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

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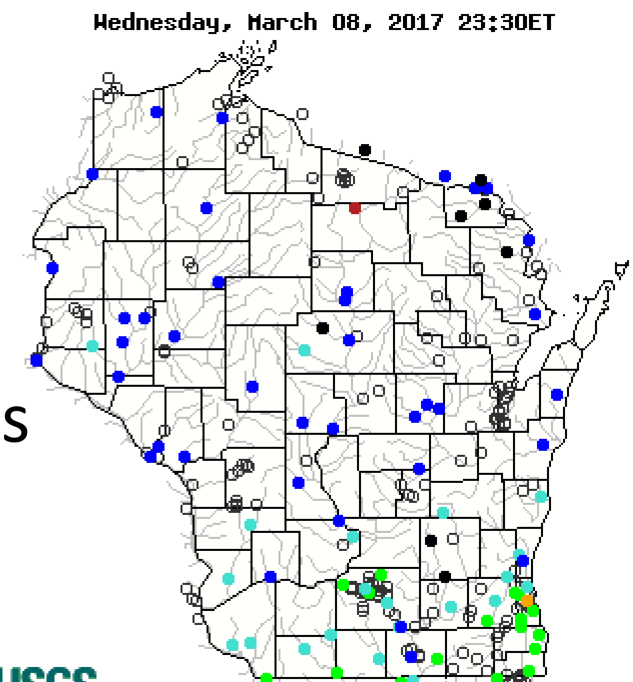
Motivation

- 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

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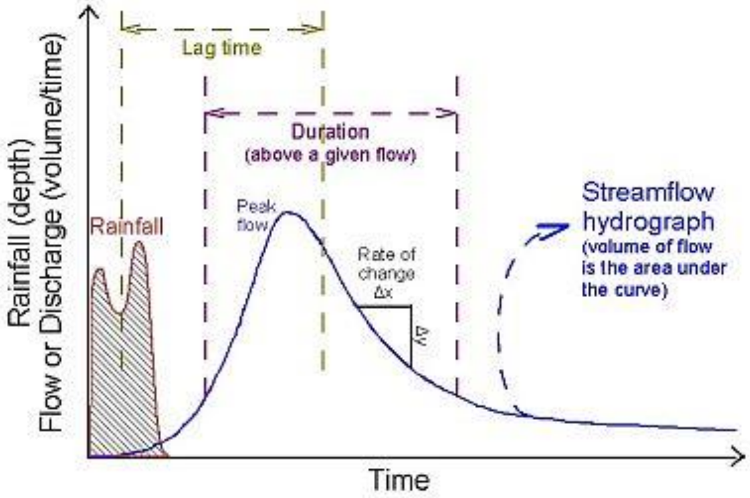
Use ***antecedent precipitation*** instead of *discharge*

Antecedent precipitation in lieu of discharge



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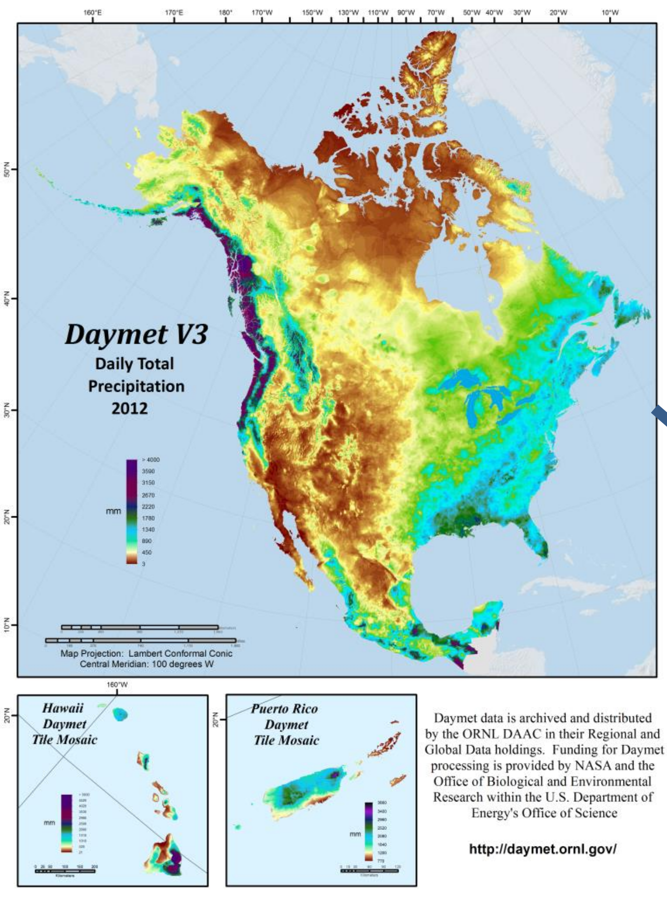
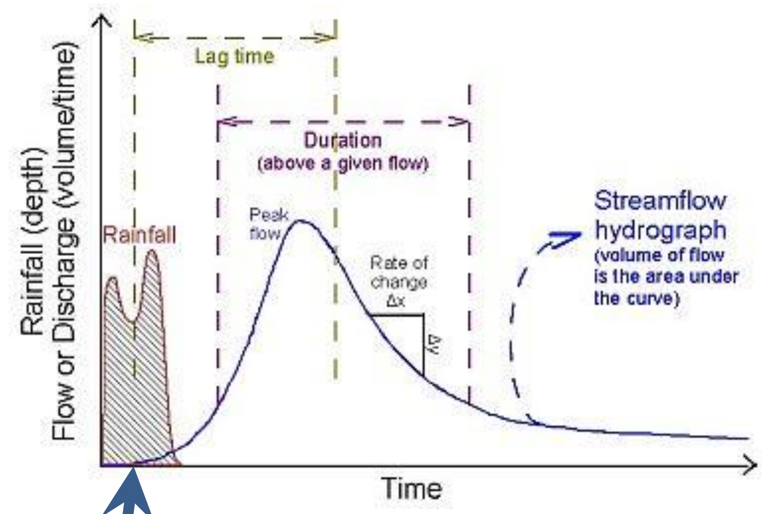
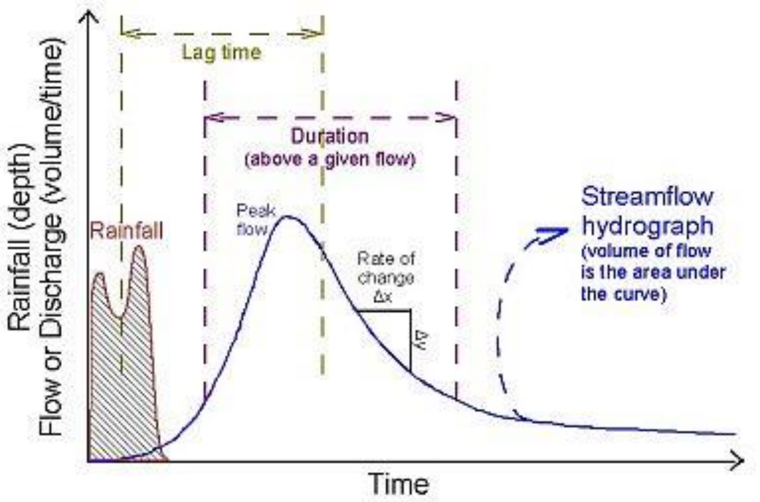




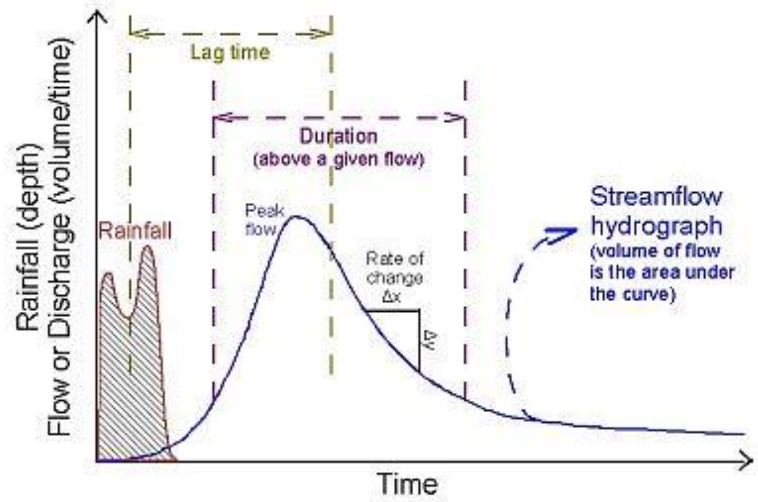
Antecedent precipitation in lieu of discharge

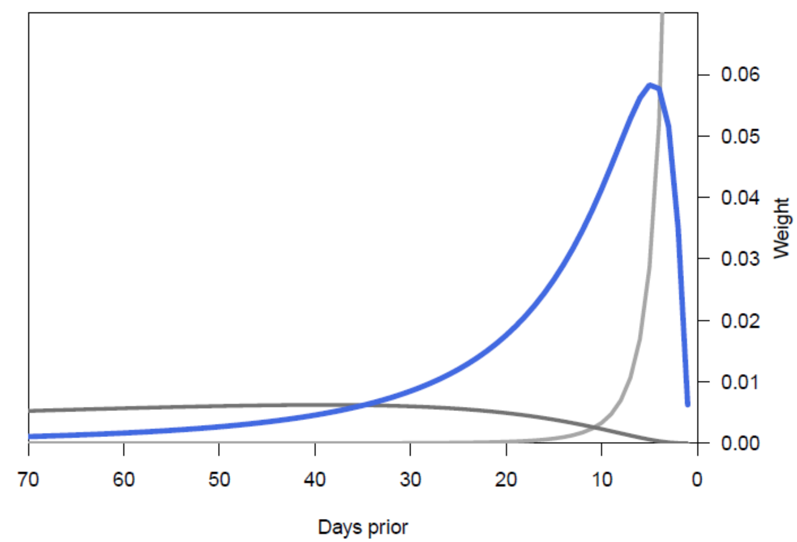
- Calculated effective precipitation
  - Precipitation + snowmelt – snow
- Sum effective precip on day of interest and 365 preceeding days, where each day is weighted by a decay function



Antecedent precipitation in lieu of discharge

- Calculated effective precipitation
  - Precipitation + snowmelt – snow
- 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*log(WSA)
  - For TP: M = 0.528 + 0.203*log(WSA) -0.043*(SLOPE)





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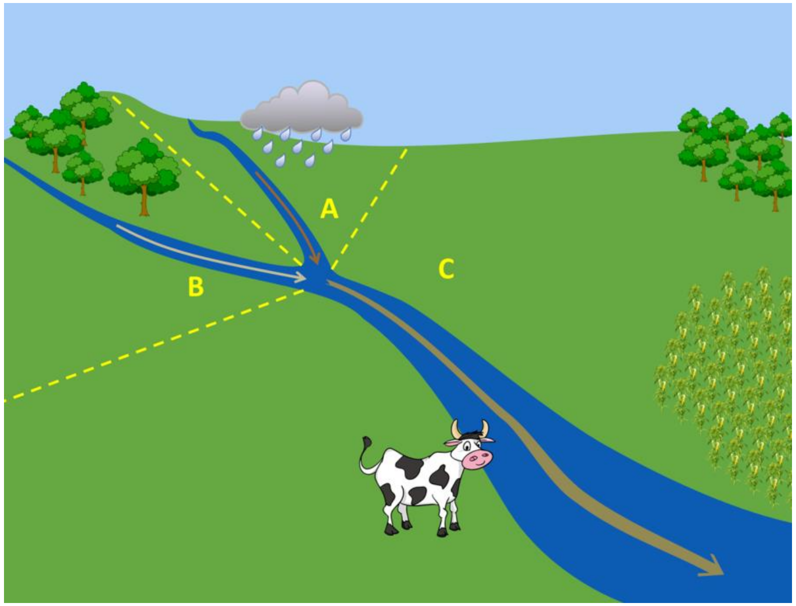
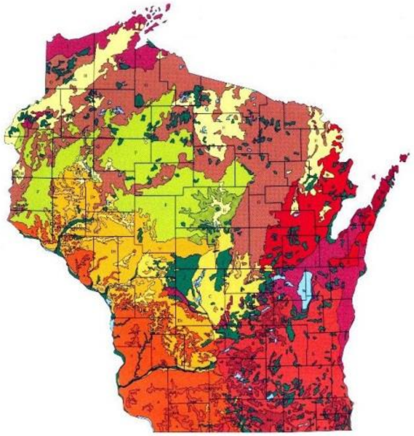
TP/TSS Model

- 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





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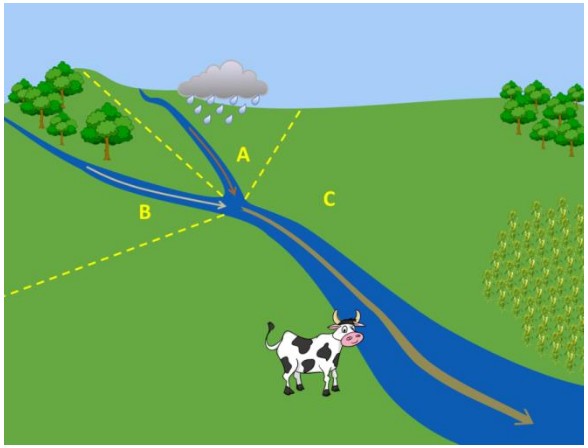
Model structure



Predict TP and TSS for stream reach C on day 1

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

<u>*X (fixed effects)*</u>
**slope*$_{ABC}$
**log(watershed area*$_{ABC}$*)*
**permeability*$_{ABC}$
**percent agriculture*$_{ABC}$
**percent urban*$_{ABC}$
sin(2πDOY)
cos(2πDOY)
7-day temp anomaly$_{ABC,1}$
antecedent precipitation index$_{ABC,1}$

<u>*Z (random effects)*</u>
intercept
sin(2πDOY)
cos(2πDOY)
7-day temp anomaly$_{ABC,1}$
antecedent precipitation index$_{ABC,1}$
antecedent precipitation index$_{ABC,1}{}^{2}$

**allowed to interact with antecedent precipitation*

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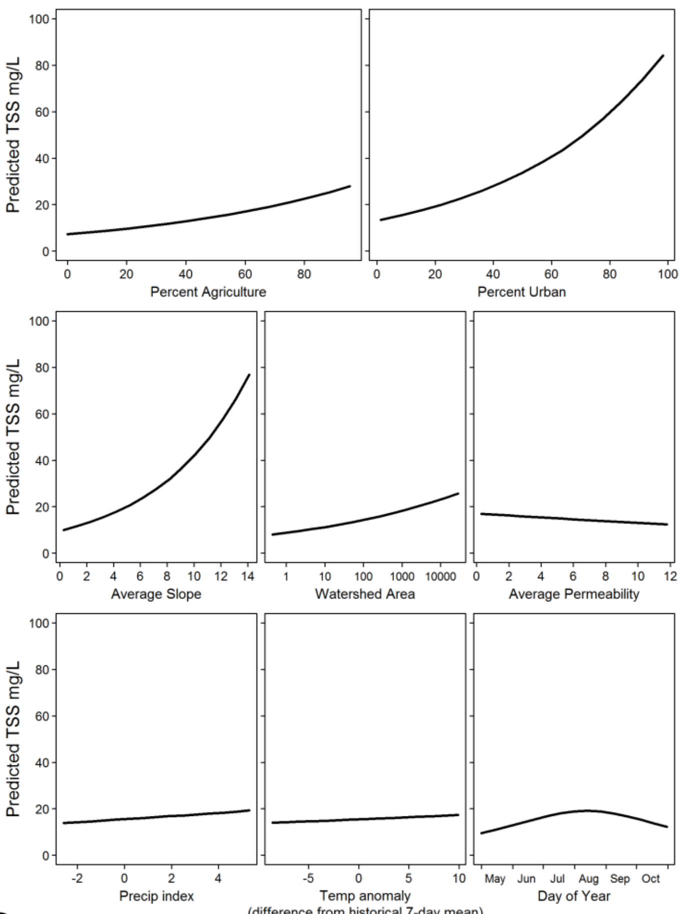
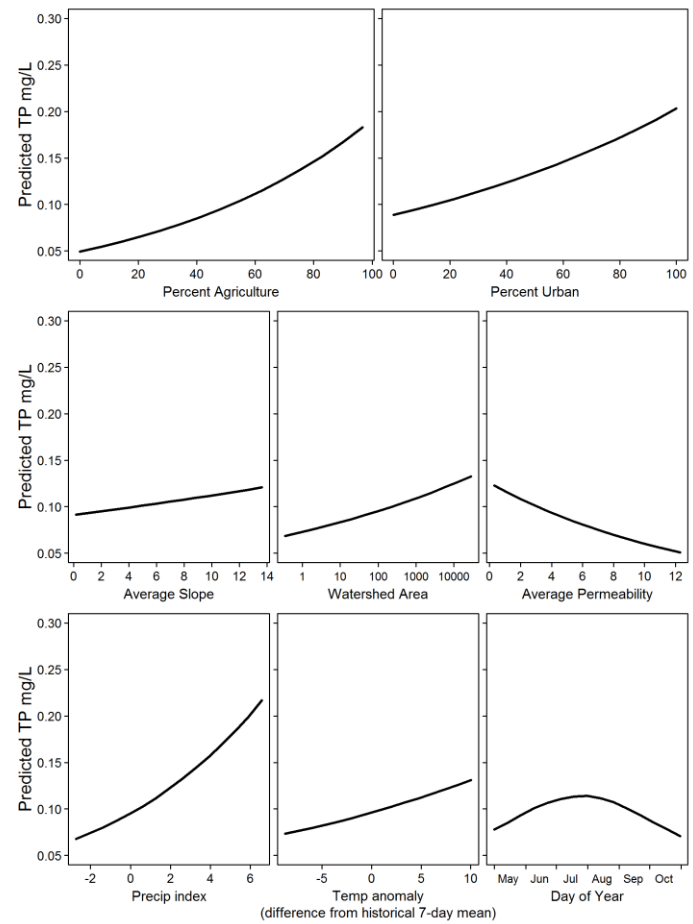
Model summary
Relative effects of each predictor

TSS Model



TP Model



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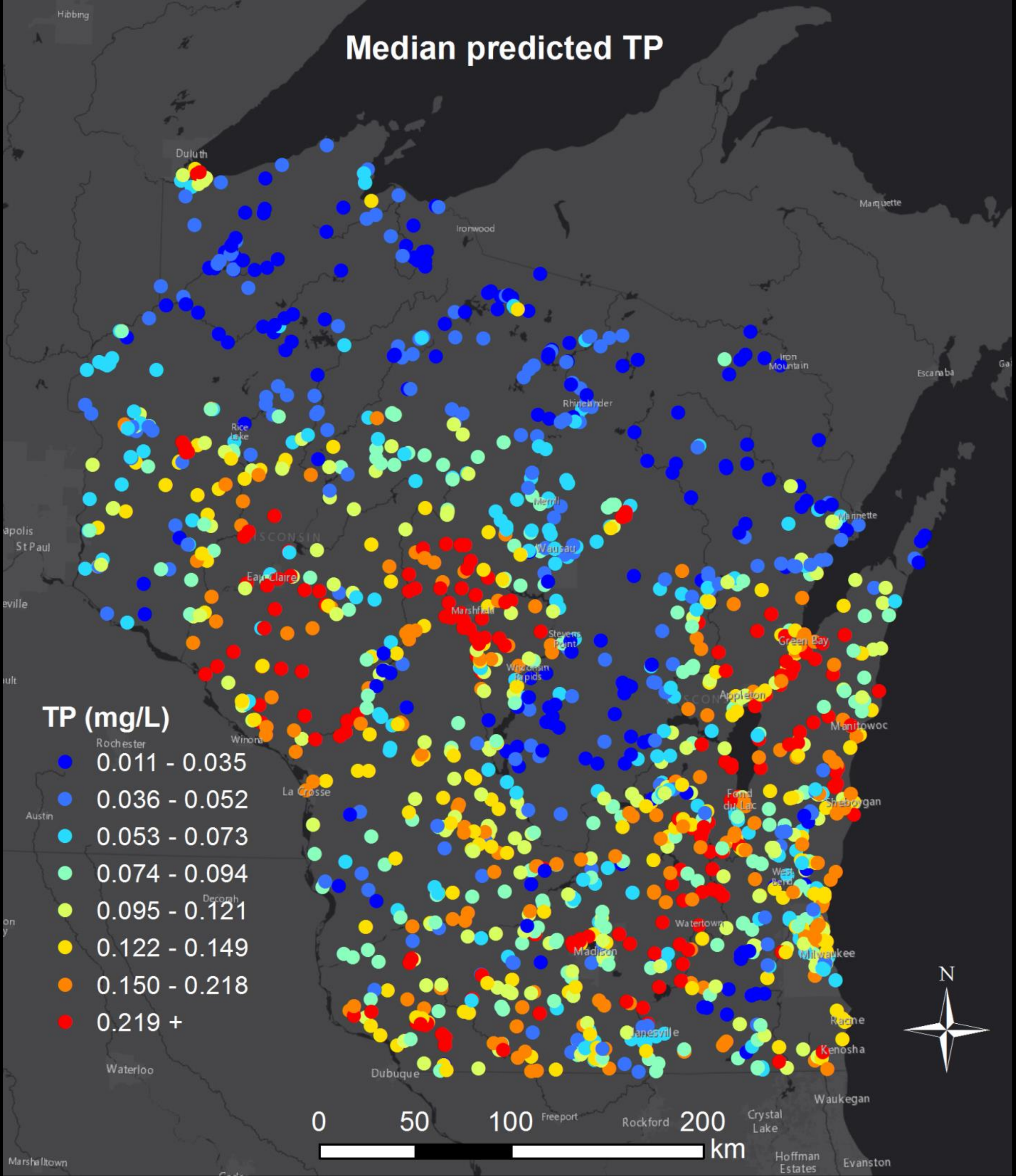
…holding other variables constant at their average values



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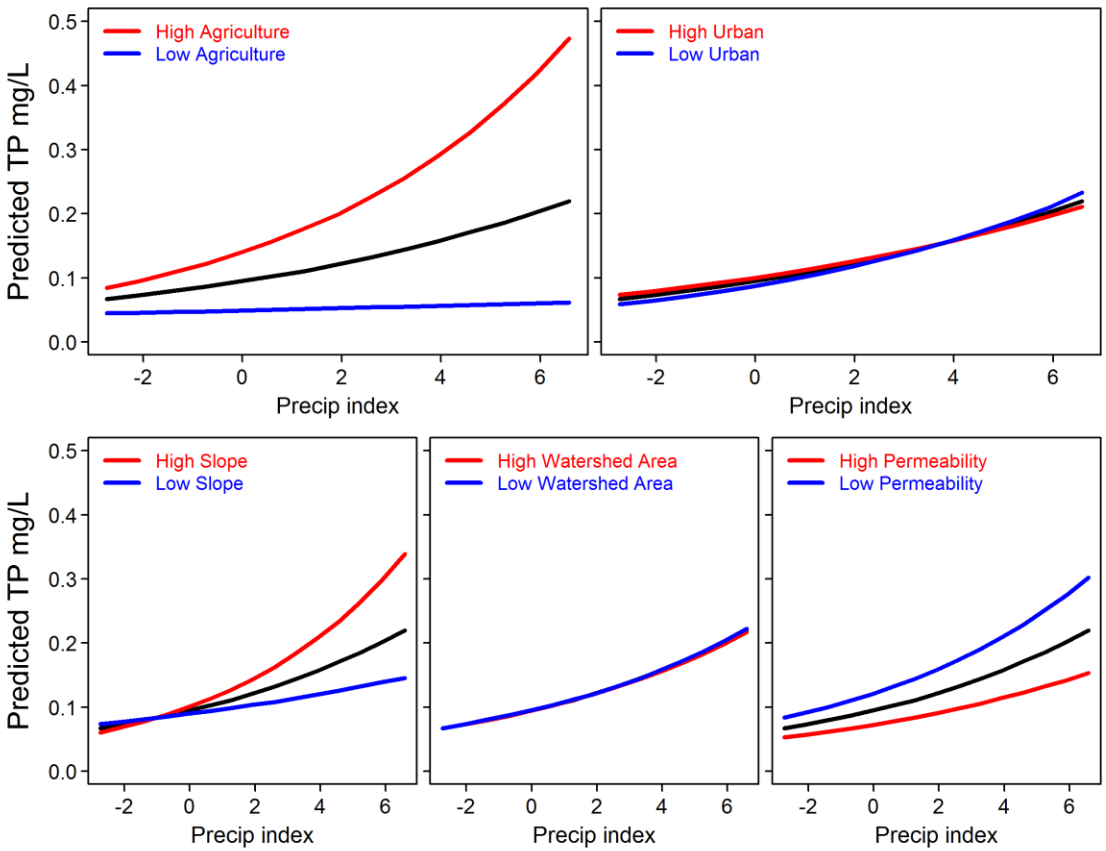
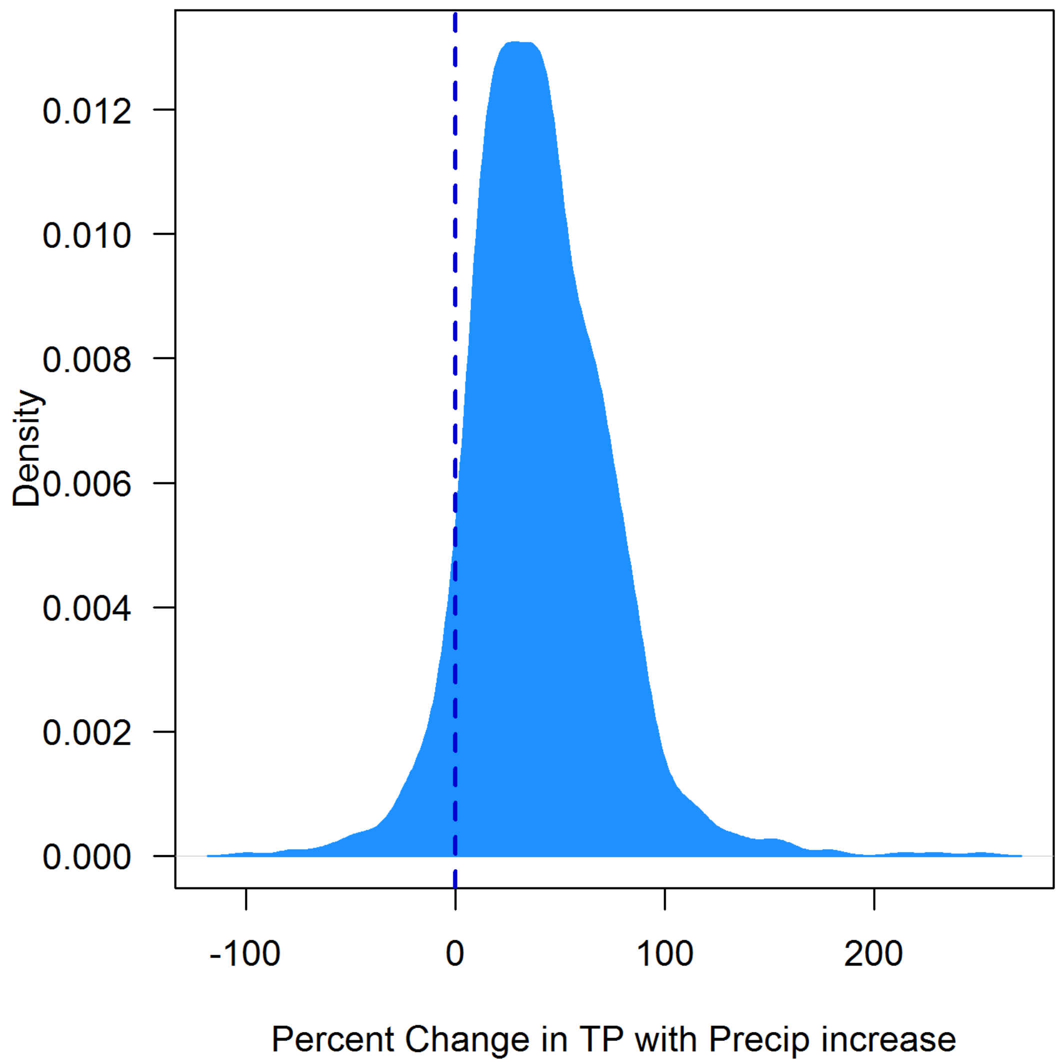
Model summary
Interactions with Precipitation

TP Model



…holding other variables constant at their average values

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



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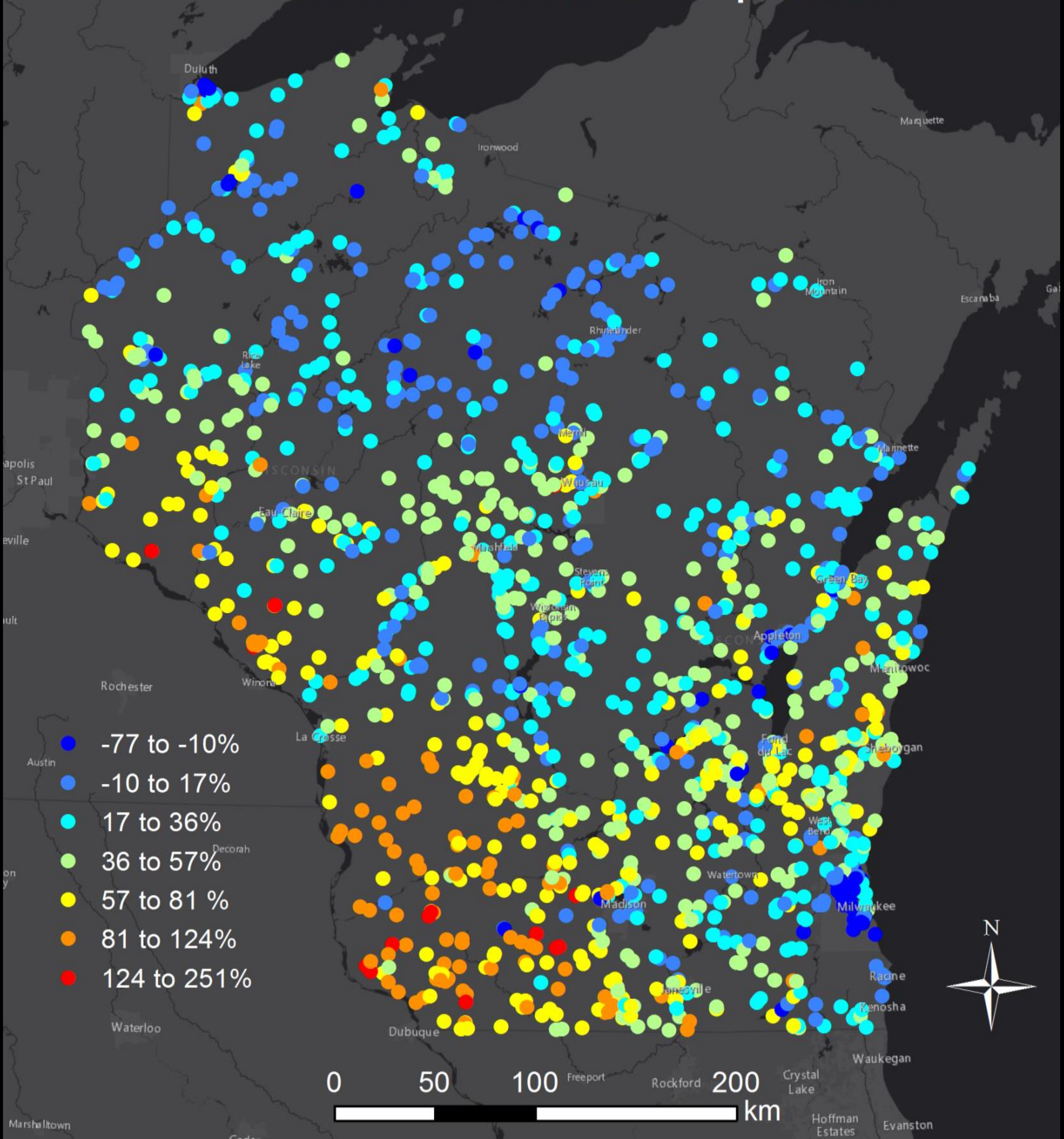
How much does TP increase if antecedent precipitation increases from 10th to 90th percentile?



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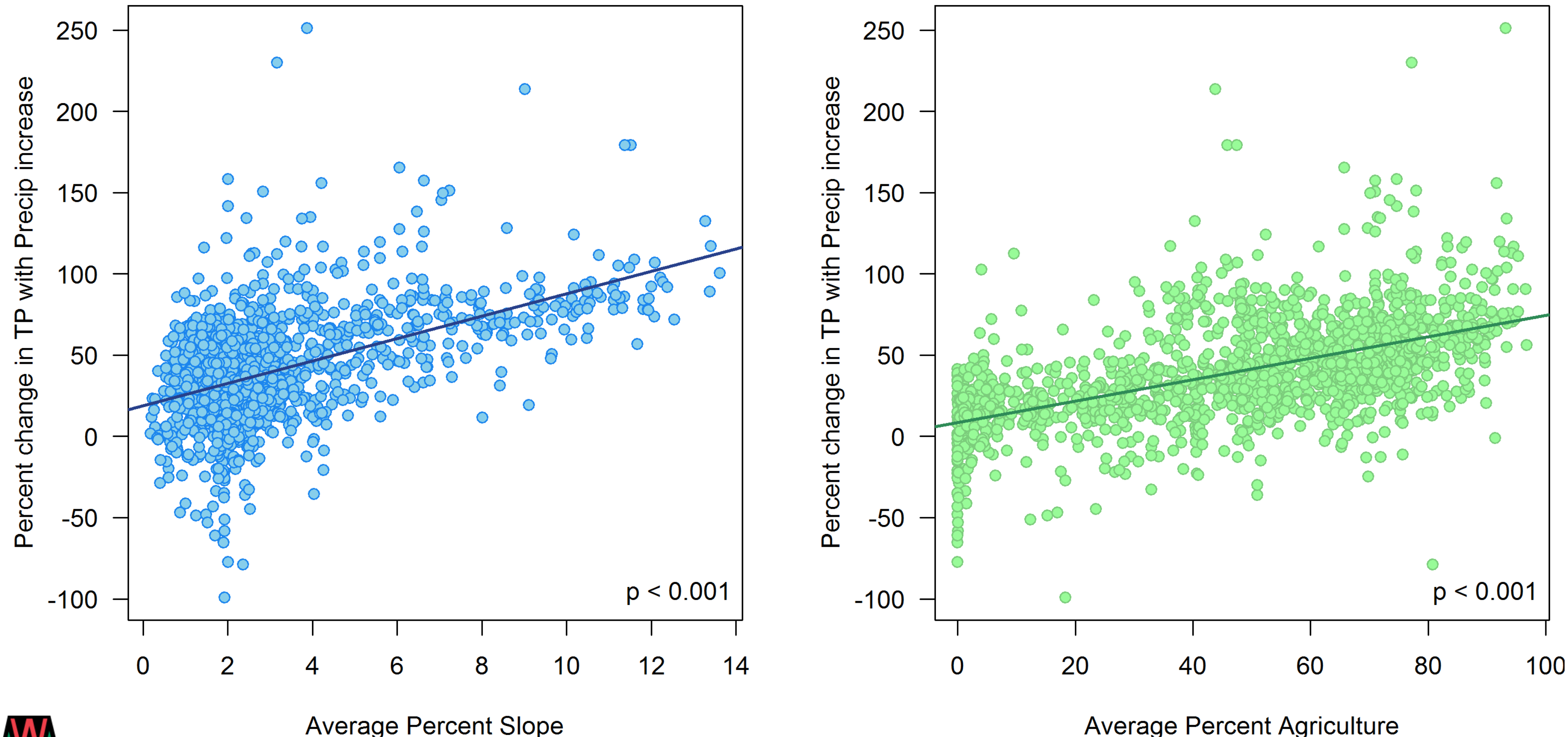
What causes differences in response to precipitation?



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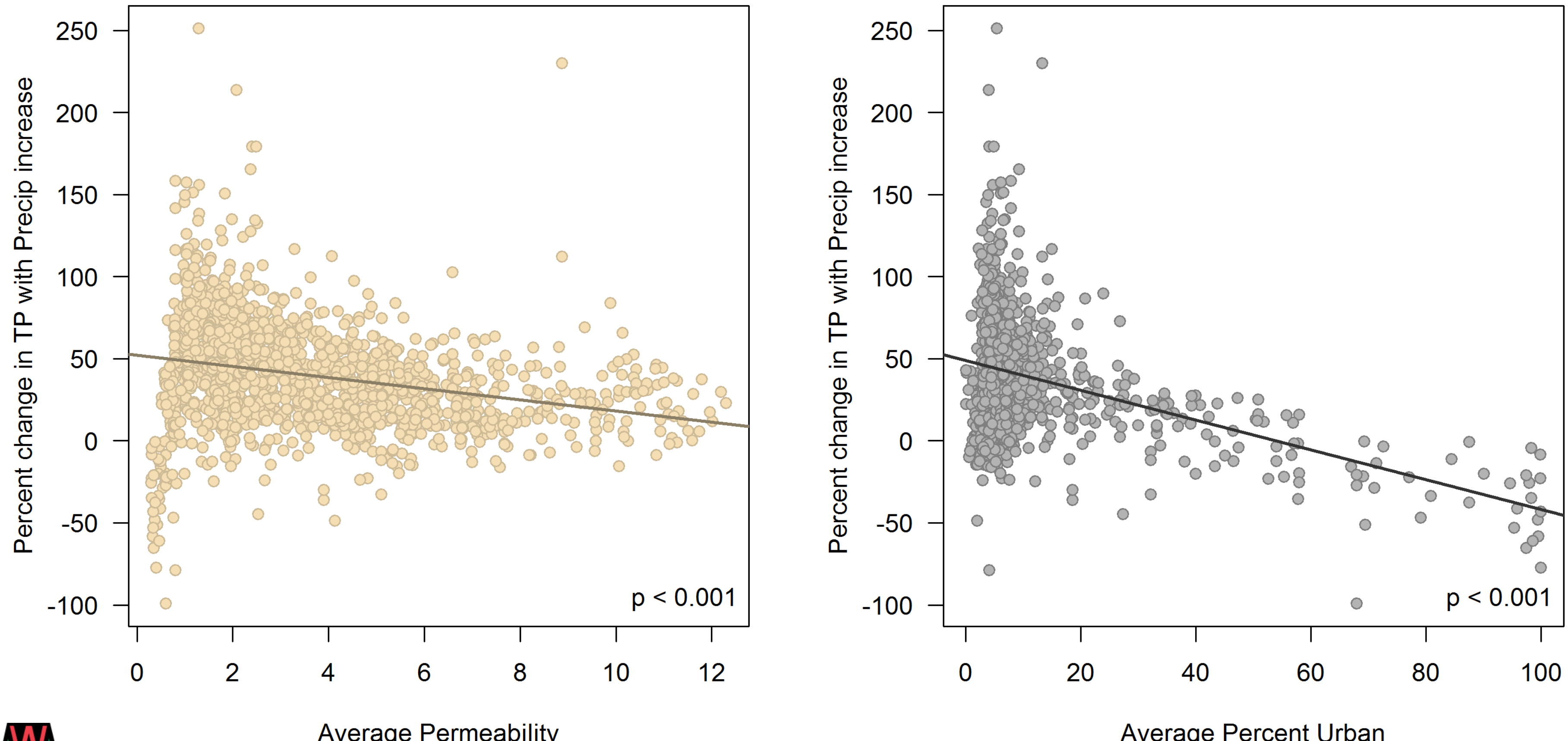
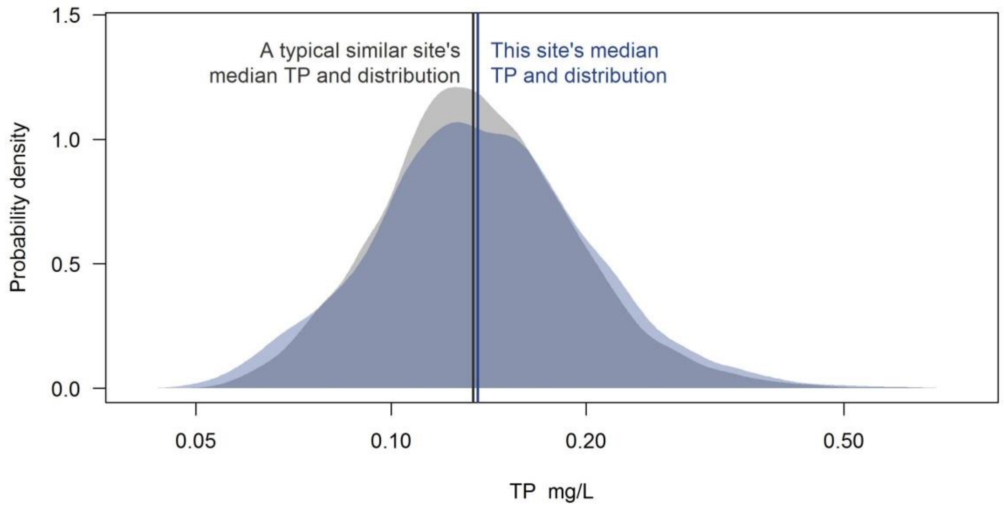
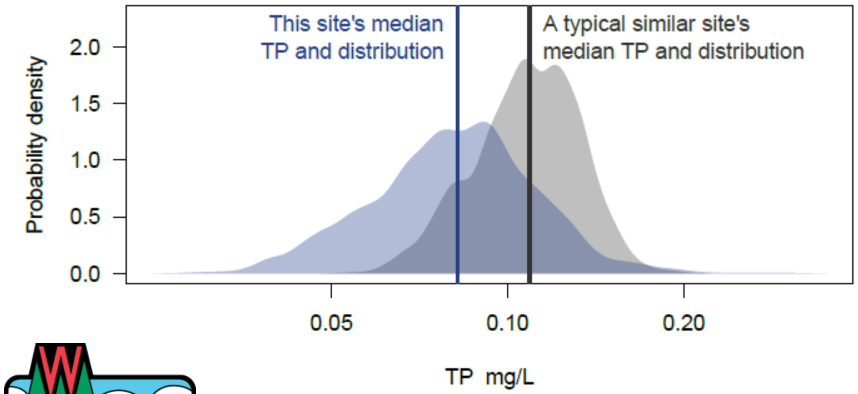


Effect of random effects

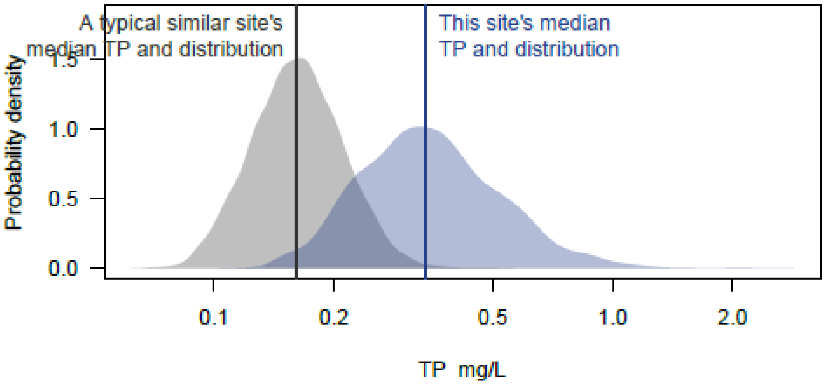
Kickapoo River



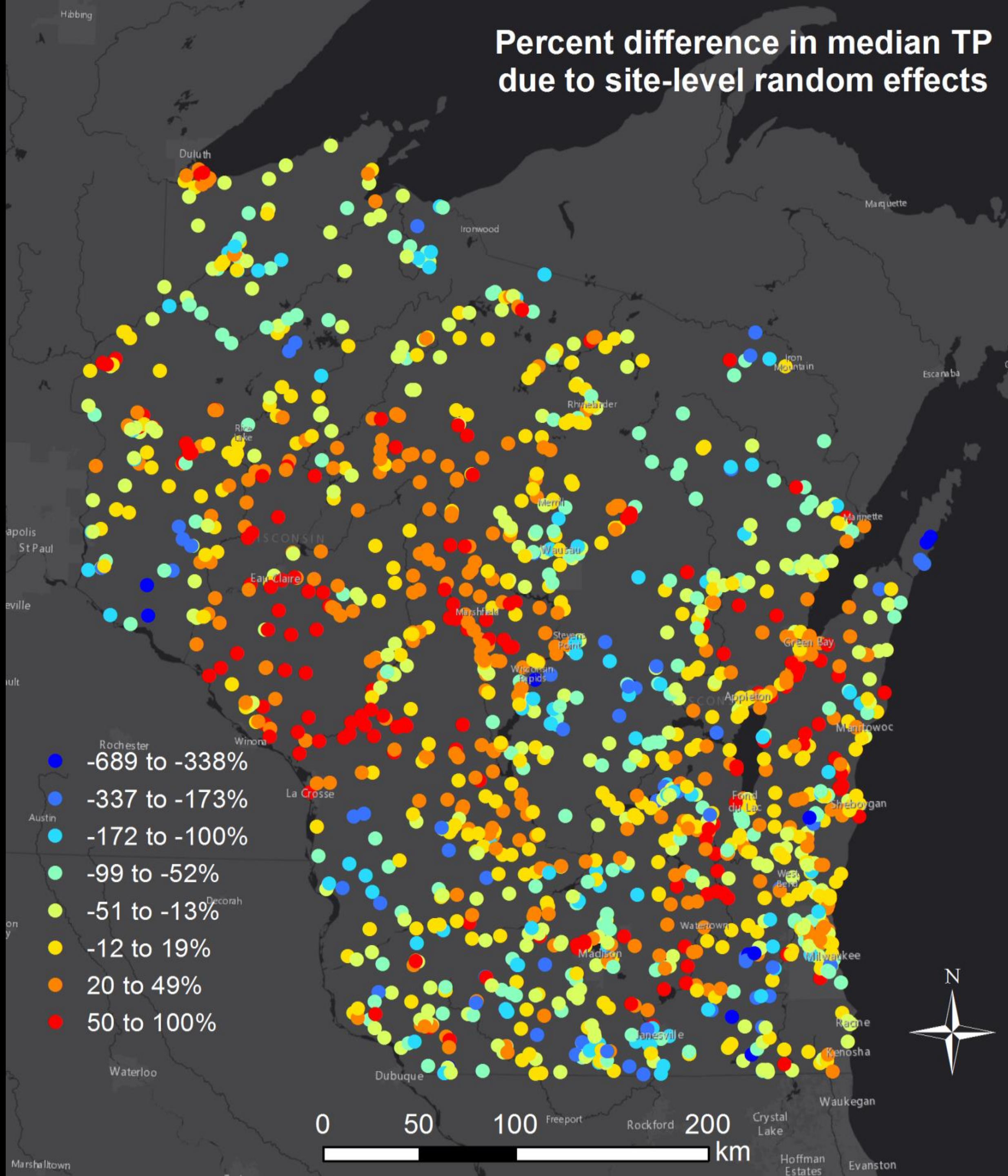
Milwaukee River



Bower Creek



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



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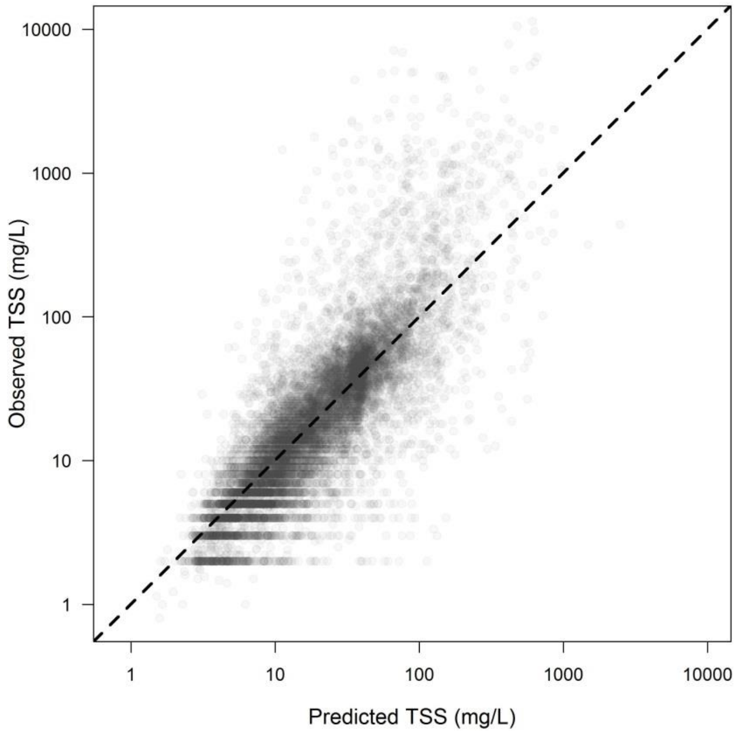
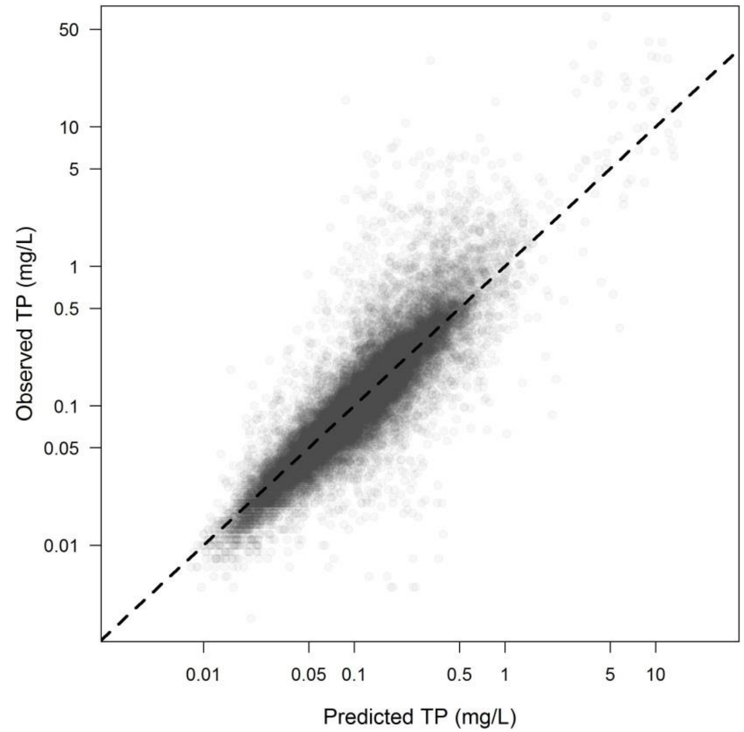
Model summary

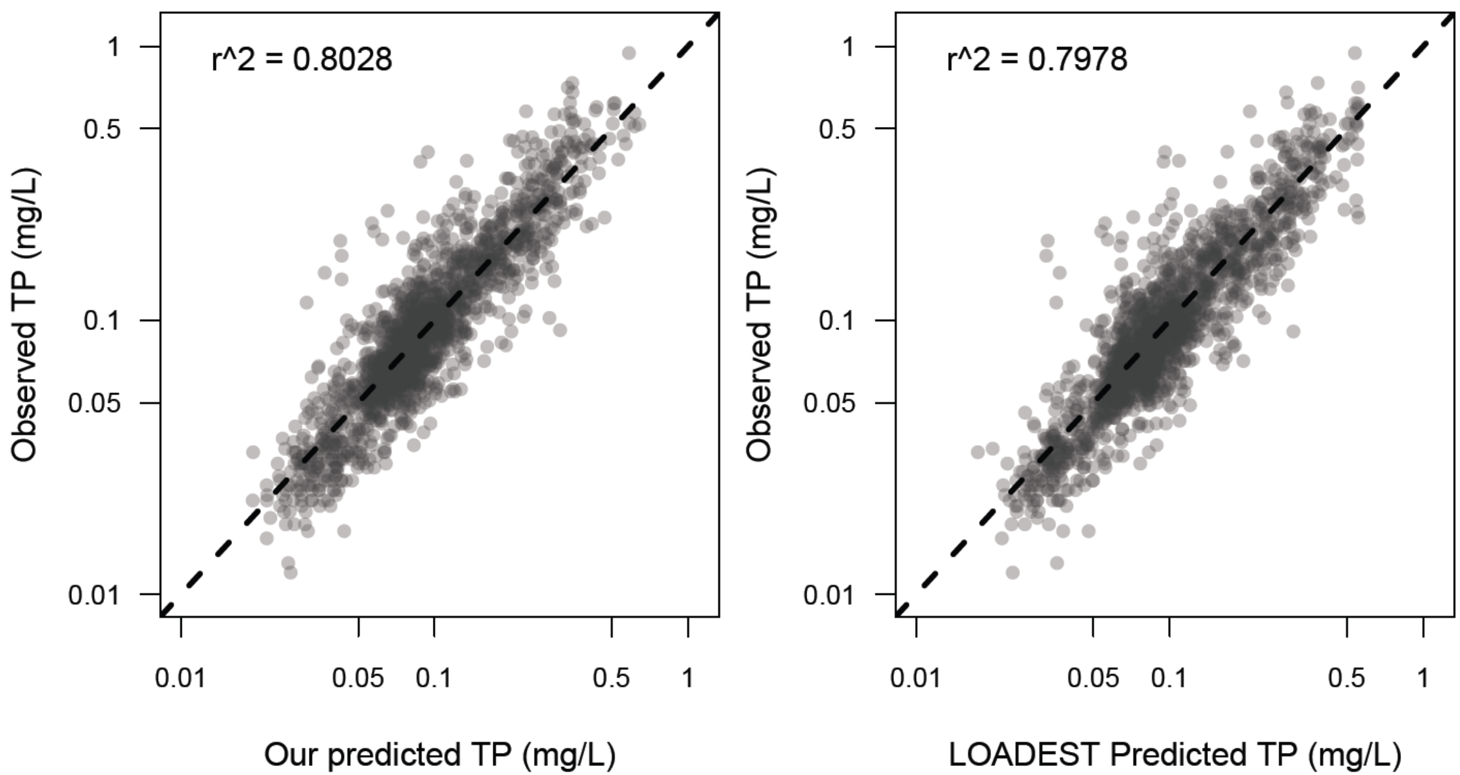
TSS Model



TP Model



Overall, TP model performs similarly to LOADEST



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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

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Questions?
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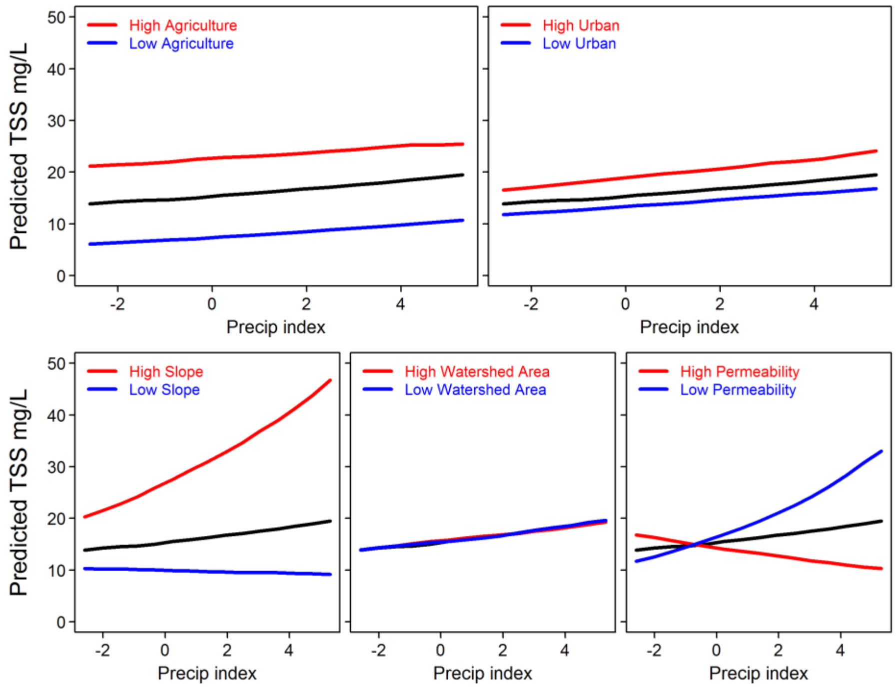
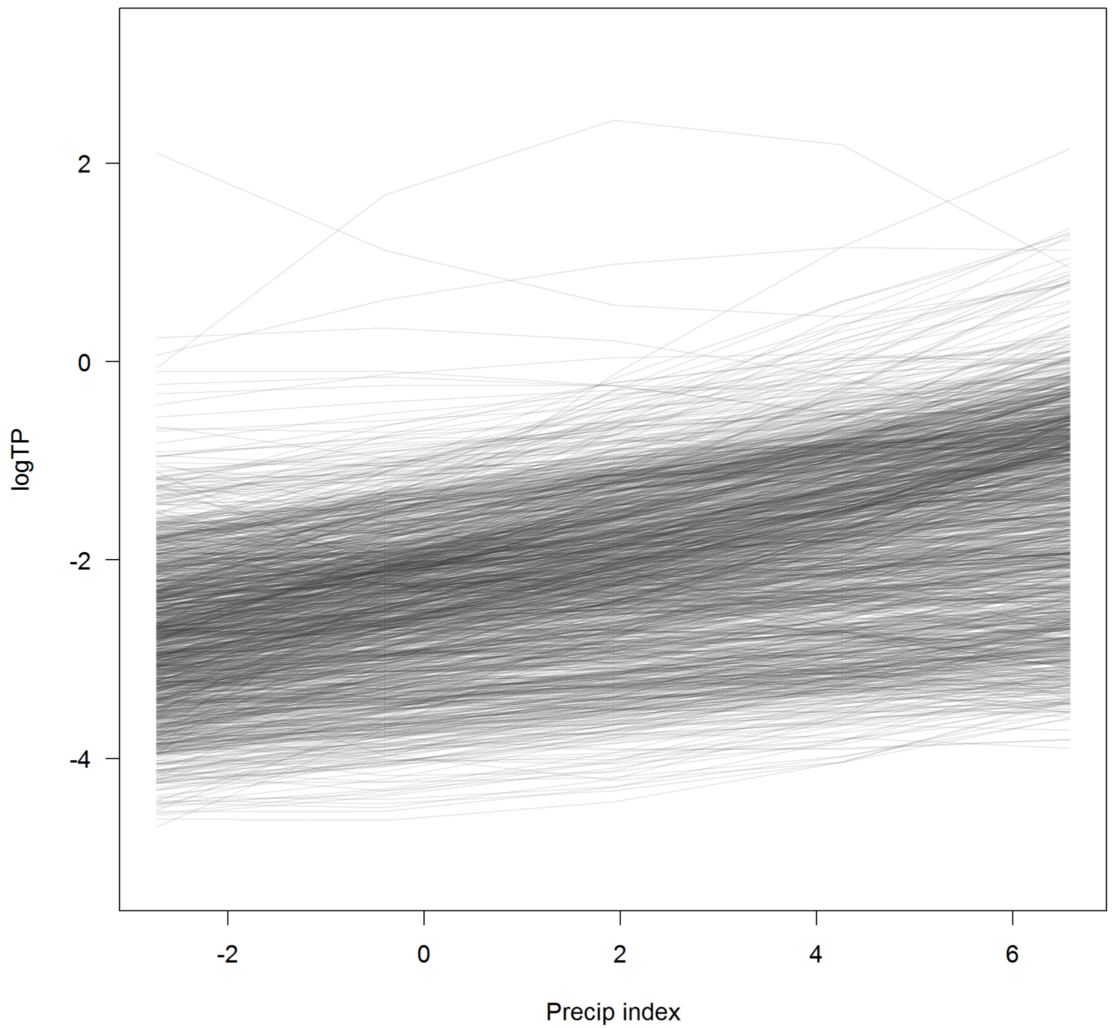
TSS Model



Predicted TSS mg/L
50
40
30
20
10
0
High Agriculture
Low Agriculture
-2
0
2
4
Precip index
High Urban
Low Urban
-2
0
2
4
Precip index
Predicted TSS mg/L
High Slope
Low Slope
Precip index
High Watershed Area
Low Watershed Area
Precip index
High Permeability
Low Permeability
Precip index

Site-specific responses of TP to precip.



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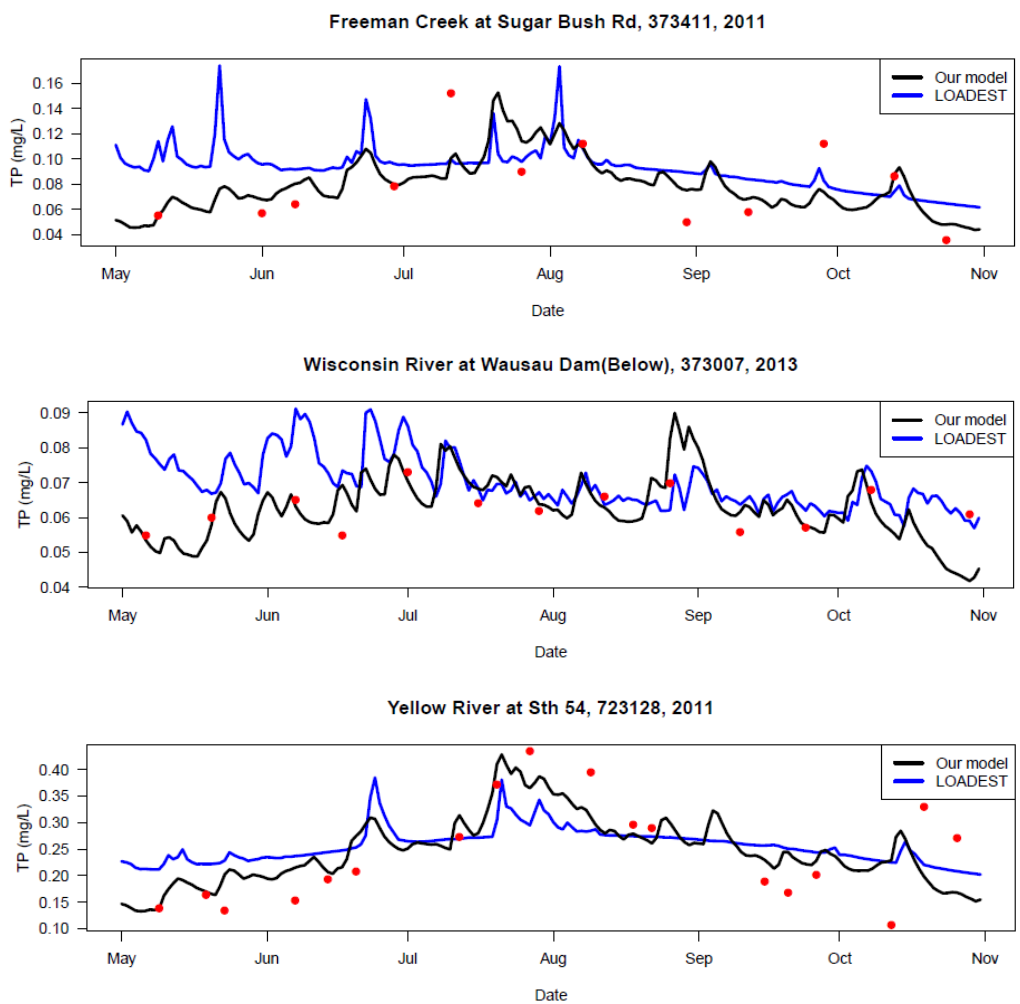
Site-level comparisons to LOADEST: Our model is similar, and sometimes better



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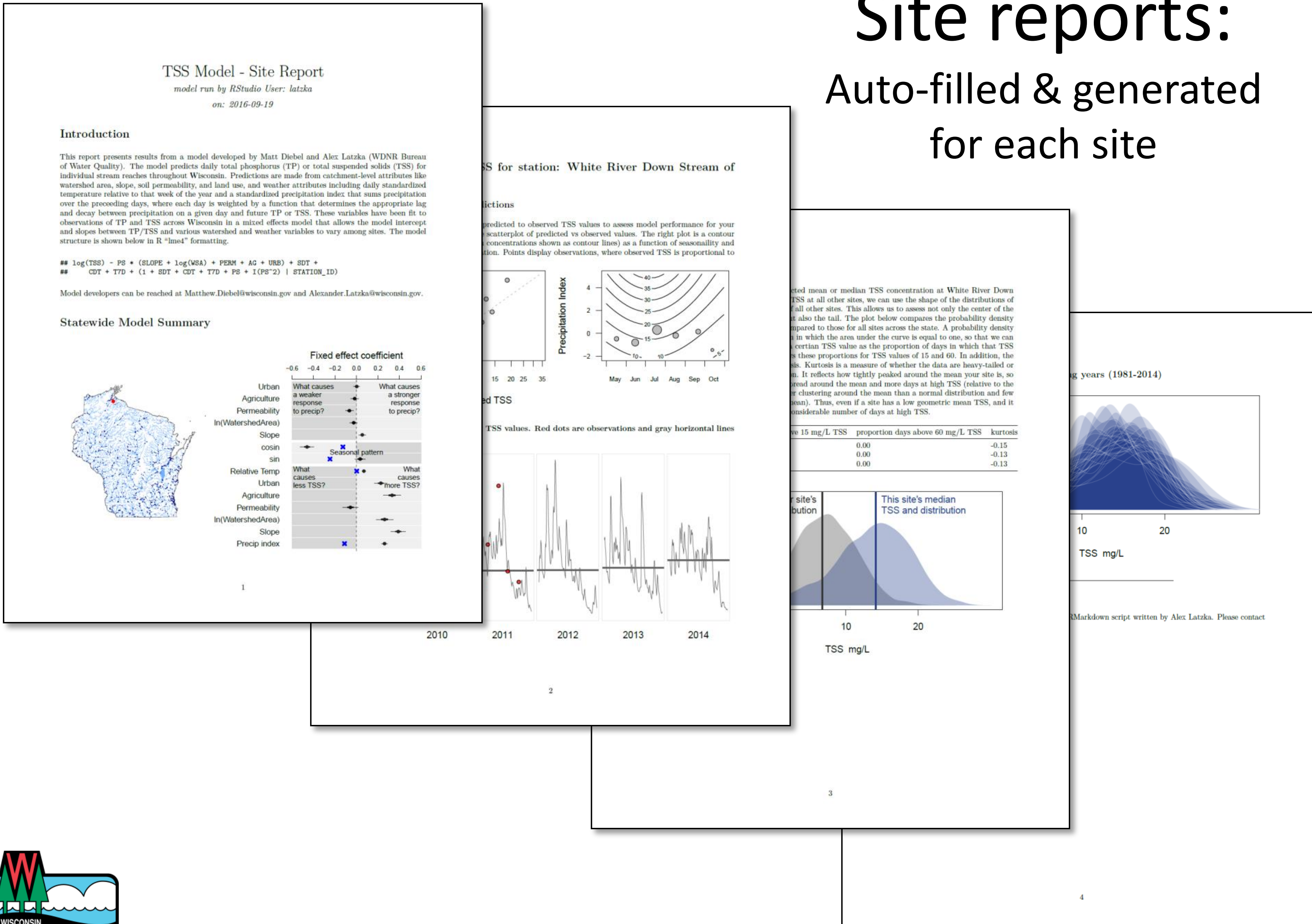
Site reports:

Auto-filled & generated for each site



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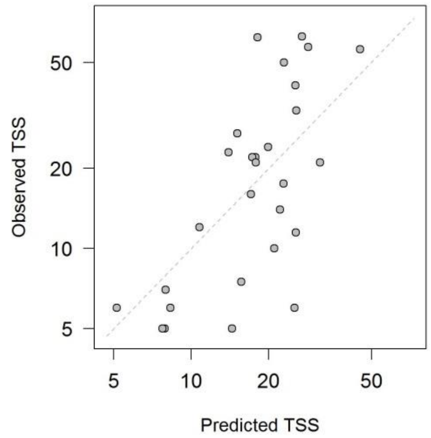
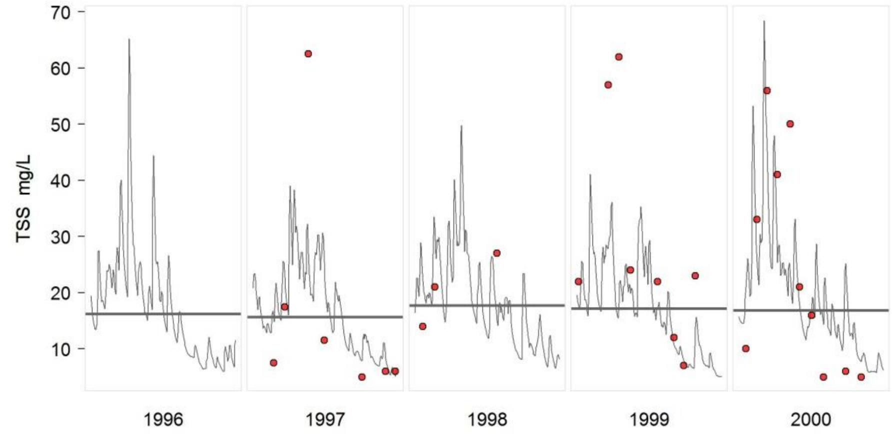
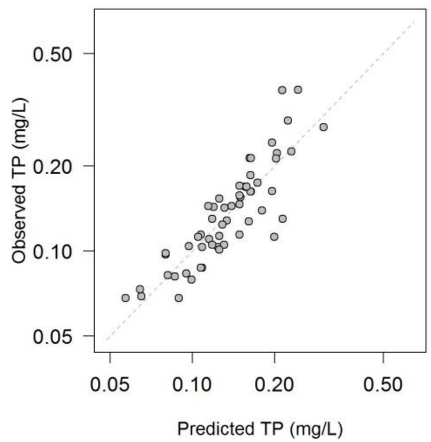
Site-level model outputs

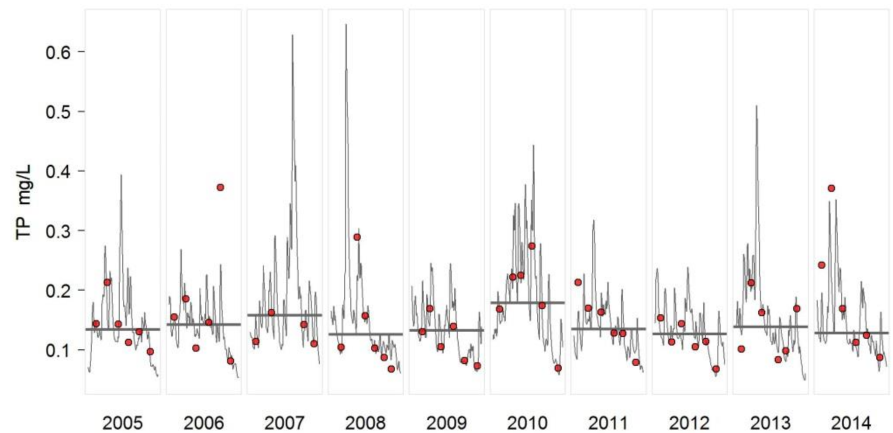
TSS Model (Sugar River)





TP Model (Kickapoo River)





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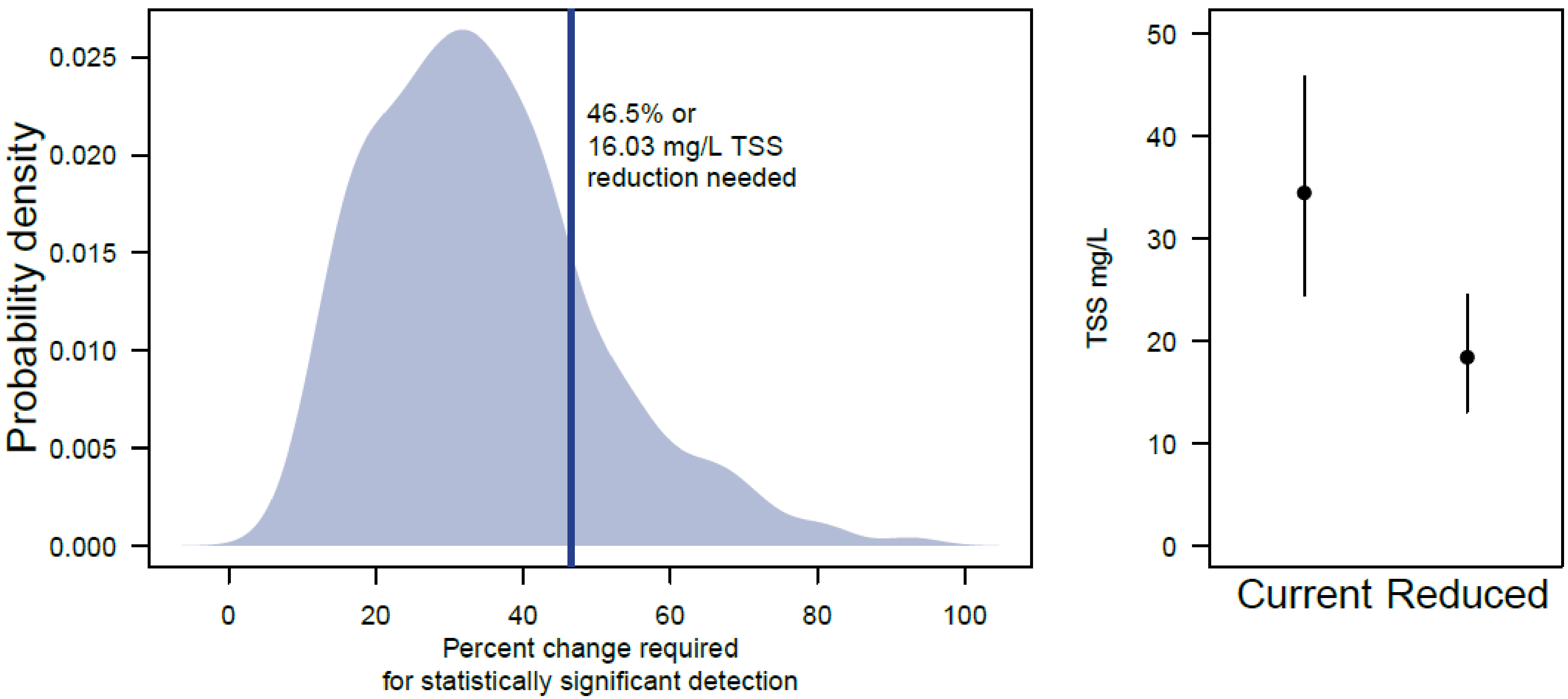
Inferring power to detect change

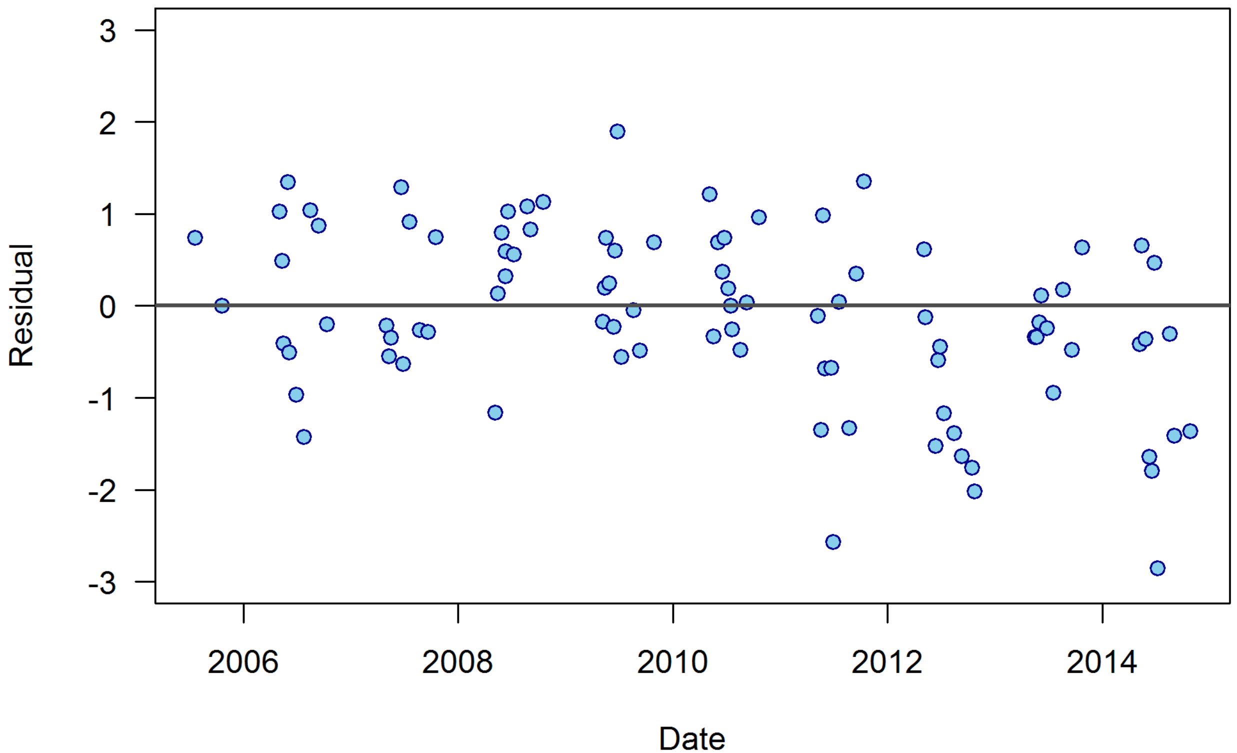
What is the minimum detectable TP/TSS reduction?



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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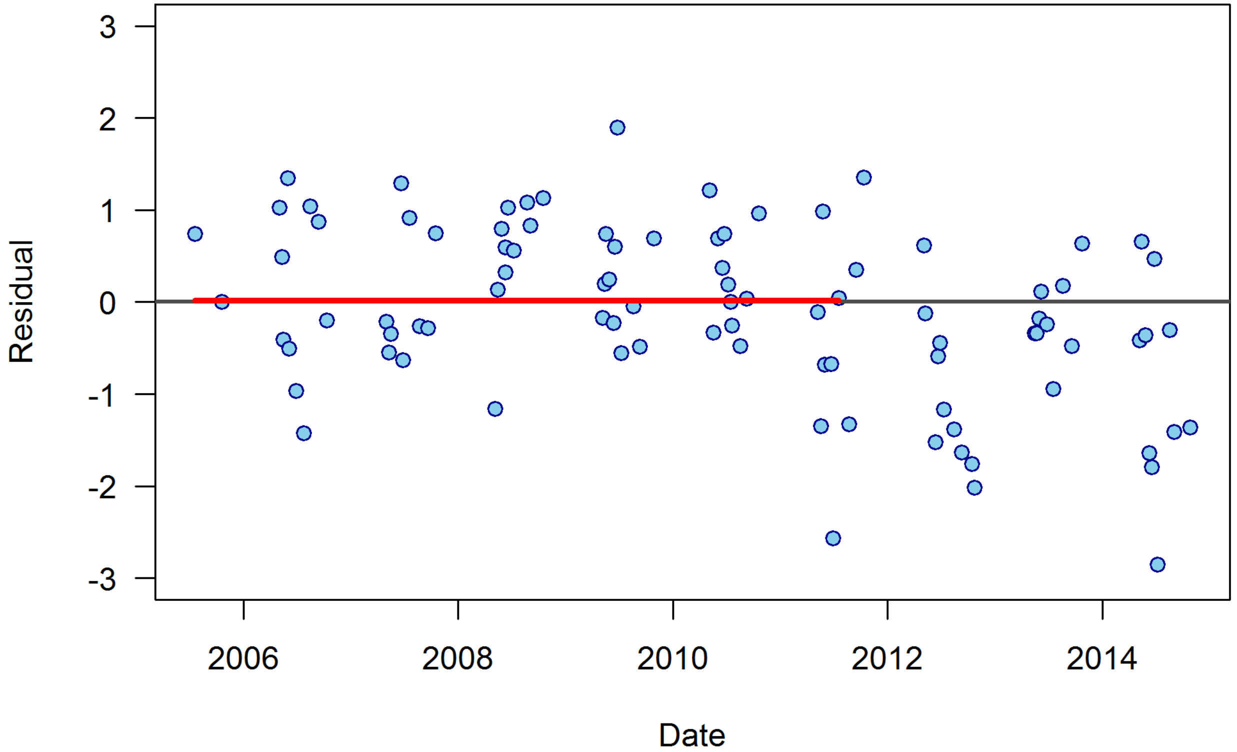

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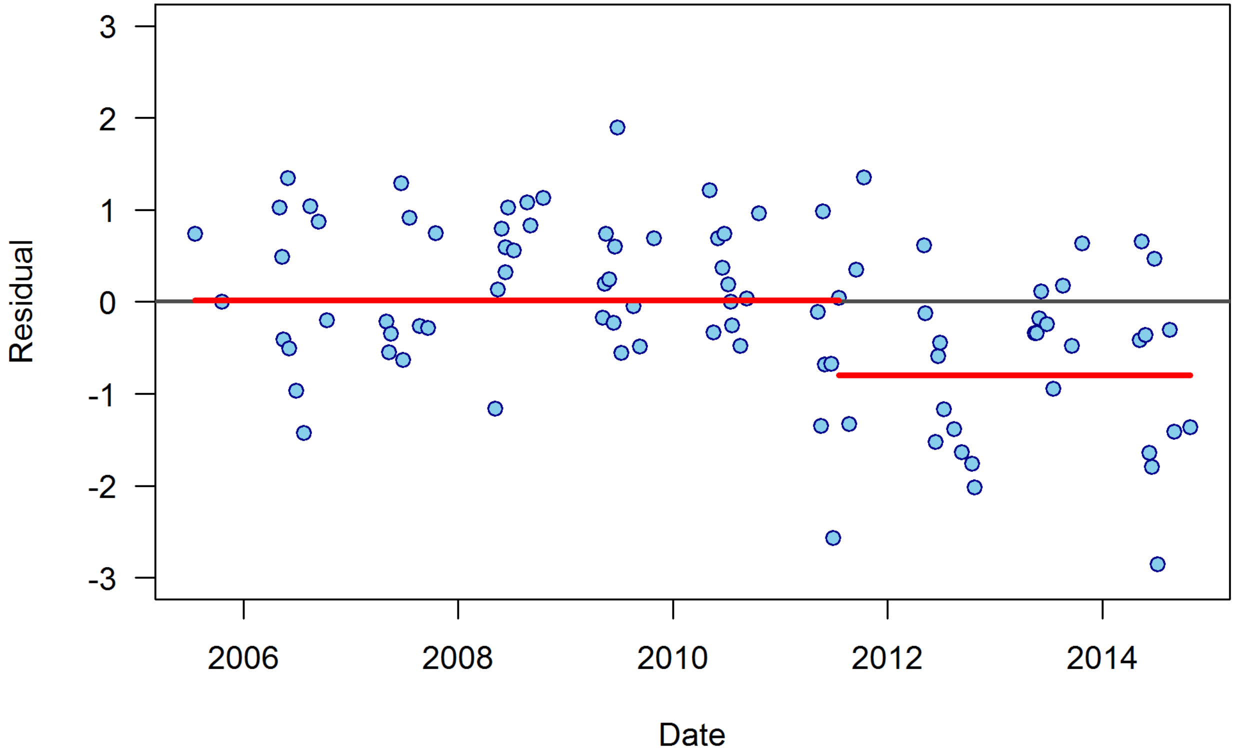

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