# Effects of climate and watershed variability on lake cyanobacteria blooms

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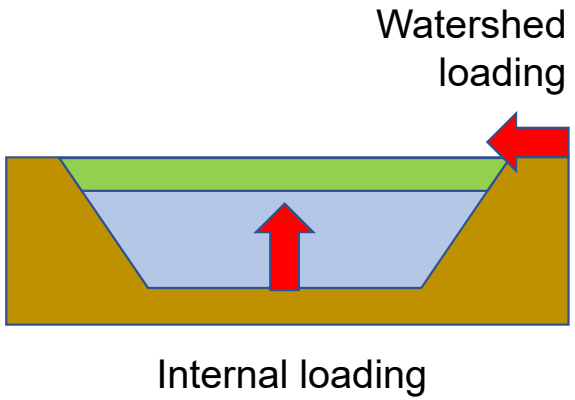
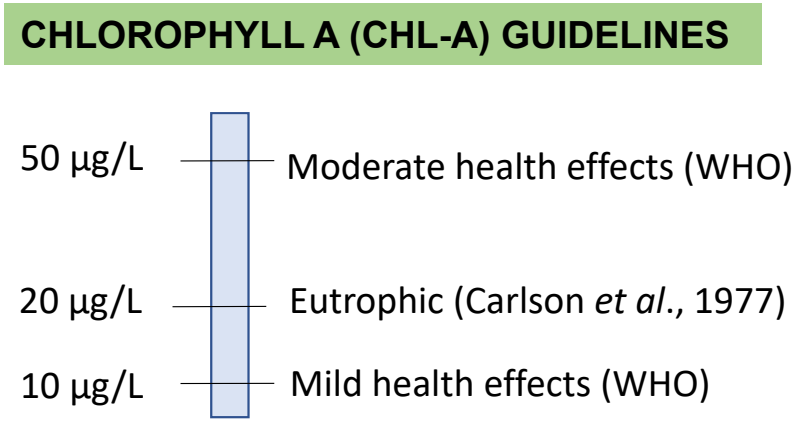
# Highlights

- **Paper 1: Bloom responses to changes in precipitation and temperature variability**
  - Bloom responses to changes in temperature variability depend on mean temperature
  - Blooms more sensitive to precipitation variability under higher mean temperatures
  - Projected changes in precipitation and temperature



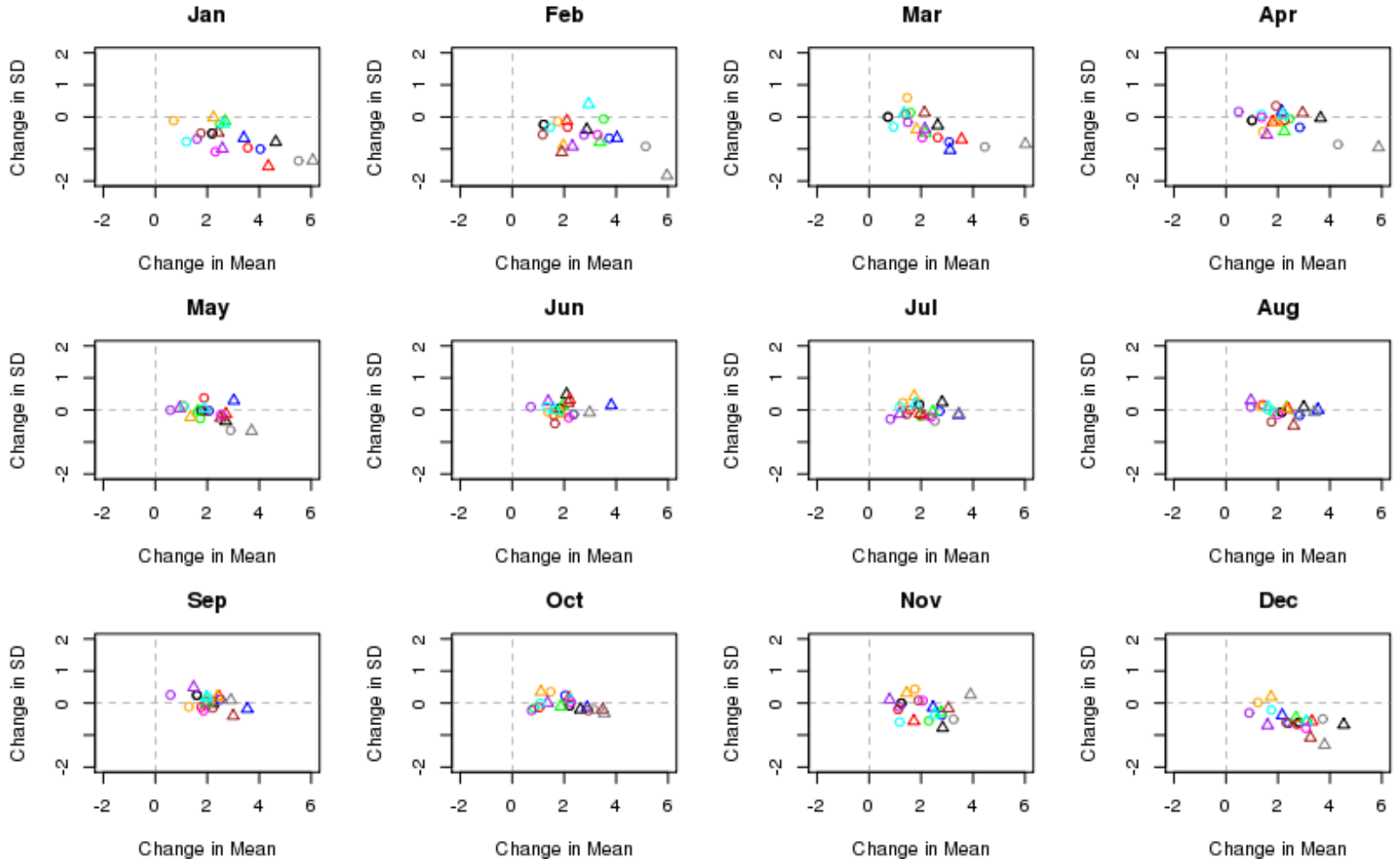

- **Paper 2: Watershed model residuals important for simulating blooms**
  - Increases peak blooms, especially in years with large floods
  - Tempered by loading of legacy P in other years

- **Setting the stage for future BREE research**



# Daily Average Temperature Changes

○ RCP 4.5 △ RCP 8.5



# GCM-informed sensitivity analysis scenarios

**12 Temperature Scenarios**

| Δ(sd) | 1° C | | | | |
|---|---|---|---|---|---|
| | 0° C | | | | |
| | -1° C | | | | |
| | | 0° C | 2° C | 4° C | 6° C |
| | | Δ(mean) | | | |

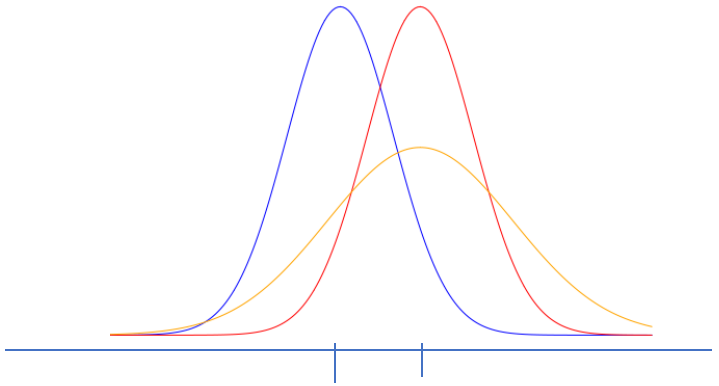
**X**

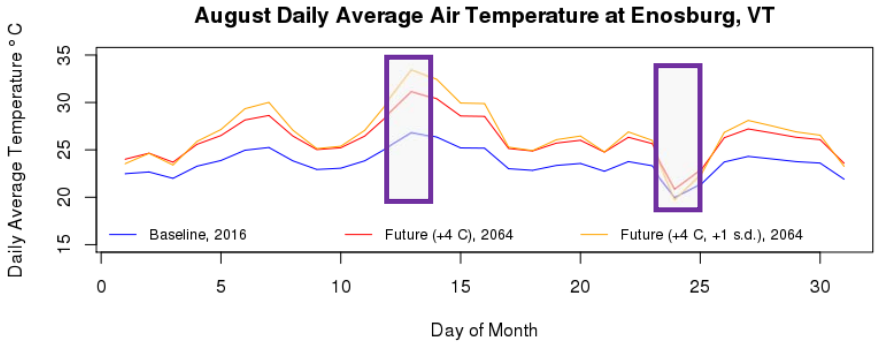
| Δ(Cv) | 20% | | | | |
|---|---|---|---|---|---|
| | 0 | | | | |
| | -20% | | | | |
| | | -20% | 0% | 20% | 40% |
| | | Δ(mean) | | | |

**=**

**144 Total Scenarios**

Winds from baseline period unchanged

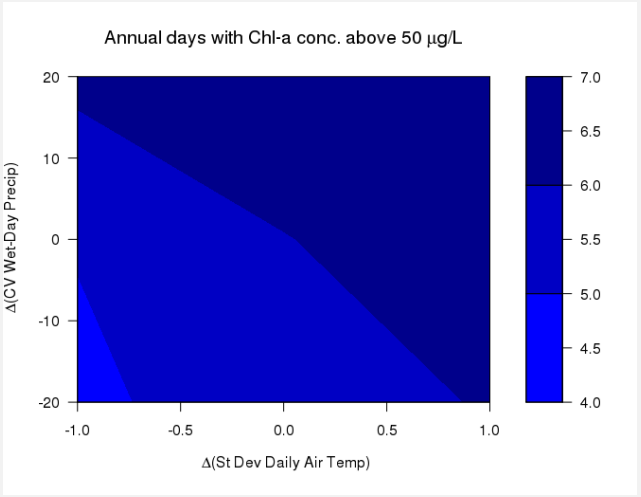


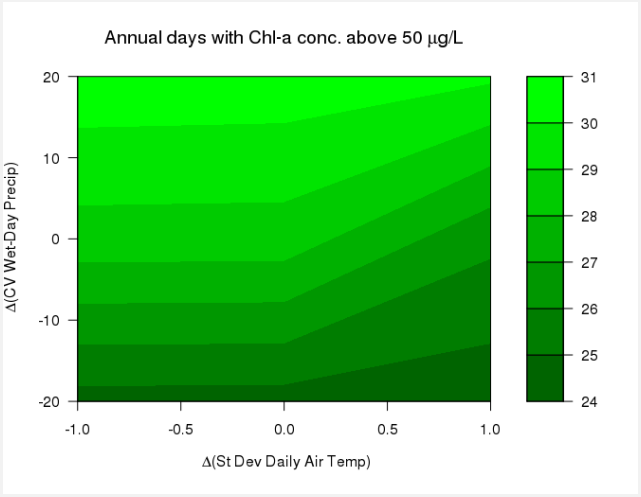
# Bloom responses to changes in climate variability depend on changes in mean temperature

- **Effects of temperature variability on days > 50 µg/L**
  - Without warming, greater temperature variability increases blooms (days > 50 µg/L)
  - Under +4° C warming , greater temperature variability reduces blooms
- **Effects of precipitation variability on days > 50 µg/L**
  - More floods, more droughts, more blooms!
  - Precipitation variability controls blooms more under warning
- **Projected changes in variability will affect blooms less than projected changes in means**
- **Variability less critical at 10 and 20 µg/L thresholds**

**Change in mean temperature: +0° C**



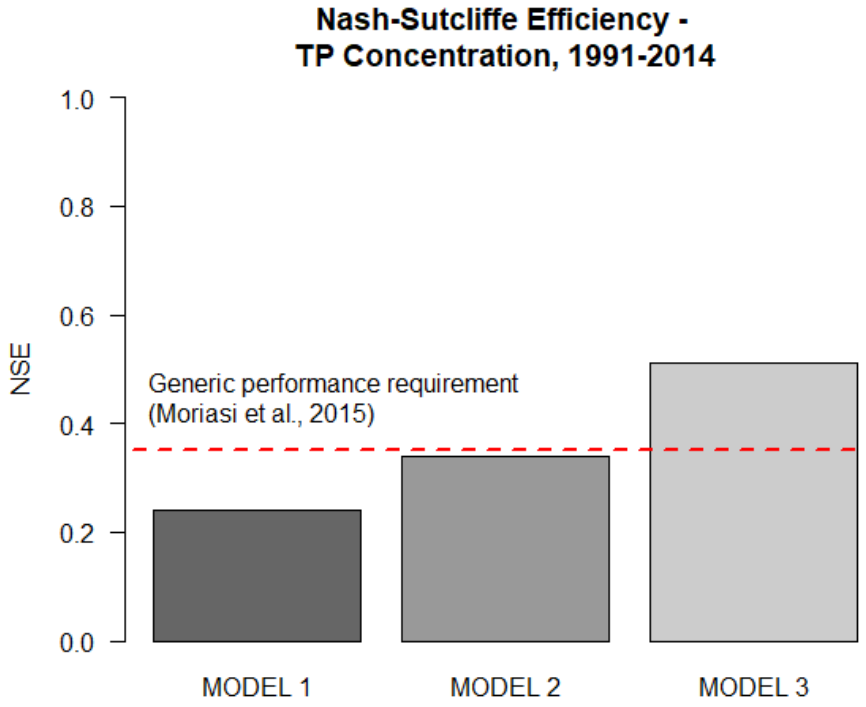

**Change in mean temperature: +4° C**



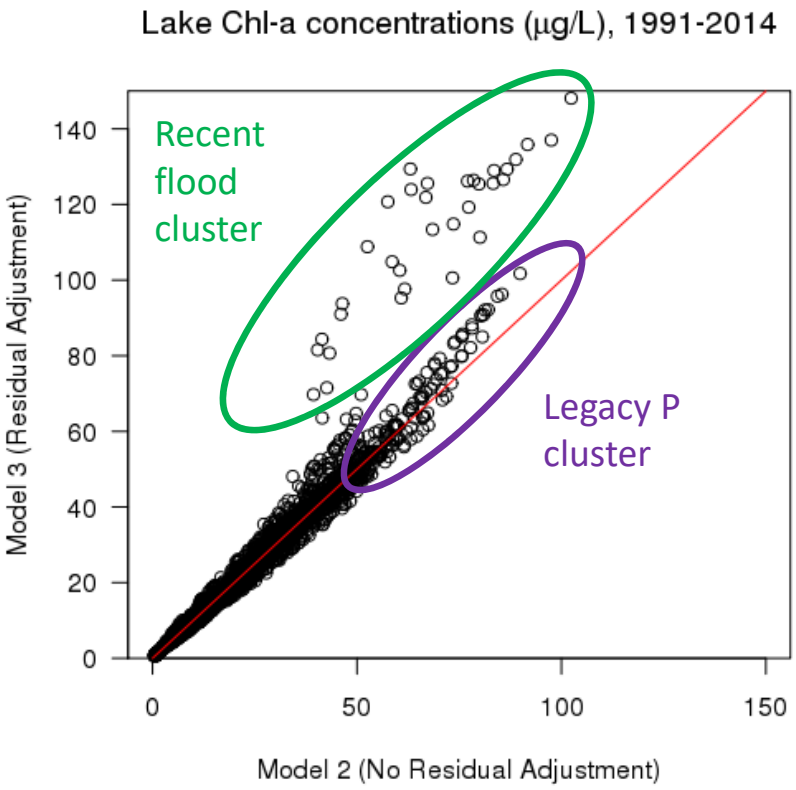
# Incorporating calibration residuals in streamflow and water quality time series improves TP concentration estimates

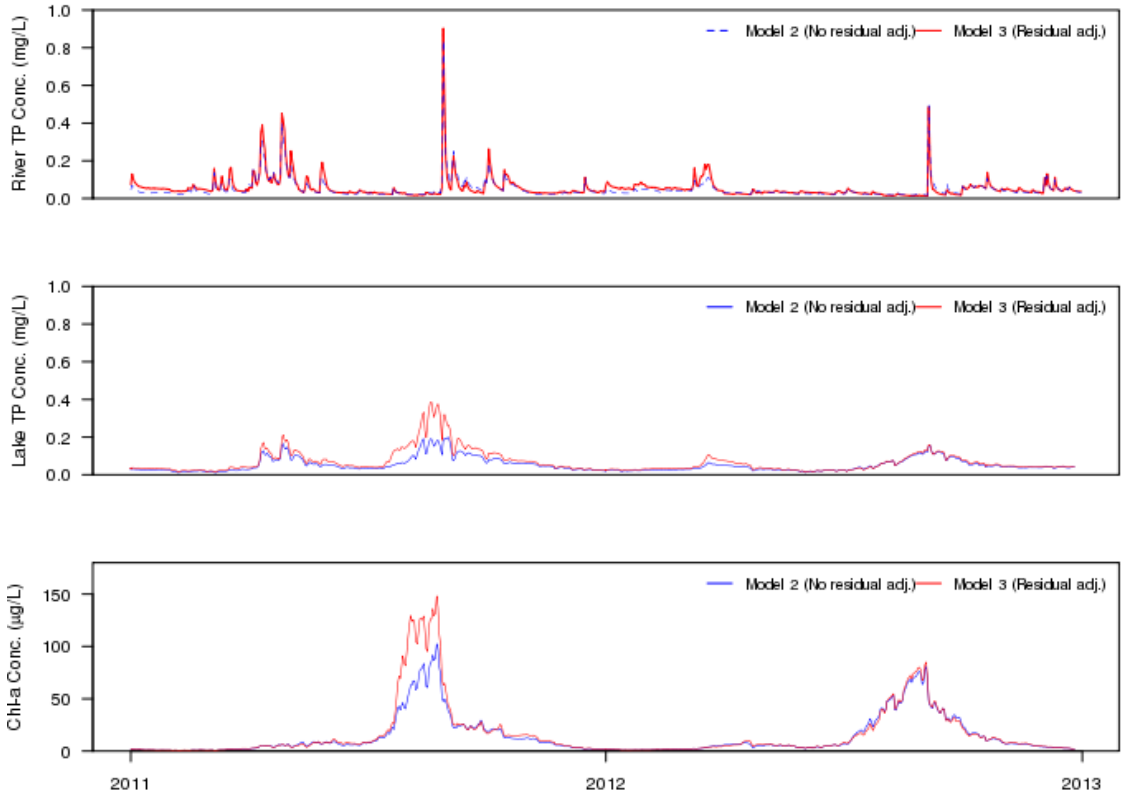
Three modeling chains:

- **Model 1:** SWAT streamflow and water quality (TMDL)
- **Model 2:** SWAT streamflow + Weighted Regression on Time, Discharge & Season (WRTDS)
- **Model 3:** SWAT streamflow + WRTDS with residual adjustments:
  - Linear regression on streamflow residuals + quantile mapping
  - Monthly residual adjustment for TP concentration



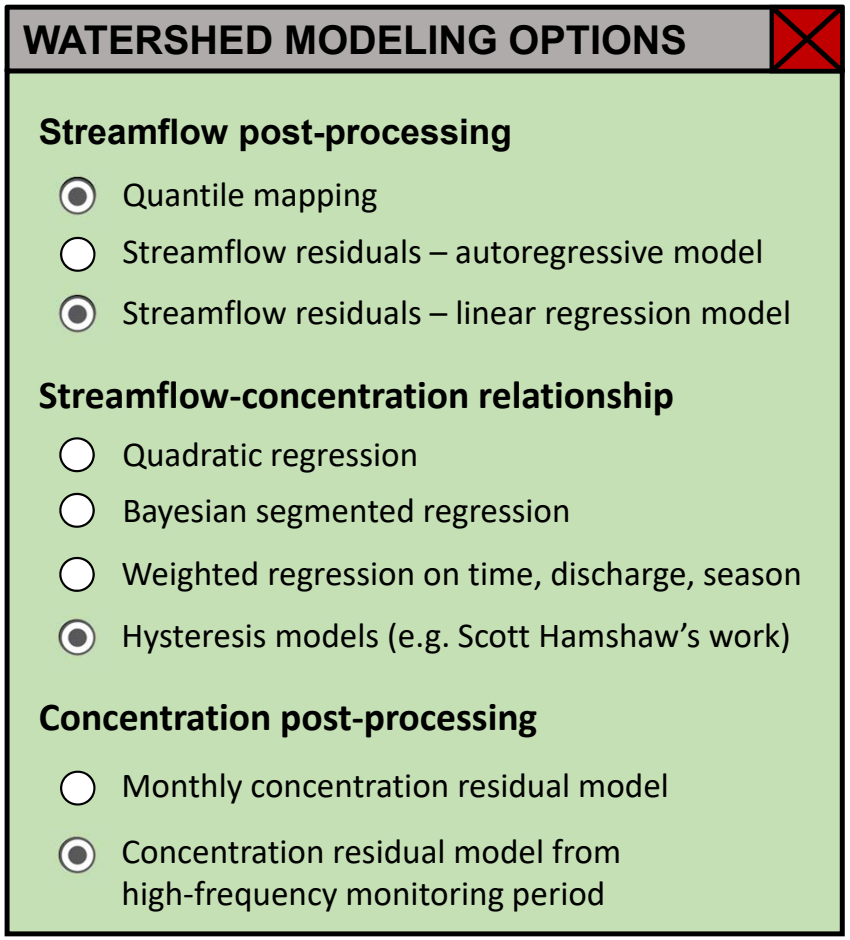
# Incorporating calibration residuals amplifies bloom extremes following floods; tempered by internal loading



# Wrap-up and follow-up work plan includes:

- Publishing first-author manuscripts
  - Including model documentation
- Major co-author papers:
  - US agri-environmental incentive programs
  - Climate change-internal loading synergy
  - Thresholds, lags and inertia
- Concept notes:
  - Effects of seasonal and interannual persistence on blooms
  - Watershed management optimization



# Some other lower-hanging fruit for the team?

- Seasonal climatic changes and blooms
- Bloom sensitivity to N:P ratios in inflow
- Compare P load estimates with residual adjustments throughout Lake Champlain basin
- Pike and Rock modeling (undergraduate or master's project)

# Thank you!

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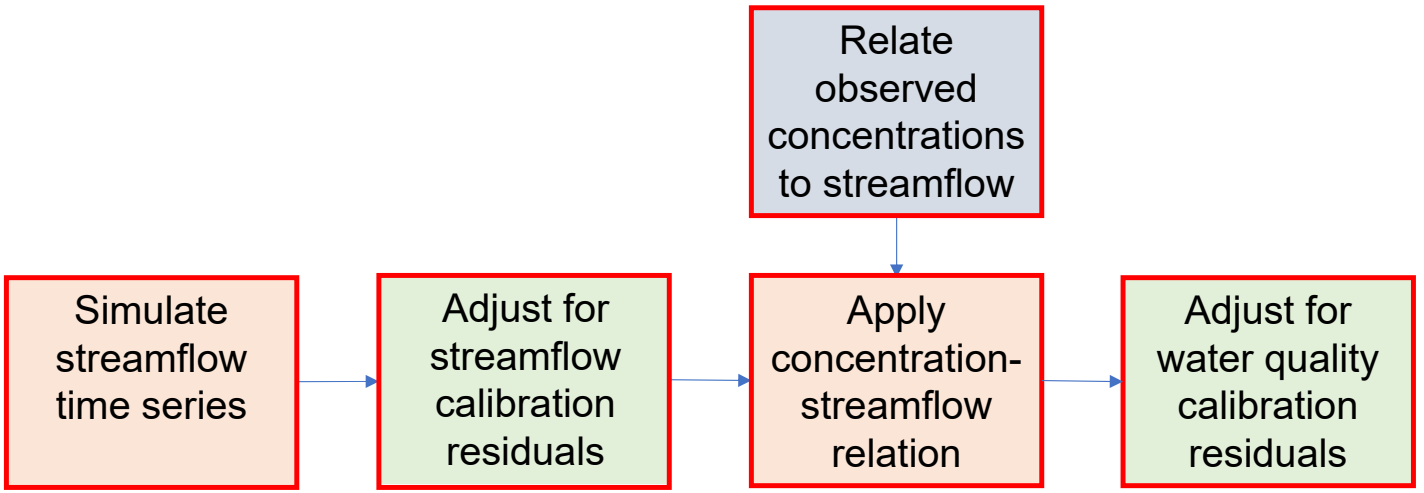
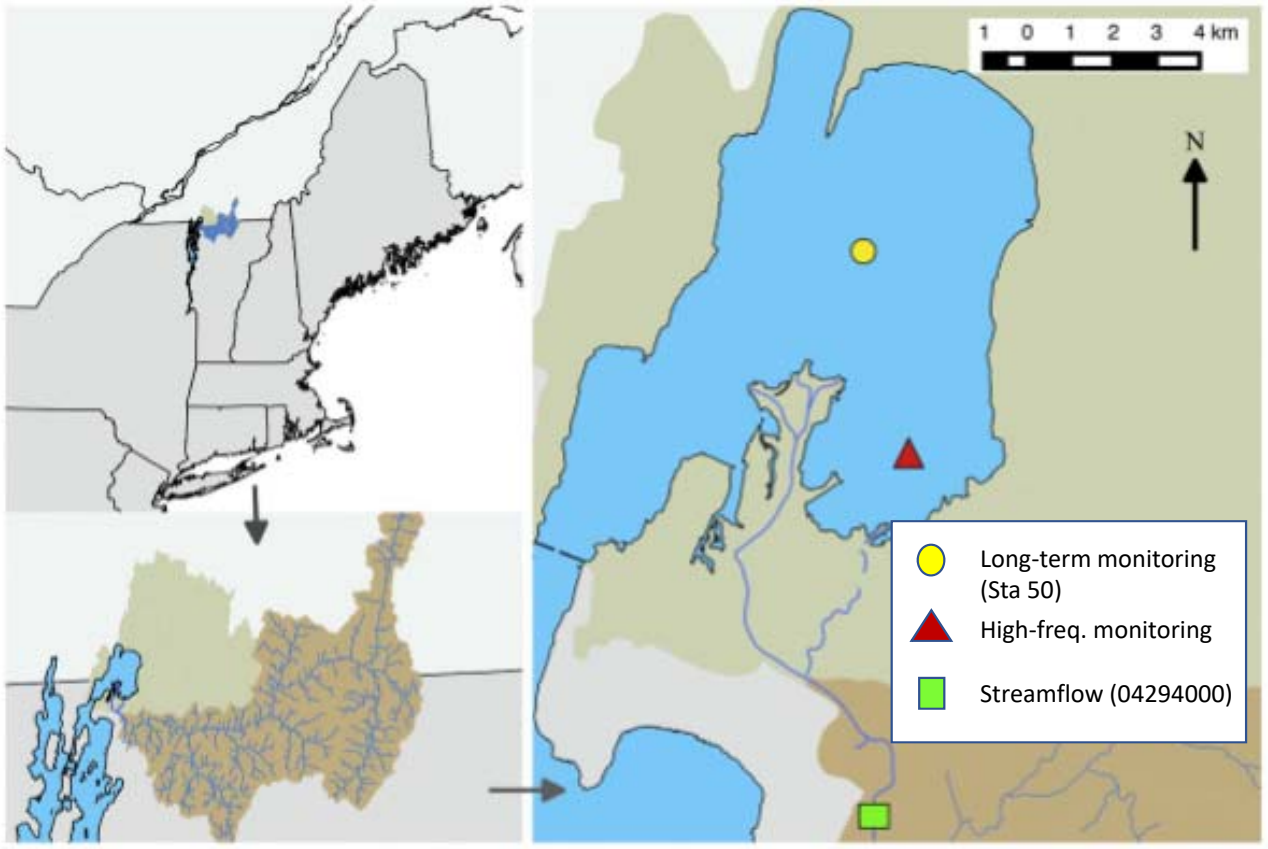
https://www.flwfishing.com/news/2016-06-22-where-to-catch-bass-on-lake-champlain

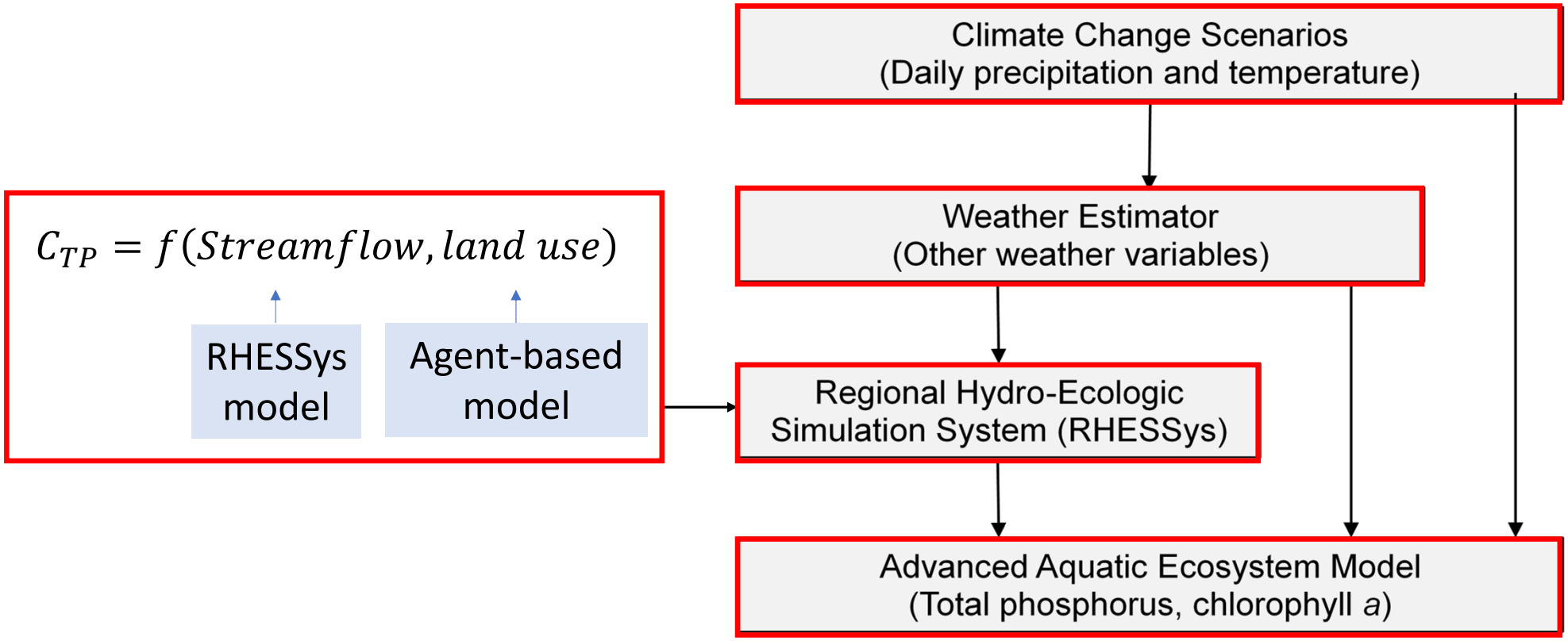
# Streamflow-water quality modeling chains



# Missisquoi Bay station locations



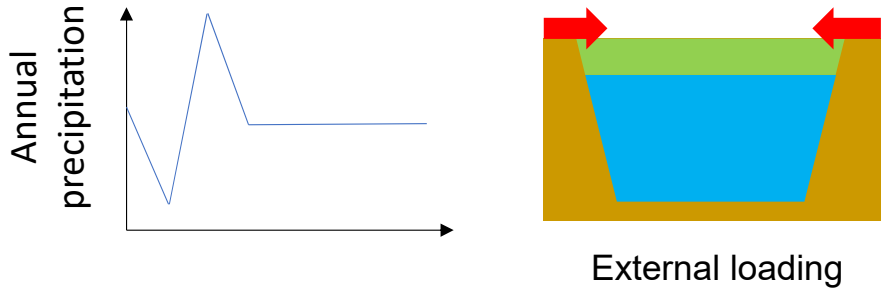
# BREE Integrated Assessment Model in TMDL analysis



# 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**

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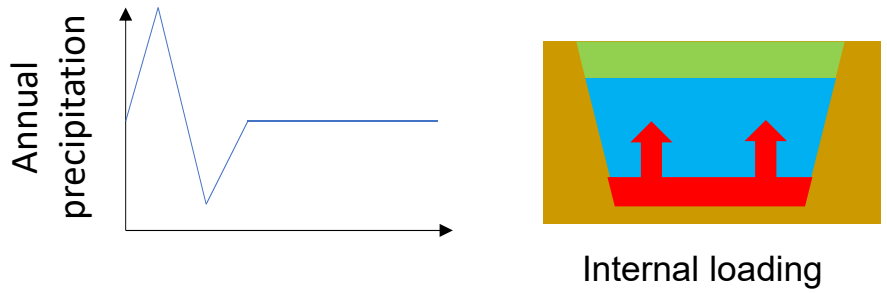

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