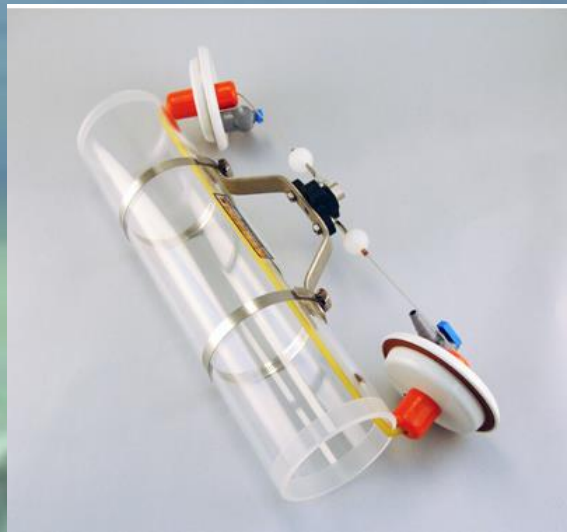
❑ Weather, river variables (temp, wind, discharge, water level)

Every 8 hours (5am, 1pm, 9pm)

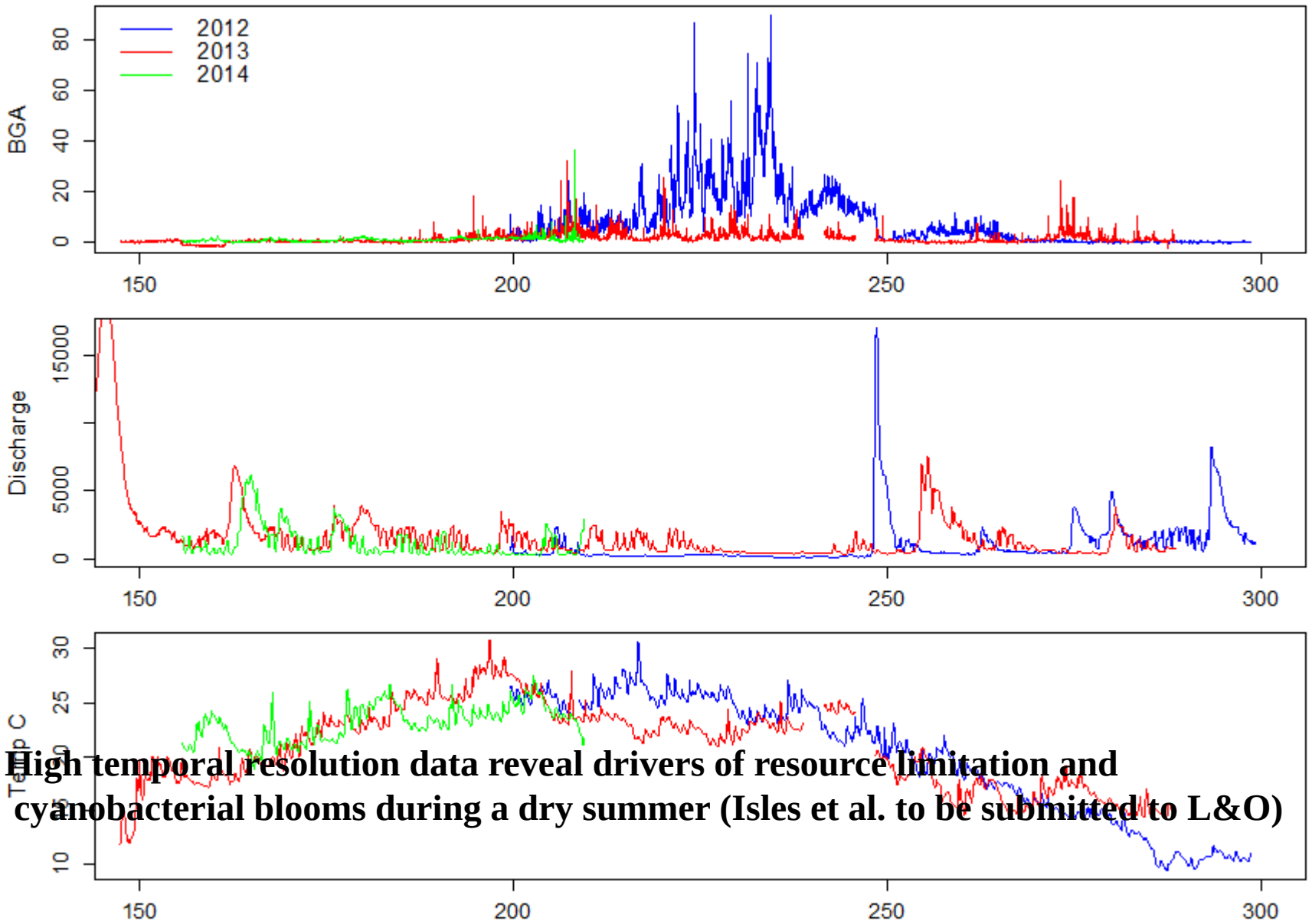
❑ Total nitrogen, total phosphorus, total metals (3 depths)

- **Weekly**

❑ SRP, TDP, NO_3^-, NH_4^+, dissolved metals, colloidal metals, phytoplankton, zooplankton, TSS, **sediment cores (biweekly)**



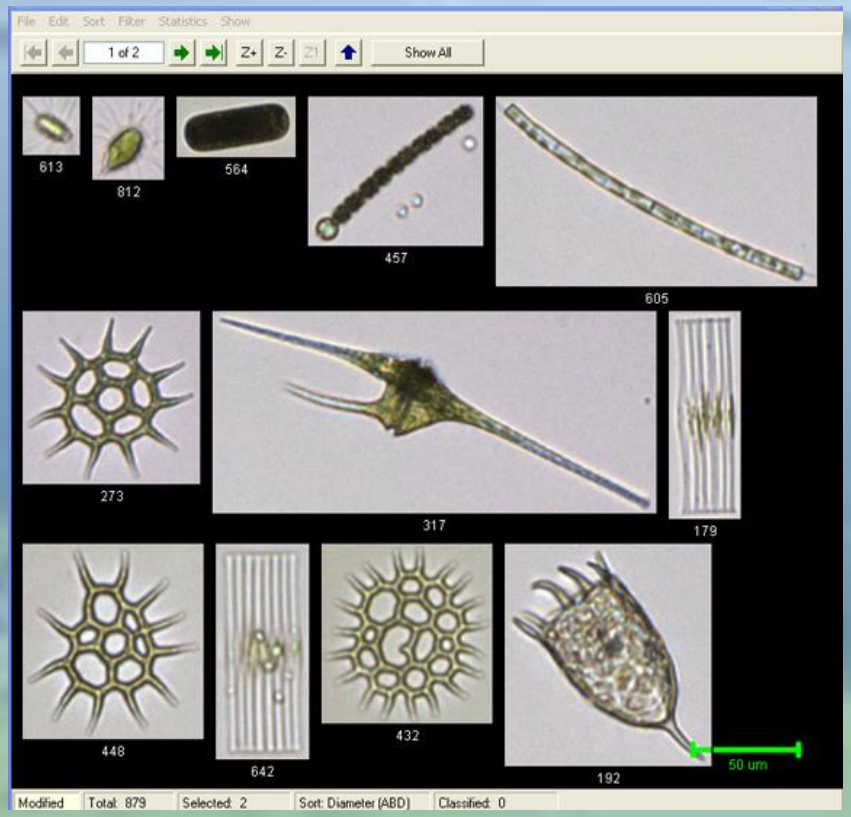
Ongoing Bloom Stage Monitoring



High temporal resolution data reveal drivers of resource limitation and cyanobacterial blooms during a dry summer (Isles et al. to be submitted to L&O)

What are we working on?

Bioindicators to explore the effects of nutrient dynamics on aquatic food web structure



Sampling & identification

Phytoplankton

Zooplankton

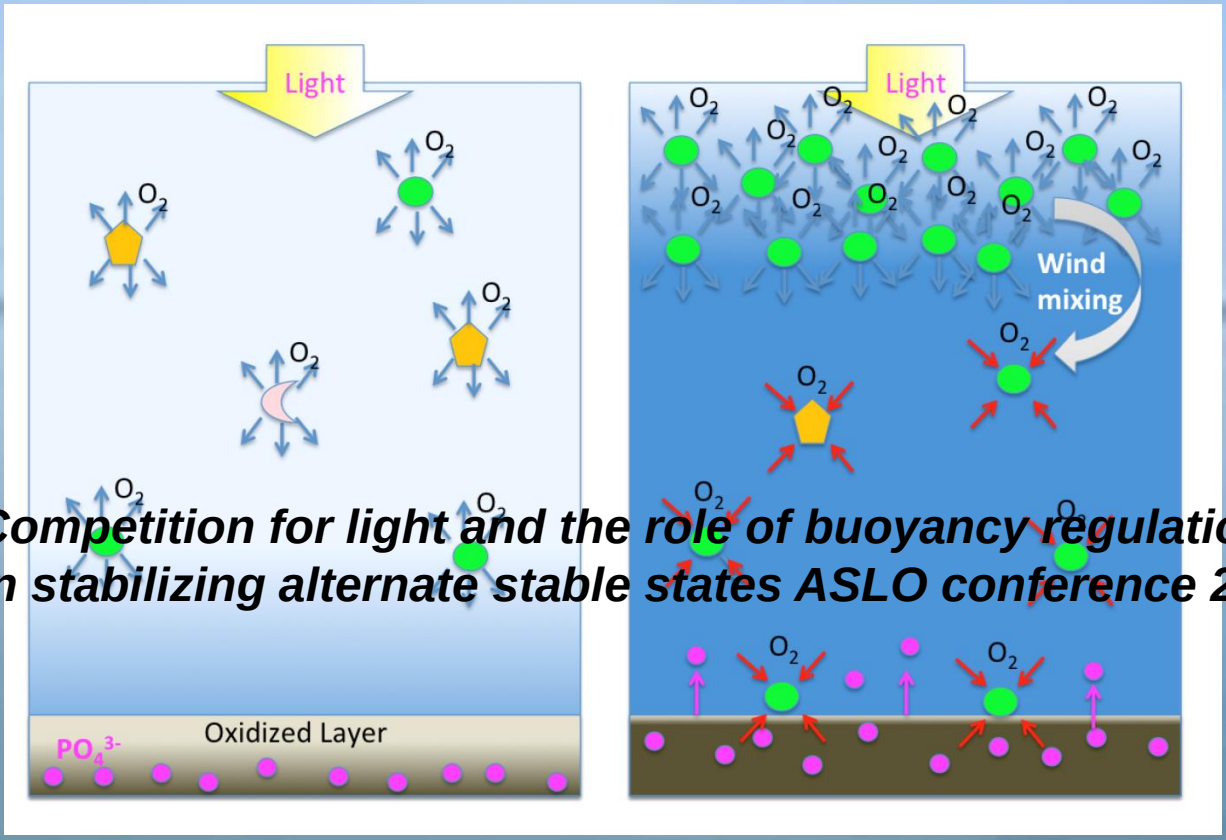
Benthic invertebrates

Aquatic plants

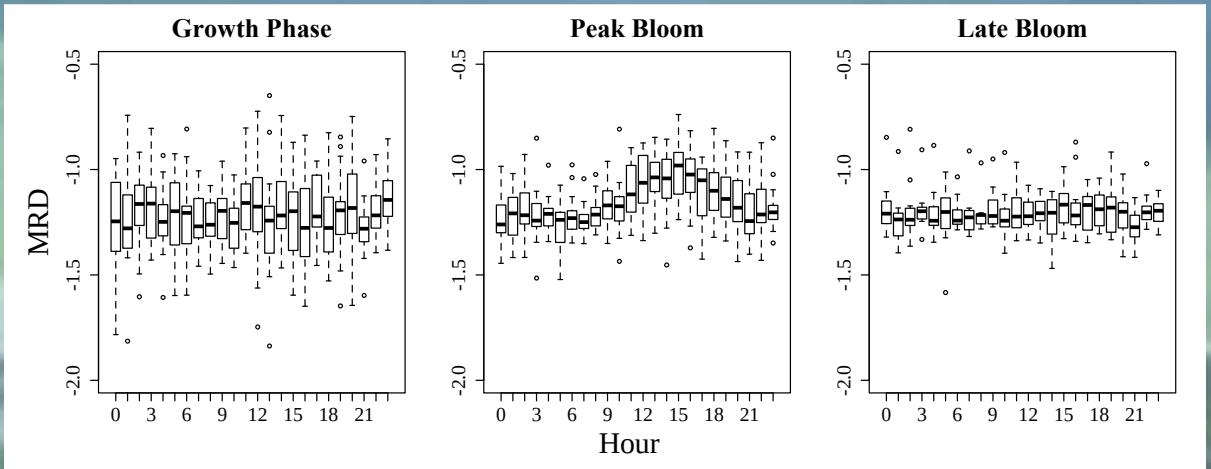
Fish

FlowCAM in 2013

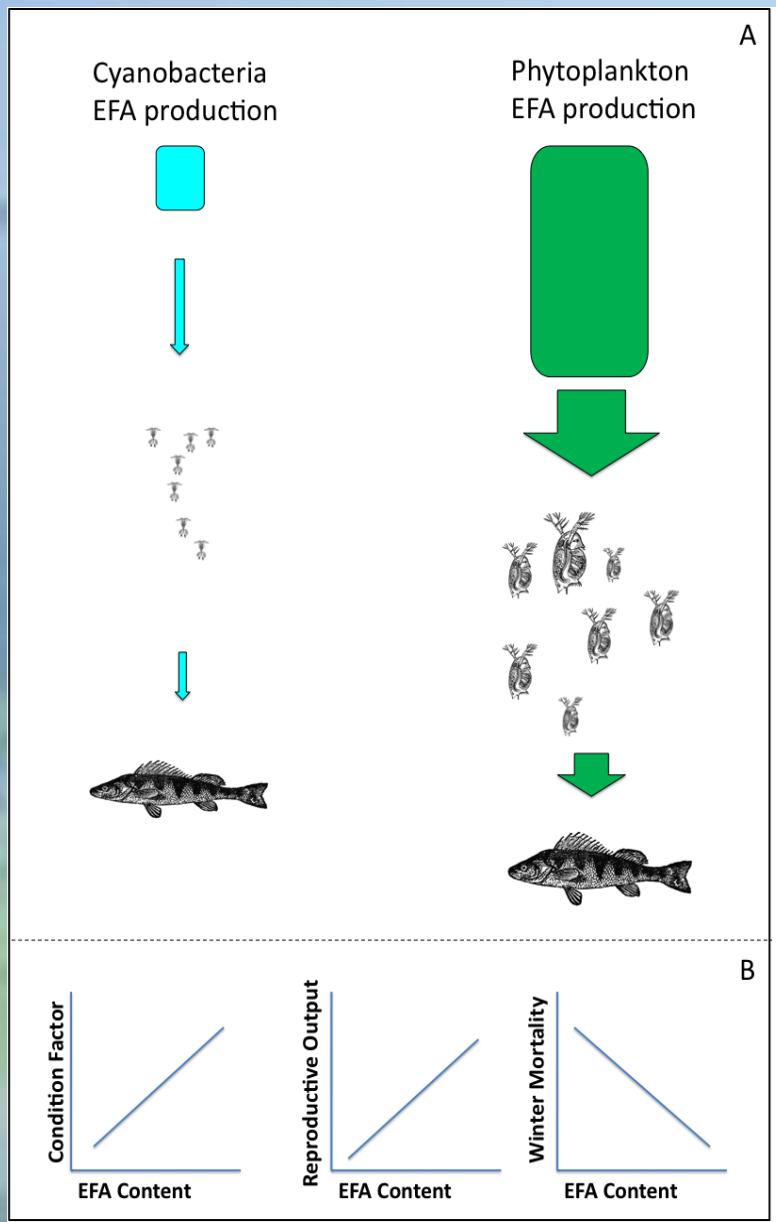
Light Limitation and Alternate Stable States: Isles



Competition for light and the role of buoyancy regulation in stabilizing alternate stable states ASLO conference 2014



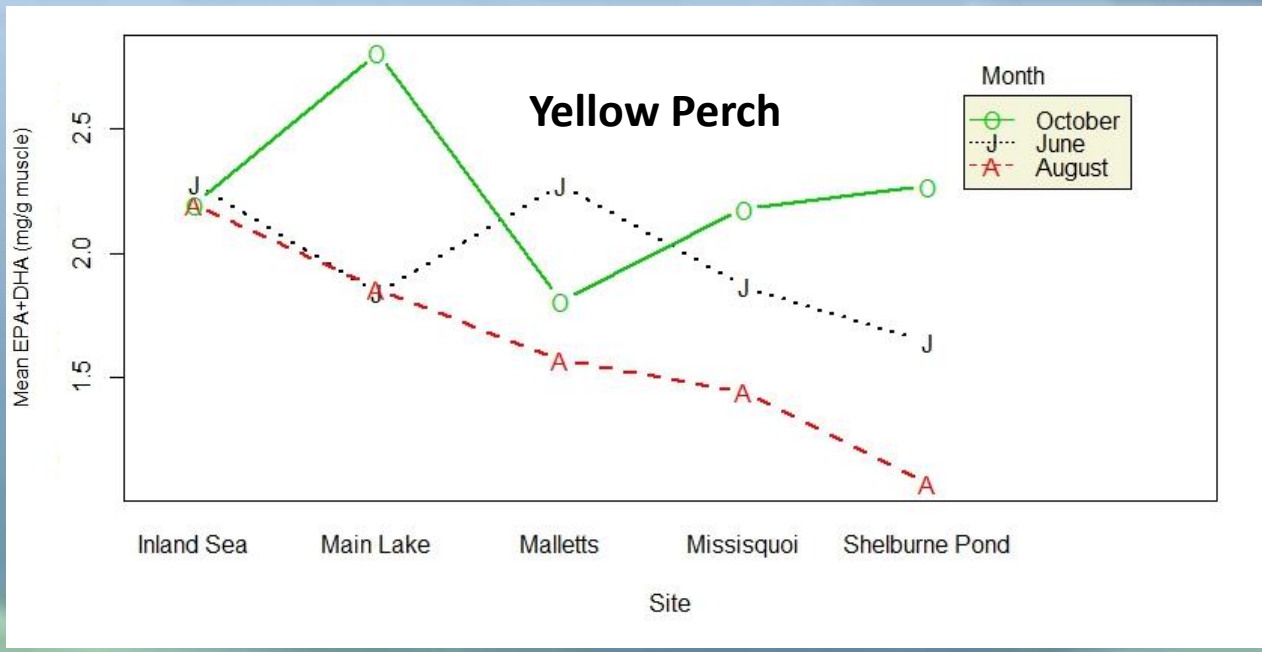
Consequences of Cyanobacteria on Essential Fatty Acid Limitation in Fish (Gearhart and Stockwell)



- Cyanobacteria produce very low levels of essential fatty acids(EFA)
- Decreases zooplankton EFAs, growth, and fecundity
- Decrease available essential fatty acids to fish and could have impacts on their fitness

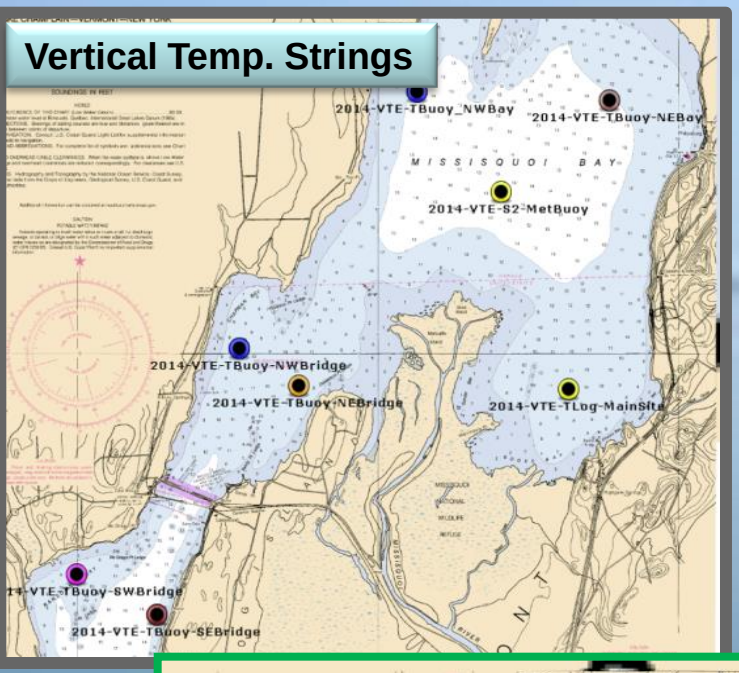
Fish Studies: Preliminary Results (Gearhart and Stockwell)

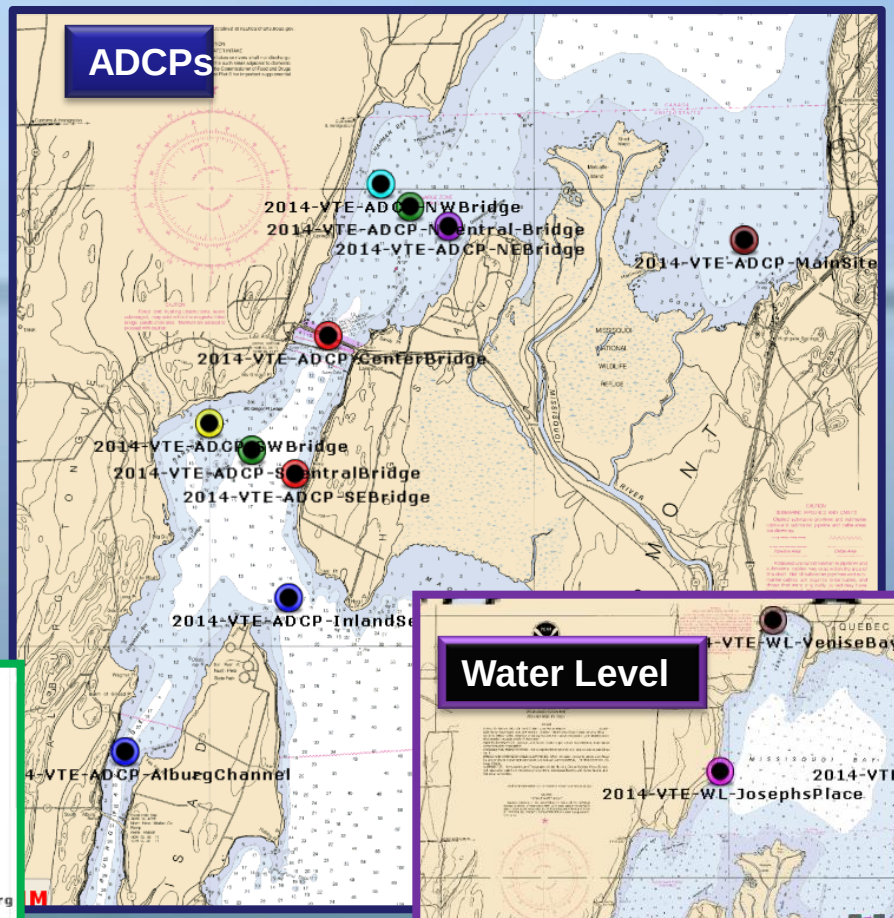
- Preliminary results show trends similar to our hypothesis
- Further analysis of liver tissue will show complete picture
- Lab experiments are in progress to determine the exact impacts of BGA on perch fatty acids

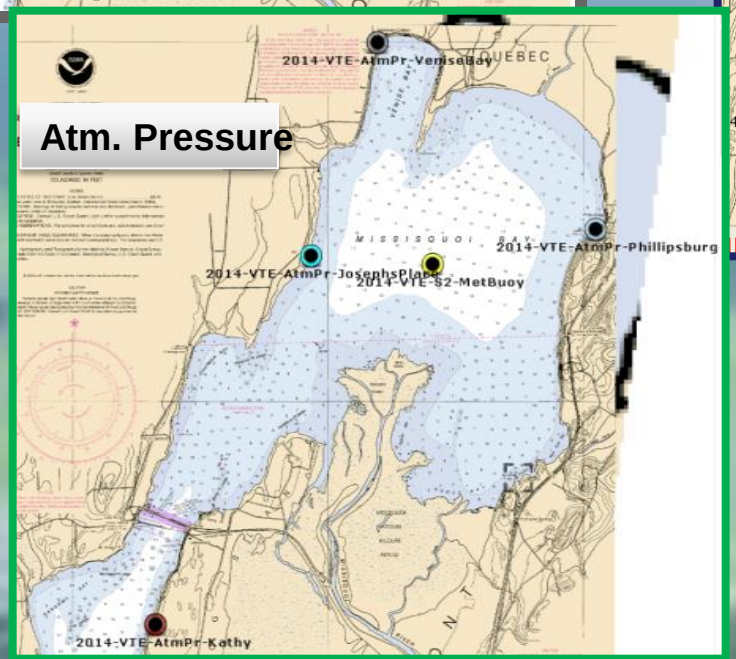


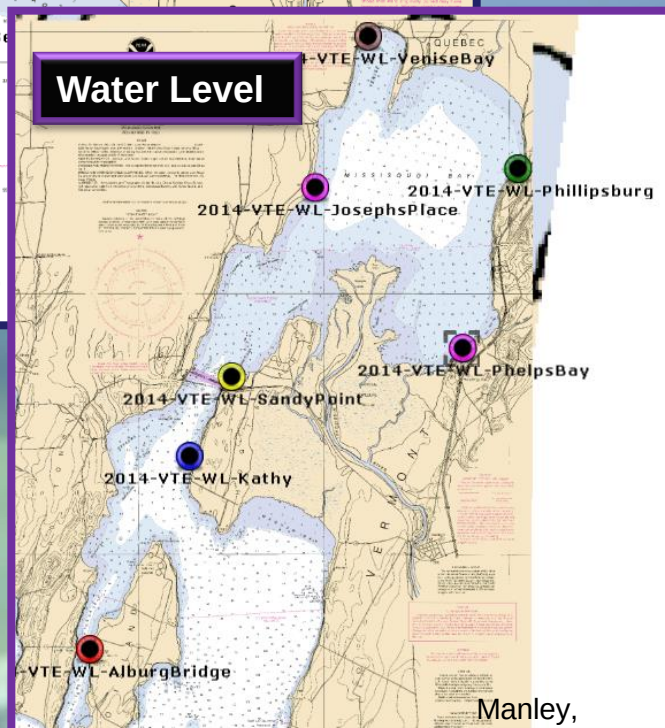
DO CYANOBACTERIA BLOOMS SHIFT FOOD-WEB PATHWAYS IN FRESHWATER LAKES?
Gearhart ASLO 2014

2014/2015 Hydrodynamic Array (Presently Operational, T. Manley)







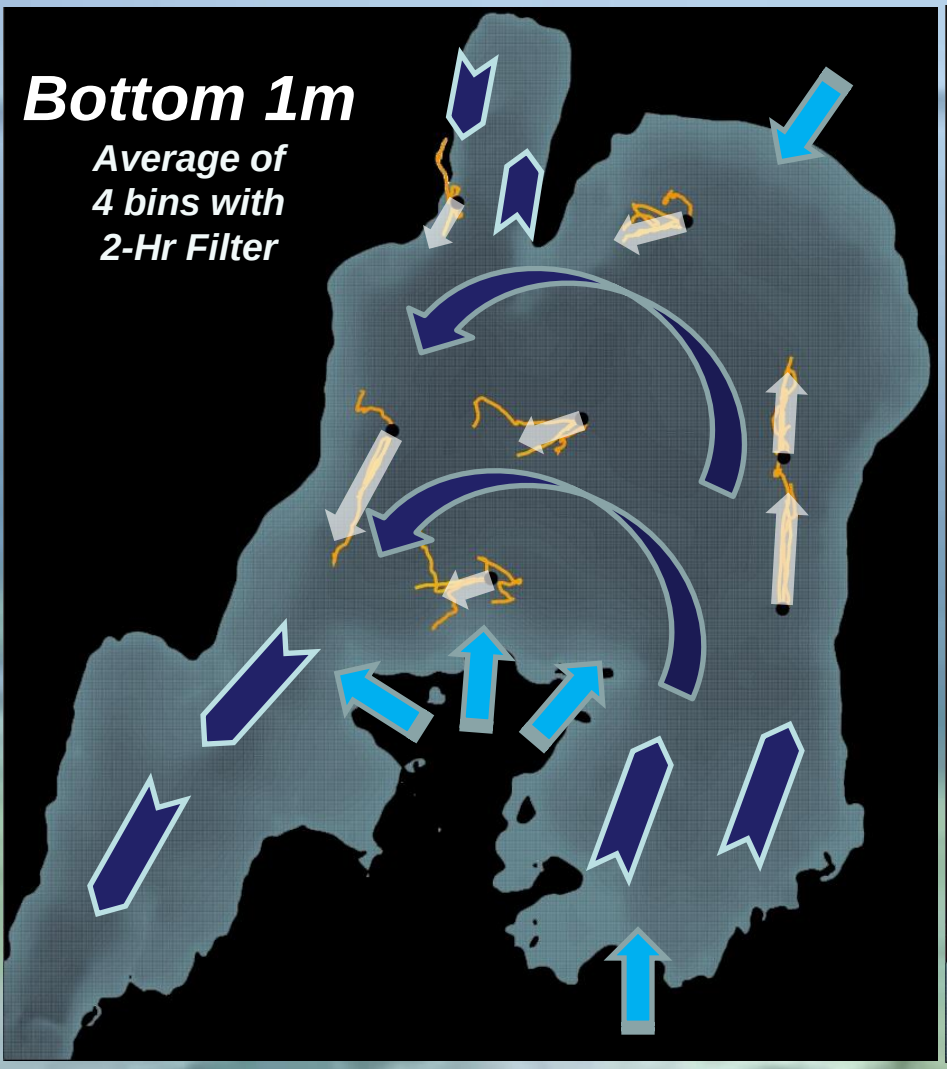


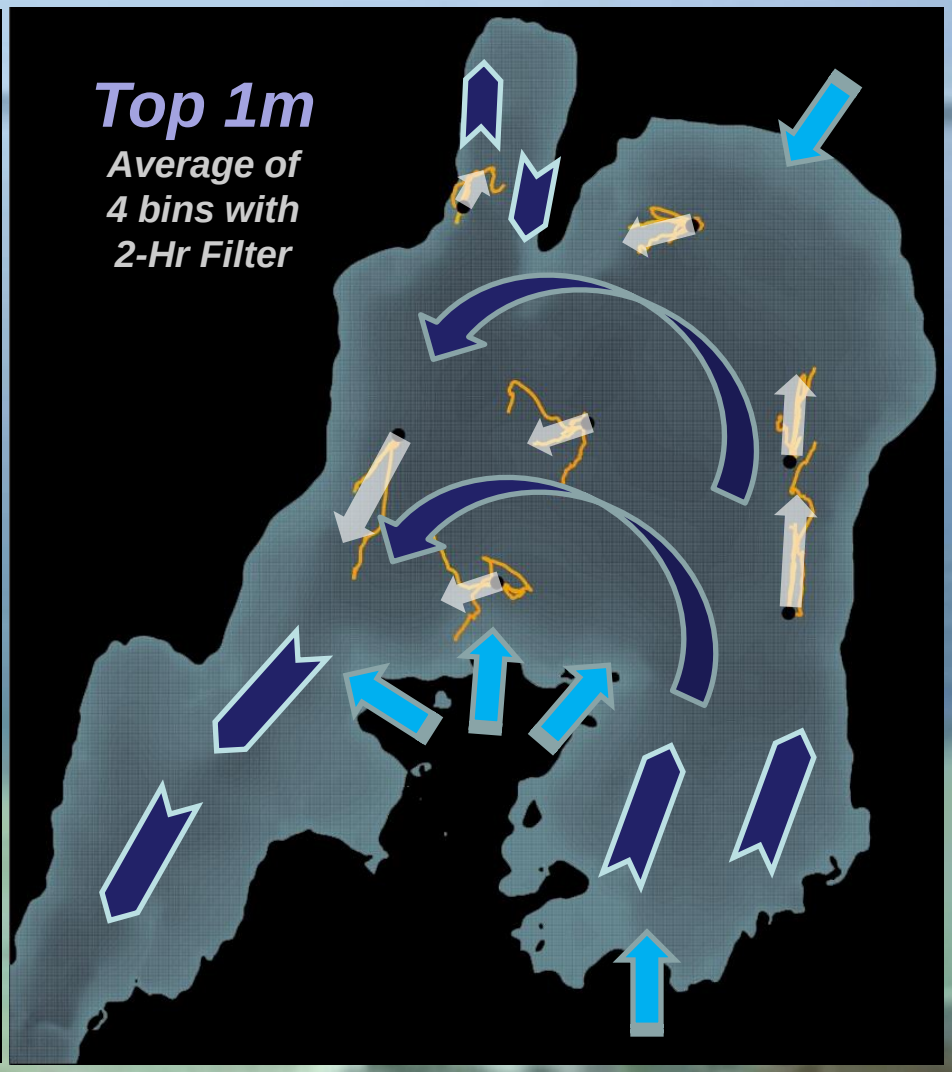
Manley,

What we have accomplished?

Dynamic circulation models

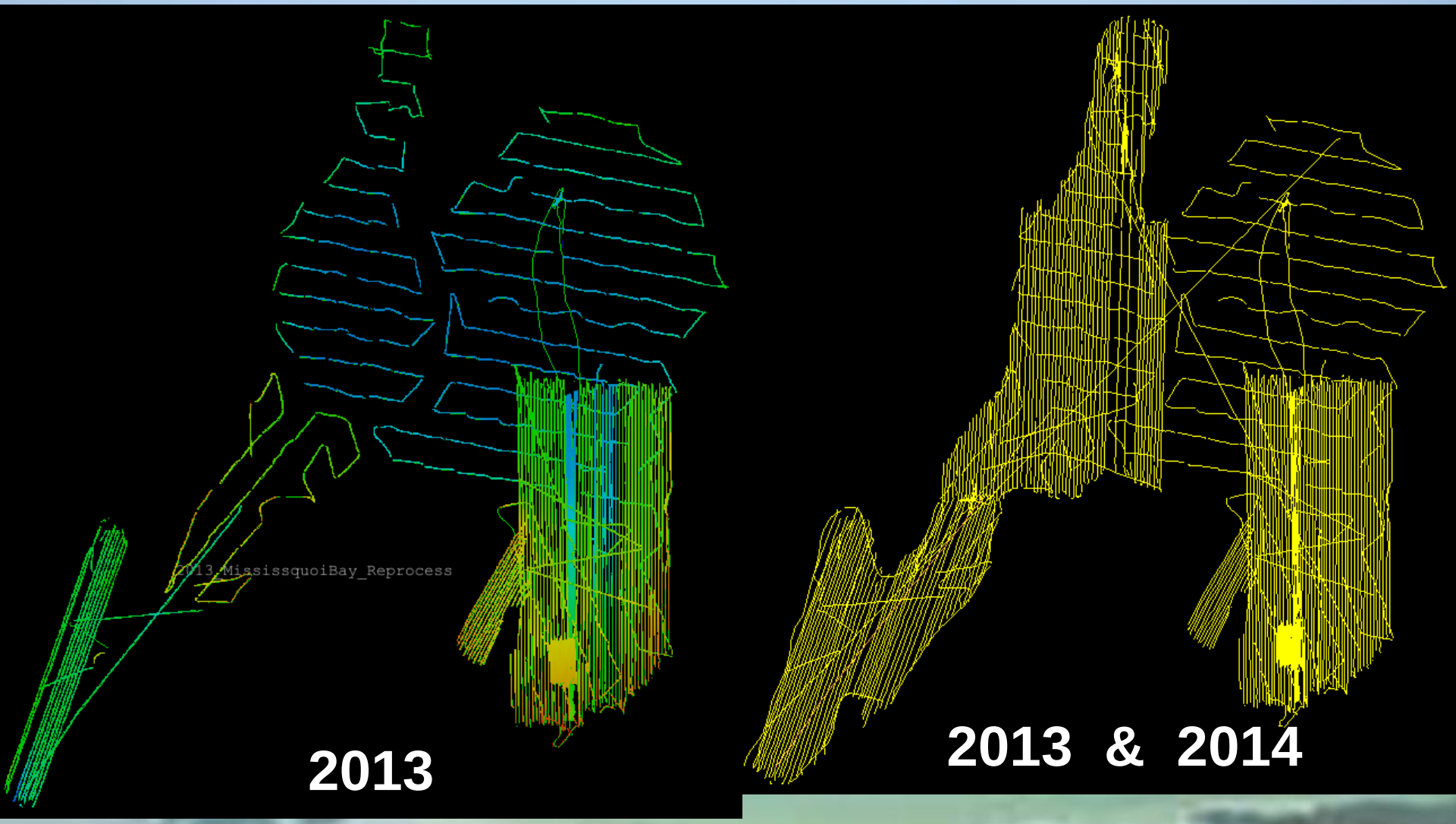
High Spring River Inflow Drives Consistent Mean CCW Circulation





Perzan & Manley, 201

What we have accomplished?
High-Resolution Bathymetric Mapping



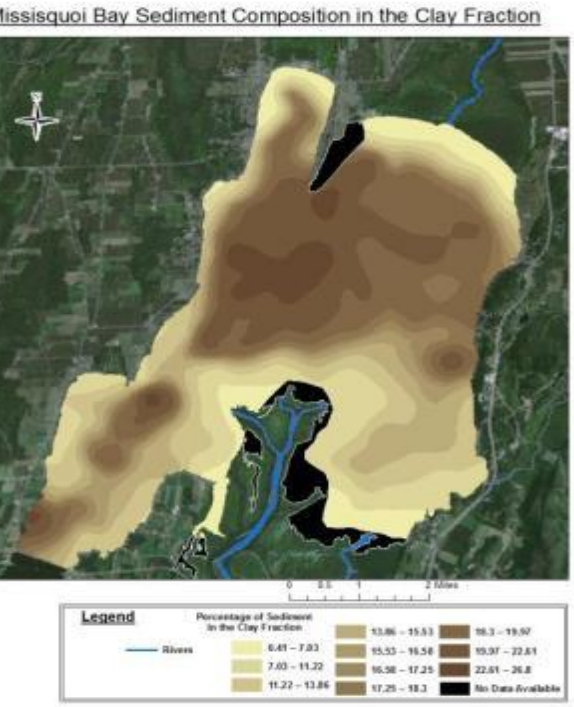
Fishbin & Manley, 2014

What we have accomplished?

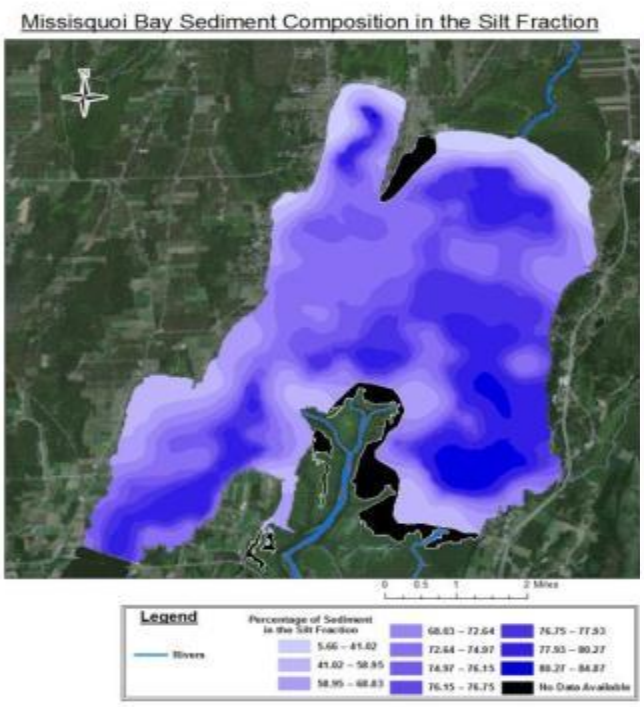
Spatial Sampling of Sediment: Sediment Trend Analysis and Benthic Community Mapping

P Manley, D. McCabe

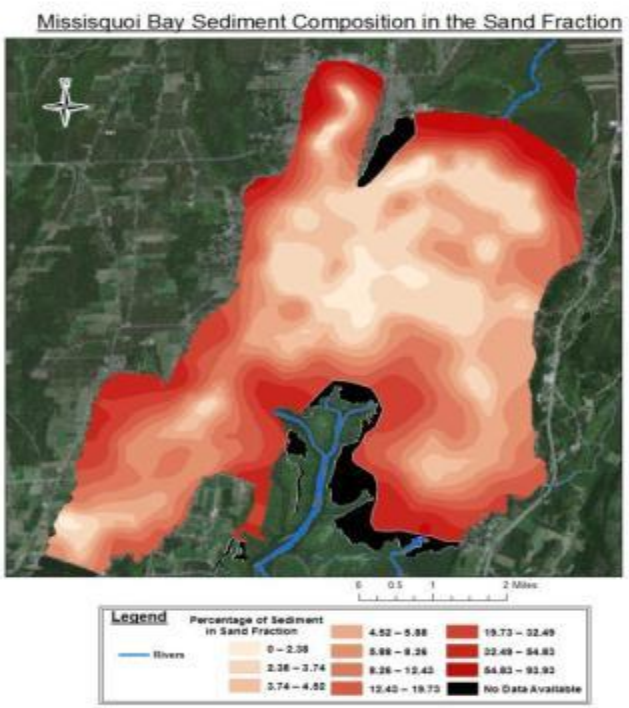
Sampling Conducted 2013, Analyzed 2014



Clay%



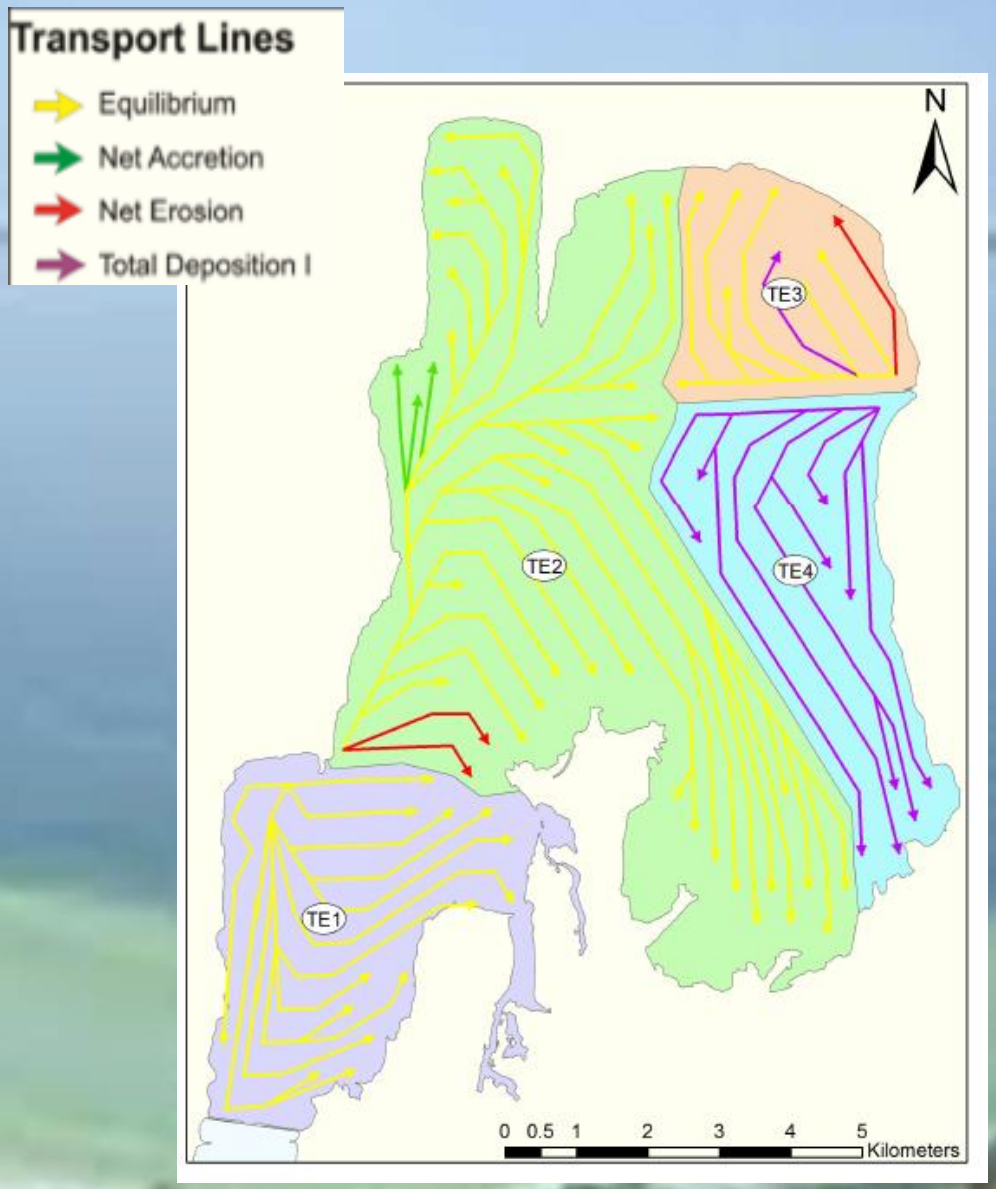
Silt%



Sand %

Sediment Transport Modeling

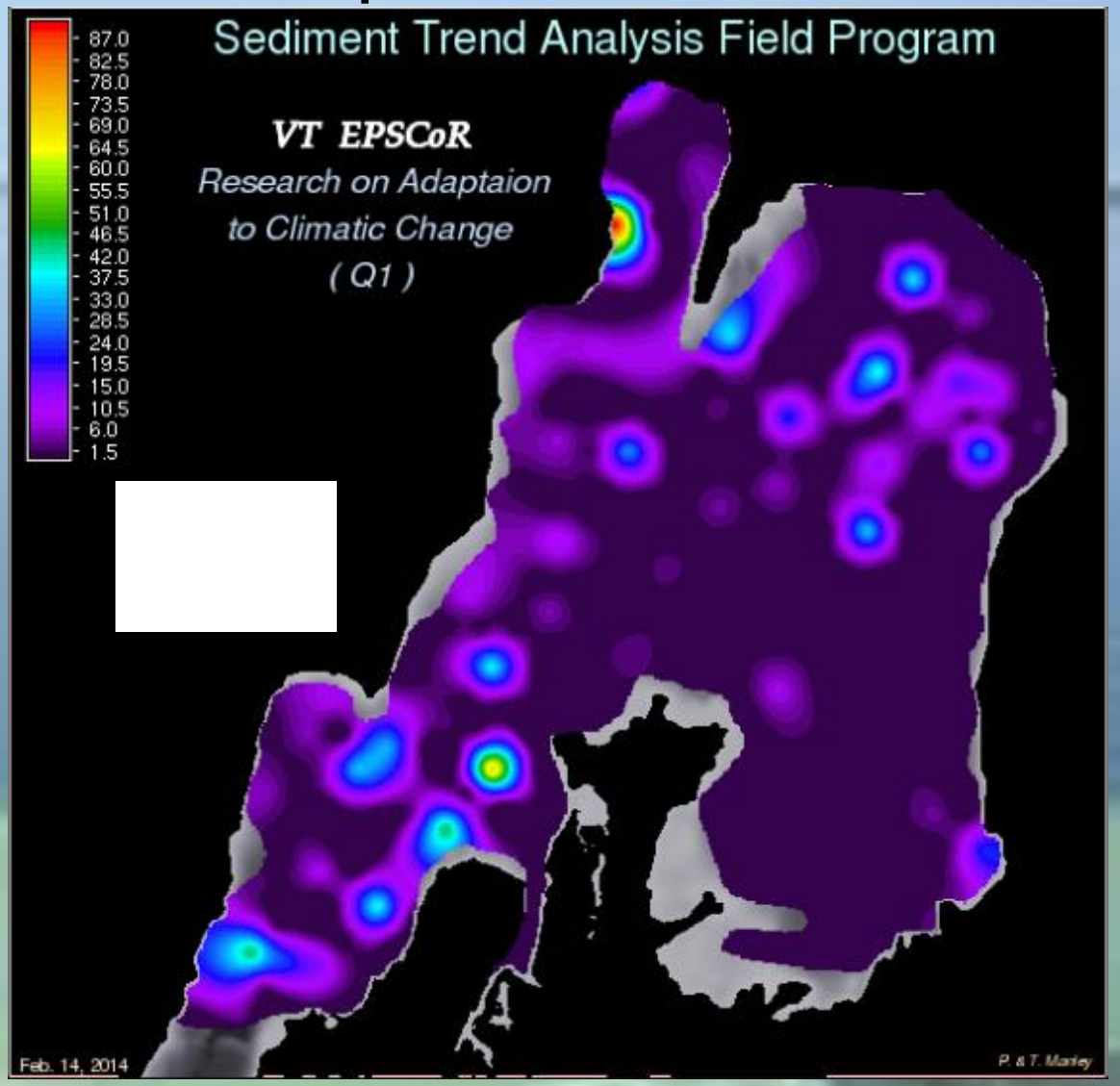
- Transport lines group into 4 Transport Environments (TE)
- Each TE has transport related to each other



Microfaunal Sediment Study– Preliminary Trends in Species Location

- Distribution and abundance of *D. polymorpha (Zebra mussels)* in Missisquoi Bay

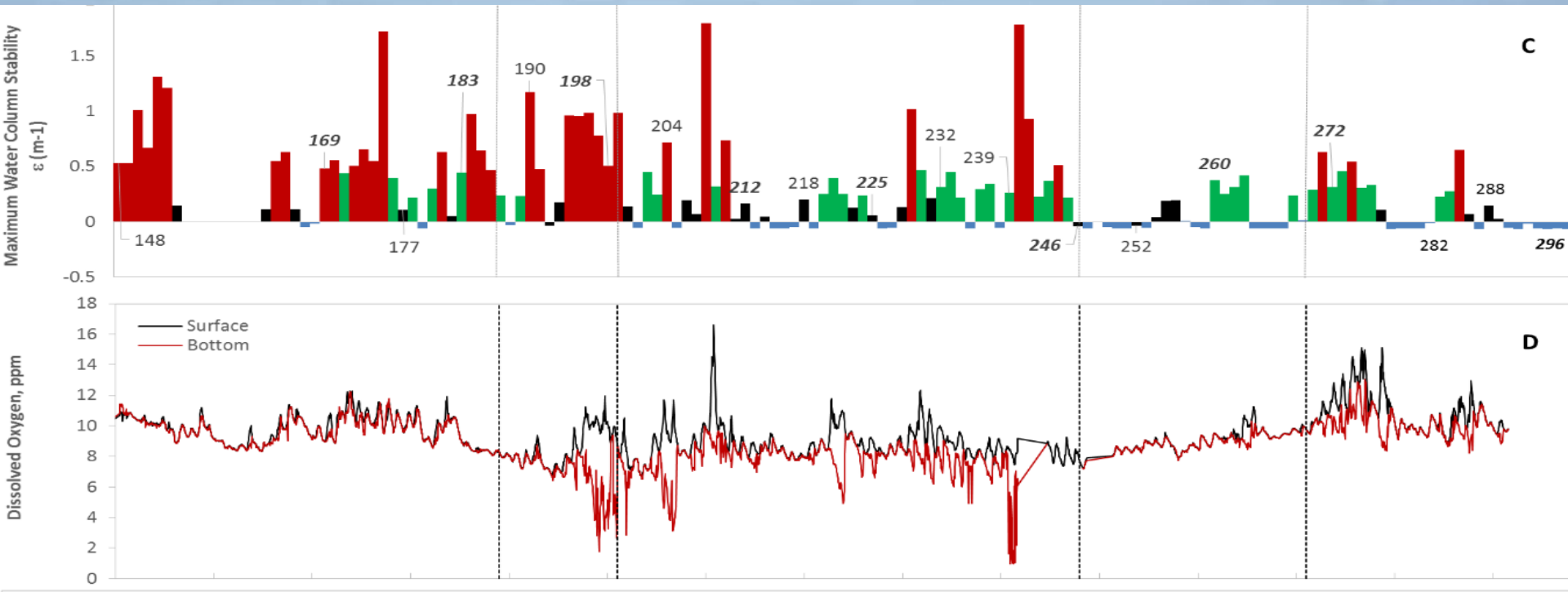
- *D. polymorpha* most abundant on east side of bay, absent in SE corner



What we have accomplished?

Drivers of P and Metals Dynamics in Missisquoi Bay: Novel Holistic Approach (Giles)

Used physical and biogeochemical high-frequency sensor data to **identify periods of: *Stability and Disturbance***



Drivers of P and Metals Dynamics in Missisquoi Bay:

Novel Holistic Approach (Giles)

Water Column:

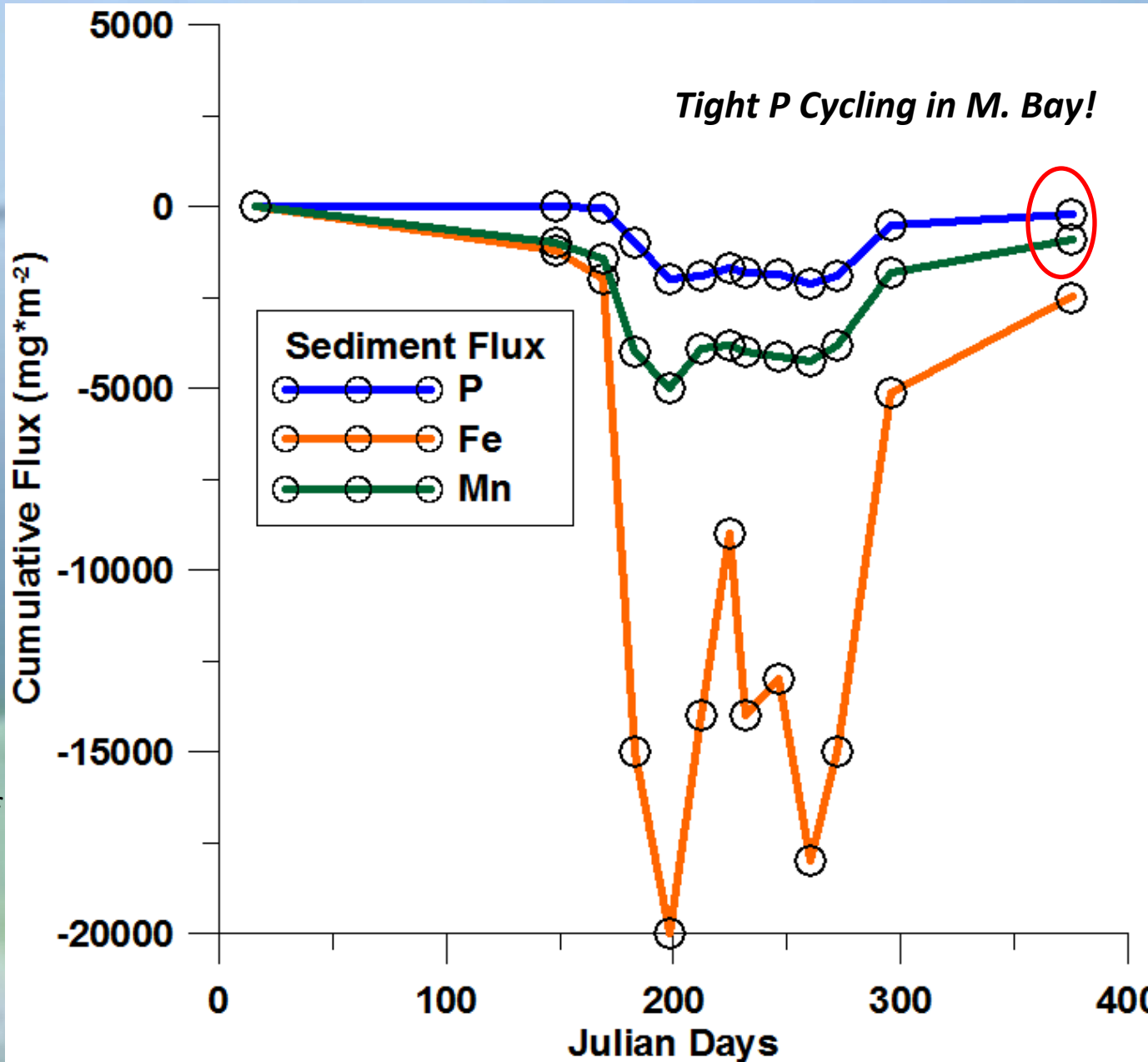
Stable: *Enriched Bottom Water Mn, Pronounced DO Stratification*

Disturbed: *Minimal Stratification, low Mn, SRP/Fe depend on degree riverine input*

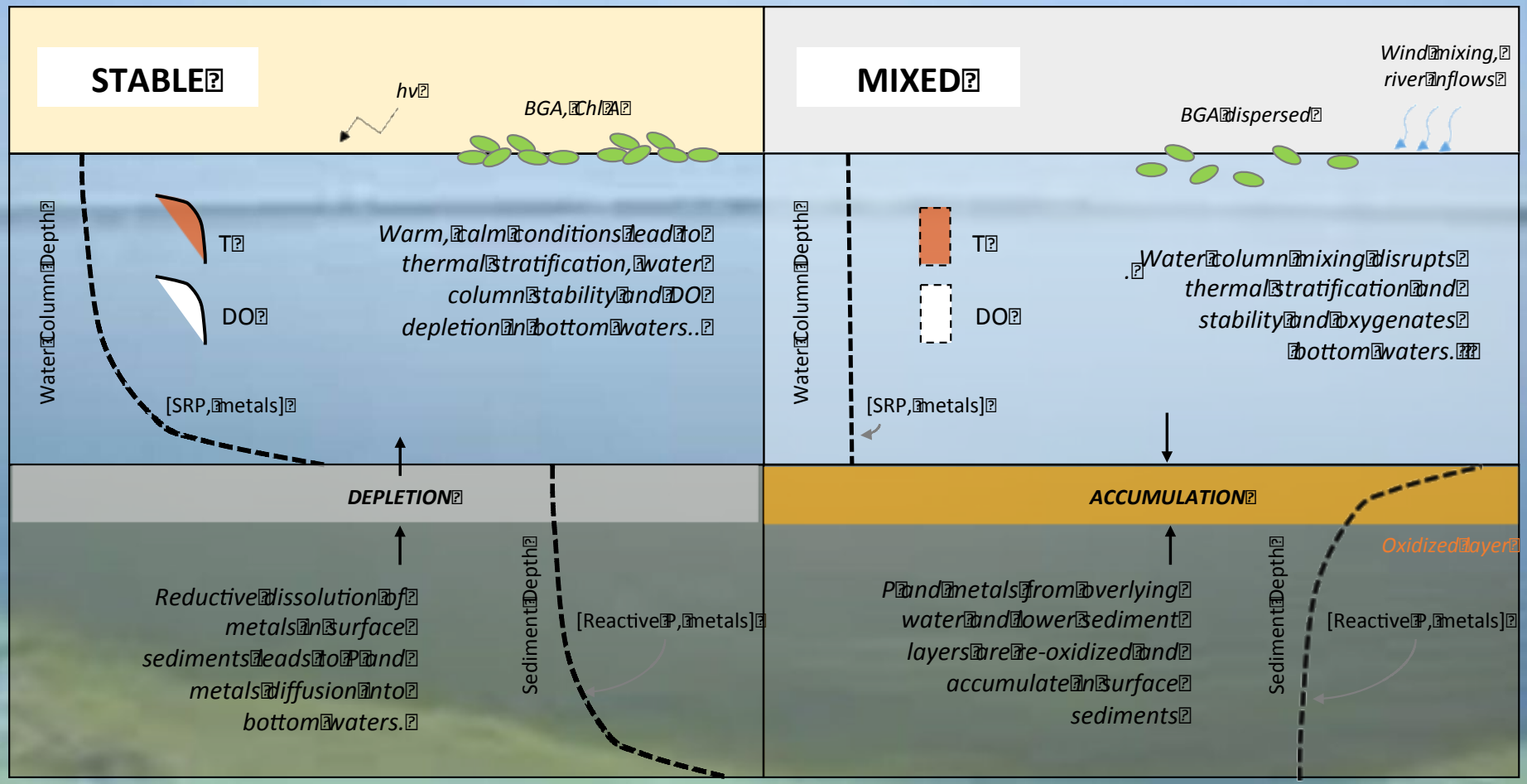
Sediment:

Stable: *Depletion of P, Fe, Mn from sediment*

Disturbed: *Accumulation of P, Fe, Mn in sediment*



Conceptual Model: Stable vs. Disturbed

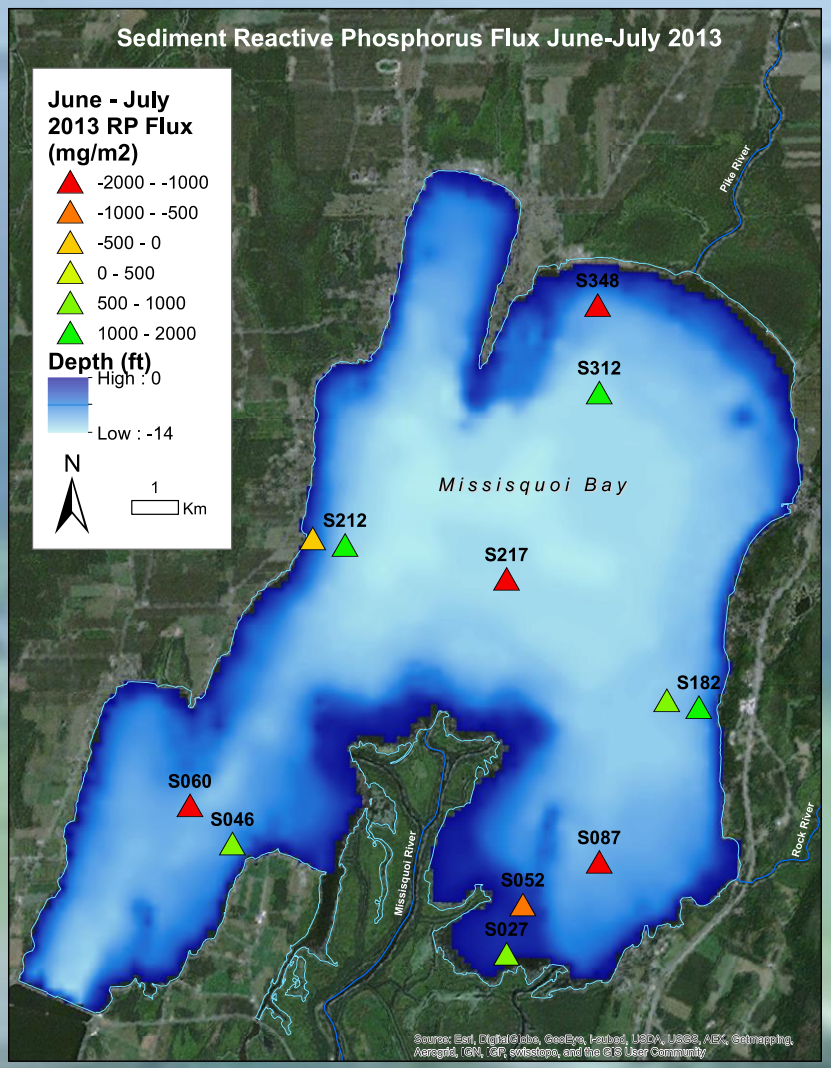


PHOSPHORUS AND METALS MOBILITY IN THE SEDIMENT-WATER CONTINUUM OF A SHALLOW, FRESHWATER LAKE UNDER STRATIFIED AND MIXED WATER-COLUMN CONDITIONS

What are we working on?

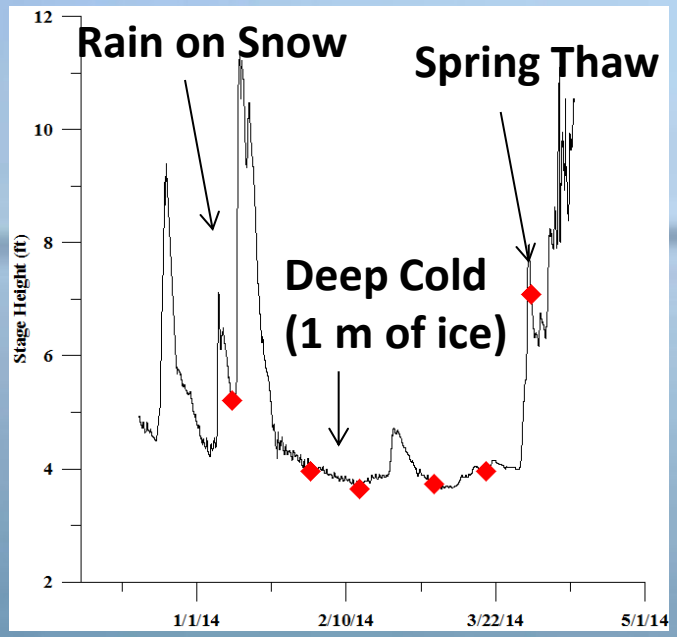
Spatial SWI Dynamics

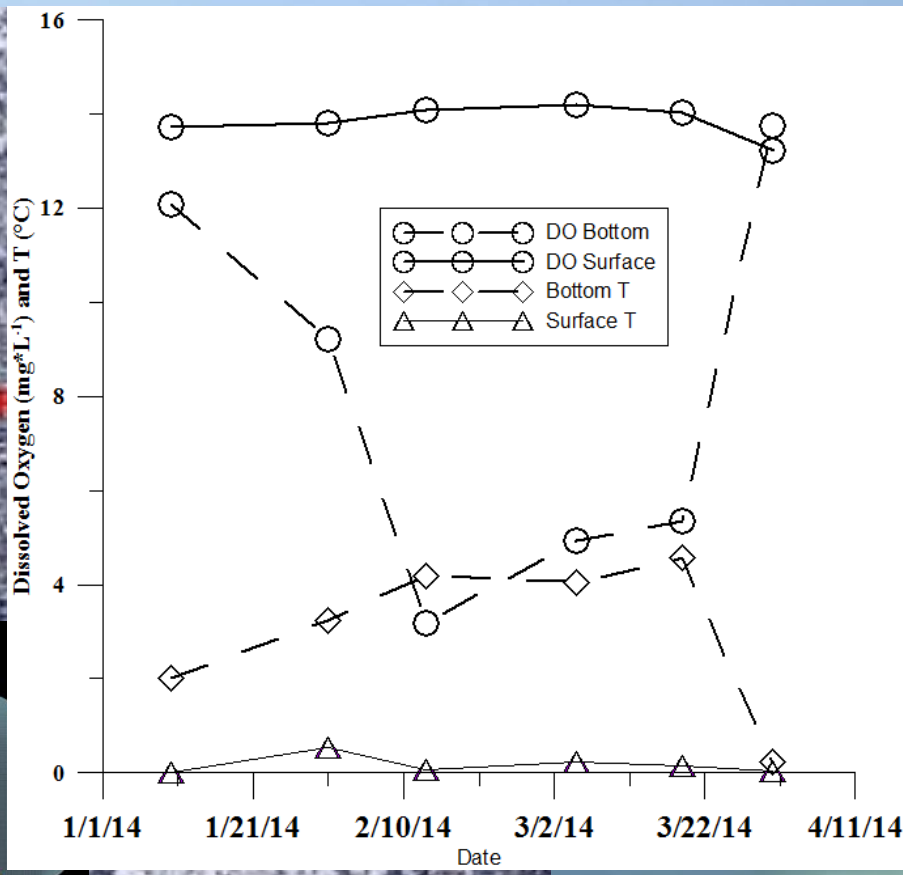
Welcome DongJoo (DJ) Joung!

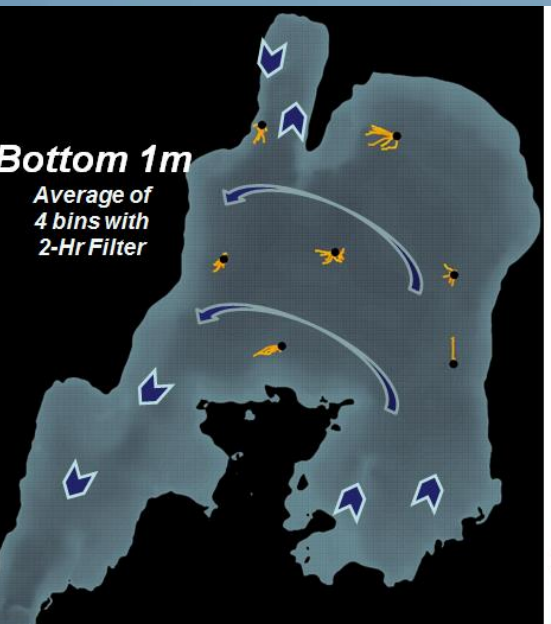


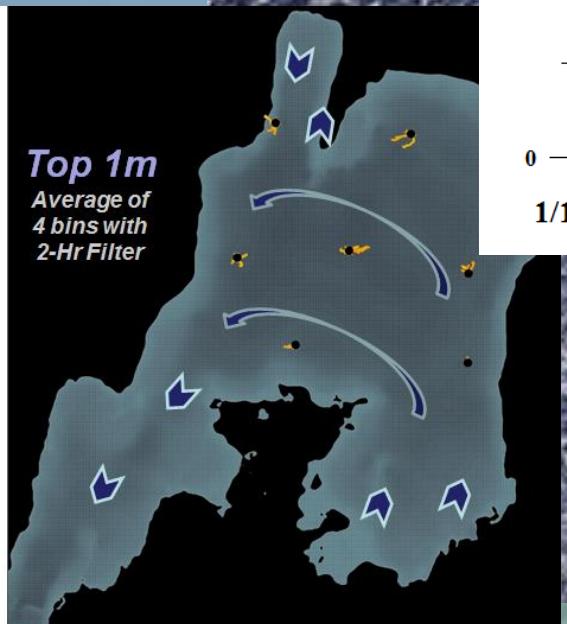
What We have Accomplished?

Under Ice Biogeochemical/Hydro Dynamics







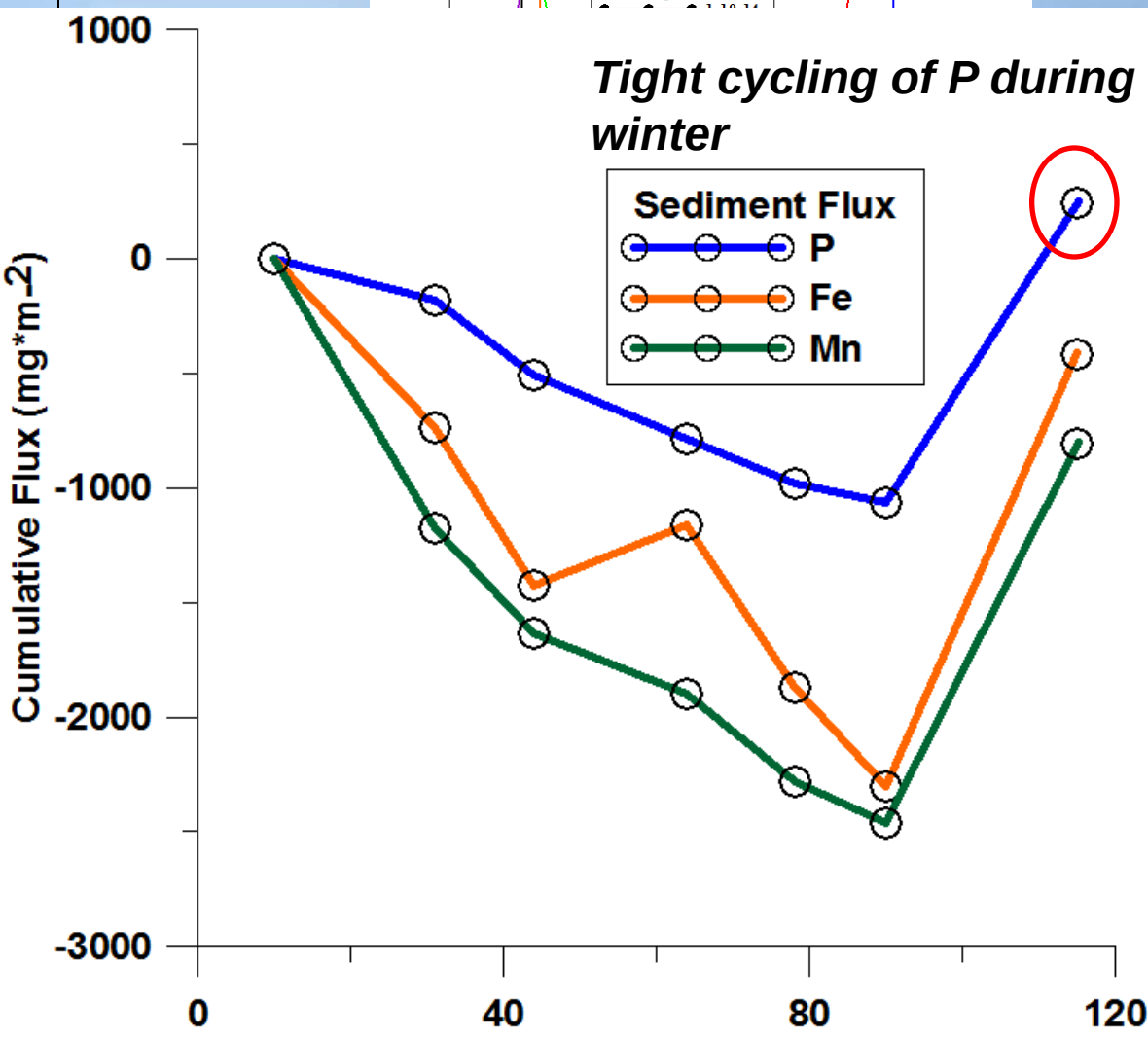


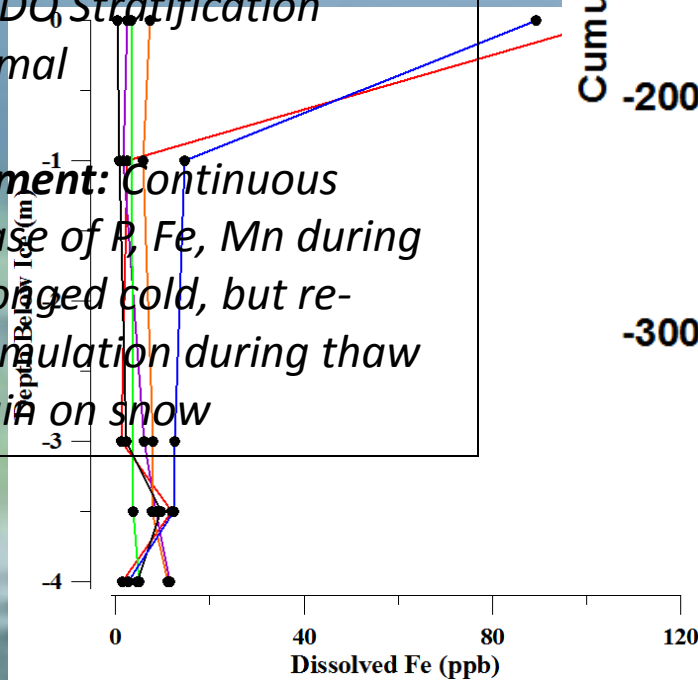
Under Ice Metal/P Dynamics

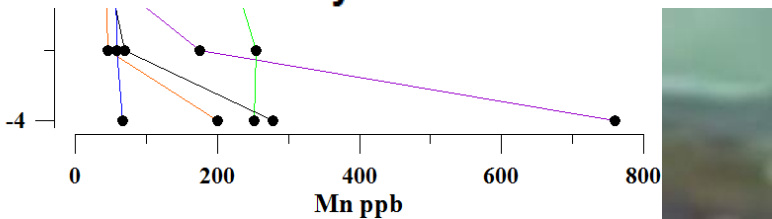
Water Column:
Ice Development(Stable): *Enriched Bottom Water M*
Stratification: *Enriched Bottom Water Mn, SRP, Pronounced DO Stratification*
Rain on Snow/Thaw (Disturbed): *Inverted stratification of SRP, Fe low and DO stratification minimal*

Water Column:
Ice Development(Stable): *Enriched Bottom Water Mn, SRP, Pronounced DO Stratification*
Rain on Snow/Thaw (Disturbed): *Inverted stratification of SRP, Fe low and DO stratification minimal*

Sediment: *Continuous release of P, Fe, Mn during prolonged cold, but re-accumulation during thaw or rain on snow*



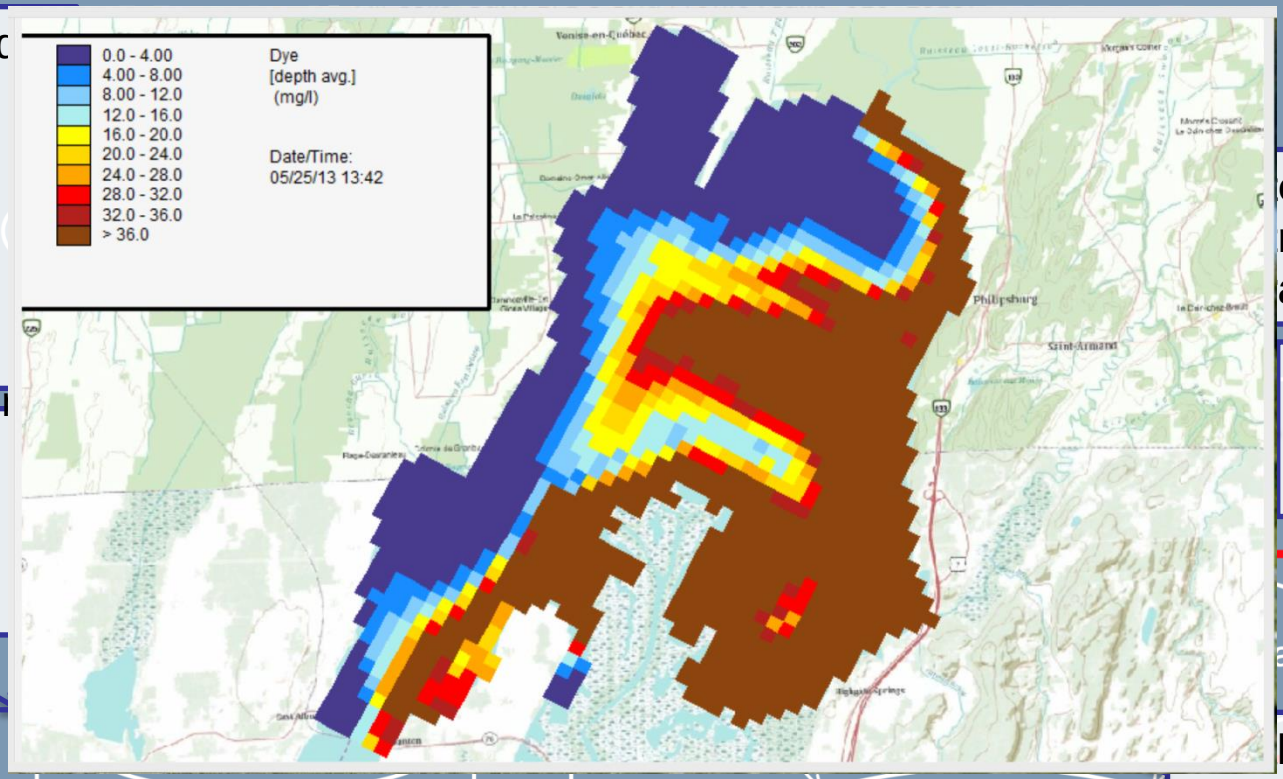




Advanced Aquatic Ecosystem Model (A2EM)

Wind (speed direction)
Temp
RH
Pressure
Solar Radiation
Cloud Cover

Bathymetry
River Inputs,
Main lake level



o growth and rient uptake ameters

Initial nutrients, phytoplankton, zooplankton

l mussel densities

Sediment
Nutrients
Diagenesis

Initial Conditions

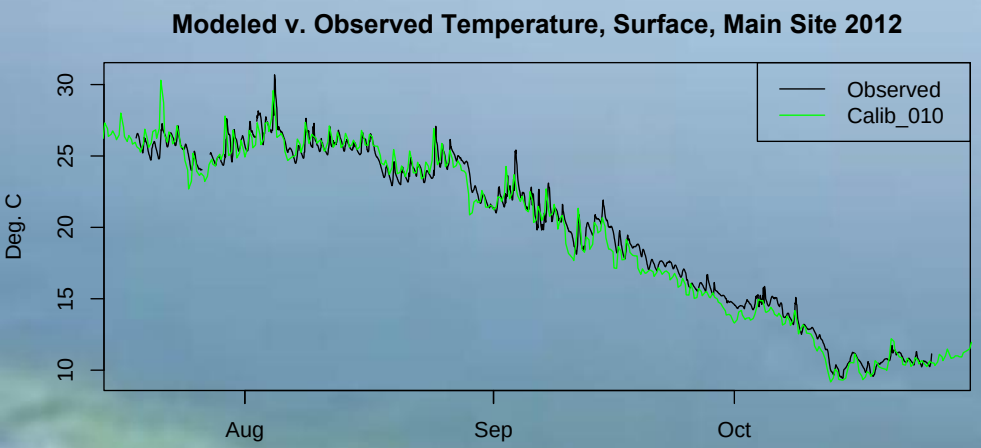
Initial water levels, temp

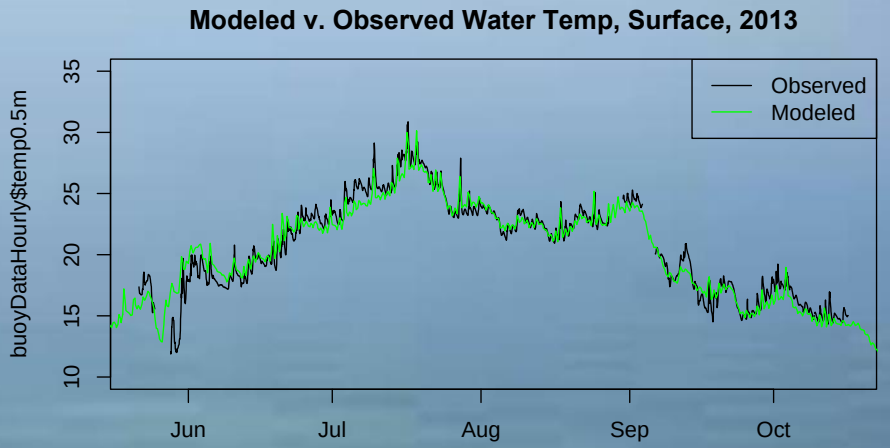
- 240m grid cells
- 5 vertical layers
- > 30 state variables simulated

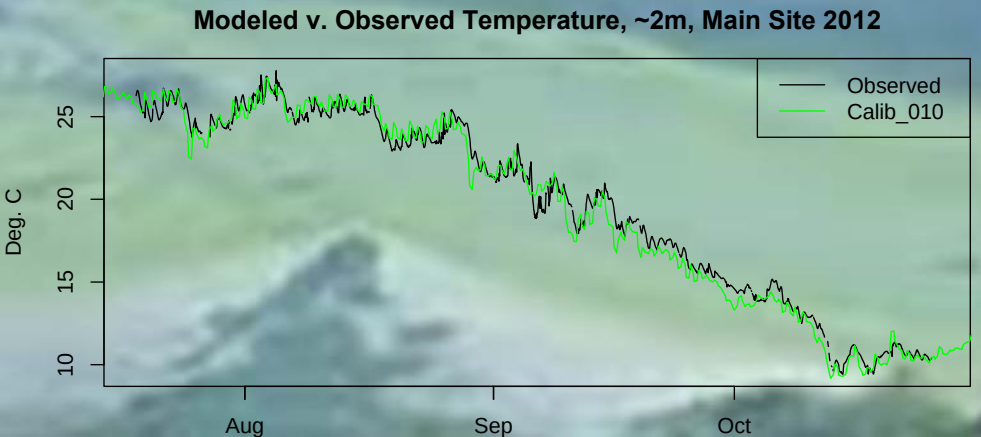
Initial sediment nutrient concentrations, bulk density, sediment diagenesis parameters

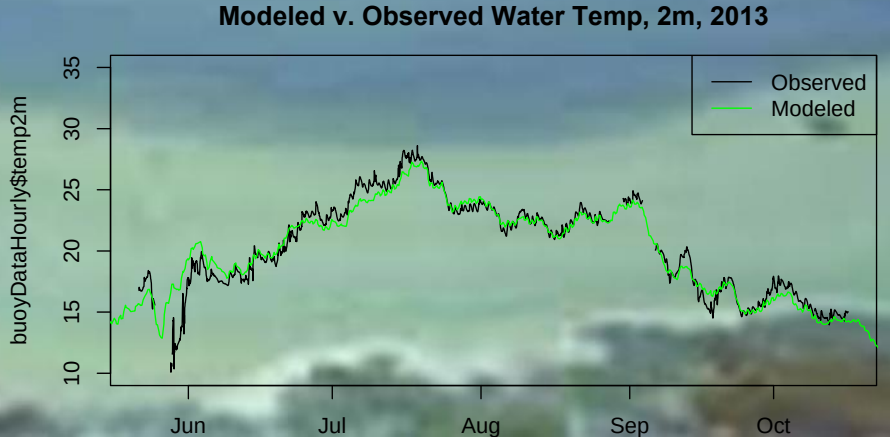
A2EM Progress

- EFDC calibrated for 2012, 2013
- RCA input data and boundary conditions prepared, ready for parameter calibration

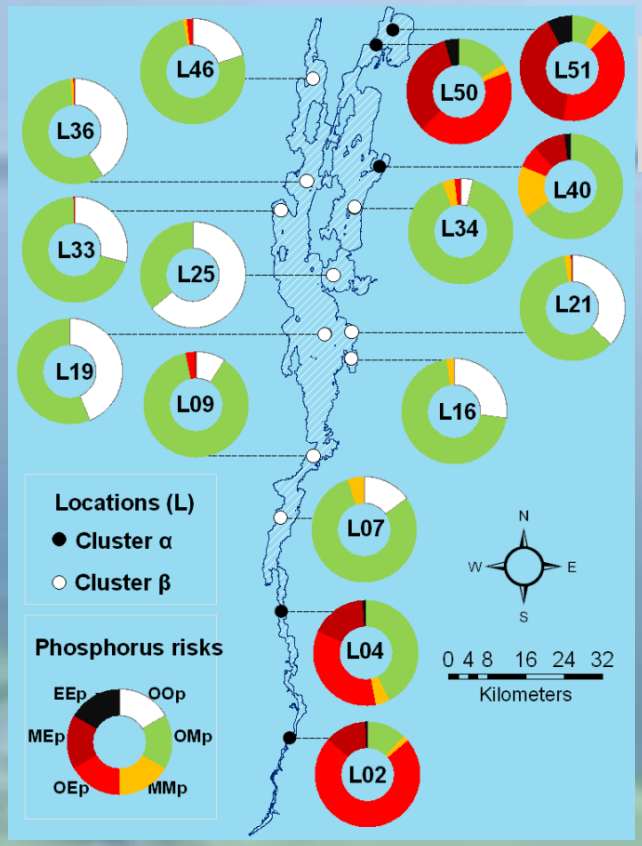








Statistical Modeling of Lake Datasets



Eutrophication assessment (Trophic State Index , TSI): Original framework (Carlson, 1977):

21st century framework: Integrating statistical advance (i.e. Upper bound method) and increasingly availability of lake-specific datasets (e. g. Lake Champlain)

States of Lake Champlain:

Cluster α: Eutrophic with high risks of phosphorus;

Cluster β: oligotrophic and mesotrophic without risks of phosphorus

Carlson R. E. 1977. *Limnology and Oceanography.* 22: 361-369

Xu Y., Schroth A., Rizzo D. 2014. *Limnology and Oceanography: Methods* (Submitted)

Big Data – Q1

AQUATIC Informatics