



# Predicting daily total phosphorus and suspended solids across Wisconsin stream reaches for impairment assessment

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AWRA – WI  
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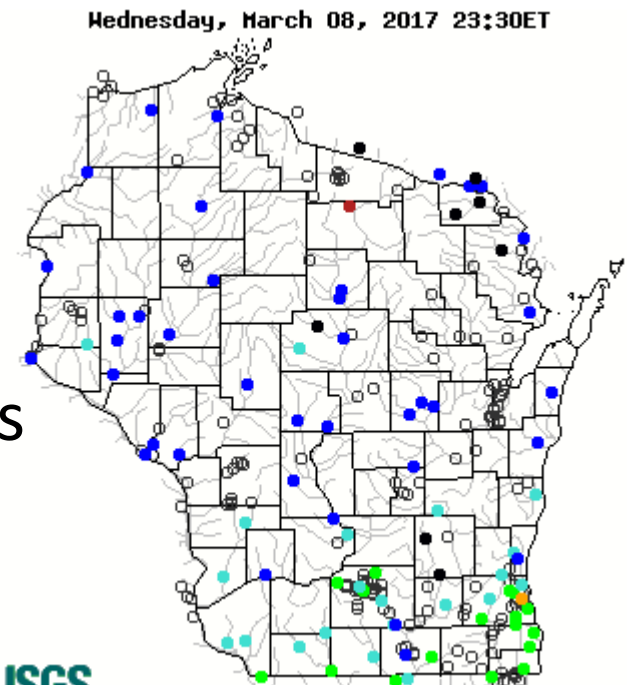
# Motivation

- Predict total phosphorus and total suspended solids for Wisconsin streams
  - High-resolution & large spatial scope



# Motivation

- Predict total phosphorus and total suspended solids for Wisconsin streams
  - High-resolution & large spatial scope
- **Challenge:** 235 USGS gages in WI, but 162,000 stream reaches including many headwaters
  - What to do for ungauged streams without discharge?







Look back in time to see what  
precipitation was :  
- leading up to day of prediction  
- for each watershed





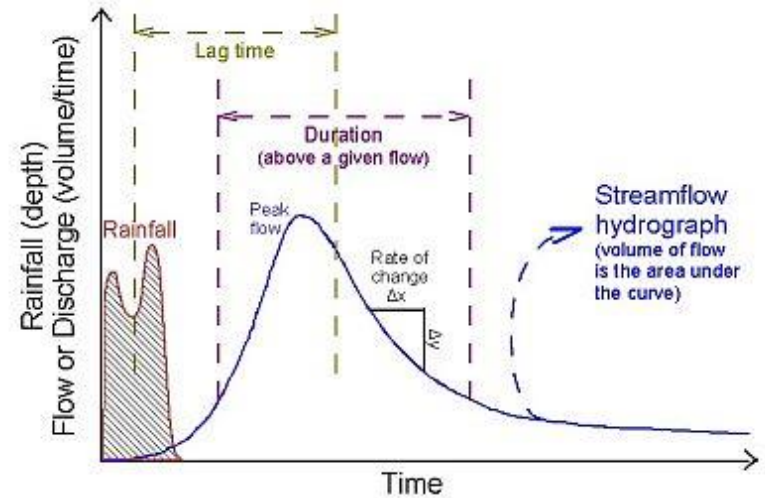
Look back in time to see what precipitation was :

- leading up to day of prediction
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Use ***antecedent precipitation*** instead of *discharge*

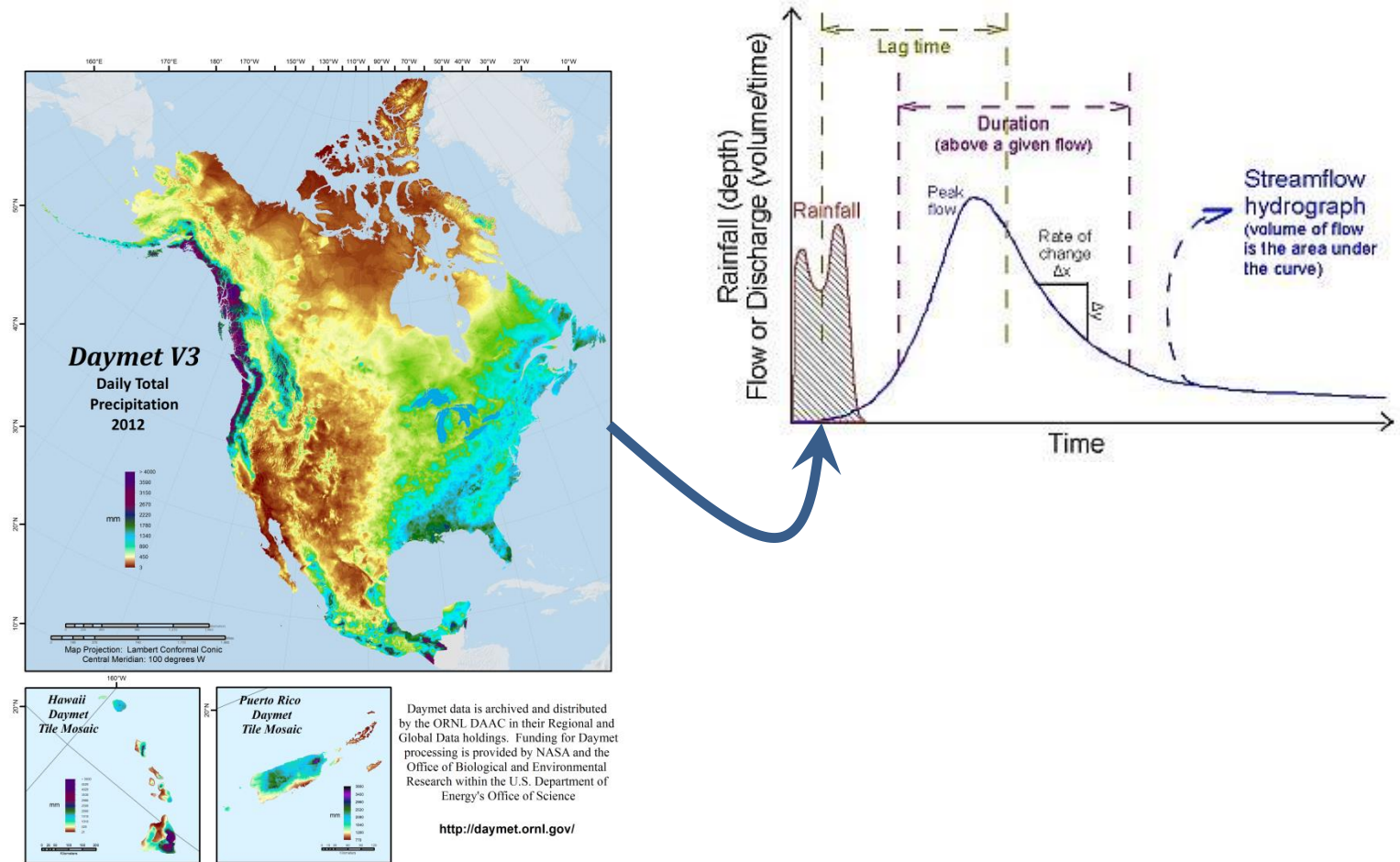


# Antecedent precipitation in lieu of discharge



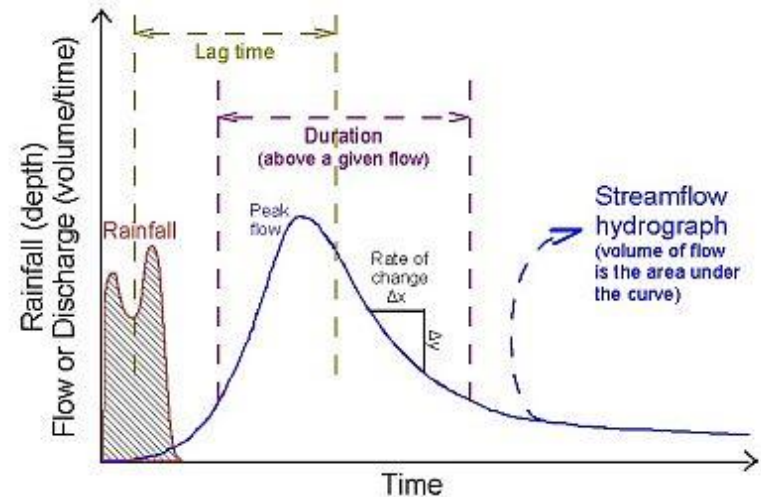


# Antecedent precipitation in lieu of discharge



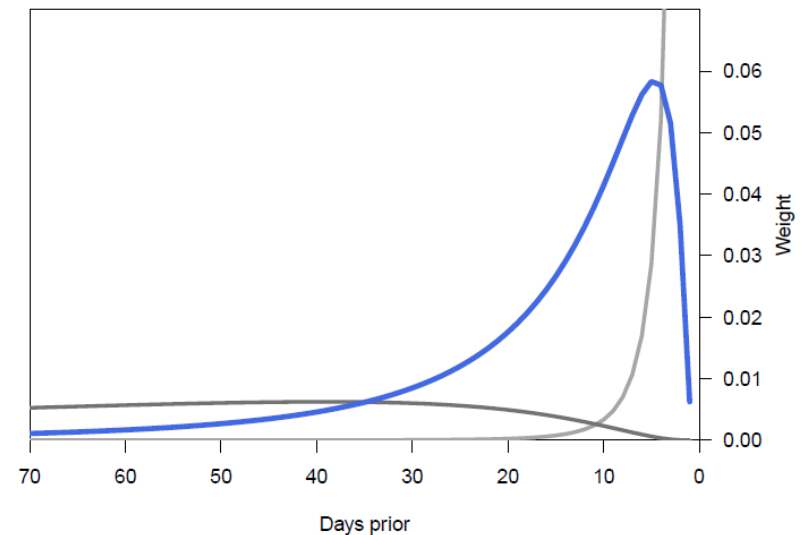
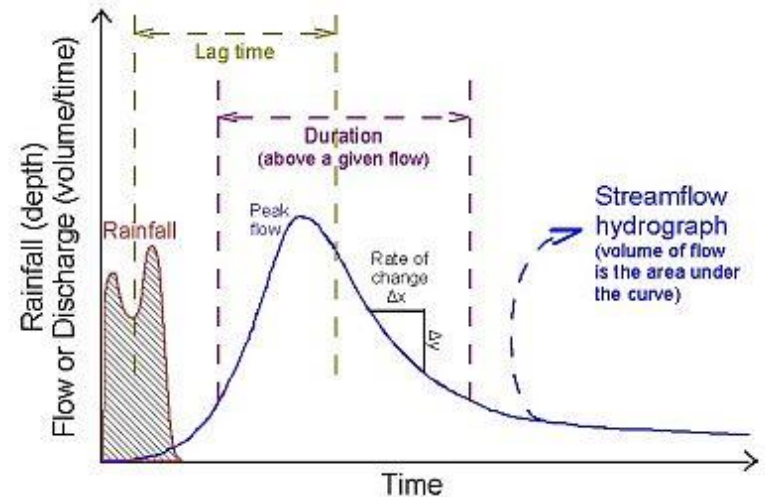
# Antecedent precipitation in lieu of discharge

- Calculated effective precipitation
  - Precipitation + snowmelt – snow
- Sum effective precip on day of interest and 365 preceeding days, where each day is weighted by a decay function



# Antecedent precipitation in lieu of discharge

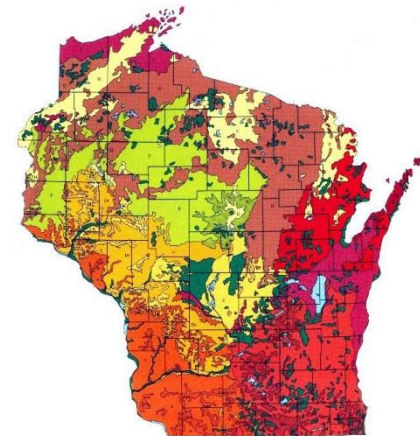
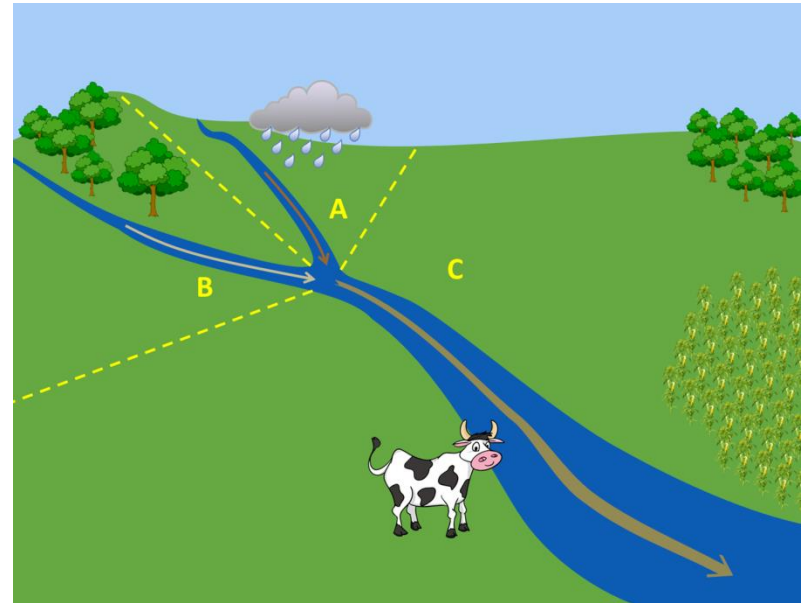
- Calculated effective precipitation
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- Sum effective precip on day of interest and 365 preceding days, where each day is weighted by a decay function
- Lag/Decay function: Calculate a “lag” parameter based on WSA & SLOPE for each reach
  - For TSS:  $M = 0.011 + 0.204 \cdot \log(\text{WSA})$
  - For TP:  $M = 0.528 + 0.203 \cdot \log(\text{WSA}) - 0.043 \cdot (\text{SLOPE})$





# TP/TSS Model

- Spatio-temporal predictors:
  - Weather (daily temp. and preceding precipitation)
- Fixed spatial predictors:
  - Reach and watershed characteristics (land use, soils, etc.)
- Measured TP (23,028 obs. at 1,473 sites) & TSS (11,859 obs. at 513 sites) for model fitting



# Model structure

Predict TP and TSS for stream reach C on day 1

$$\log(TP_{c,1}) \text{ or } \log(TSS_{c,1}) = \beta X_{c,1} + \gamma_c Z_{c,1} + \epsilon$$

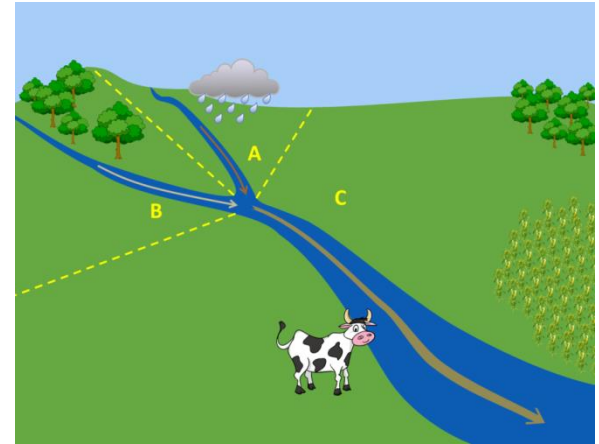
## *X (fixed effects)*

*\*slope<sub>ABC</sub>*  
*\*log(watershed area<sub>ABC</sub>)*  
*\*permeability<sub>ABC</sub>*  
*\*percent agriculture<sub>ABC</sub>*  
*\*percent urban<sub>ABC</sub>*  
*sin(2πDOY)*  
*cos(2πDOY)*  
*7-day temp anomaly<sub>ABC,1</sub>*  
*antecedent precipitation index<sub>ABC,1</sub>*

## *Z (random effects)*

*intercept*  
*sin(2πDOY)*  
*cos(2πDOY)*  
*7-day temp anomaly<sub>ABC,1</sub>*  
*antecedent precipitation index<sub>ABC,1</sub>*  
*antecedent precipitation index<sub>ABC,1</sub><sup>2</sup>*

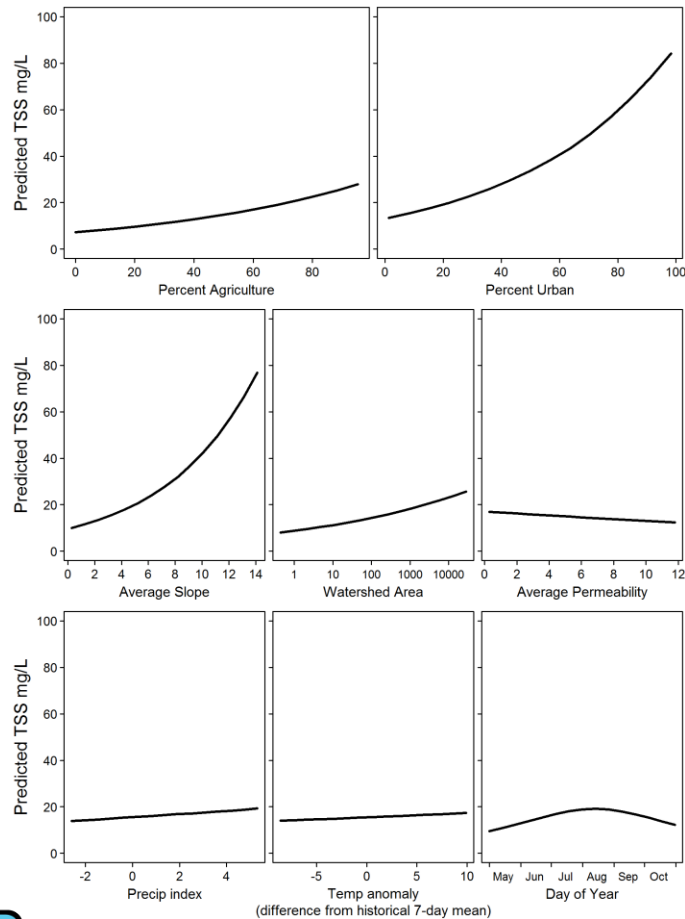
*\*allowed to interact with antecedent precipitation*



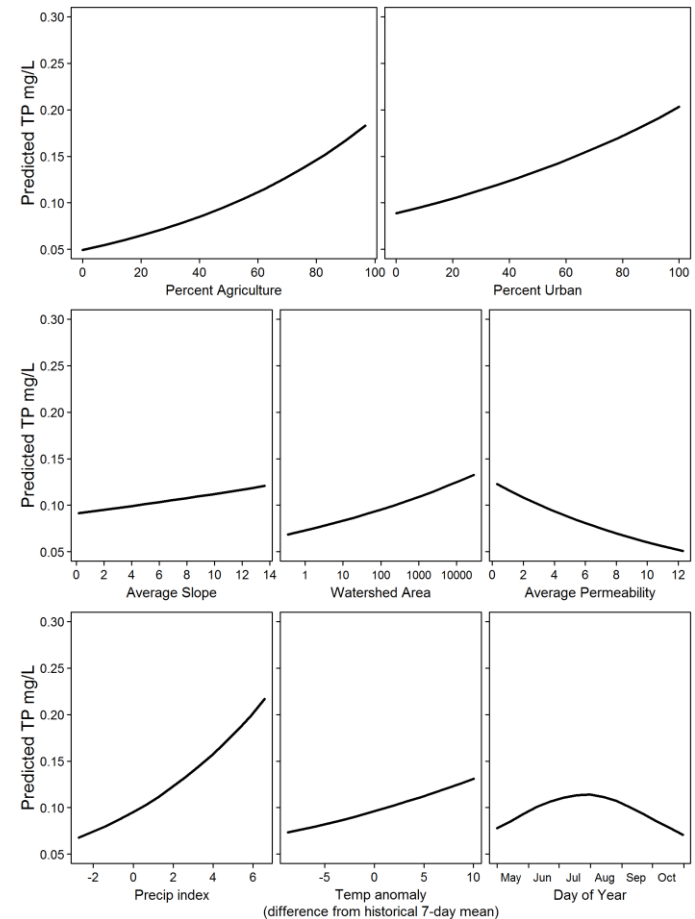
# Model summary

## Relative effects of each predictor

**TSS Model**



**TP Model**



...holding other variables constant at their average values





# Median predicted TP

TP (mg/L)

- 0.011 - 0.035
- 0.036 - 0.052
- 0.053 - 0.073
- 0.074 - 0.094
- 0.095 - 0.121
- 0.122 - 0.149
- 0.150 - 0.218
- 0.219 +

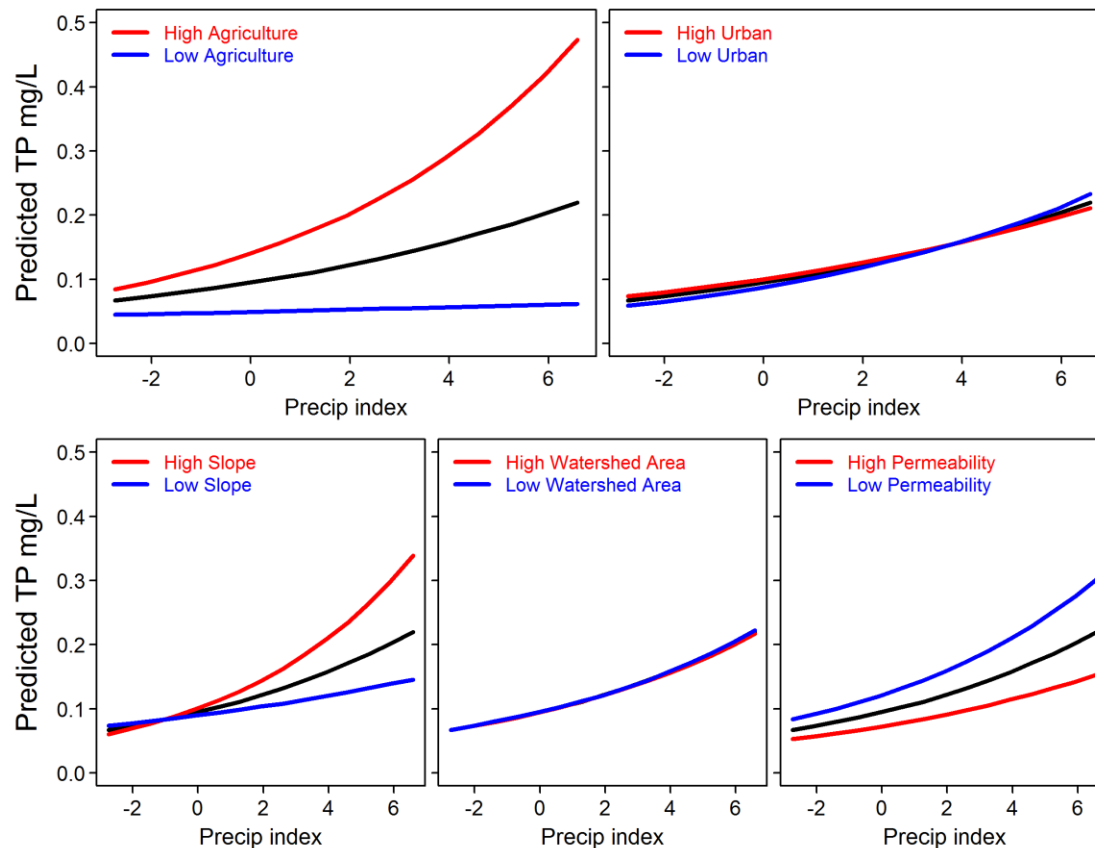
0 50 100 200 km



# Model summary

## Interactions with Precipitation

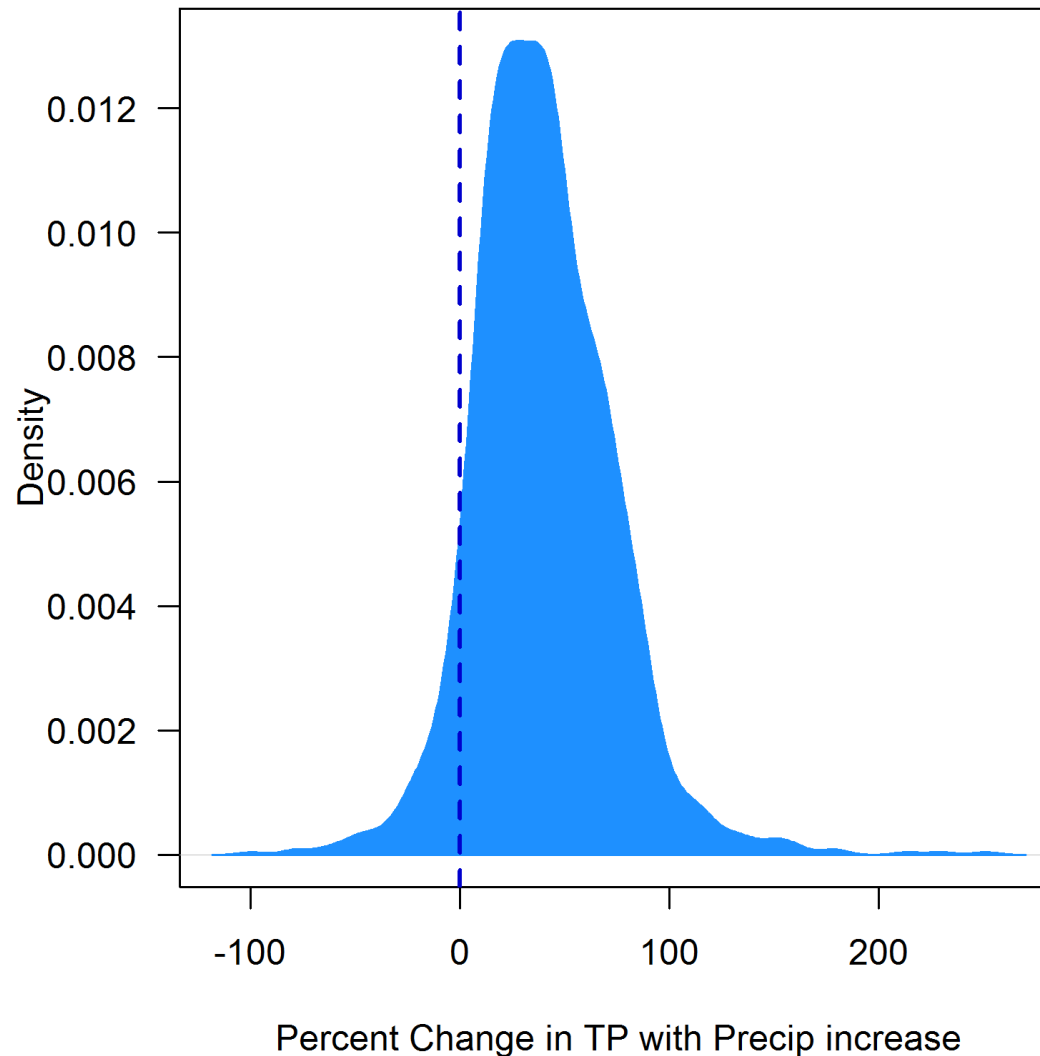
### TP Model



...holding other variables constant at their average values



How do sites' TP concentrations vary between 10<sup>th</sup> percentile and 90<sup>th</sup> percentile of precip?





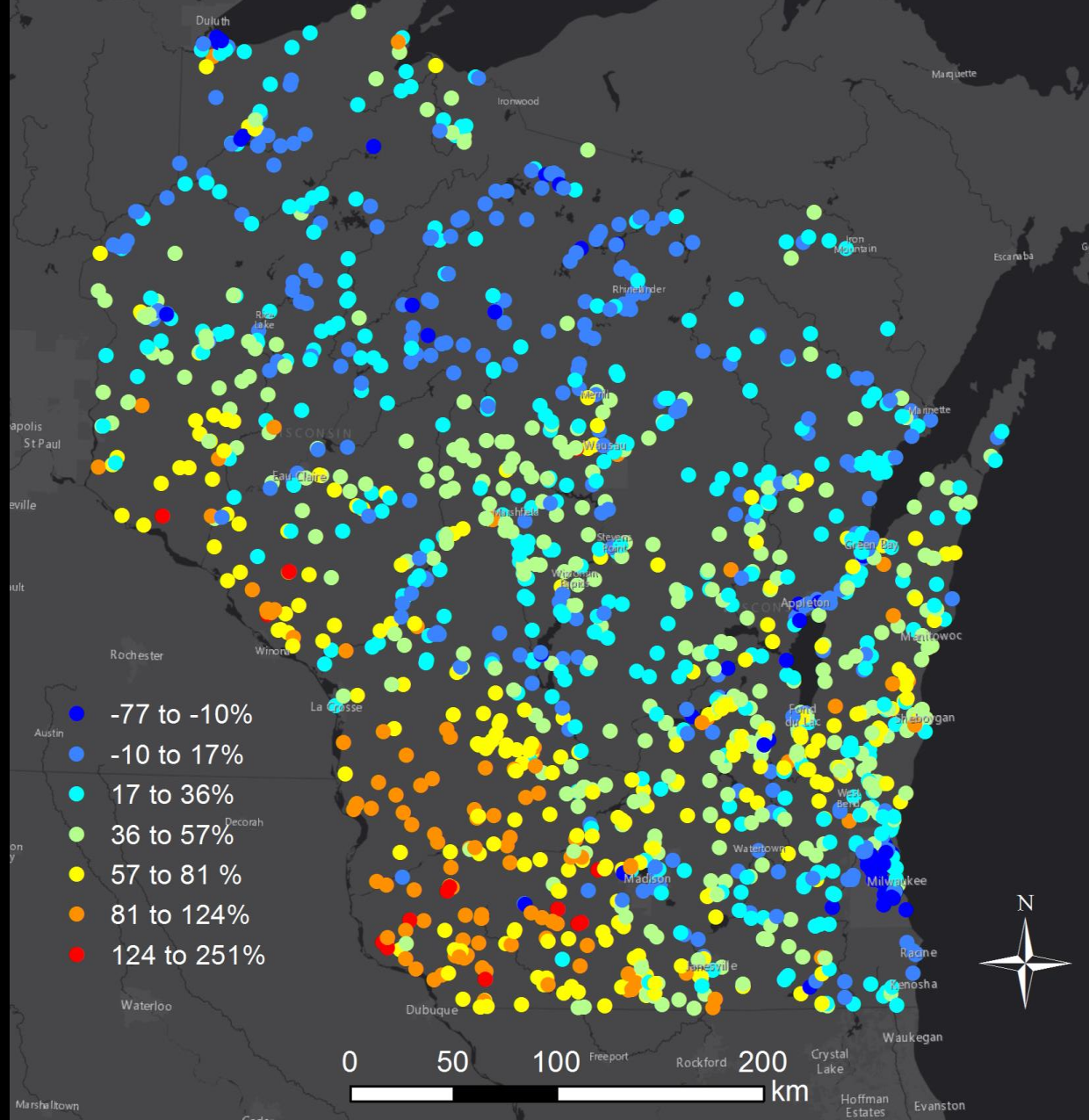
### How much does TP increase if antecedent precipitation increases from 10th to 90th percentile?

Legend:

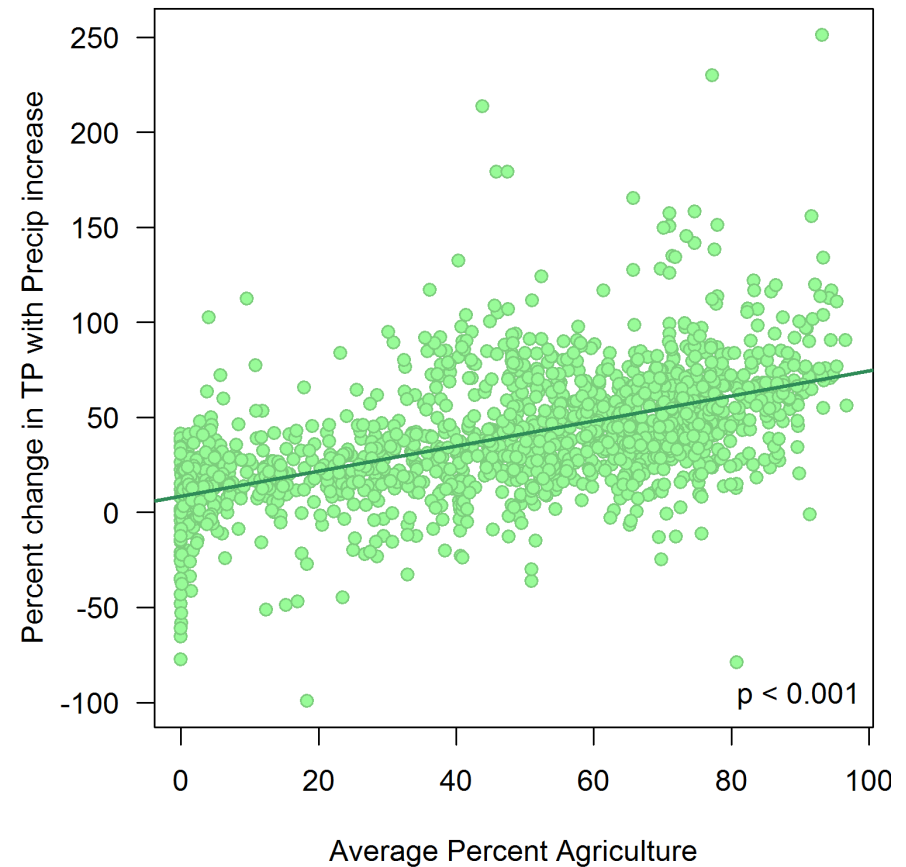
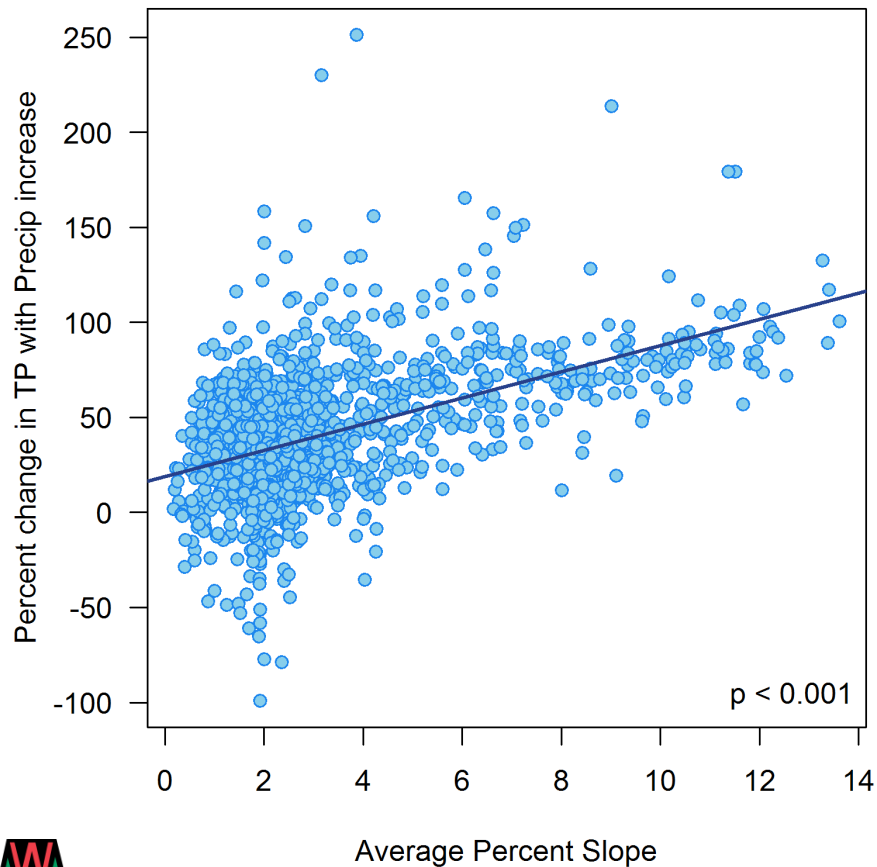
- 77 to -10%
- 10 to 17%
- 17 to 36%
- 36 to 57%
- 57 to 81 %
- 81 to 124%
- 124 to 251%

Scale: 0 50 100 200 km

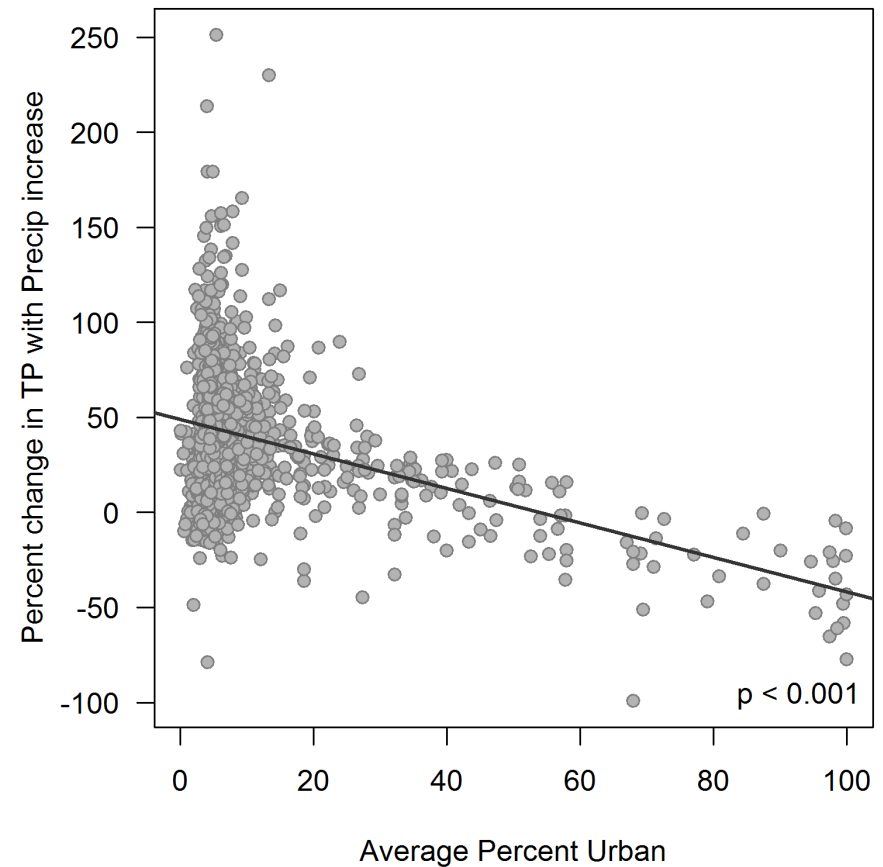
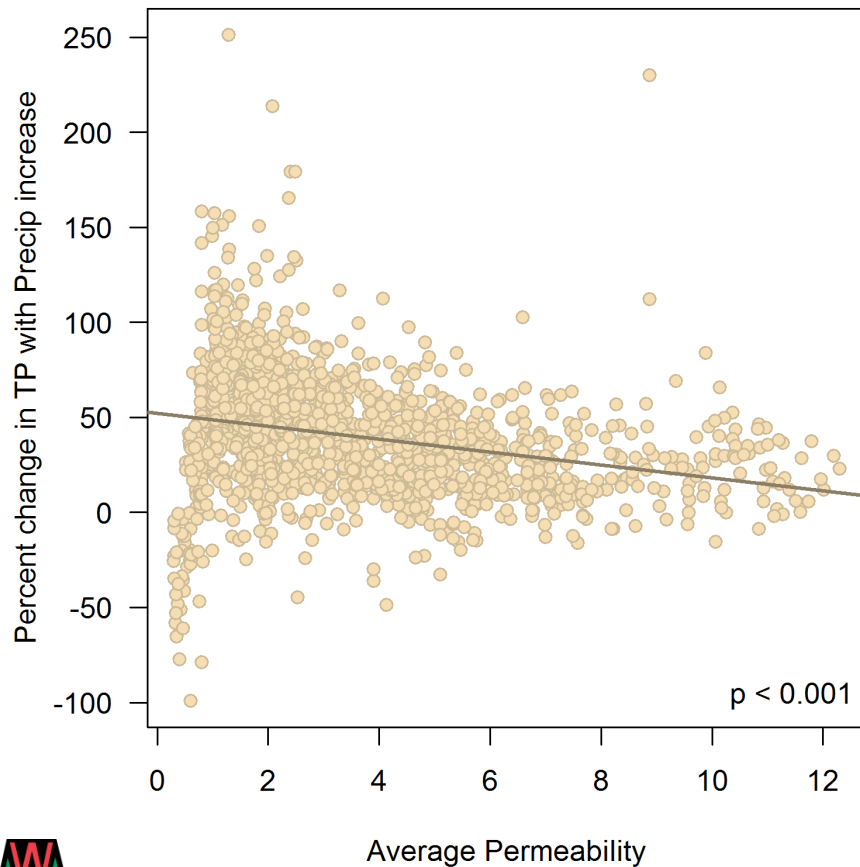
North Arrow



# What causes differences in response to precipitation?

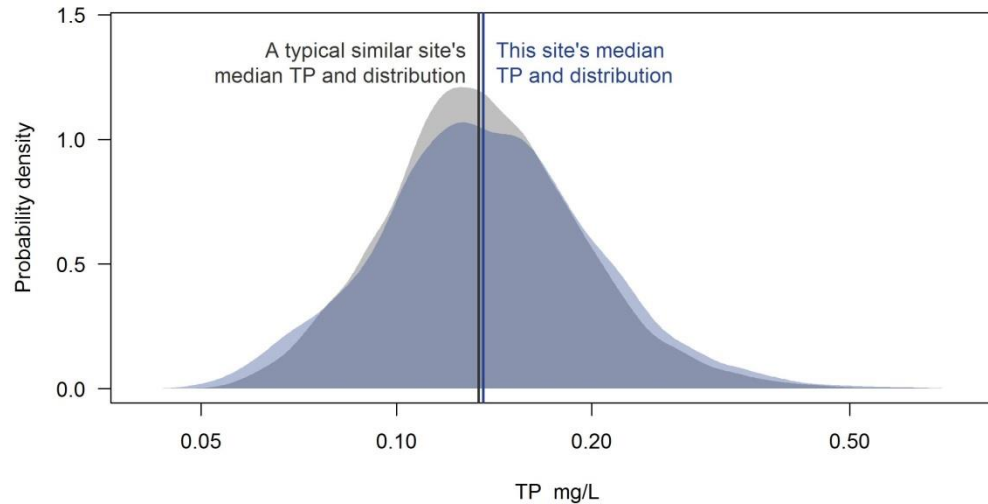


# What causes differences in response to precipitation?

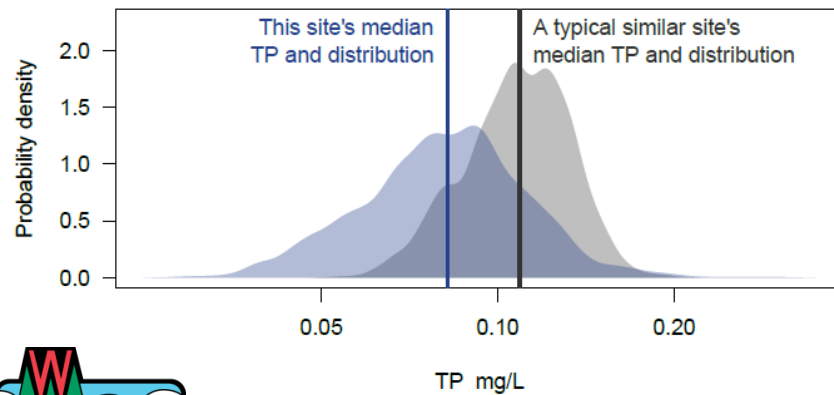


# Effect of random effects

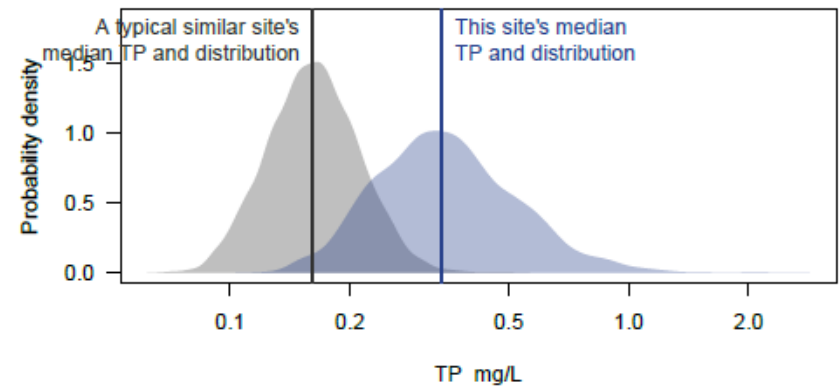
## Kickapoo River



## Milwaukee River



## Bower Creek





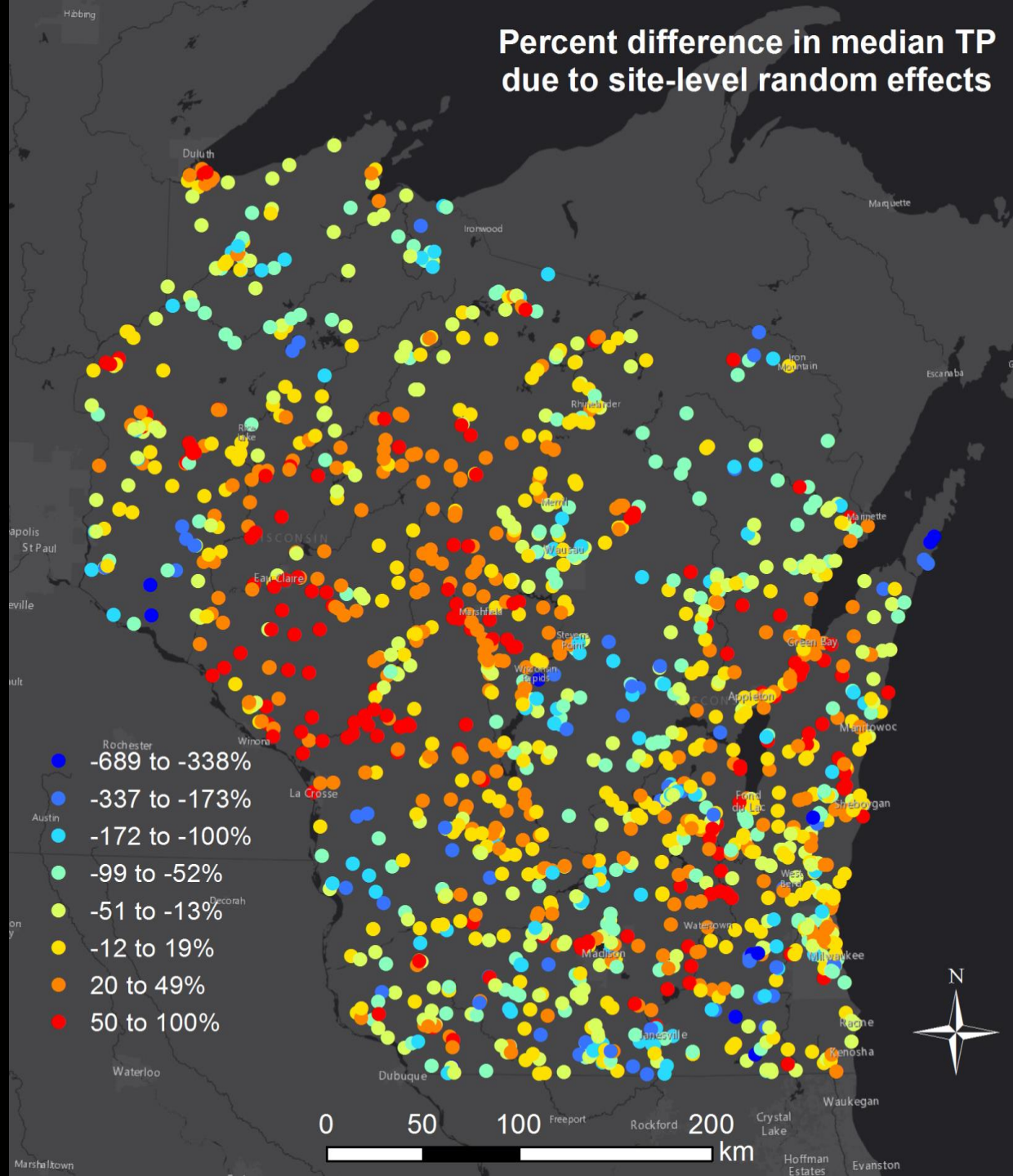
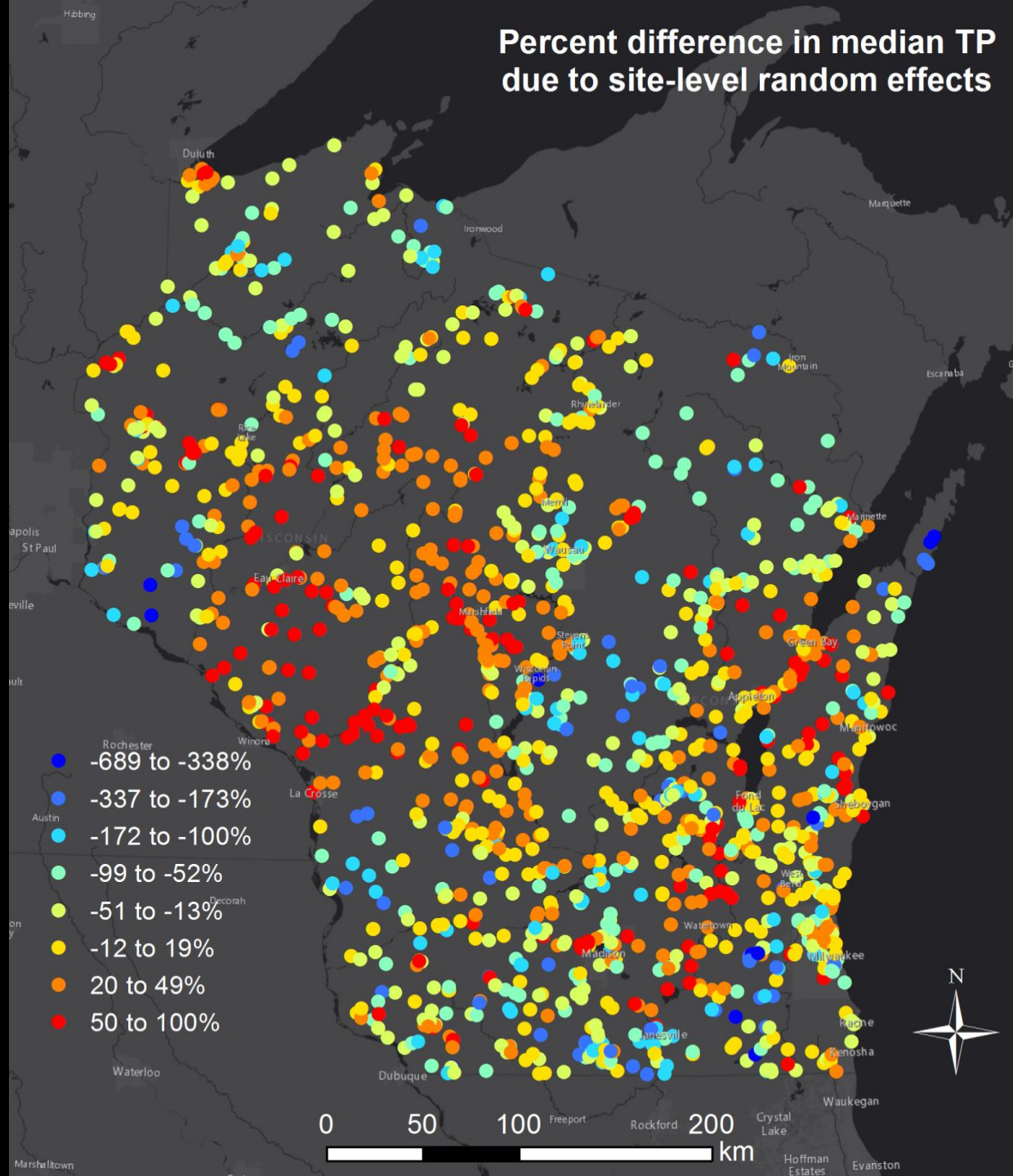
**Percent difference in median TP due to site-level random effects**

Legend:

- 689 to -338%
- 337 to -173%
- 172 to -100%
- 99 to -52%
- 51 to -13%
- 12 to 19%
- 20 to 49%
- 50 to 100%

Scale: 0 50 100 200 km

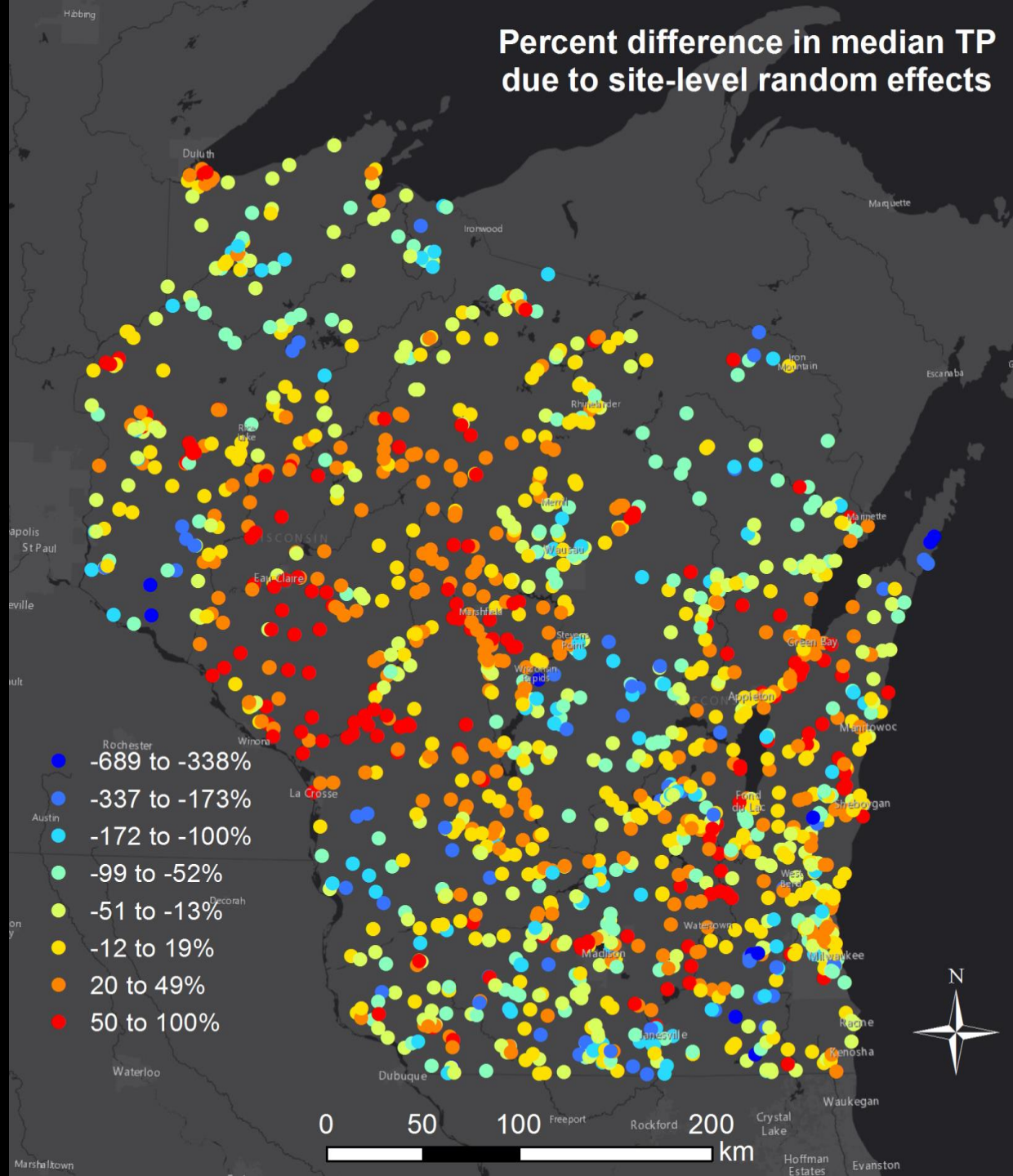
North Arrow



**Percent difference in median TP due to site-level random effects**

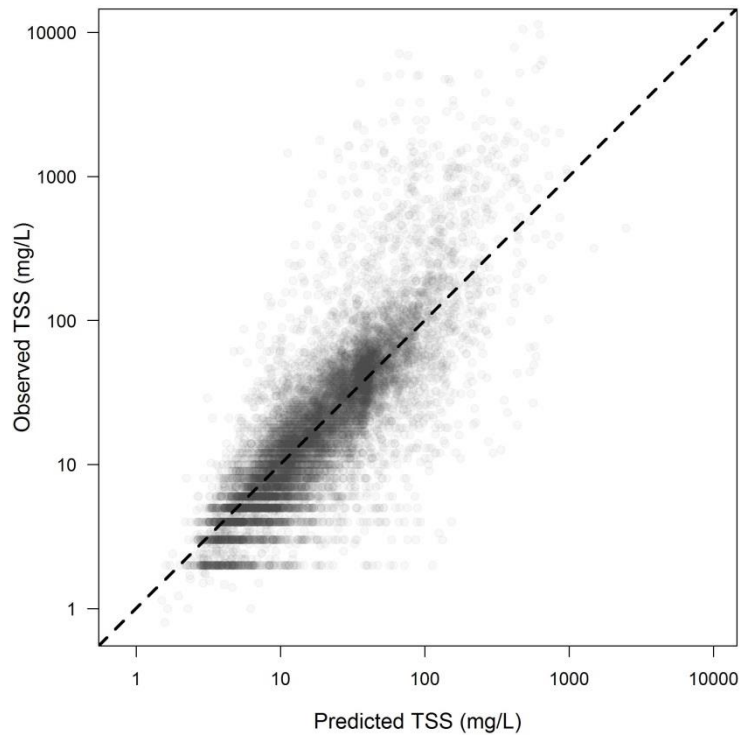
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0 50 100 200 km

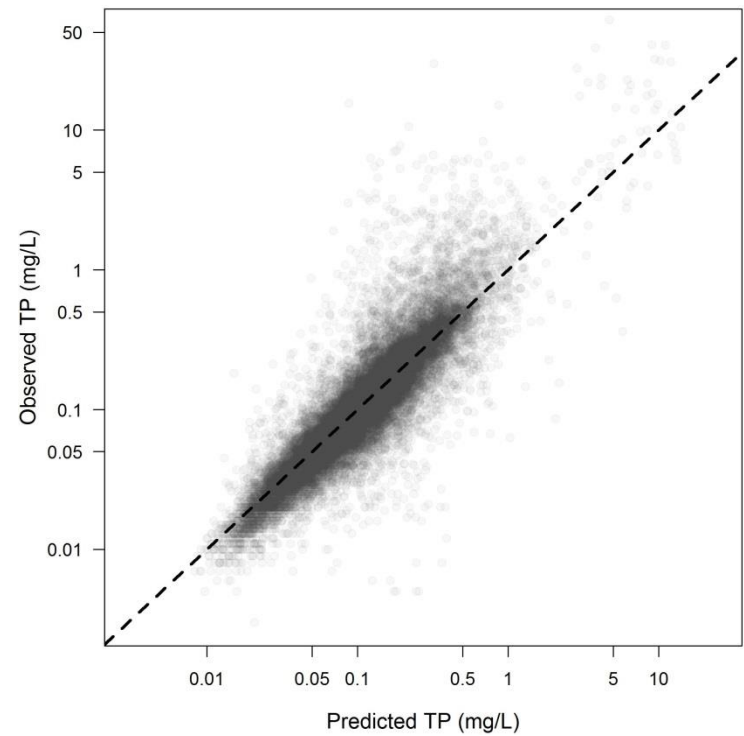


# Model summary

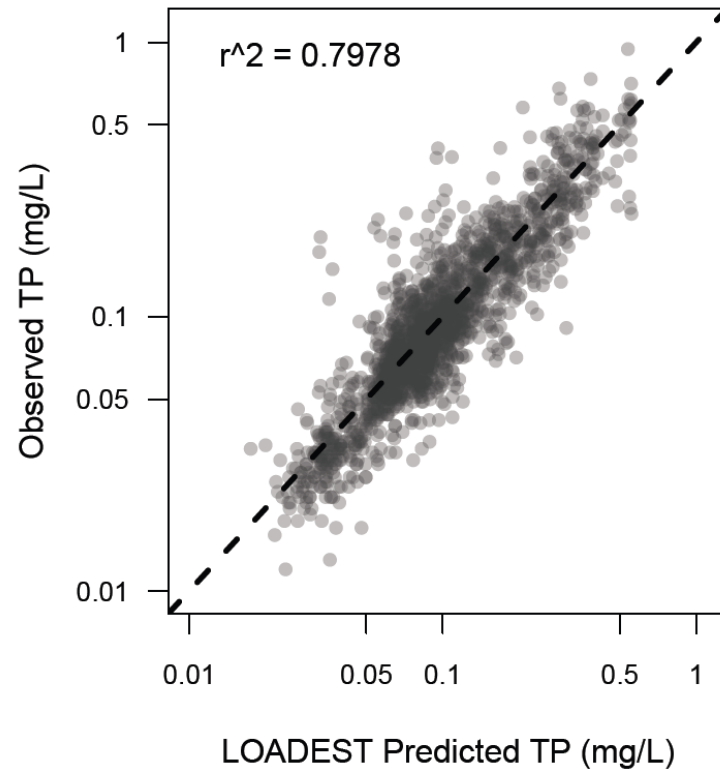
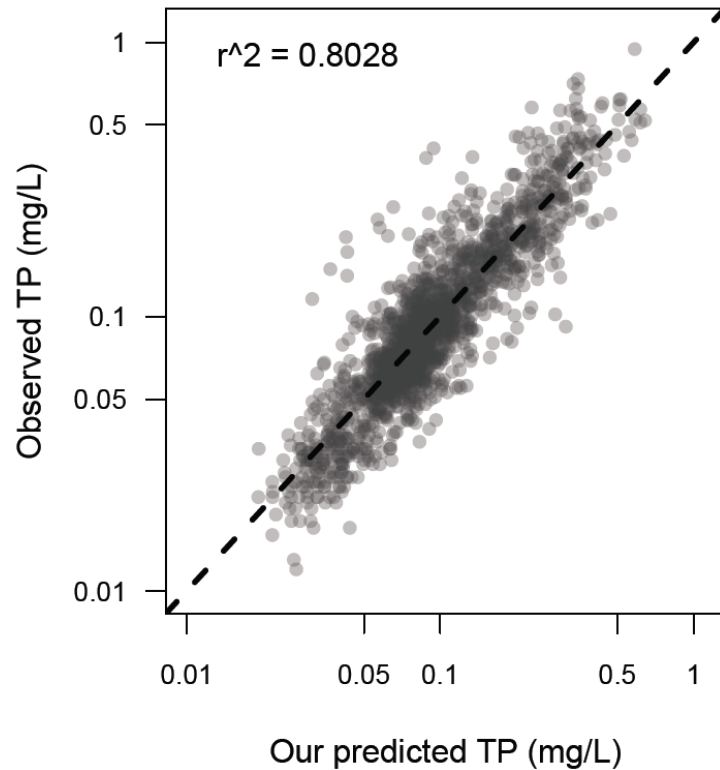
## TSS Model



## TP Model



# Overall, TP model performs similarly to LOADEST



# Applications

- Incorporate hourly precipitation data
- Incorporate spatial autocorrelation terms
- Provide predictions, reports, and apps to local biologists and stakeholders
- Use AUCs from predicted TSS distributions to test effects on macroinvertebrates and fish
  - Assess impairment due to TSS





# Acknowledgments

- Funding:
  - EPA
  - Water Resources Institute
- Support
  - Wisconsin DNR
  - UW Aquatic Sciences Center
- DNR Water Evaluation Section, Streams Tech. Team, and Modeling Tech. Team



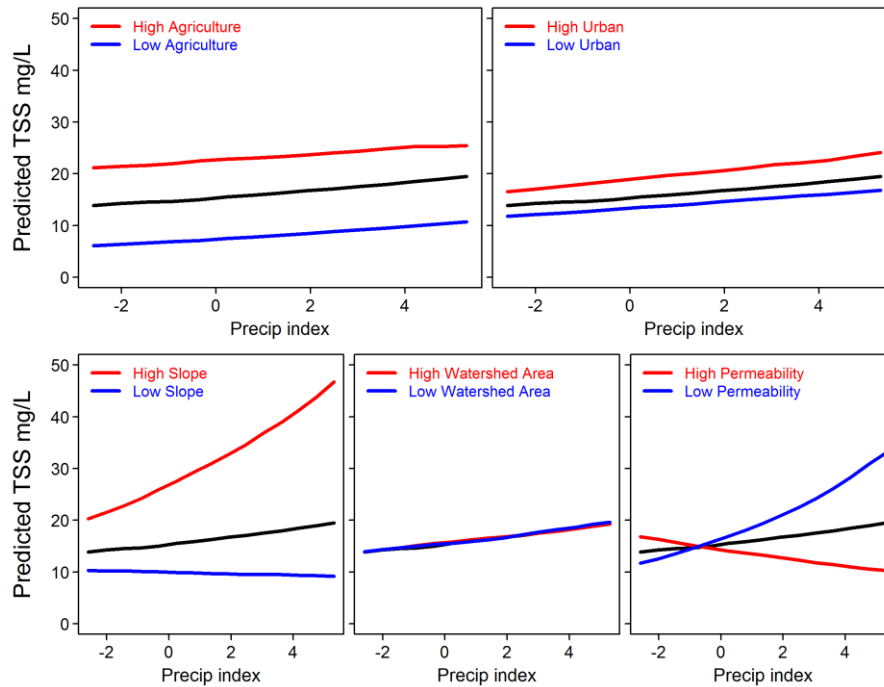
# Questions?



[Alexander.Latzka@wisconsin.gov](mailto:Alexander.Latzka@wisconsin.gov)

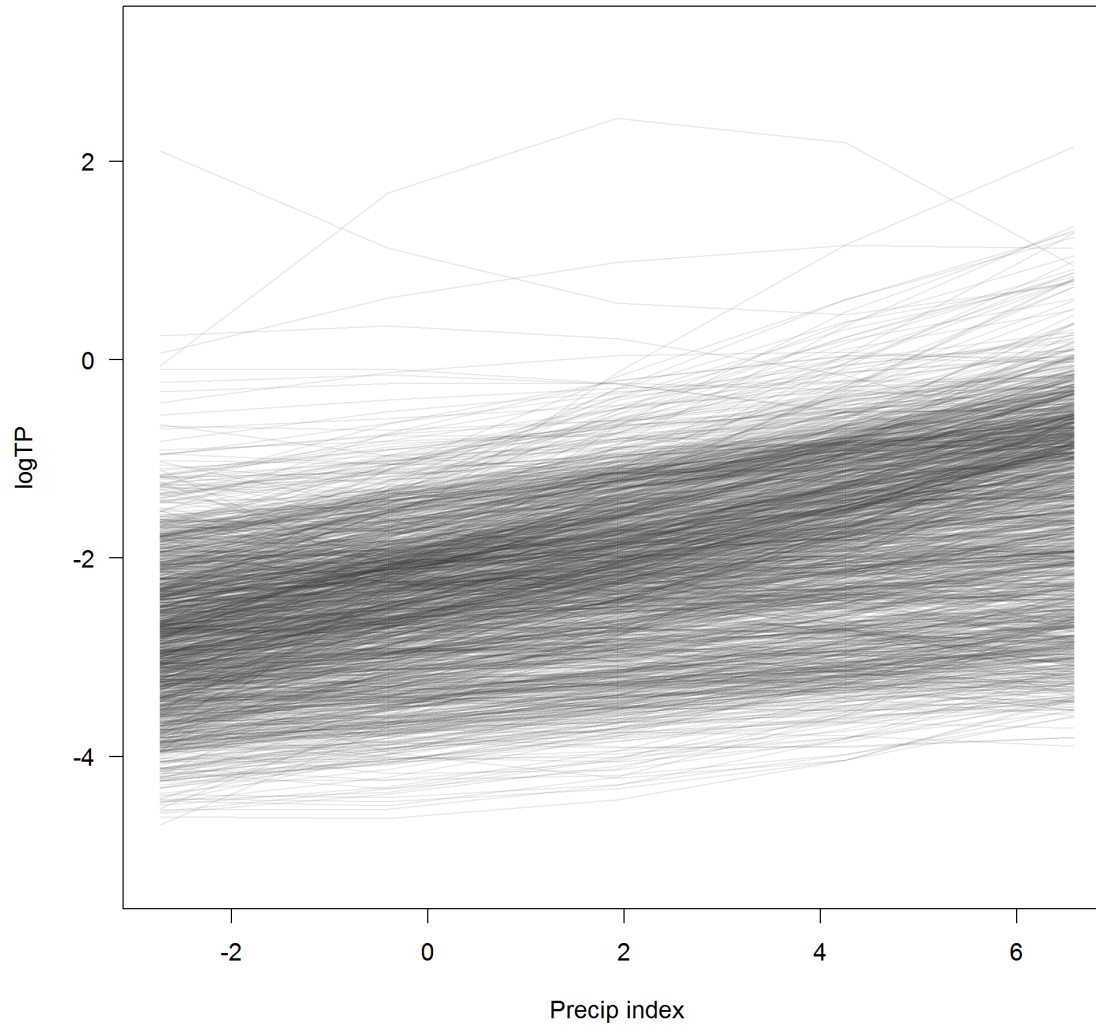
[Matthew.Diebel@wisconsin.gov](mailto:Matthew.Diebel@wisconsin.gov)

## TSS Model





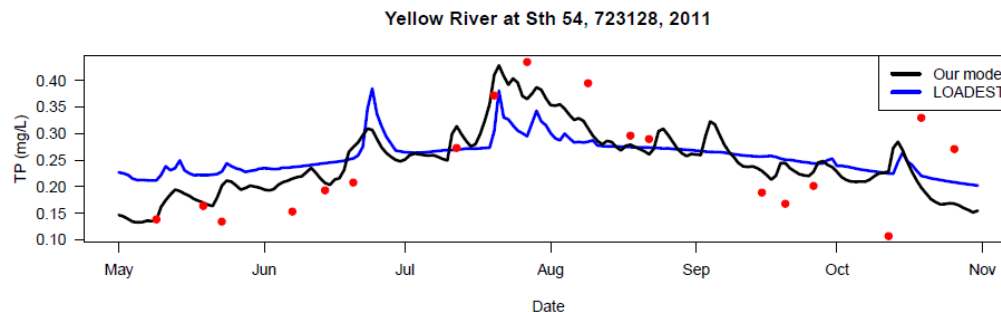
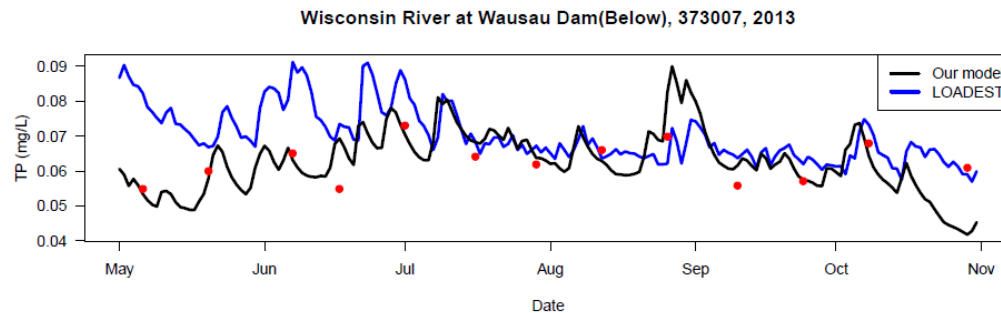
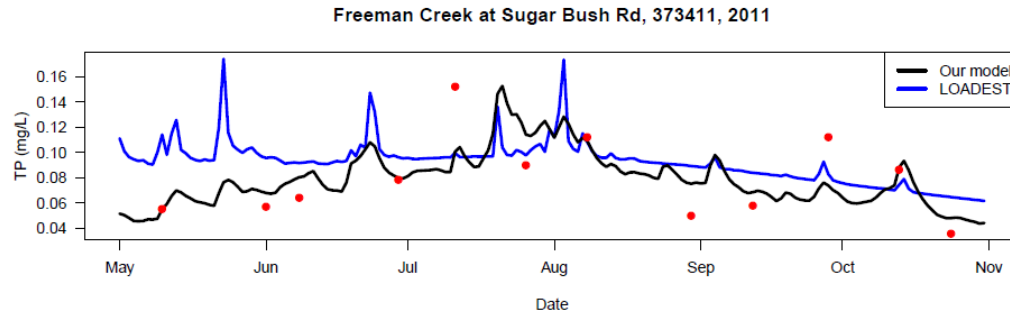
# Site-specific responses of TP to precip.





# Site-level comparisons to LOADEST:

## Our model is similar, and sometimes better



# Site reports:

Auto-filled & generated  
for each site

## TSS Model - Site Report

model run by RStudio User: latzka

on: 2016-09-19

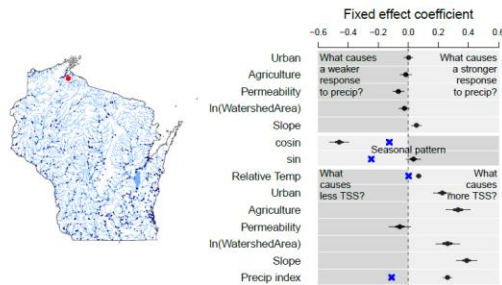
### Introduction

This report presents results from a model developed by Matt Diebel and Alex Latzka (WDNR Bureau of Water Quality). The model predicts daily total phosphorus (TP) or total suspended solids (TSS) for individual stream reaches throughout Wisconsin. Predictions are made from catchment-level attributes like watershed area, slope, soil permeability, and land use, and weather attributes including daily standardized temperature relative to that week of the year and a standardized precipitation index that sums precipitation over the preceding days, where each day is weighted by a function that determines the appropriate lag and decay between precipitation on a given day and future TP or TSS. These variables have been fit to observations of TP and TSS across Wisconsin in a mixed effects model that allows the model intercept and slopes between TP/TSS and various watershed and weather variables to vary among sites. The model structure is shown below in R "lme4" formatting.

```
## log(TSS) ~ PS * (SLOPE + log(WSA) + PERM + AG + URB) + SDT +  
## CDT + TTD + (1 + SDT + CDT + TTD + PS + I(PS^2) | STATION_ID)
```

Model developers can be reached at Matthew.Diebel@wisconsin.gov and Alexander.Latzka@wisconsin.gov.

### Statewide Model Summary

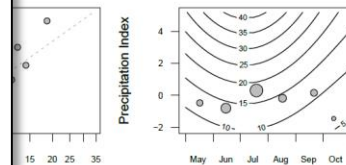


1

TSS for station: White River Down Stream of

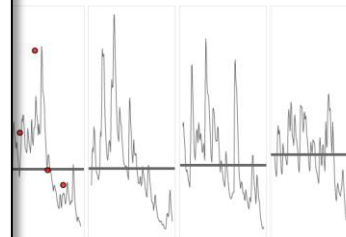
### Predictions

predicted to observed TSS values to assess model performance for your site. The left plot is a scatterplot of predicted vs observed values. The right plot is a contour plot of predicted vs observed values as a function of seasonality and precipitation index. Points display observations, where observed TSS is proportional to predicted TSS.



### Observed TSS

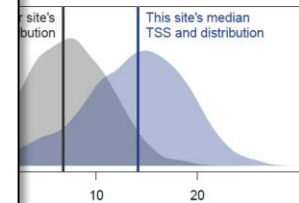
TSS values. Red dots are observations and gray horizontal lines



2

ated mean or median TSS concentration at White River Down Stream of all other sites, we can use the shape of the distributions of all other sites. This allows us to assess not only the center of the distribution but also the tail. The plot below compares the probability density function for this site to those for all sites across the state. A probability density function in which the area under the curve is equal to one, so that we can compare the proportion of days in which that TSS is greater than or equal to a certain TSS value as the proportion of days in which that TSS is greater than or equal to a certain TSS value. In addition, the kurtosis is a measure of whether the data are heavy-tailed or light-tailed. It reflects how tightly peaked around the mean your site is, so that we can compare the proportion of days in which that TSS is greater than or equal to a certain TSS value as the proportion of days in which that TSS is greater than or equal to a certain TSS value. Thus, even if a site has a low geometric mean TSS, and it has a considerable number of days at high TSS.

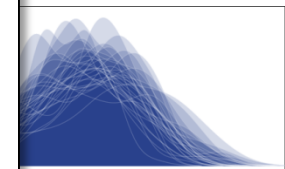
ave 15 mg/L TSS	proportion days above 60 mg/L TSS	kurtosis
0.00	-0.15	-0.13
0.00	-0.13	-0.13
0.00	-0.13	-0.13



TSS mg/L

3

g years (1981-2014)



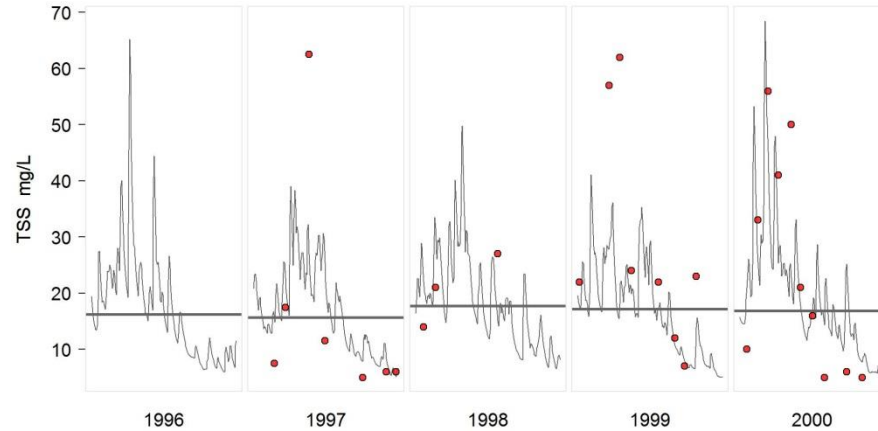
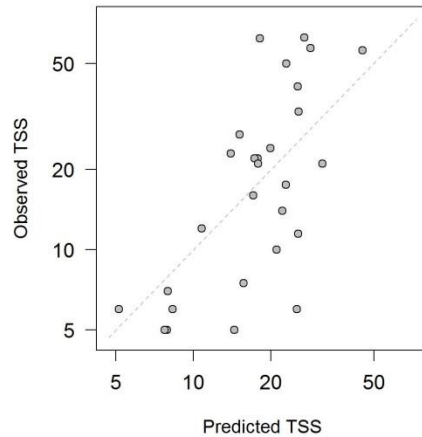
TSS mg/L

Markdown script written by Alex Latzka. Please contact

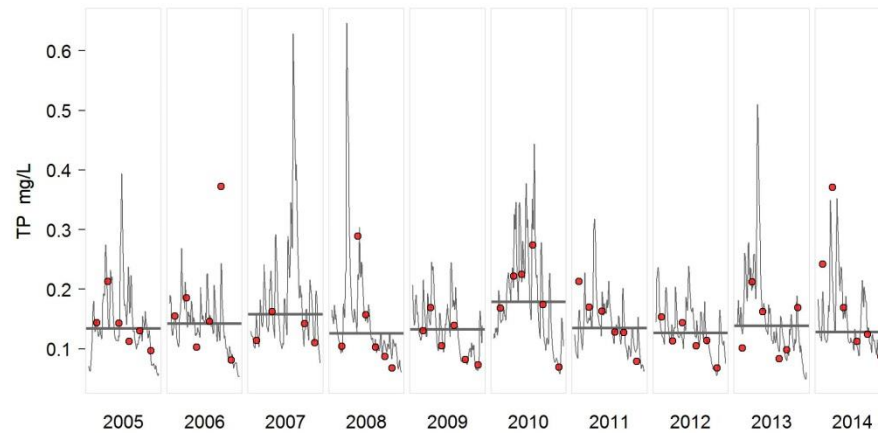
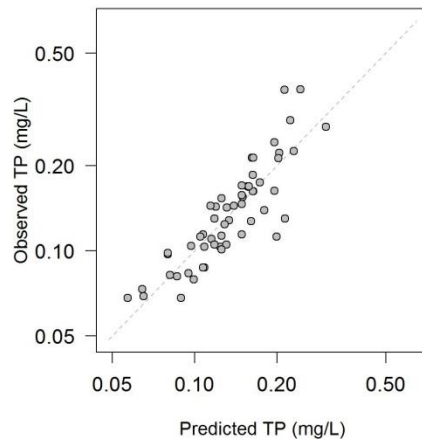
4

# Site-level model outputs

## TSS Model (Sugar River)

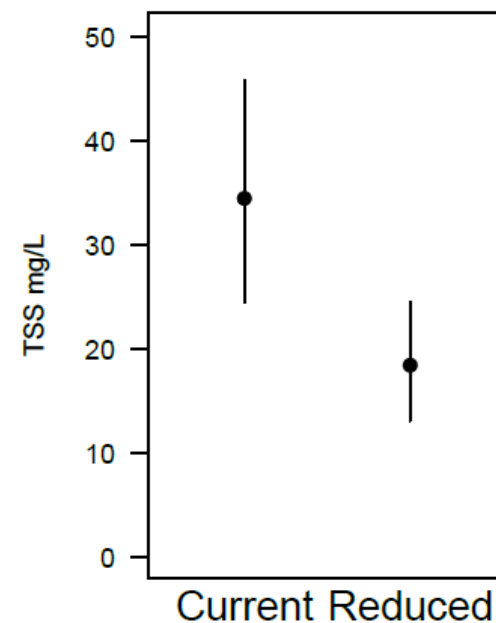
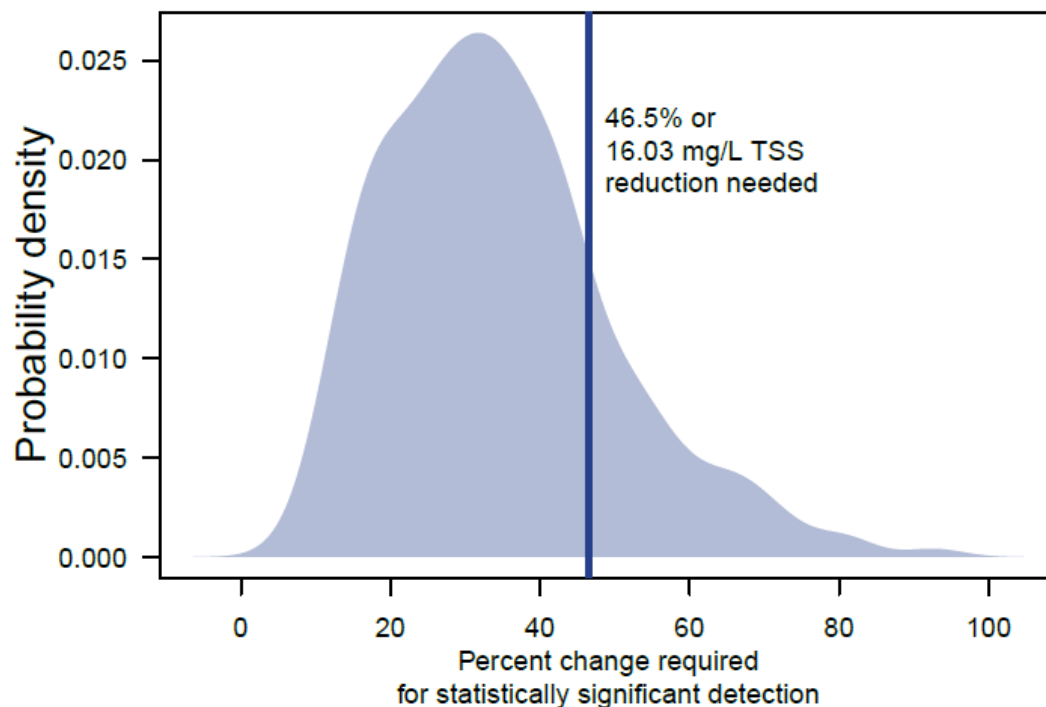


## TP Model (Kickapoo River)



# Inferring power to detect change

*What is the minimum detectable TP/TSS reduction?*

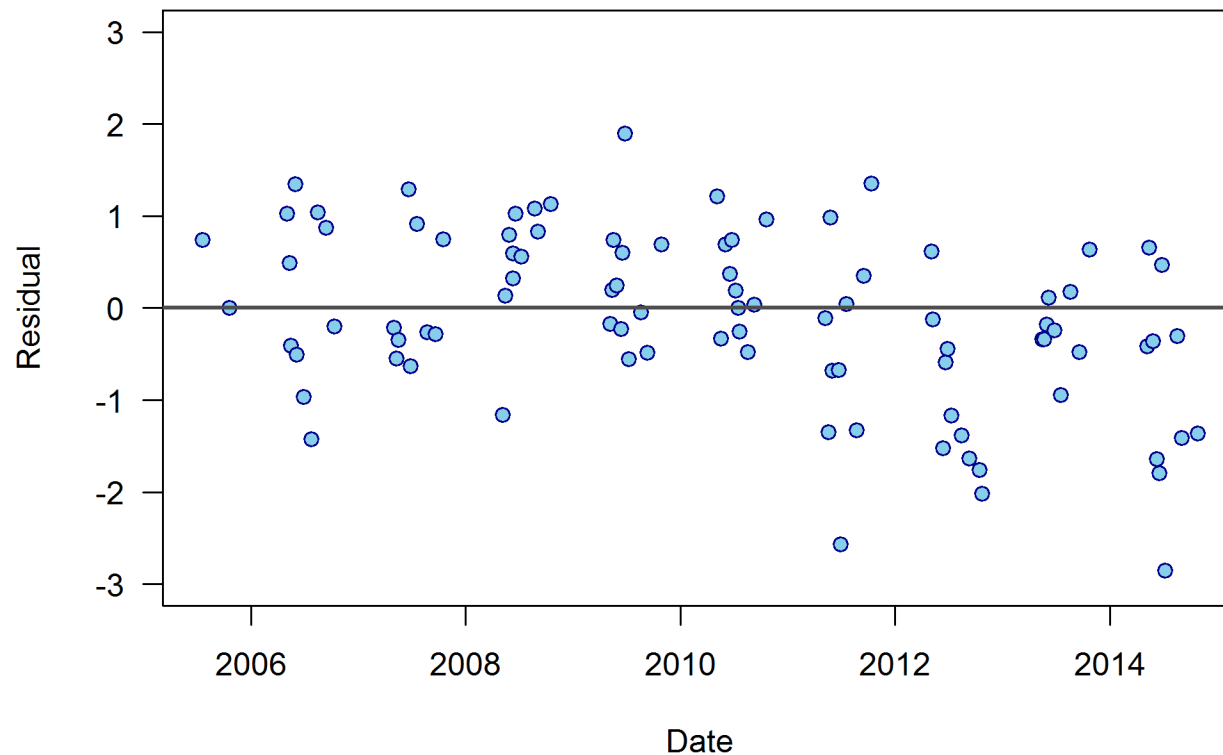




# *Has TP or TSS changed?*

Look at time series of model residuals (after controlling for weather, seasonality, etc.)

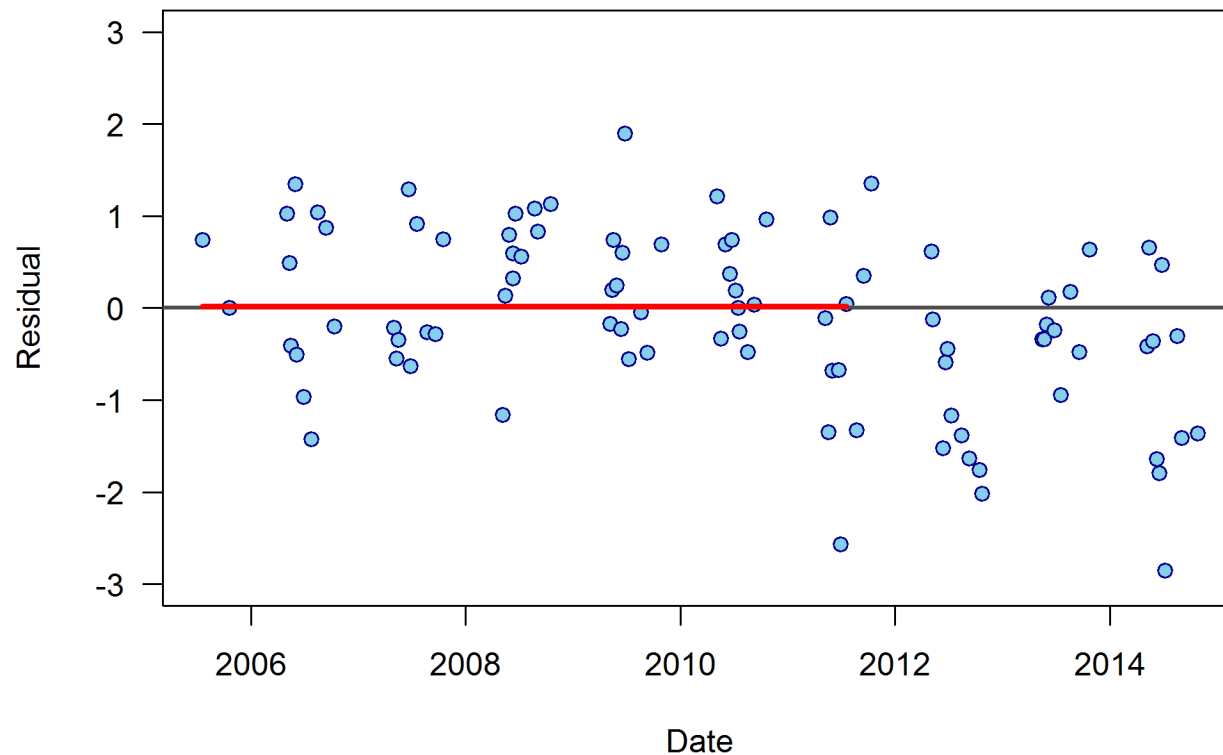
- Without any change, these should be randomly distributed along the 0 line
- If there is a change, there will be a shift at some time
- Test for a shift with “segmented regression”



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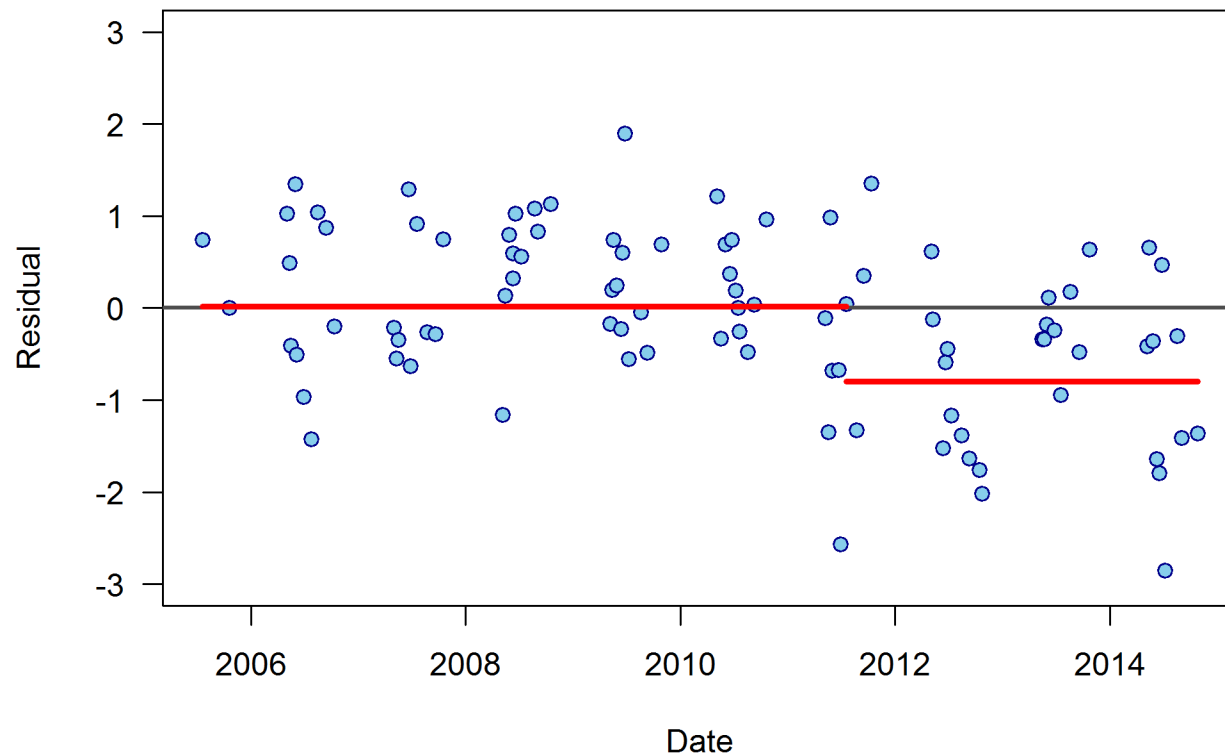
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