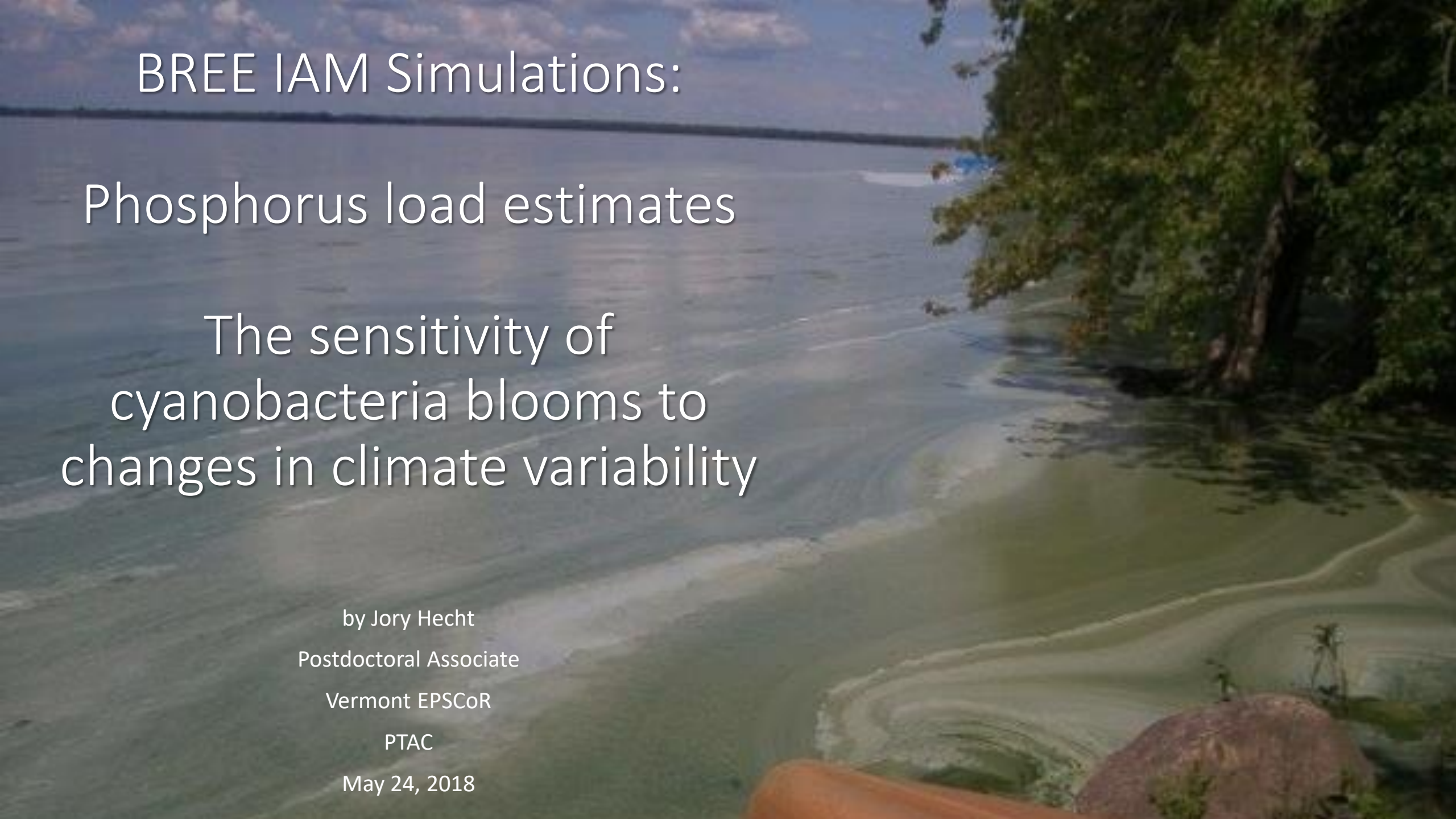


BREE IAM Simulations:

Phosphorus load estimates

The sensitivity of cyanobacteria blooms to changes in climate variability

by Jory Hecht

Postdoctoral Associate

Vermont EPSCoR

PTAC

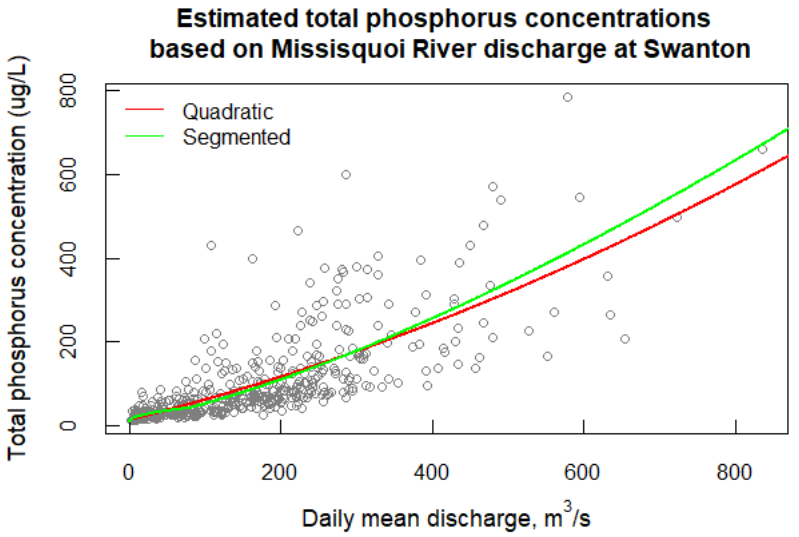
May 24, 2018

Overview of IAM research progress

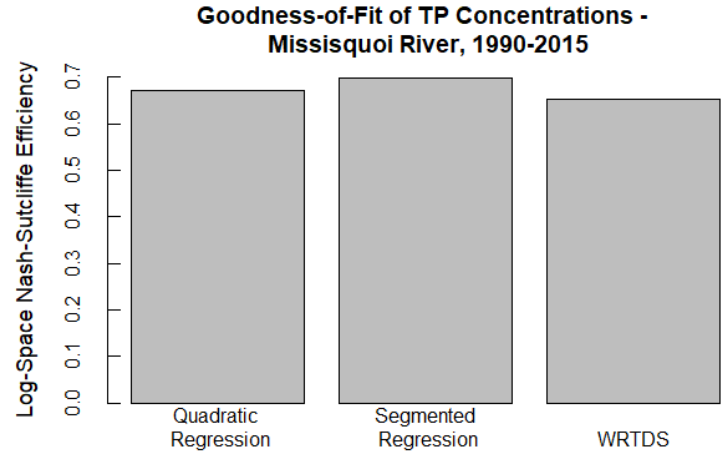
- Paper 1: Comparing discharge-based estimates of phosphorus concentrations and loads entering Missisquoi Bay
- Paper 2: Sensitivity of cyanobacteria blooms to changes in climate variability
- Paper 3: Weather whiplash and water quality: How might changes in extreme event sequences affect cyanobacteria blooms?
- Policy-relevant indicators of lake water quality

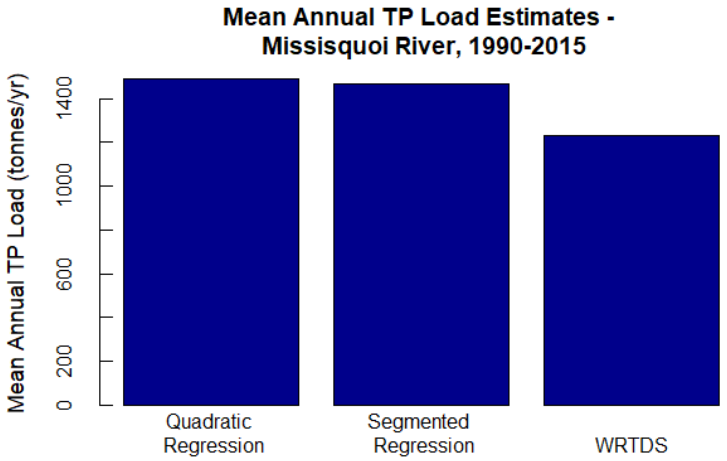
Estimating river phosphorus loads: preliminary results

- Estimating 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?

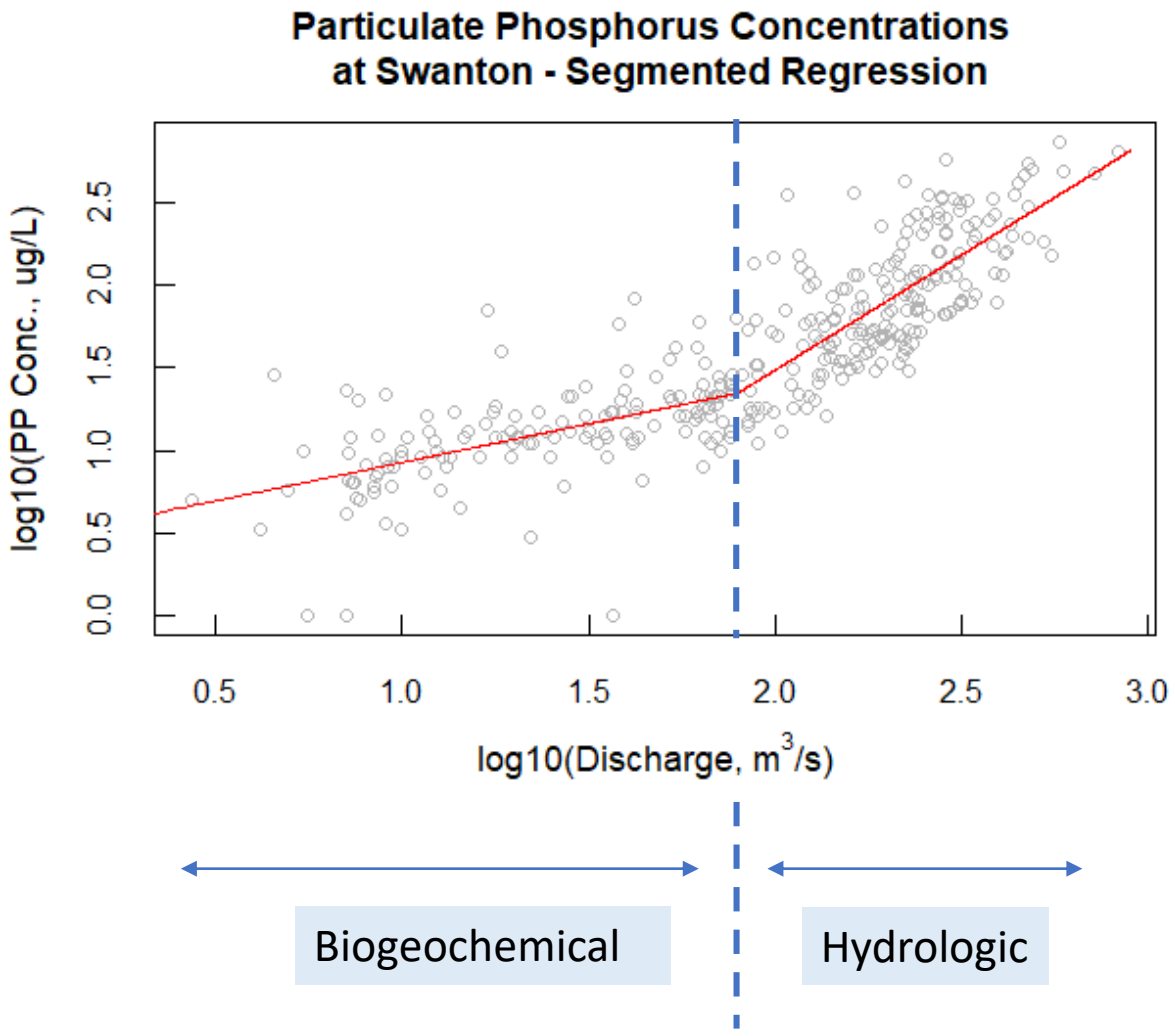


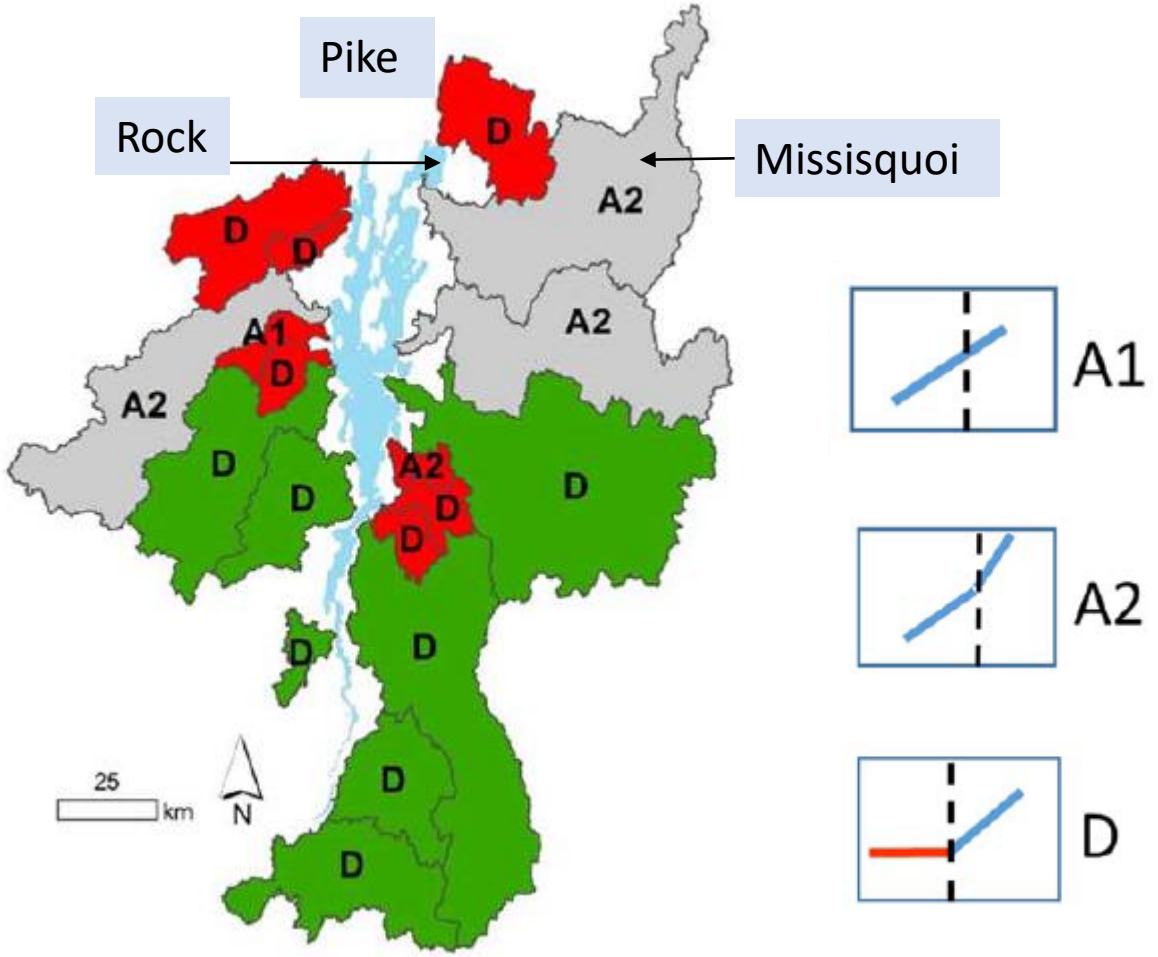
Load = Concentration * Discharge





Biogeochemical vs. hydrologic drivers of phosphorus loads

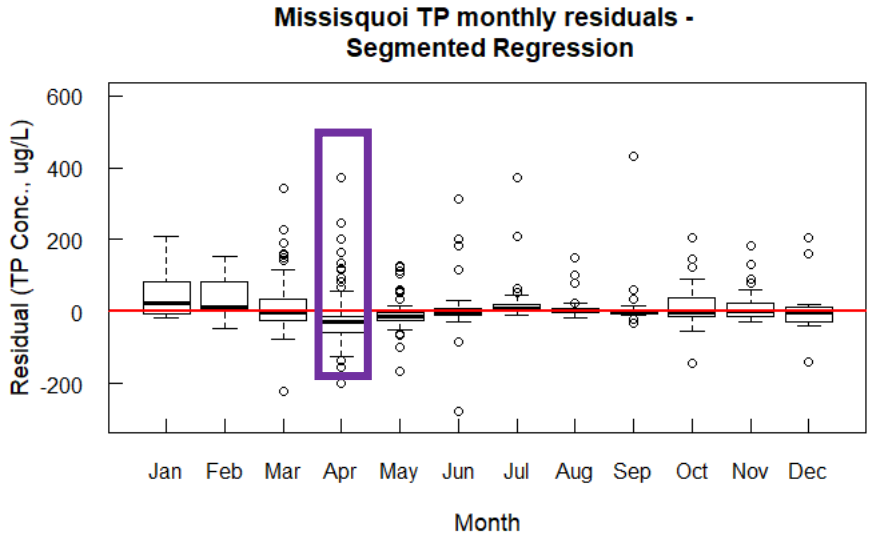


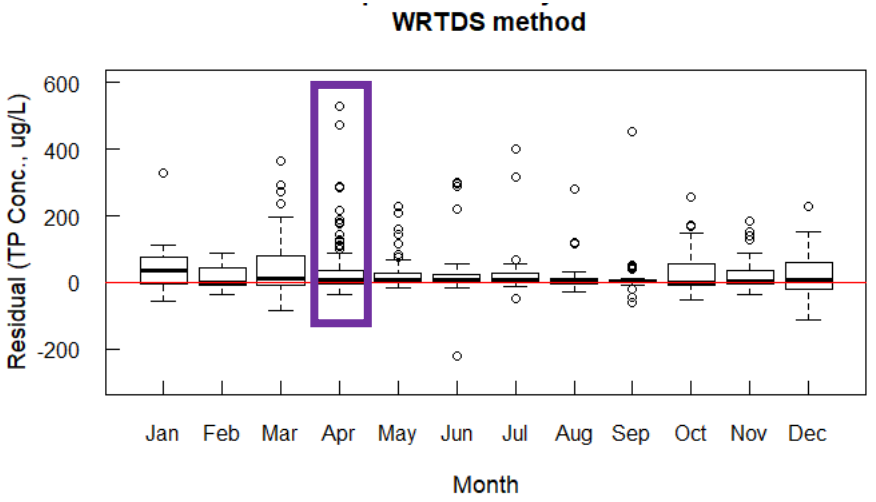


Underwood et al. (2017)

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



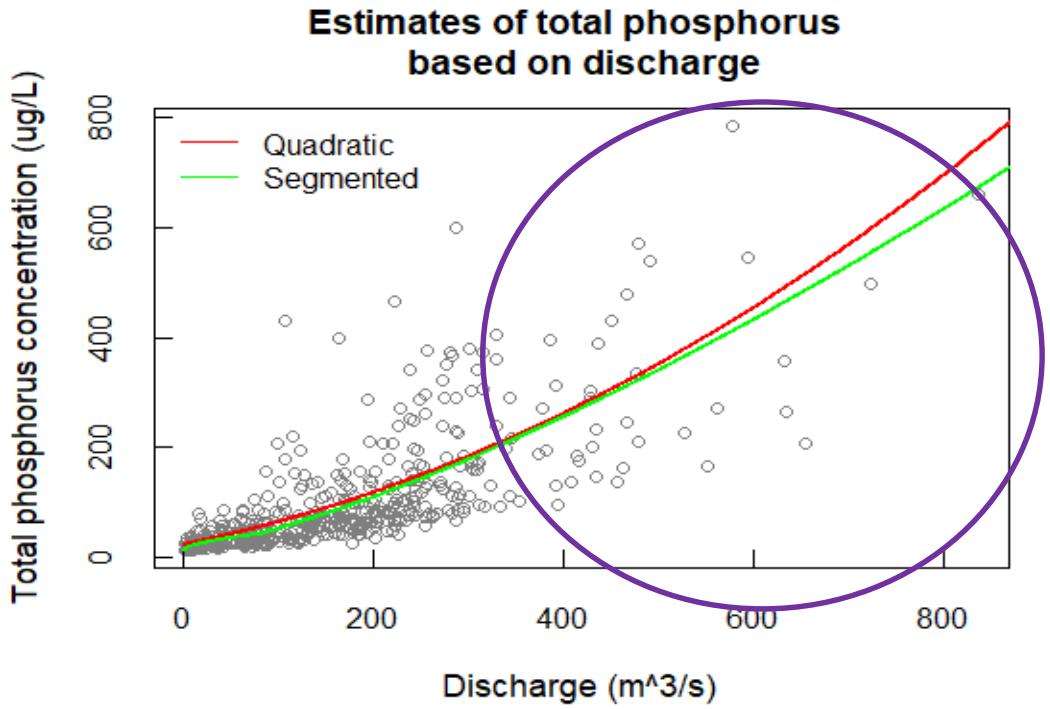


Observations higher than model

Observations lower than model

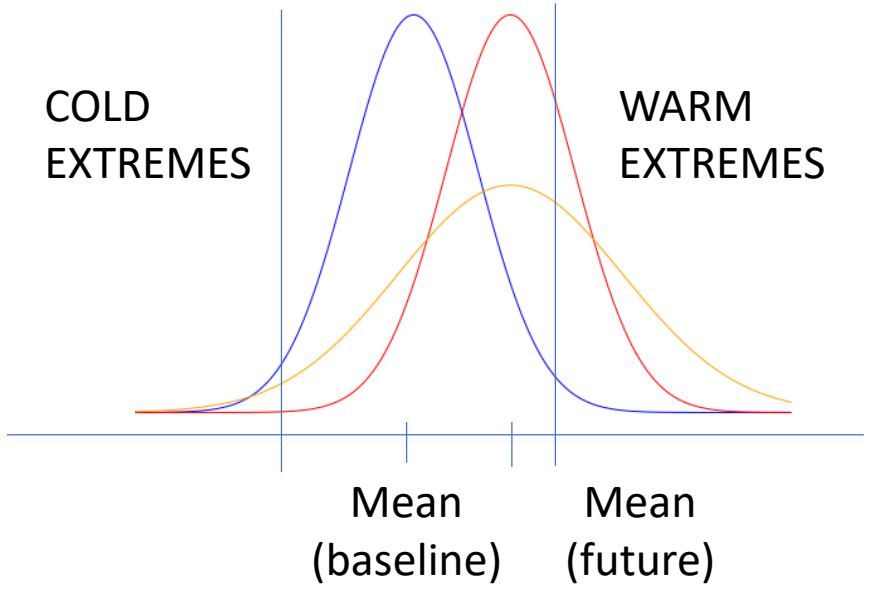
Reproducing daily phosphorus load variability

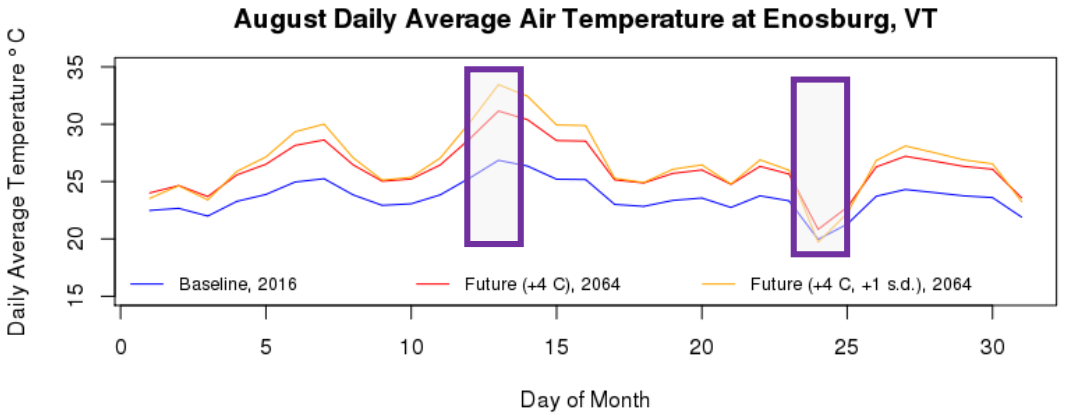
- Regression estimates tend to regress to the mean
- Underestimates highest P concentrations entering the lake!
- How can we get simulated variance to match observed variance?
- How much might this matter?
  - More if blooms driven by sub-annual variability
  - Less if blooms driven by inter-annual variability



How will changes in climate variability affect blooms?

- Changes in variability can strongly influence extreme events
- How might it change blooms (Chl *a*) between?
  - 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 observed in climate scenarios
- Sequences of extremes do not change





Change
#s, dark
orange
Babbag
back up

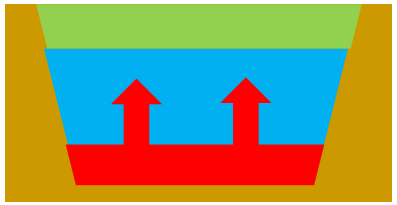
Why are impacts of changing climate variability on blooms unclear?

INCREASE IN PRECIPITATION VARIABILITY

Larger and more frequent floods

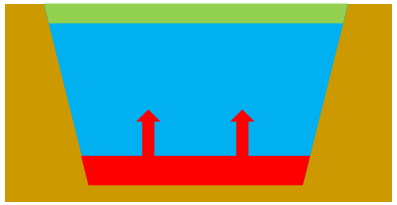
More external loading

Longer and more frequent droughts



More internal loading

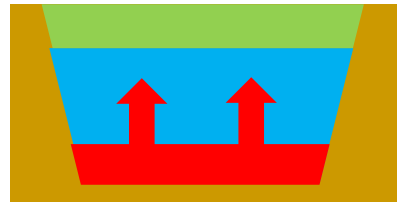
More summer storms cool and mix lake



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

Δ s.d. precipitation ($\Delta\sigma_P$)					
	+40%				
	+20%			X	
	0%				
	-20%				
		-20%	0%	+20%	+40%
	Δ mean precipitation ($\Delta\mu_P$)				

10 SCENARIOS

x

DAILY AVG. TEMPERATURE

Δ s.d. temp. ($\Delta\sigma_T$)				
	+1 C			
	0 C			
	-1 C			
		0 C	+2 C	+4 C
	Δ mean temperature ($\Delta\mu_T$)			

9 SCENARIOS

x

WIND SPEED AND DIRECTION

S1: Weather Estimator changes winds based on changes in P and T

S2: Winds from baseline period left unchanged

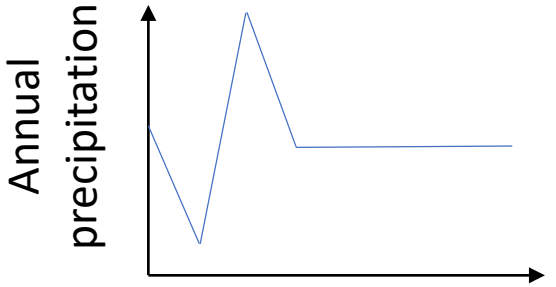
2 SCENARIOS

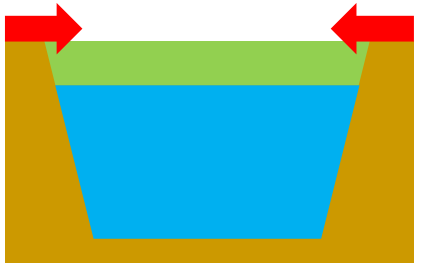
180 IAM RUNS

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

- Weather whiplash:
  - Dry year followed by wet one
  - Wet year followed by dry one
- 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?

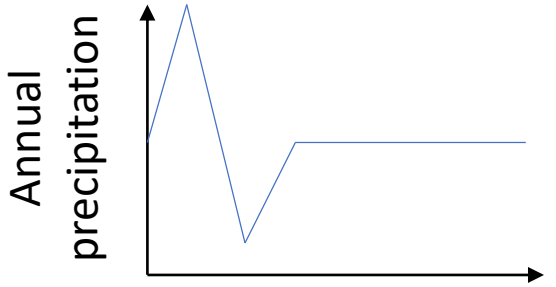
DROUGHT BEFORE DELUGE





External loading

DROUGHT AFTER DELUGE

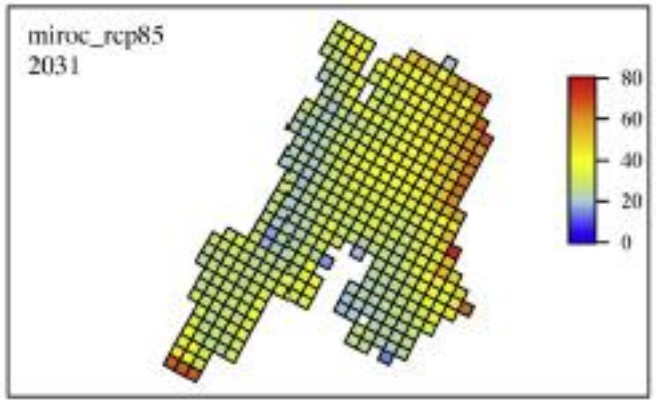


Internal loading

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



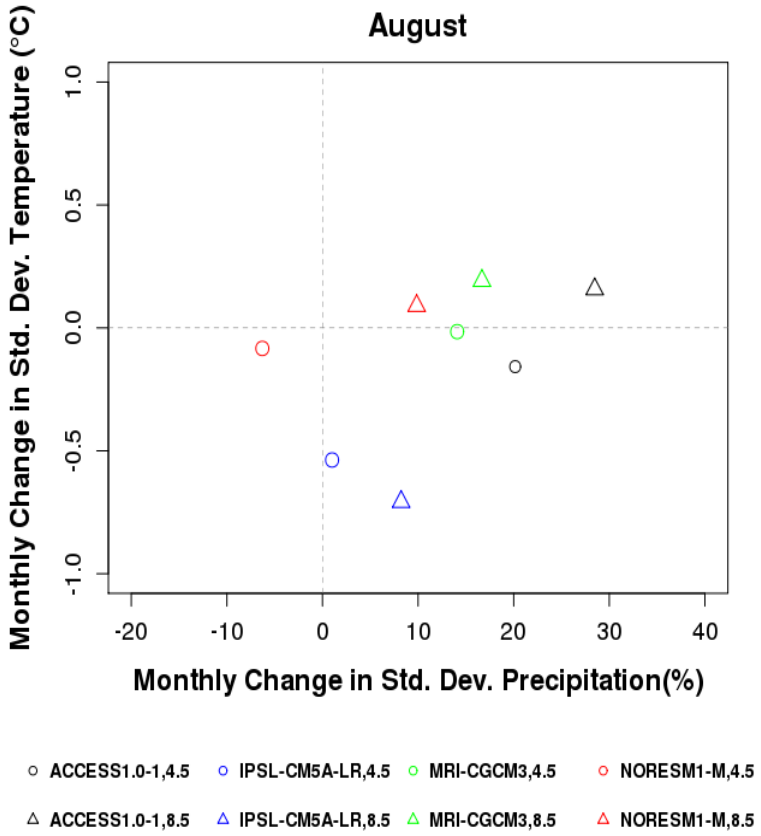
Zia *et al*. (2016)

Thank you!

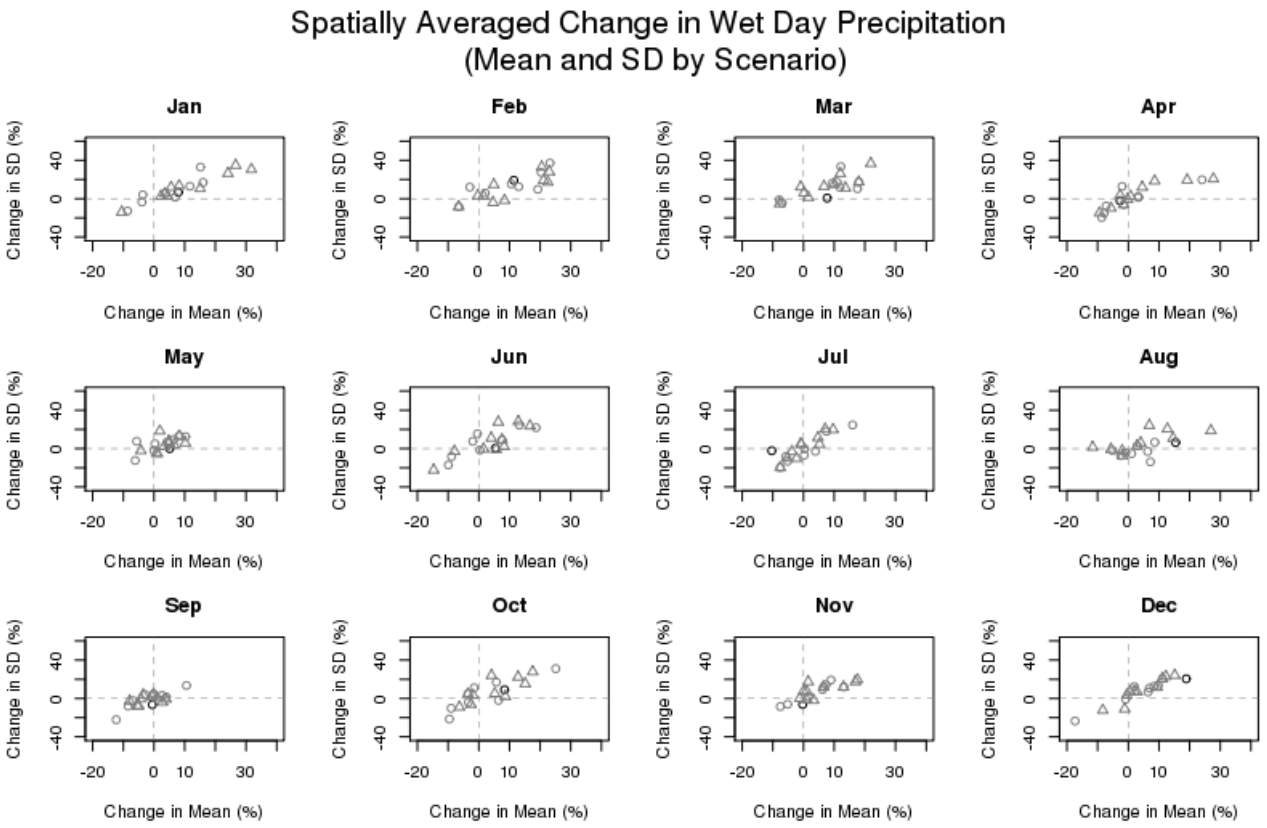
- Questions?

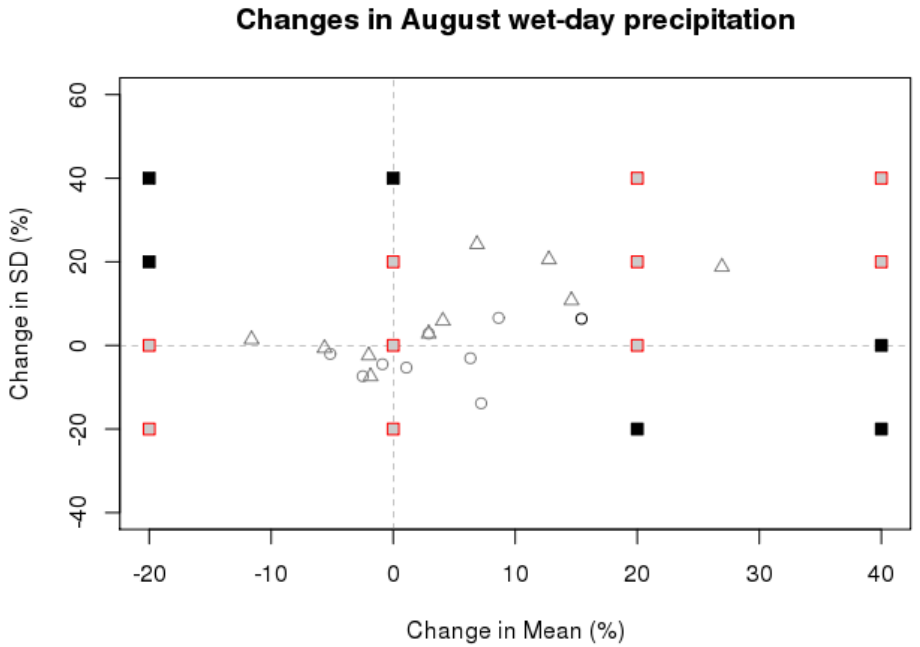
Sampling experiments underway for simulating uncertainty in climatic variability and extremes in BREE IAM

- **Compare daily precipitation and temperature simulated with plausible climate scenarios:**
  - **Baseline (1980-2009)**
  - **Future (2036-2065)**
- **Compute monthly changes in statistical moments and distribution parameters**
- **Examine changes in extreme events**
- **Perturb Daymet gridded data (1980-2009) using scenario-informed monthly changes**

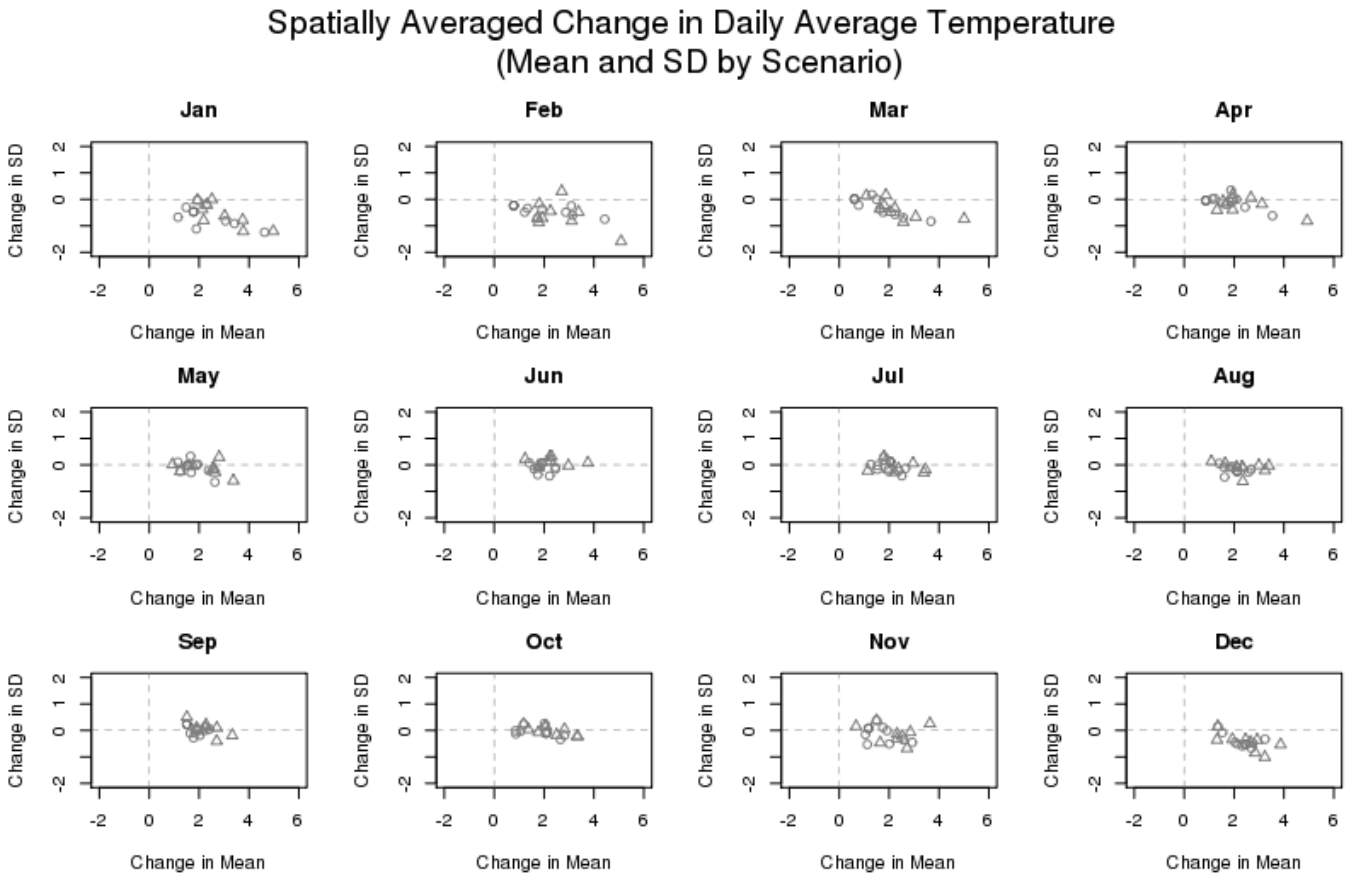


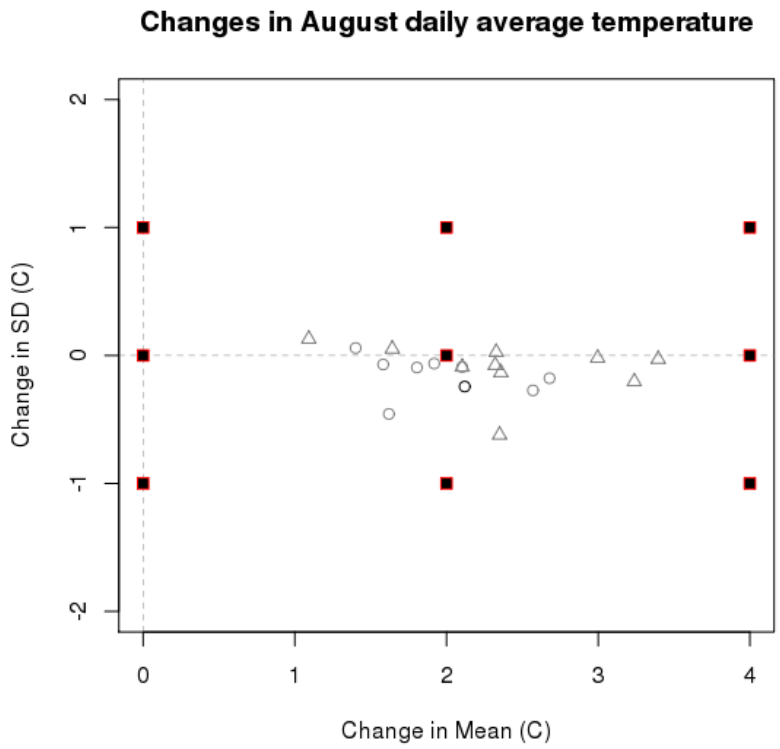
Changes in wet-day precipitation





Changes in daily average temperature





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

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