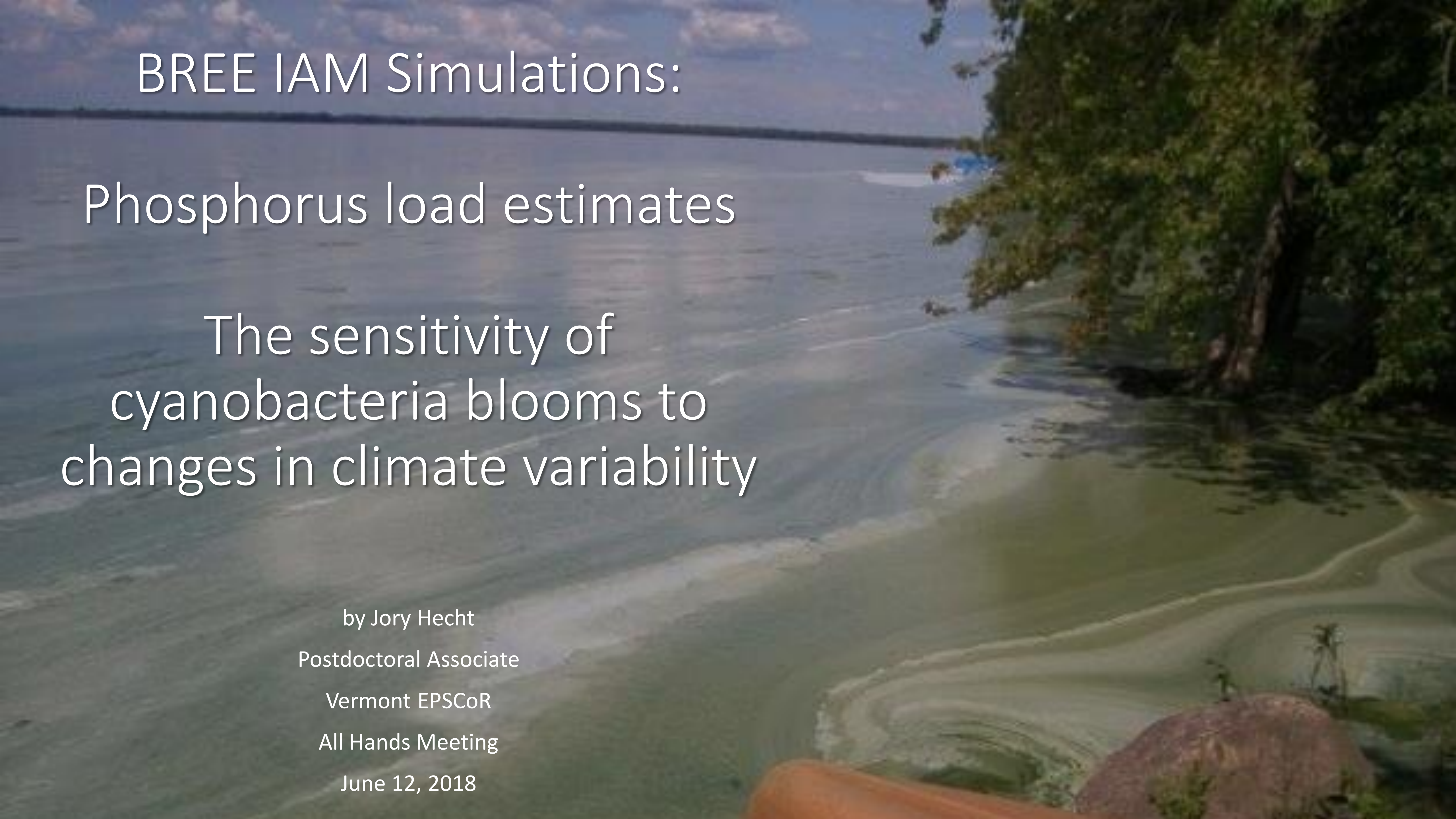


BREE IAM Simulations:

Phosphorus load estimates

The sensitivity of cyanobacteria blooms to changes in climate variability

by Jory Hecht

Postdoctoral Associate

Vermont EPSCoR

All Hands Meeting

June 12, 2018

Overview of IAM research progress

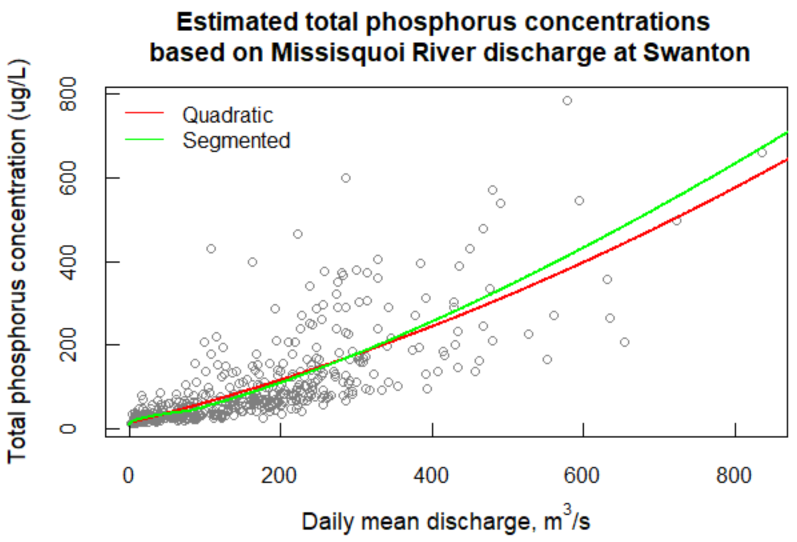
- Paper 1: Comparing discharge-based estimates of phosphorus concentrations and loads entering Missisquoi Bay

- Paper 2: Sensitivity of cyanobacteria blooms to changes in climate variability

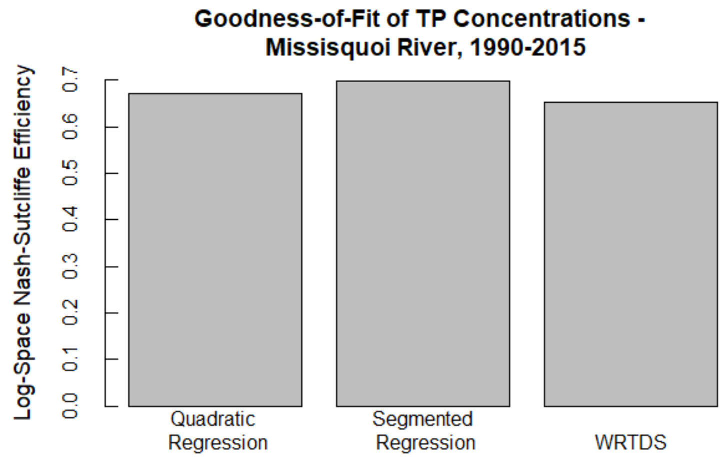
- Paper 3: Weather whiplash and water quality: How might changes in the sequences of extreme events affect cyanobacteria blooms?

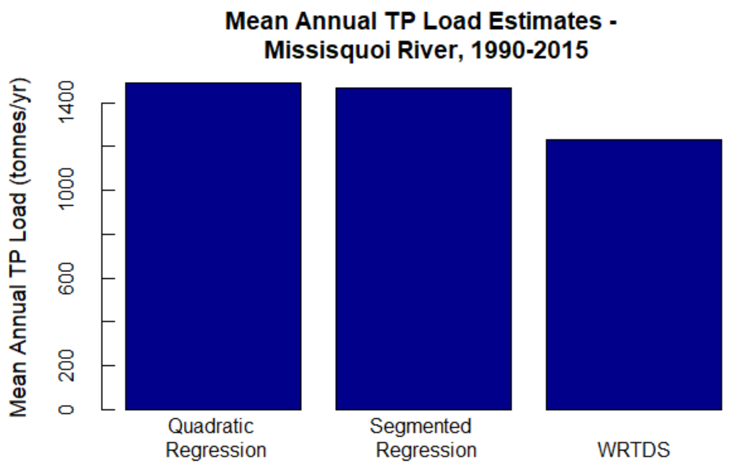
Estimating river phosphorus loads: preliminary results

- Estimating daily average TP, PP, DP concentrations based on daily mean discharge
- Starting in Missisquoi basin, expanding to Pike and Rock
- Comparing three methods:
  - Quadratic regression
  - Segmented regression
  - Weighted Regression on Time, Discharge, Season
- Will method choice affect lake water quality model results?
- How do land-use change and BMPs affect this relationship?



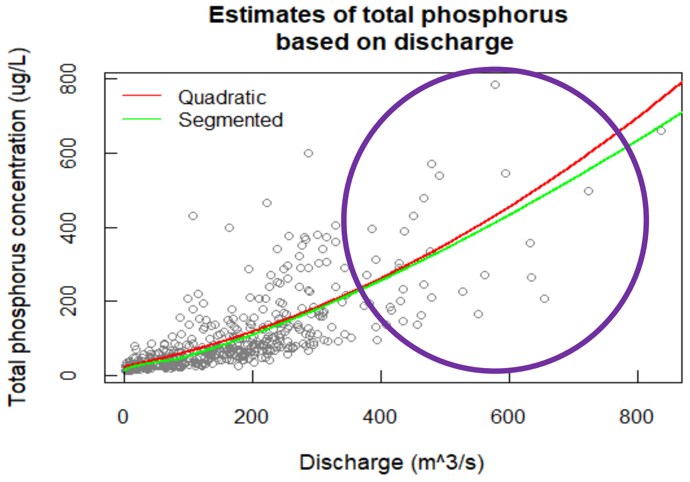
Load = Concentration * Discharge



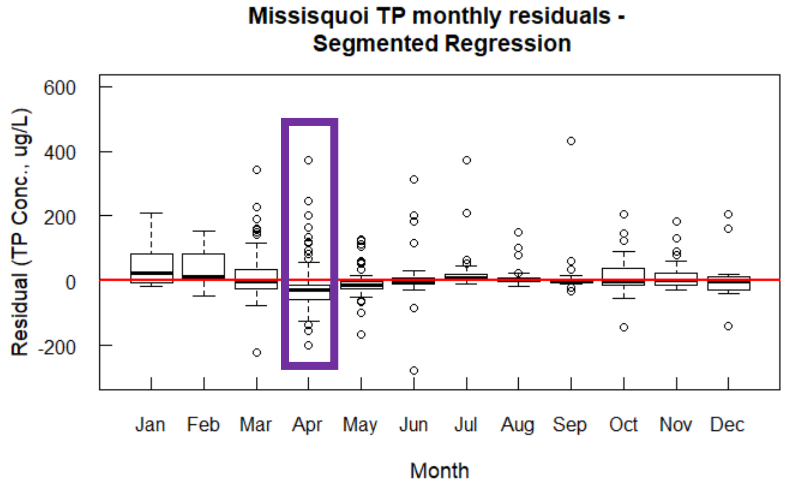


Reproducing daily phosphorus load variability

- Regression-based P concentration estimates tend to regress to the mean
- Underestimates highest P concentrations entering the lake!
- Simulated variance needs to match observed variance
- How much might this matter?
  - More if blooms driven by sub-annual variability
  - Less if blooms driven by inter-annual variability



How should we model these residuals?

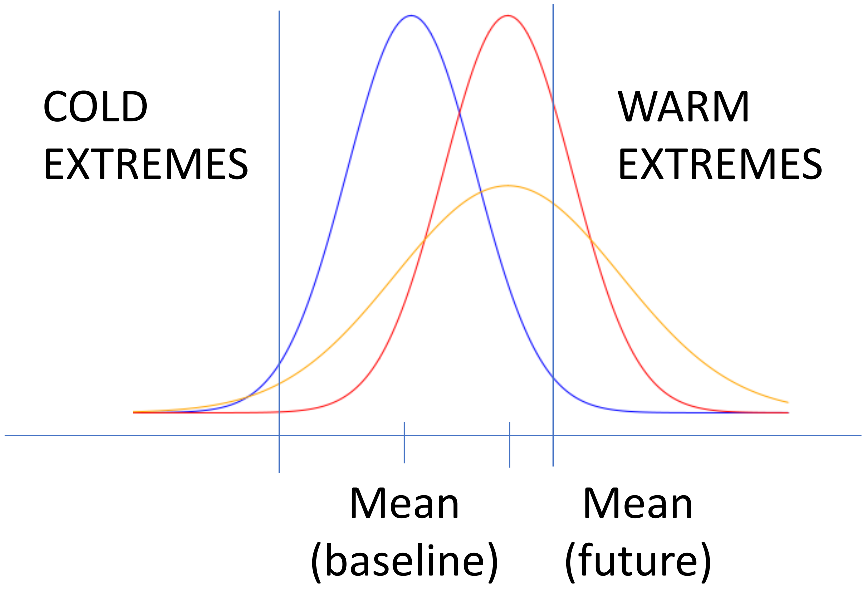


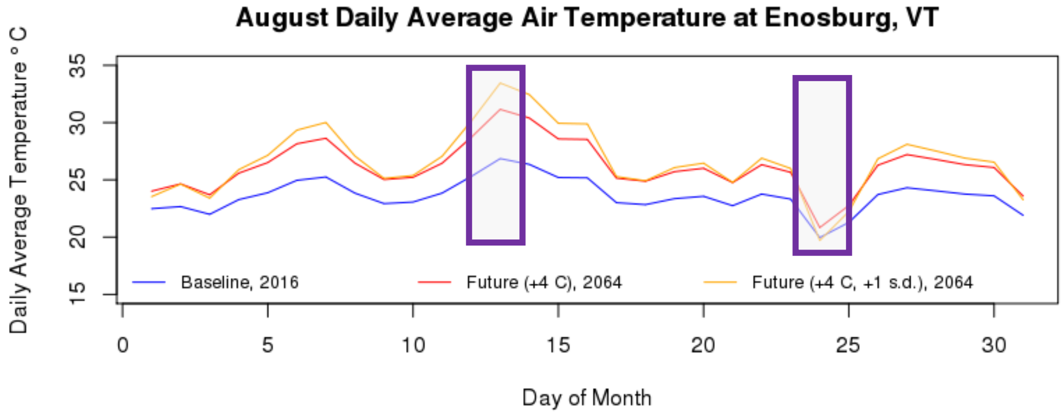
Observations greater than model

Observations less than model

How will changes in climate variability affect blooms?

- Changes in variability strongly influence extreme precipitation and temperature events
- Few lake water quality studies have examined impacts of future changes in daily variability
- How might these changes alter water quality?
    - Baseline period: 1987-2016
    - Future period: 2035-2064
- For each month, compare distributions:
    - Wet-day precipitation
    - Daily average air temperature
- Adjust time series based on distribution changes in statistically downscaled climate scenarios





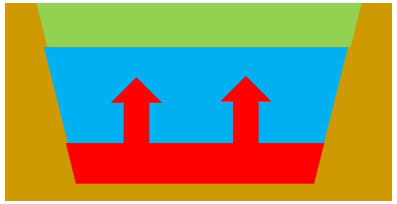
Why are impacts of changing climate variability on blooms unclear?

INCREASE IN PRECIPITATION VARIABILITY

More severe floods

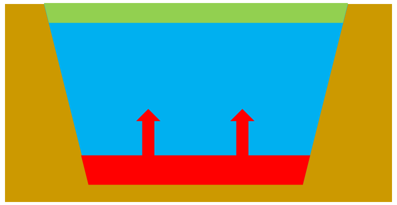
More external loading

More severe droughts



More internal loading

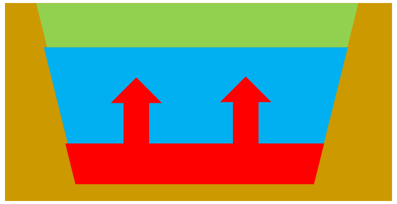
More summer storms may cool and mix lake



Less internal loading

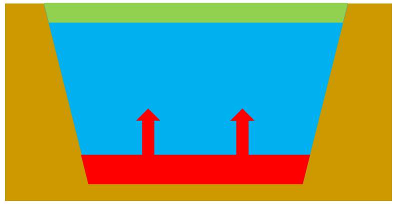
INCREASE IN TEMPERATURE VARIABILITY

More warm spells, when cyanobacteria proliferate



More internal loading

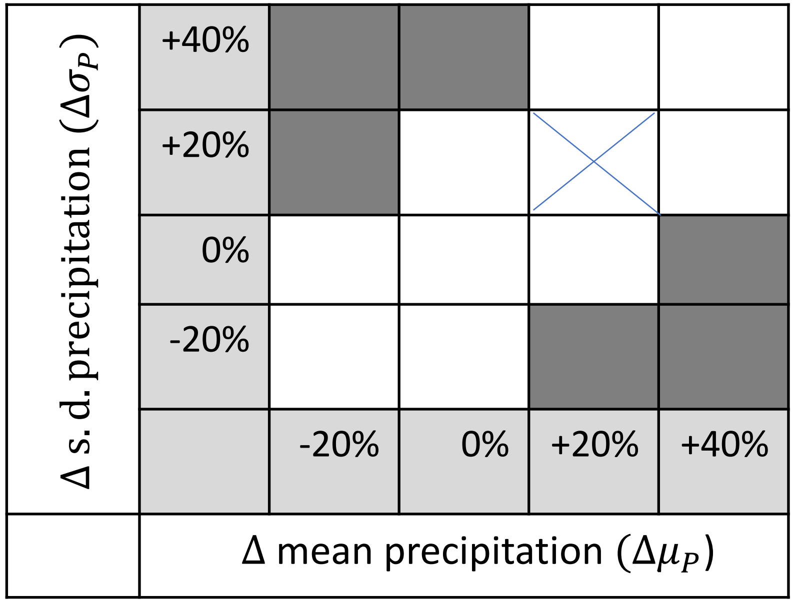
More summer cold spells



Less internal loading

What changes in climate are we examining?

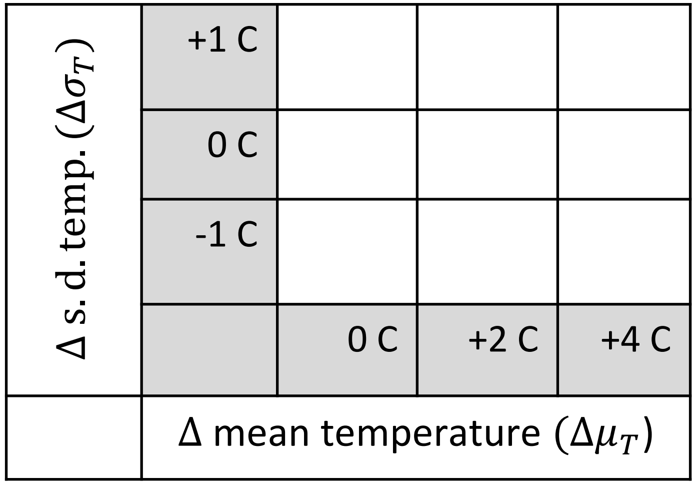
WET-DAY PRECIPITATION



10 SCENARIOS

x

DAILY AVG. TEMPERATURE



9 SCENARIOS

x

WIND SPEED AND DIRECTION

S1: Weather Estimator changes winds based on changes in precipitation and temperature

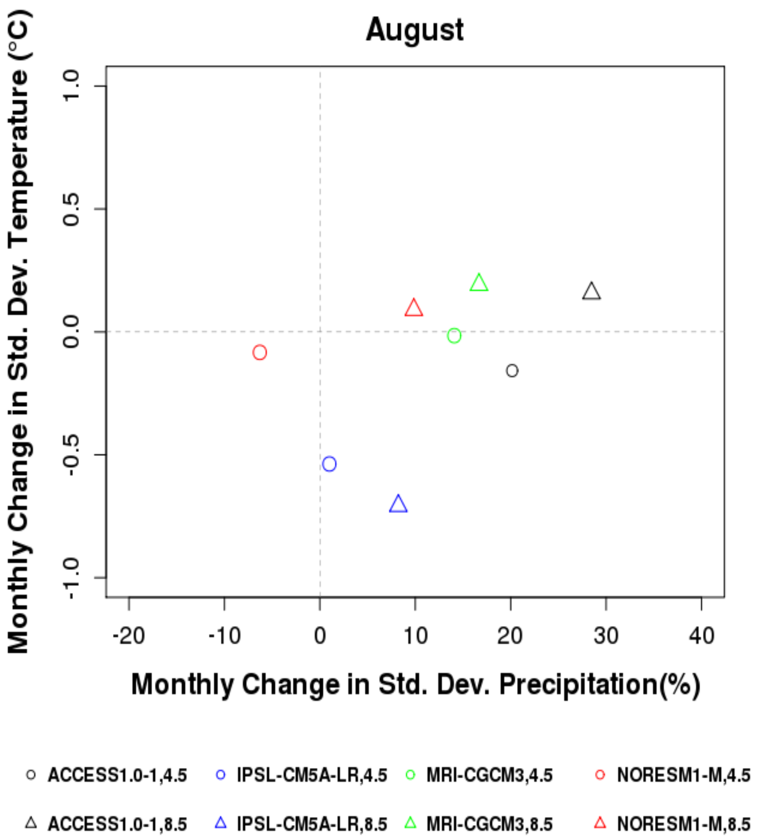
S2: Winds from baseline period left unchanged

2 SCENARIOS

180 IAM RUNS

Examining water quality responses to changes in climate variability

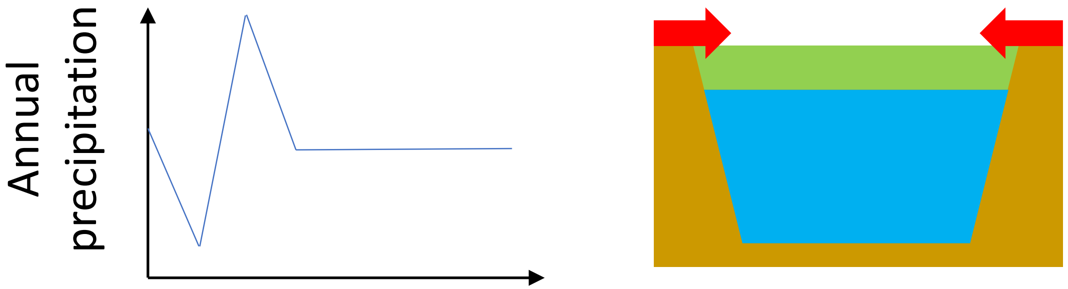
- Will examine changes in both central tendency and variability
- Climate scenarios inform range of mean and variance perturbations selected
- Determining stakeholder-relevant changes in:
  - Total phosphorus concentrations
  - Chlorophyll *a* concentrations
- Can determine worst-case cyanobacteria concentrations from chlorophyll *a* measurements
- Many intervening variables mediate impacts of precipitation and temperature on blooms



How might changes in *sequences* of extremes affect blooms?

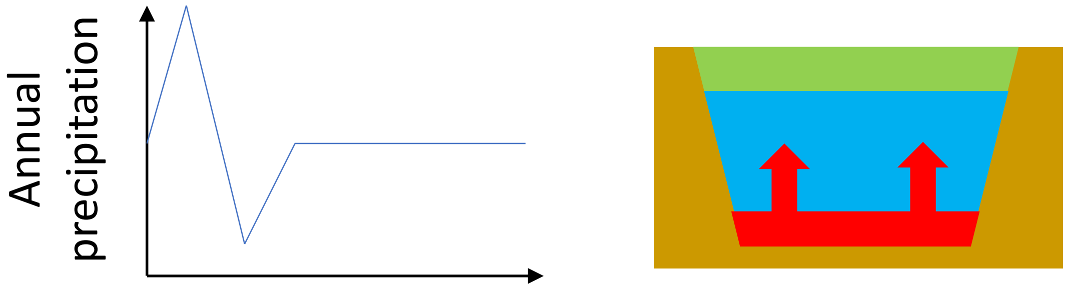
- Weather whiplash:
  - Dry year followed by wet year
  - Wet year followed by dry year
- Has been linked to blooms, but not studied extensively
- Drought after deluge common in Lake Champlain basin
- What if weather whiplash worsens in the future?

DROUGHT BEFORE DELUGE



External loading

DROUGHT AFTER DELUGE



Internal loading

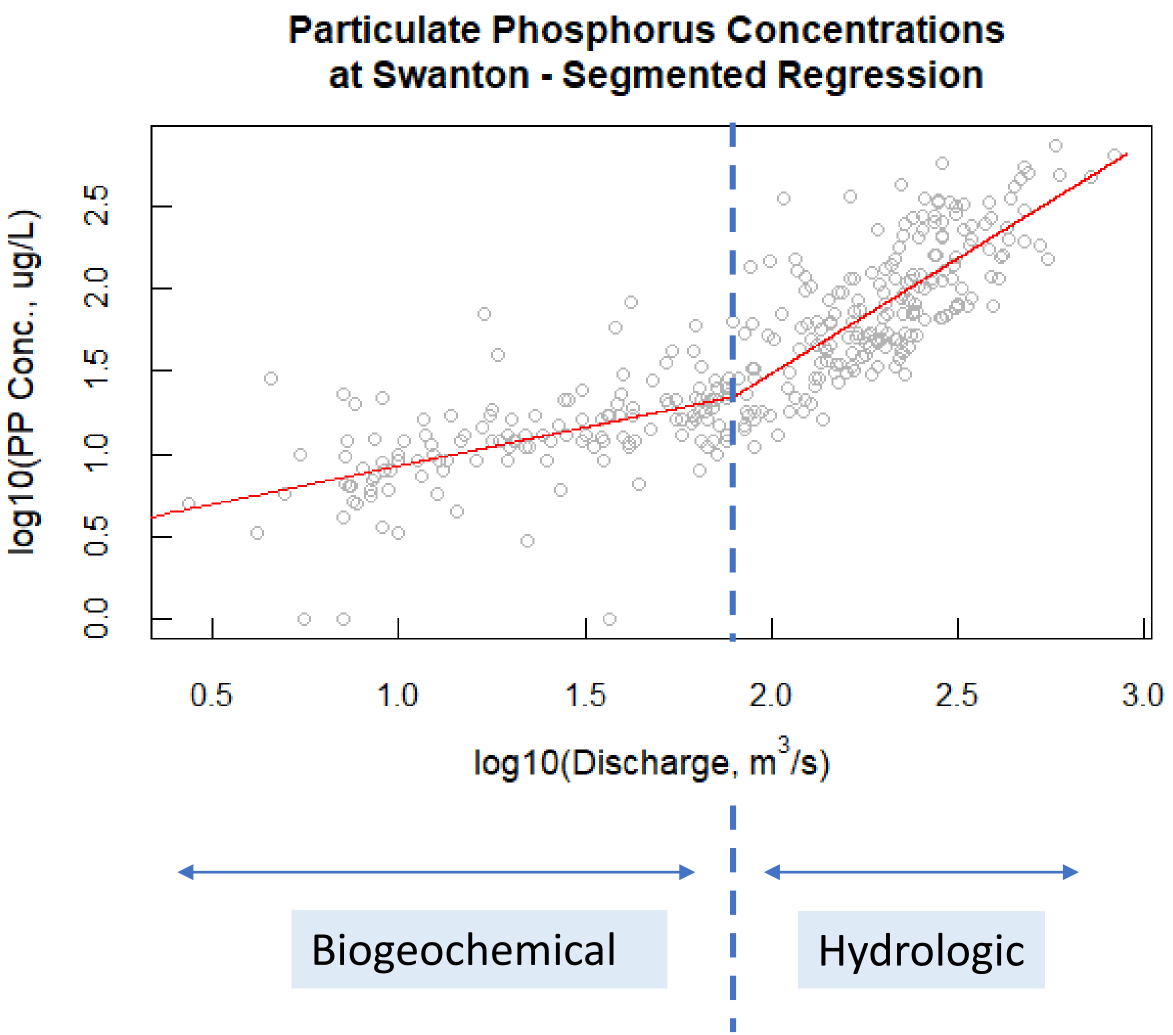
Thank you!

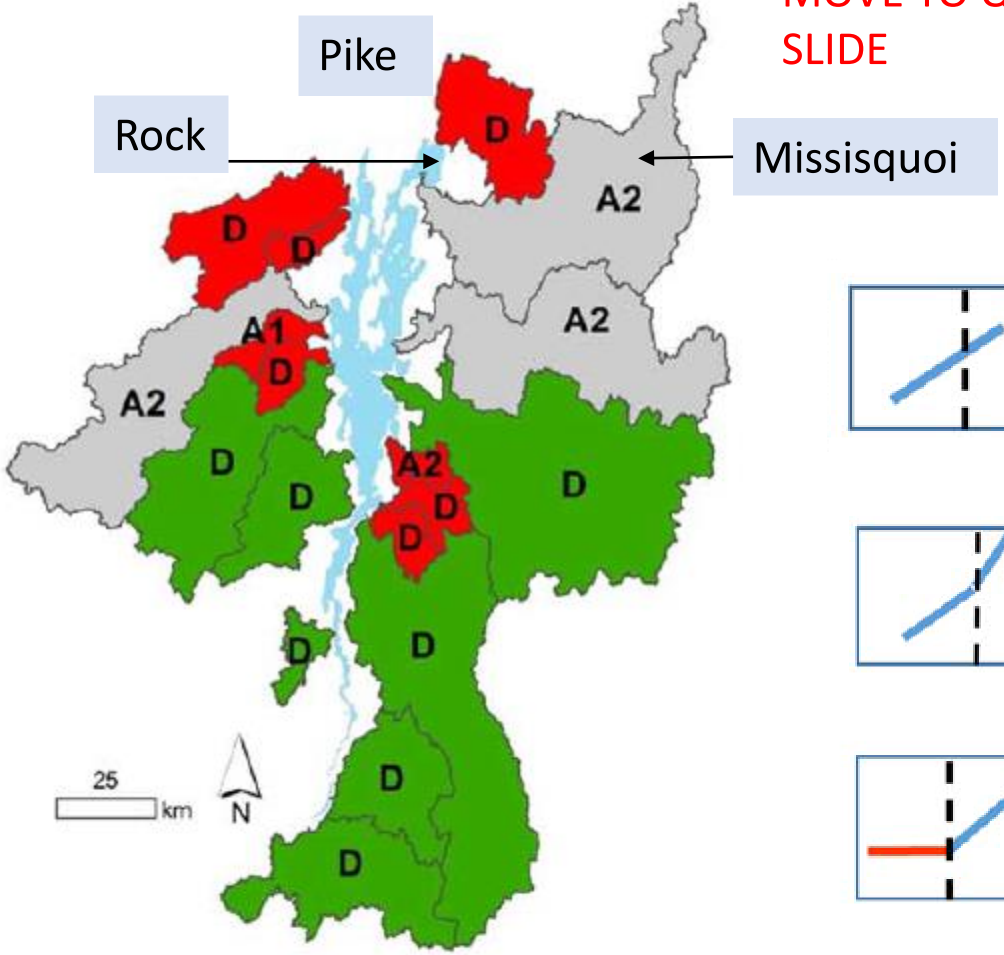
Questions?

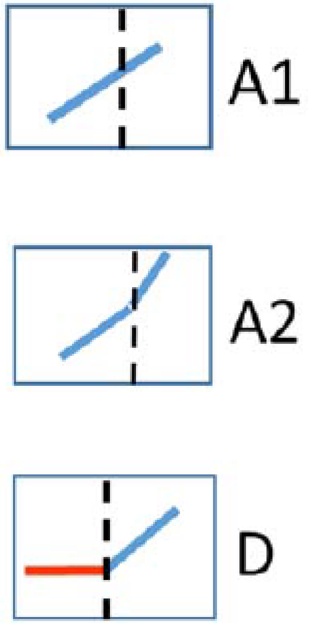
Email: Jory.Hecht@uvm.edu

Biogeochemical vs. hydrologic drivers of phosphorus loads

MOVE TO QUESTION SLIDE



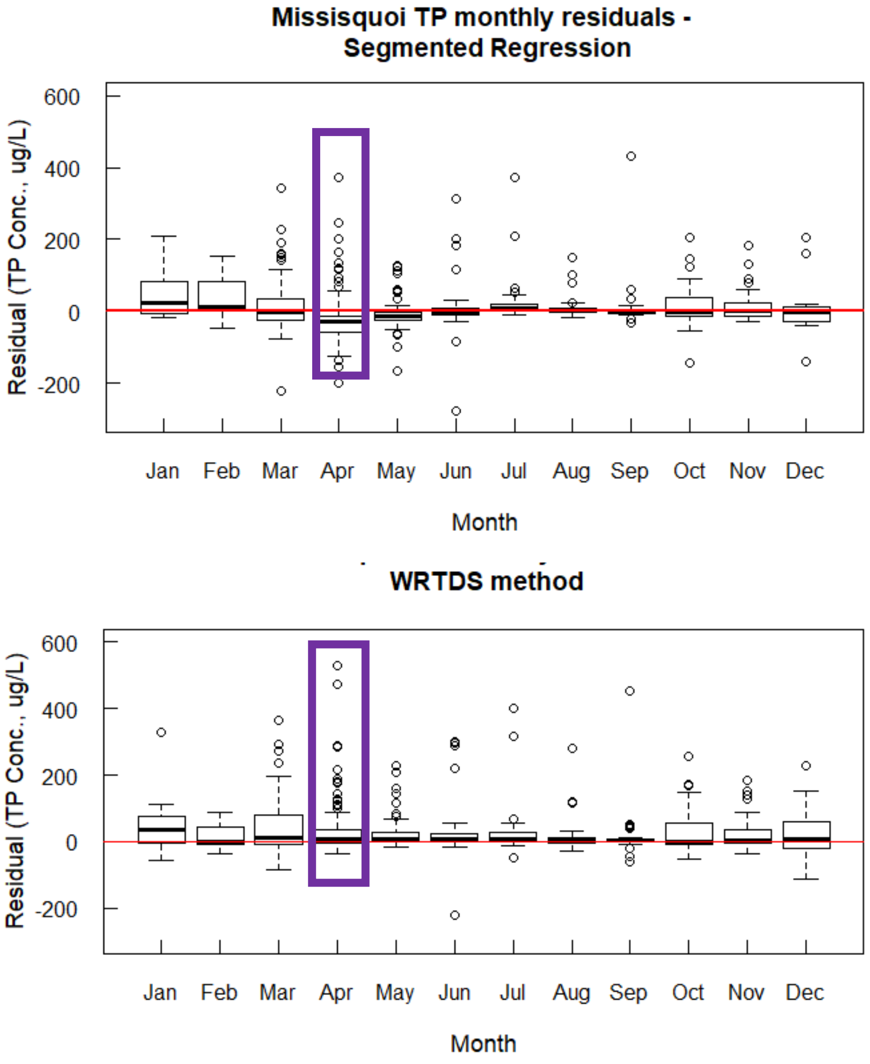




Underwood et al. (2017)

Seasonal comparison: Preliminary results

- Seasonal timing of P loads important for modeling blooms
- Loads overestimated in April
- How much can WRTDS reduce monthly biases? At what expense?
- Some high P concentrations underestimated in bloom season



Observations higher than model

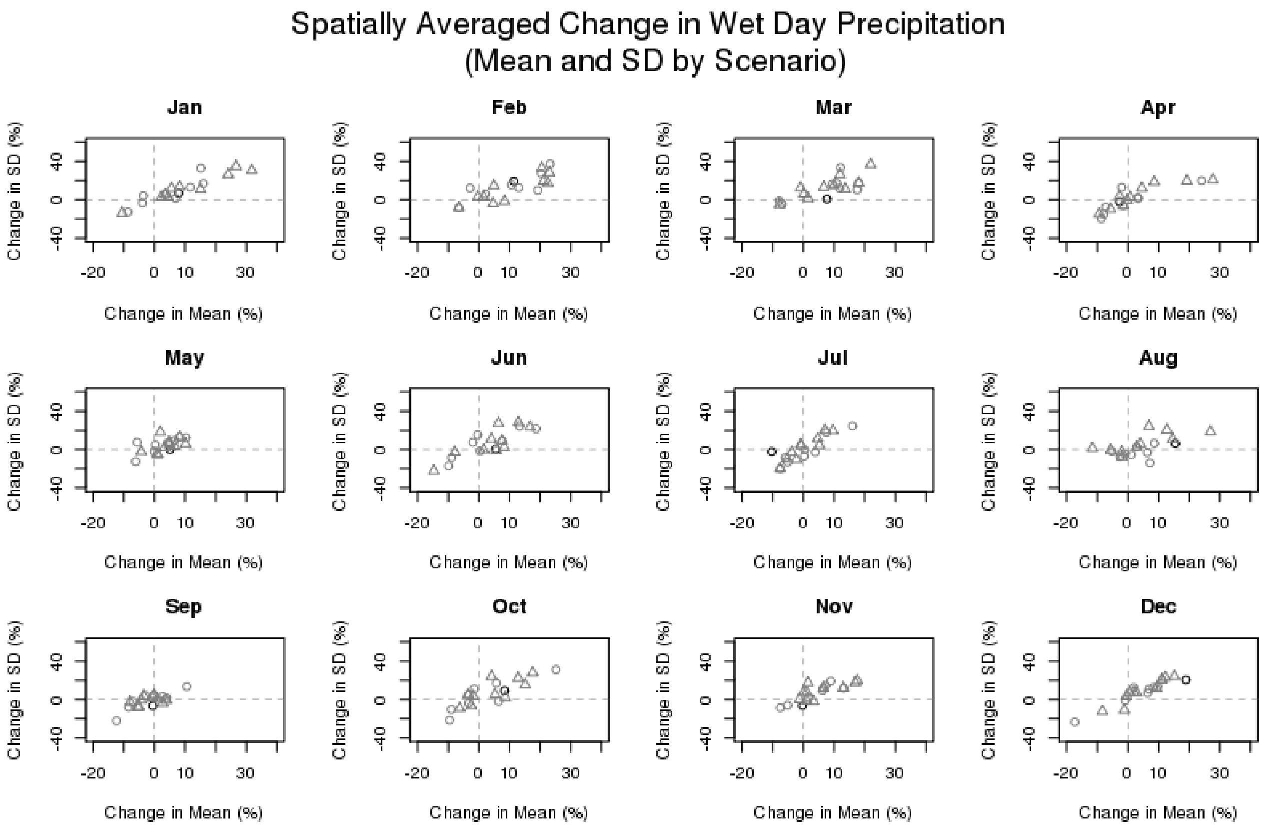
Observations lower than model

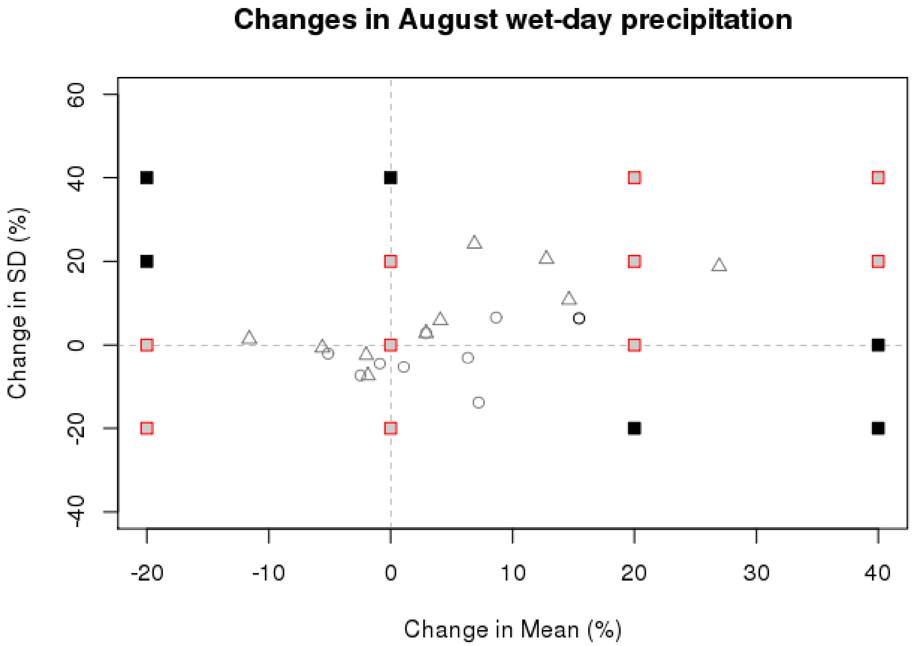
Nash-Sutcliffe Efficiency

$$E = 1 - \frac{\sum_{t=1}^{T}(C_{t,m} - C_{t,o})^2}{\sum_{t=1}^{T}(C_{t,o} - \overline{C_{t,o}})^2}$$

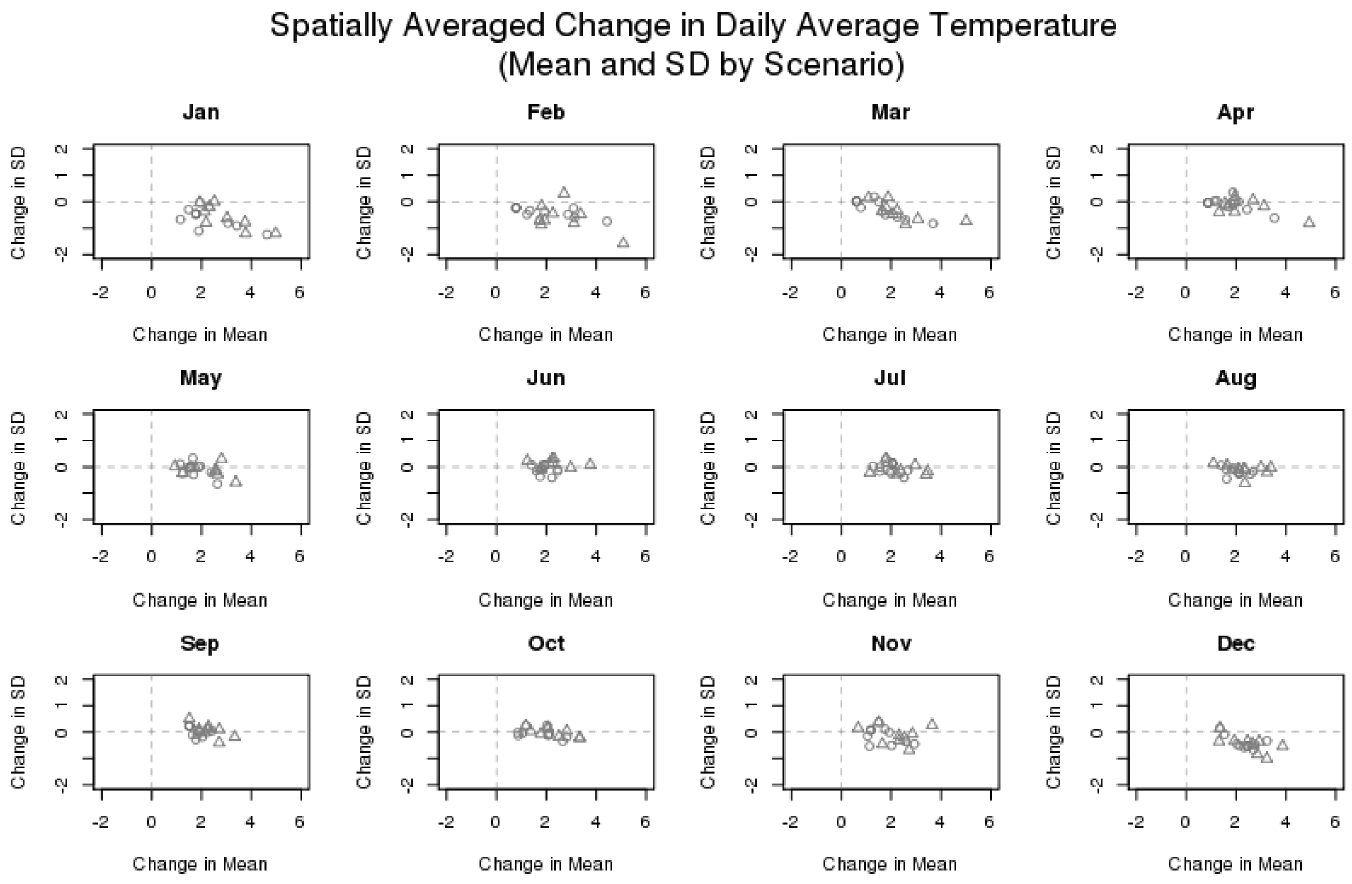
- $E = 1$ → best possible value
- $E > 0.5$ → often considered satisfactory for daily values
- $E = 0$ → as good as using the mean
- $E < 0$ → worse than using the mean

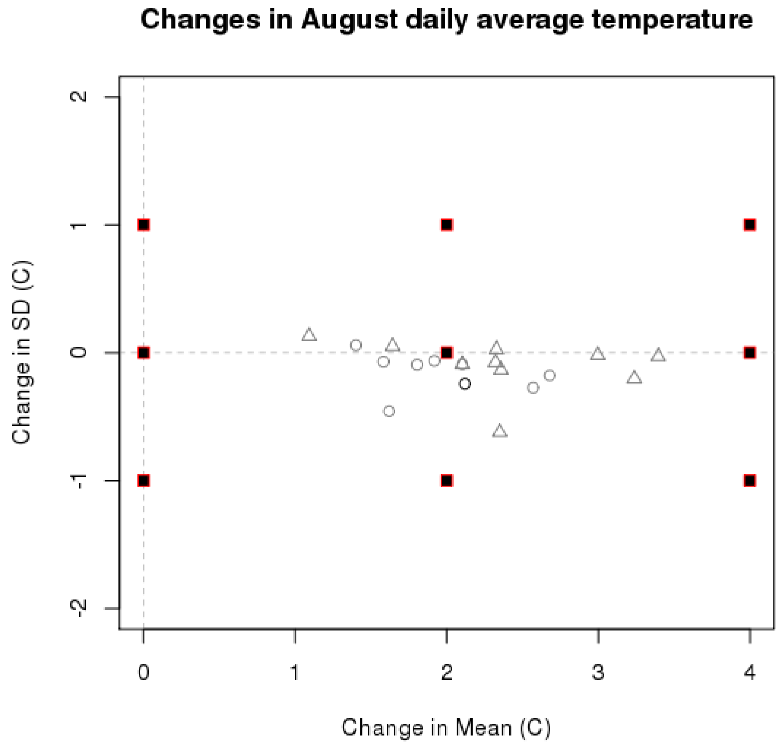
Changes in wet-day precipitation





Changes in daily average temperature





How might changing climate variability affect blooms?

Climate Change Scenarios
(Daily Precipitation and Temperature)

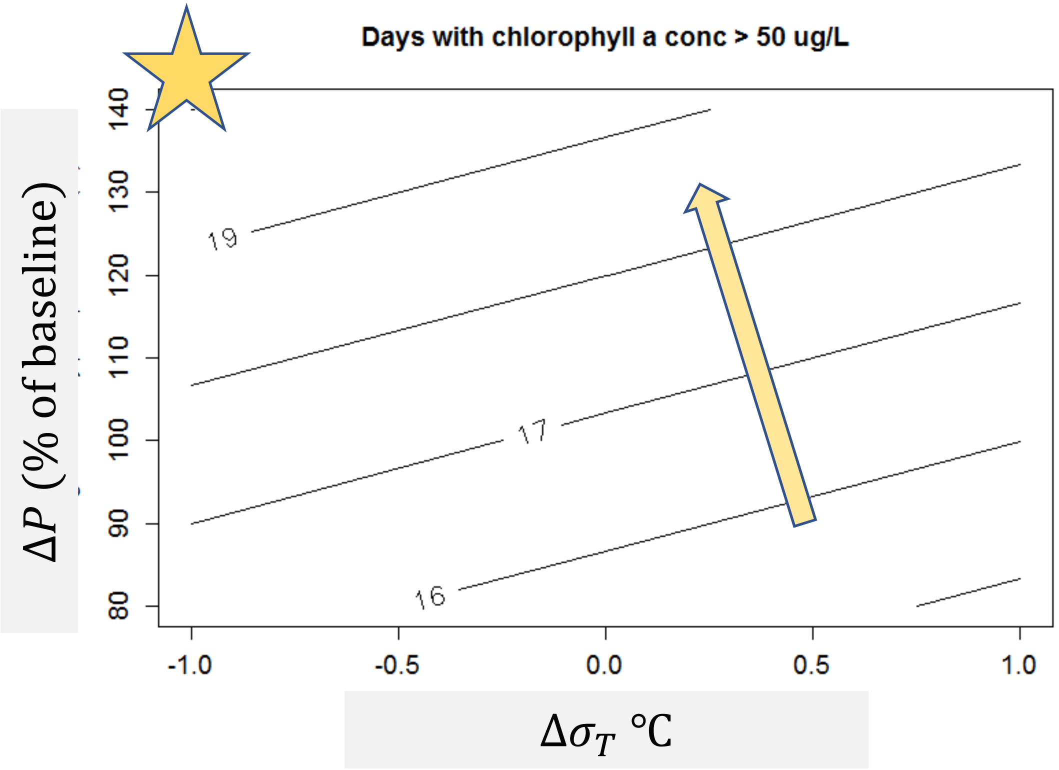
Weather Estimator
(Wind and other weather variables)

Regional Hydro-Ecologic
Simulation System (RHESSys)

Advanced Aquatic Ecosystem Model
(Total phosphorus, chlorophyll *a*)

Zia et) al. (2016

HYPOTHETICAL RESULTS



Choosing water quality indicators for IAM results: Feedback needed!

- IAM models total phosphorus (TP) and chlorophyll *a*

- Which indicators are most important for policy? For example:
  - Days above TMDL threshold?
  - Peak chlorophyll *a* concentrations?
  - Days above recreational and drinking water thresholds?

- WHO provisional recreational guidelines:
  - Short-term impacts (> 20,000 cells/mL ~ 10 µg/L)
  - Long-term impacts (> 100,000 cells/mL ~ 50 µg/L)

- Drinking water guidelines:
  - In US < 1.6 µg/L for adults, 0.3 µg/L for children
  - In Canada, < 1.5 µg/L for adults

www.lapresse.ca

Zia *et al*. (2016)