Nitrogen sensitivity to climate change-driven changes in hydrology

Modeling Workgroup Conference Call
12 September 2019

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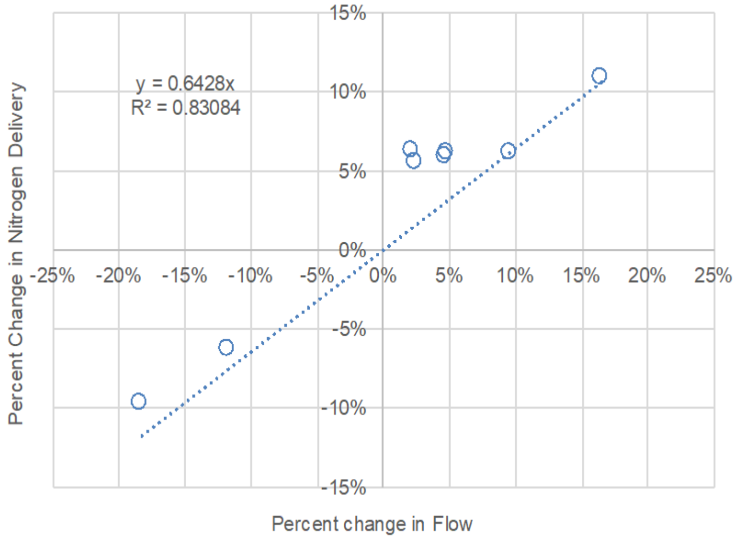
Presentation outline

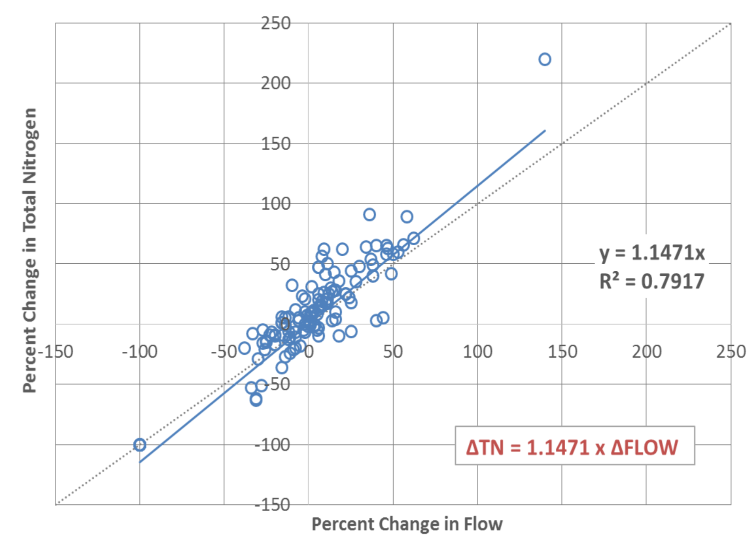
- Nitrogen sensitivity to flow
- N speciation in response to hydrology-driven changes in load

Nitrogen sensitivity to cc-driven changes in hydrology

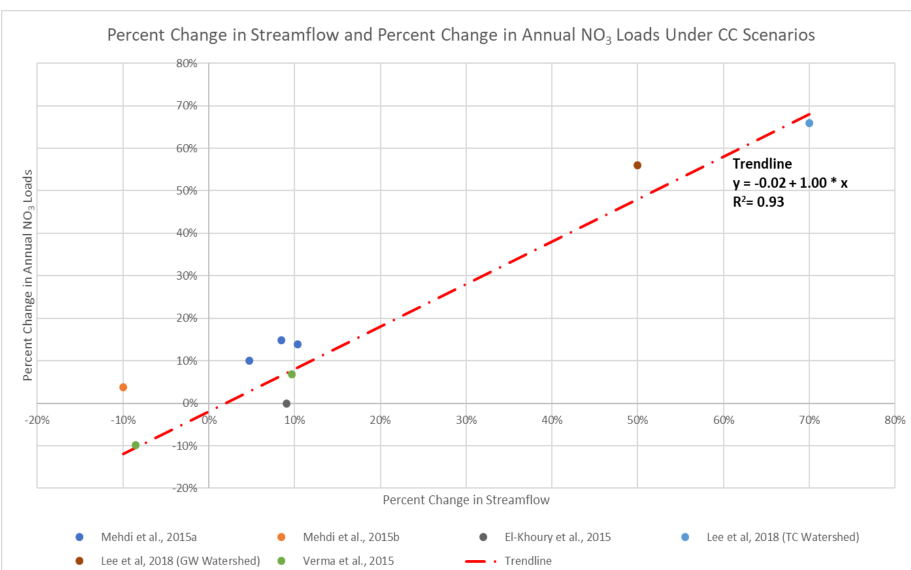
Phase 5.3.2 model



"20 watersheds" study



Literature review



Current assumption:

X% change in flow

=

X% change in TN load

Nitrogen sensitivity to cc-driven changes in hydrology

STAC CC Workshop:
Spatially vary the relationship between nitrogen and flow

"The assumed proportional relationship between change in flow and change in nitrogen output from a land use is supported at the large scale, but there may be significant differences between land use types and between geographic settings. It is suggested that the CBP undertake additional literature review to investigate these different responses. Published small-scale modeling efforts may be particularly useful. The CBP should also investigate using the existing P6WM responsiveness to groundwater recharge and available water capacity."

Nitrogen sensitivity to cc-driven changes in hydrology

1. Literature review

2. Analysis of WRTDS data

Nitrogen sensitivity to cc-driven changes in hydrology

1. Literature review

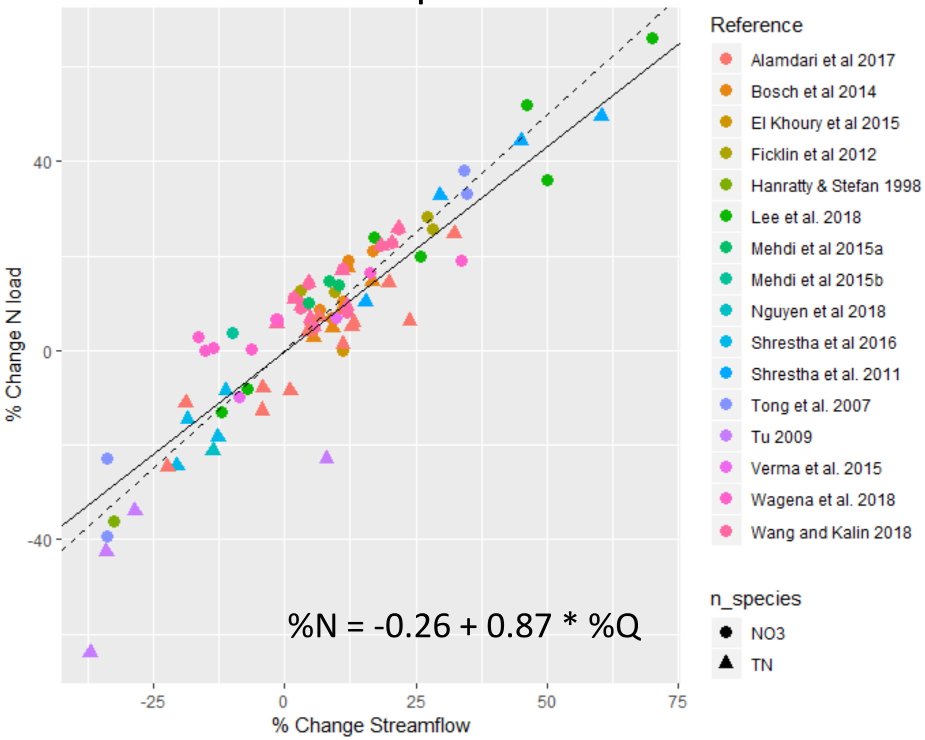
Nitrogen sensitivity to cc-driven changes in hydrology
Literature review

27 studies

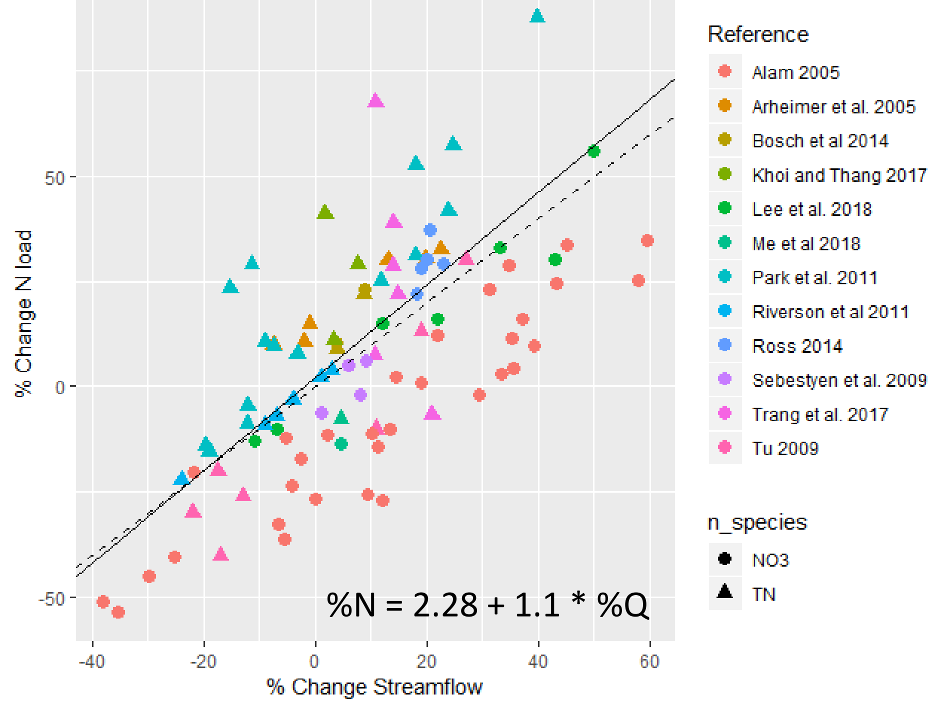
Land use description	Watershed area (km^2)	Model	N species	Number of studies
Predominantly agricultural or developed	7.3 - 23300	AVGWLF; SWAT; SWMM	TN, NO_3	16
Predominantly forested	0.41 - 78500	SWAT; AVGWLF; LSPC; Regression; SOILNDB + HBV-N	TN, NO_3	12

Nitrogen sensitivity to cc-driven changes in hydrology Literature review

Predominantly agricultural or developed



Predominantly forested



Nitrogen sensitivity to cc-driven changes in hydrology
Literature review

- ~ 1:1 relationship between flow and N in predominantly agricultural/developed watersheds

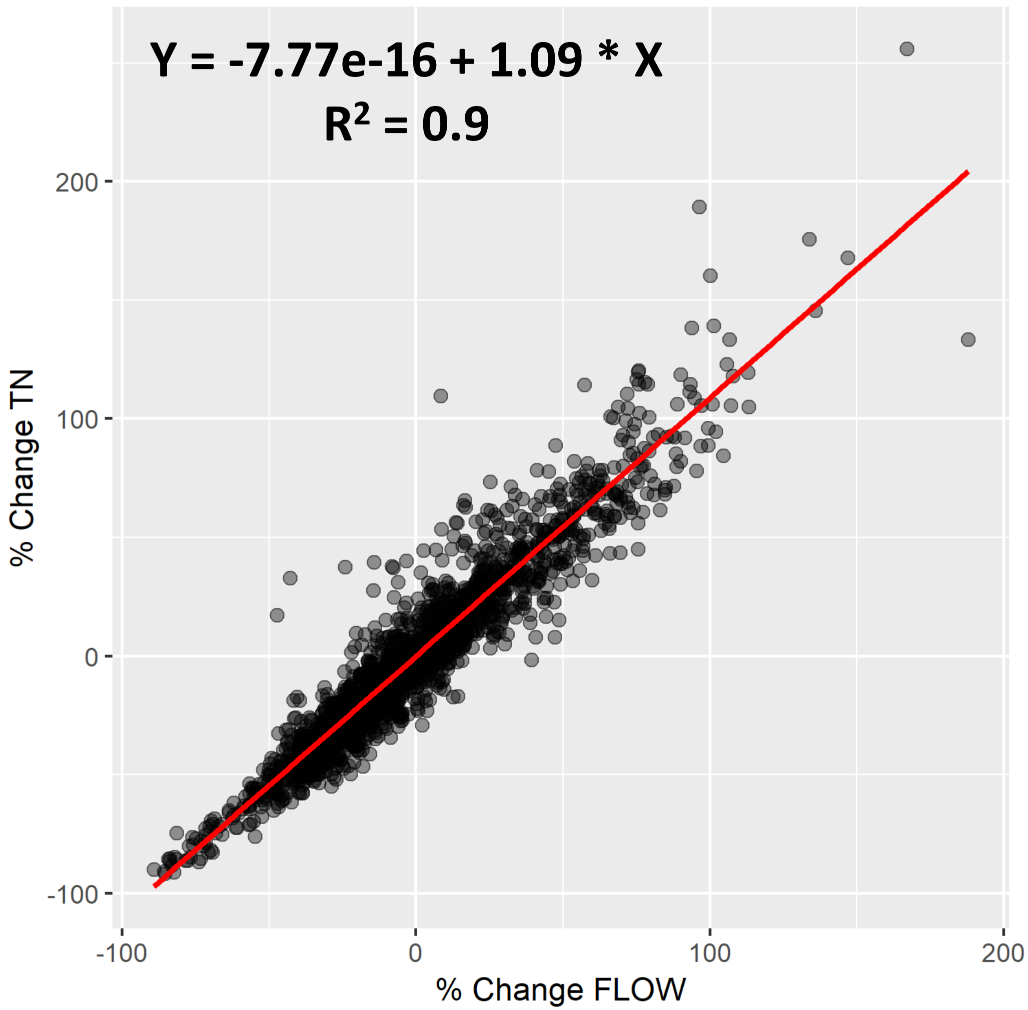
- Relatively higher uncertainty in the expected response of forested watersheds

Nitrogen sensitivity to cc-driven changes in hydrology

2. Analysis of WRTDS data

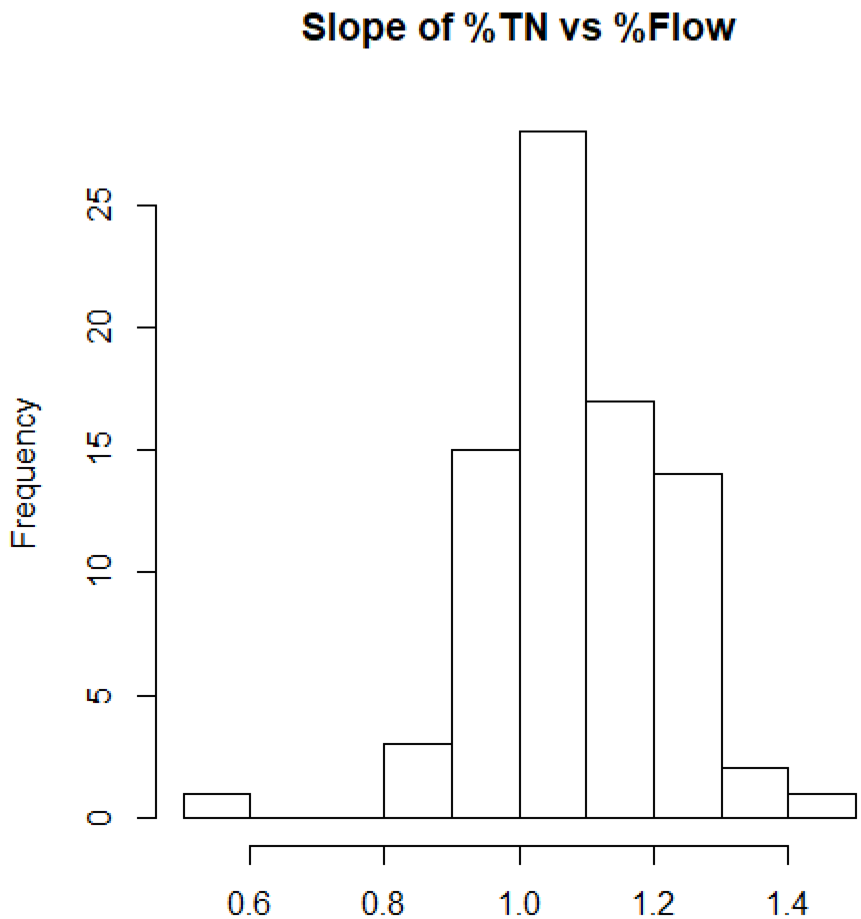
Annual WRTDS data

% Change TN: $[TN_i - mean(TN)] / mean(TN)$
% Change FLOW: $[FLOW_i - mean(FLOW)] / mean(FLOW)$

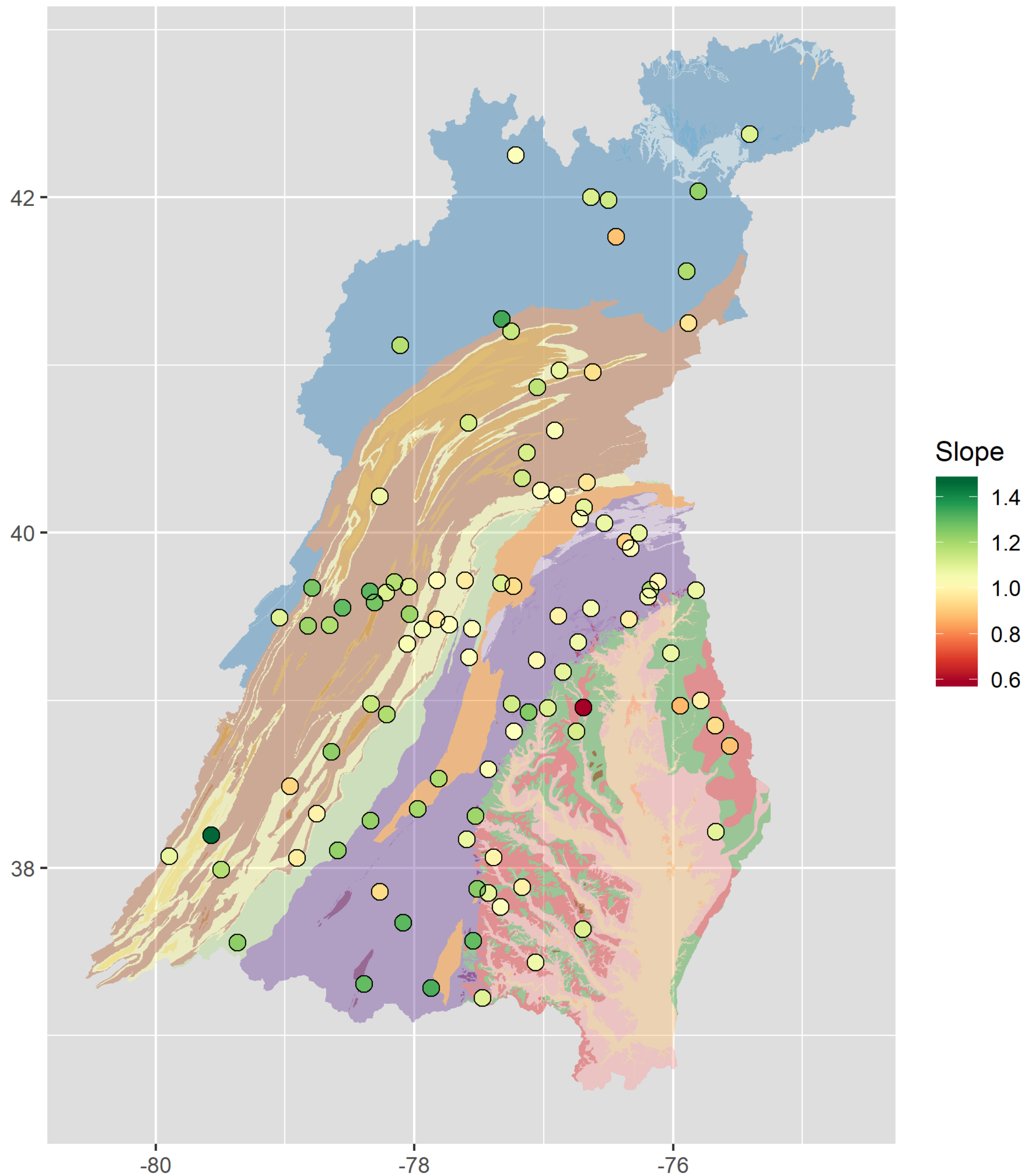


Slope ~ 1 : CHEMOSTASIS
Slope > 1: MOBILIZATION
Slope < 1: DILUTION

Annual WRTDS data



Annual WRTDS data



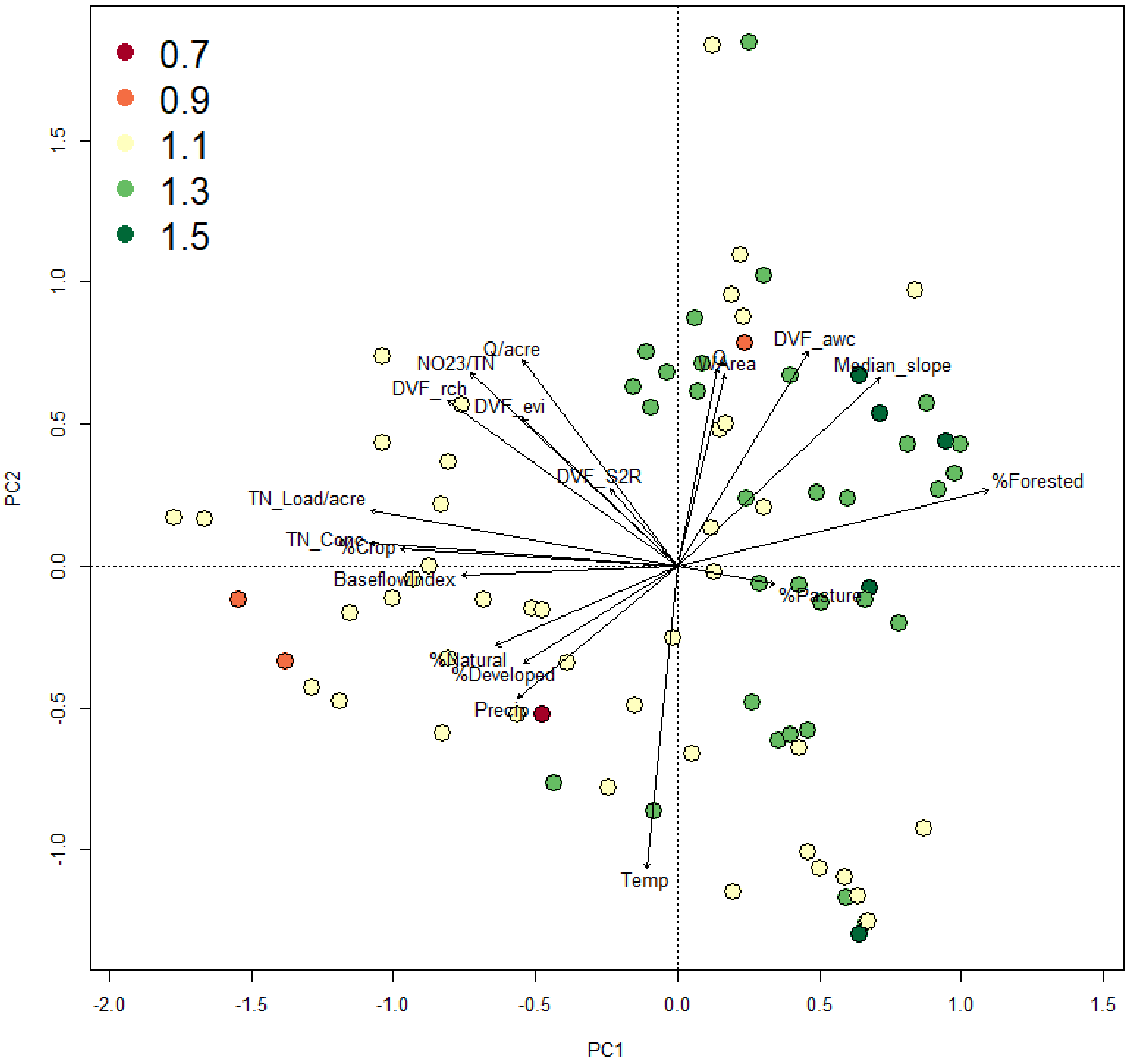
Annual WRTDS data

Candidate covariates of %TN vs %FLOW slope

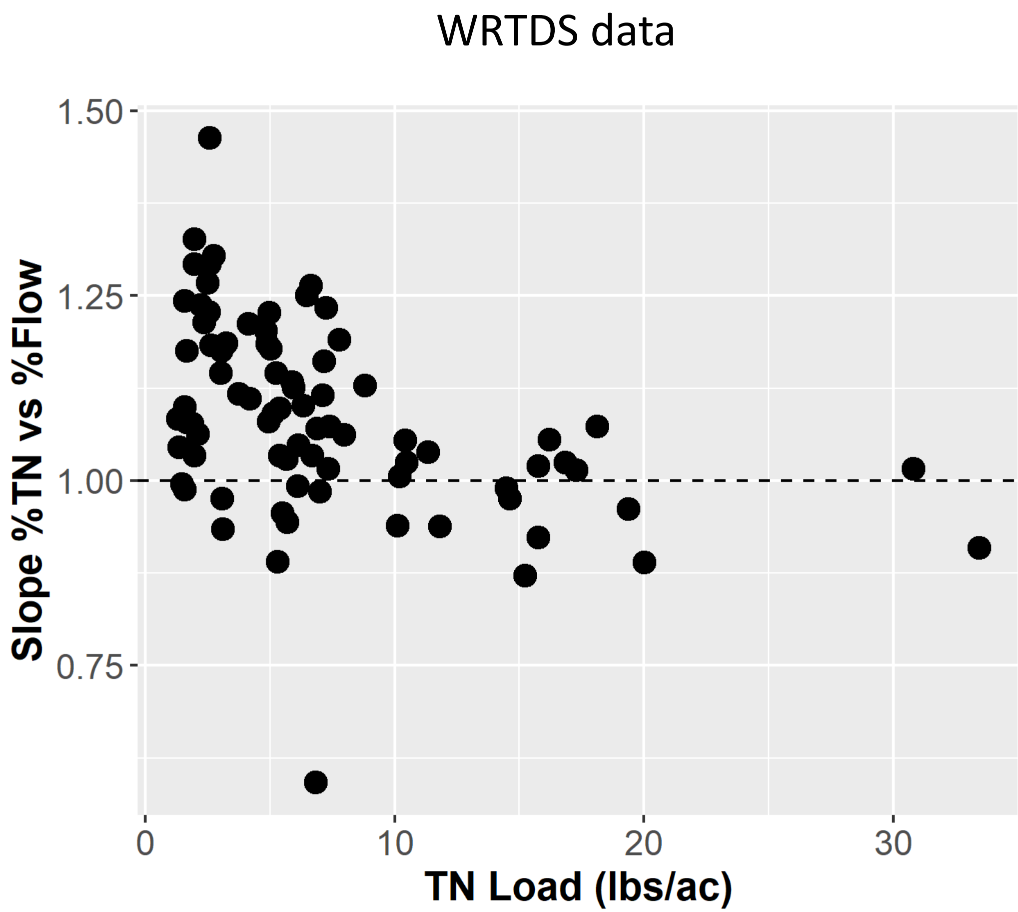
Watershed area
Average flow
Average flow per acre
Average TN Load per acre
Average TN concentration
Average NO23/TN ratio
% Crop area
% Pasture area
% Developed area
% Forested area
% Natural (non forested) area
Average temperature
Average precipitation
Median watershed slope
Hydrogeomorphic region
Average Baseflow Index

DVF_awc
DVF_evi
DVF_pca
DVF_rch
DVF_Xawc
DVF_XawcXpca
DVF_XawcXrch
DVF_Xevi
DVF_XeviXawc
DVF_XeviXpca
DVF_XeviXrch
DVF_Xpca
DVF_Xrch
DVF_XrchXpca
DVF_STR_avg

Principal Component Analysis



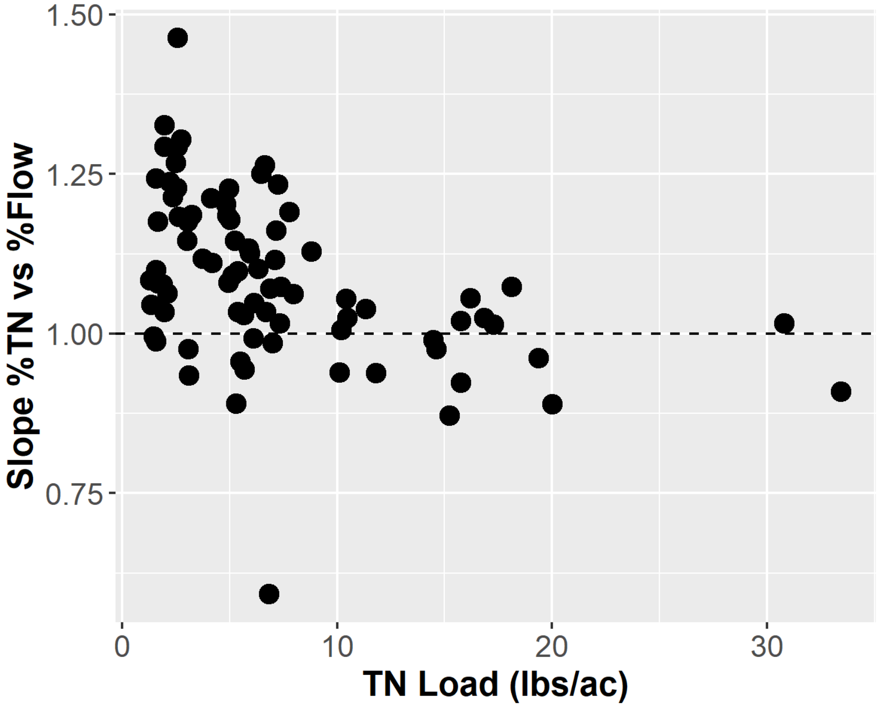
Spatial variability in TN sensitivity to flow



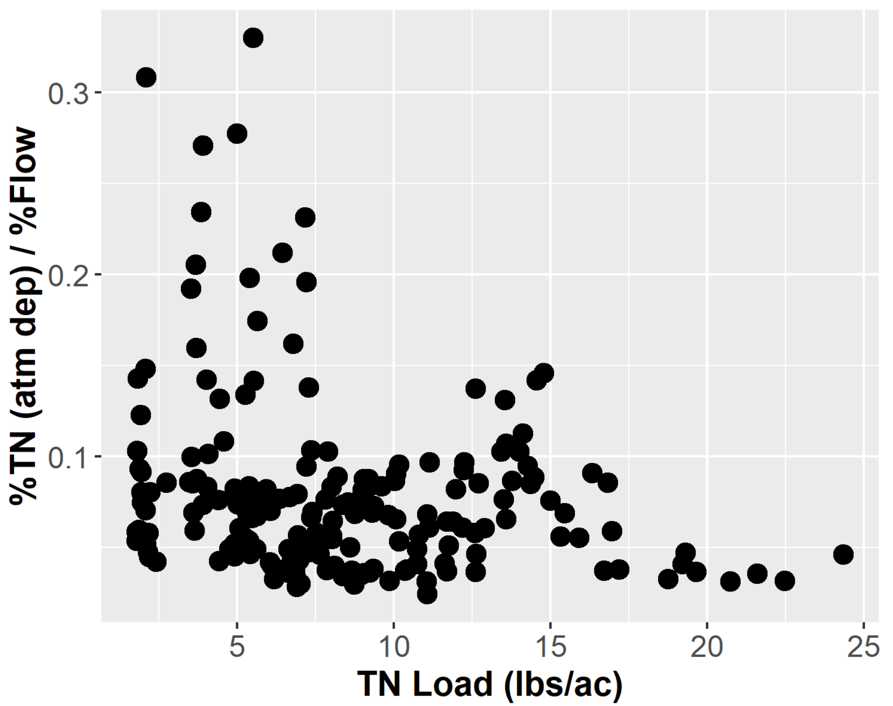
Hp: Higher N sensitivity to flow in low-impact areas due to the relatively higher influence of atmospheric deposition

Spatial variability in TN sensitivity to flow

WRTDS data



Contribution of atmospheric deposition to %TN (2025 vs 1995) at land segments



Conclusions

- Literature review and analysis of WRTDS data generally support ~1:1 relationship between % change in TN and % change in flow
- Higher sensitivity observed in forested watersheds likely a result of higher relative contribution of atmospheric deposition in less impacted watersheds (already accounted for in the model)

N speciation in response to hydrology-driven changes in load

N speciation in response to hydrology-driven changes in load

1. Literature review

2. Analysis of WRTDS data

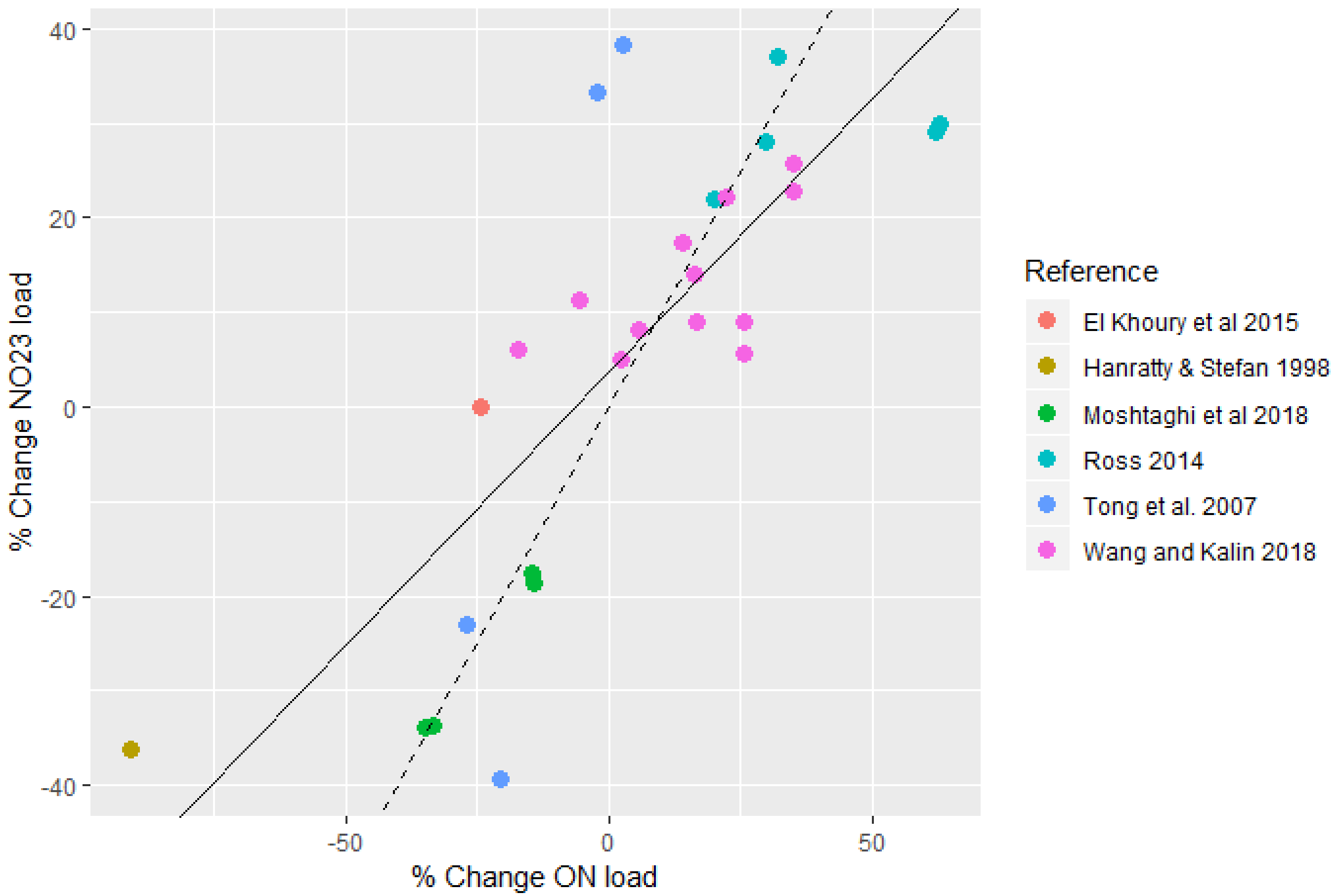
N speciation in response to hydrology-driven changes in load

1. Literature review

Nitrogen speciation in response to cc-driven changes in hydrology – Literature review

6 Studies

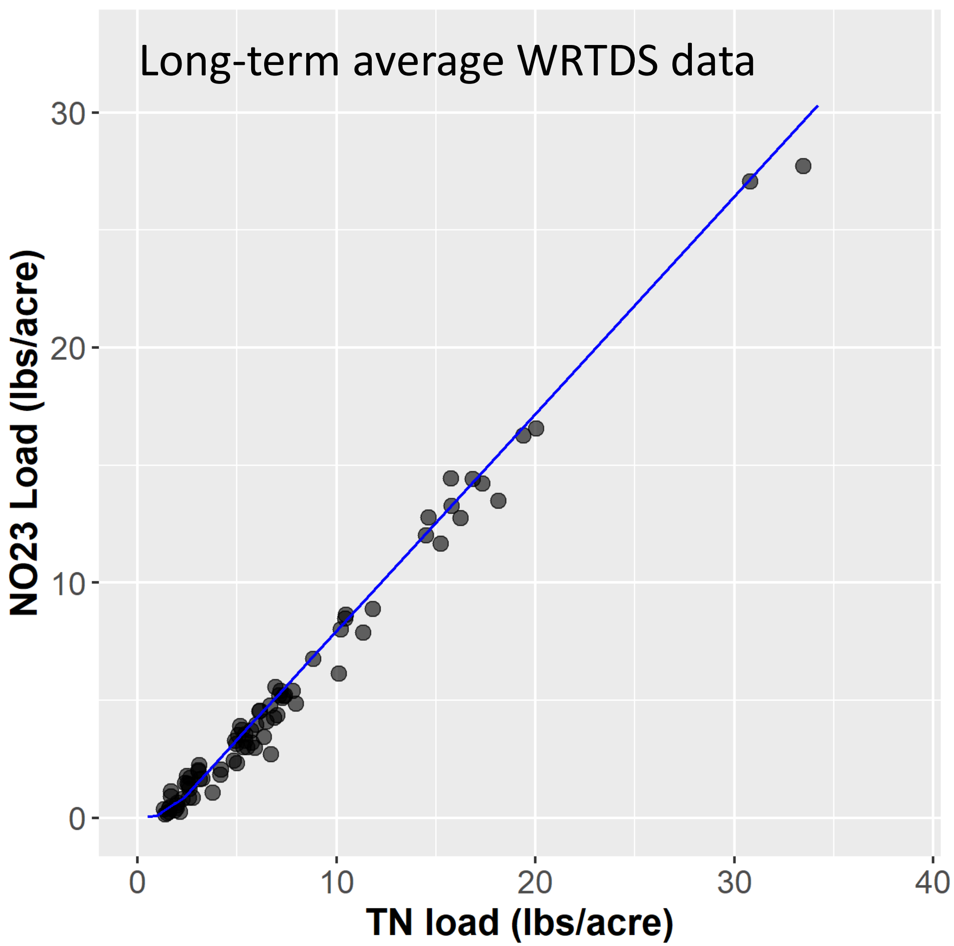
$$\%NO23 = 3.67 + 0.58 * \%ON \quad (R^2 = 0.61)$$



N speciation in response to hydrology-driven changes in load

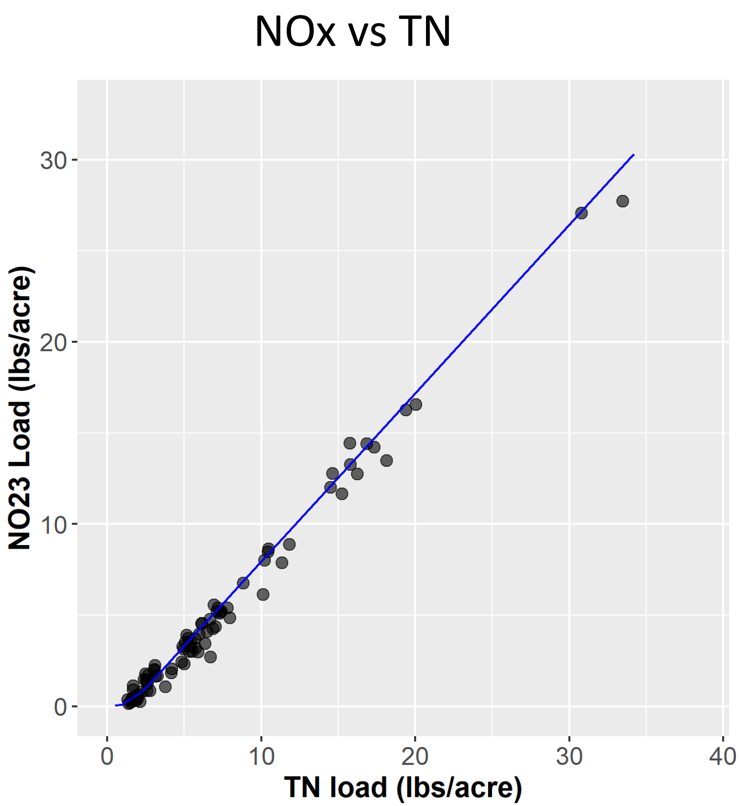
2. Analysis of WRTDS data

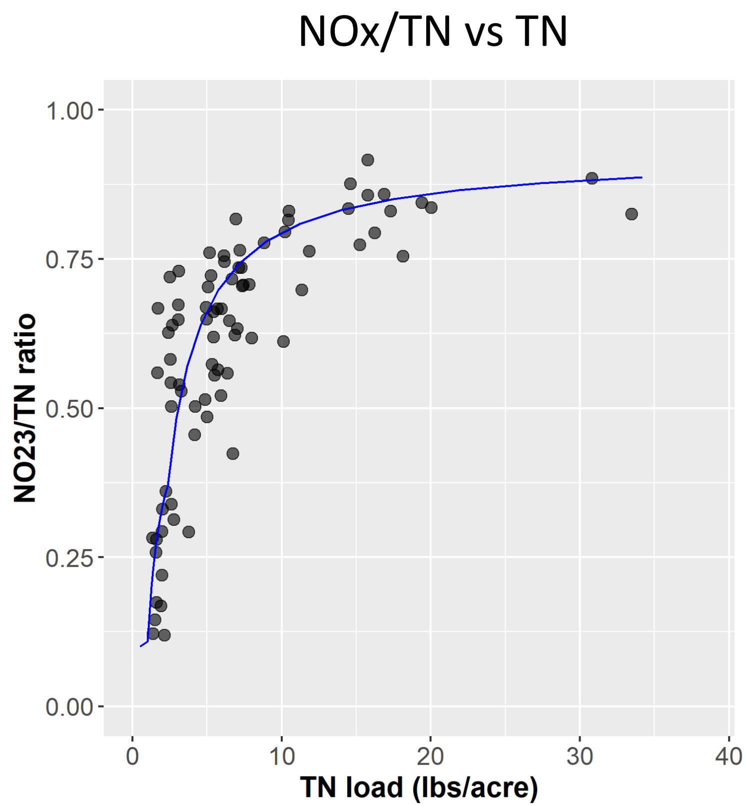
Phase 6 NO23 vs TN regression



- Used to estimate the fraction of EOR TN that is NO23
- Used to estimate NO23 fraction as TN loads are modified by **climate change**
- STAC 2018 CC Workshop: Relationship likely confounded/driven by spatial differences in land use rather than climate/hydrology

Phase 6 NO23 vs TN regression

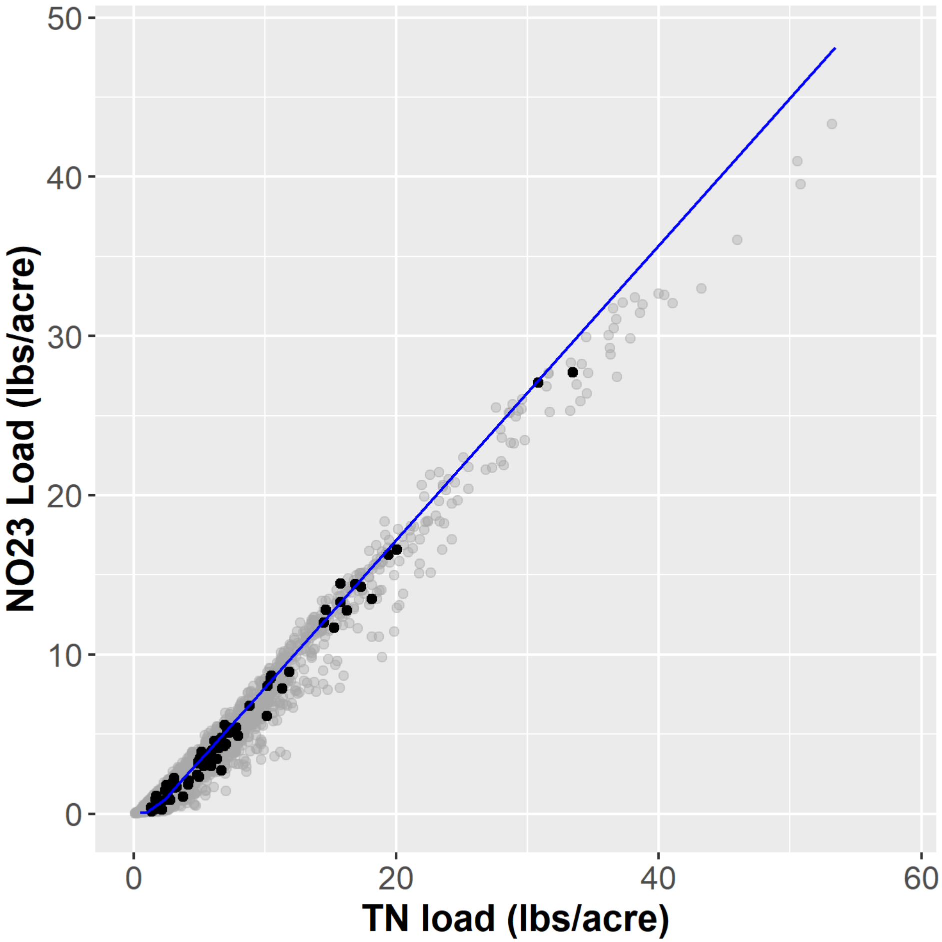




Increase in TN load -> Increase in NO23/TN ratio

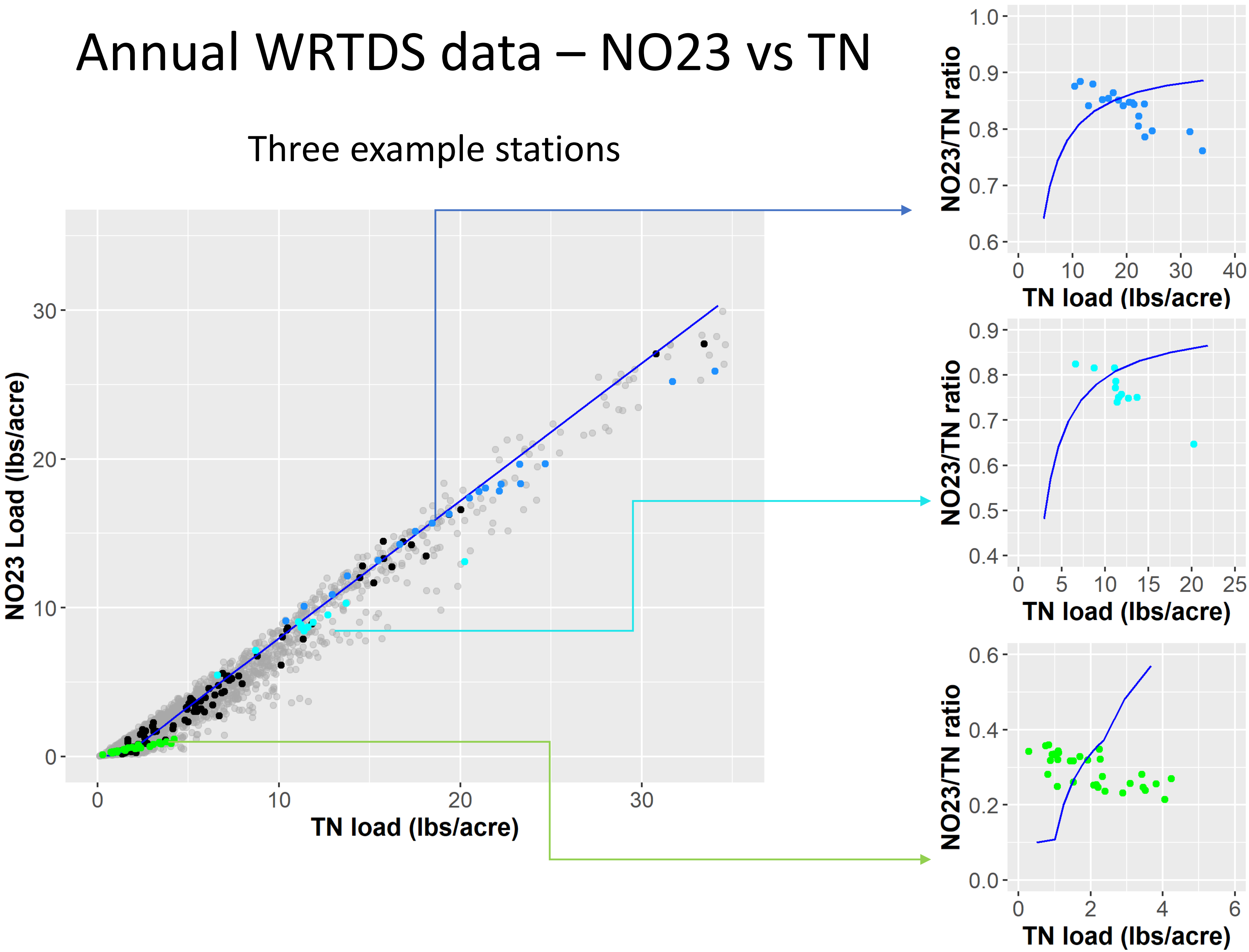
Annual WRTDS data – NO23 vs TN

Black dots: long-term average load at each station
Gray dots: annual load at each station



Annual WRTDS data – NO23 vs TN

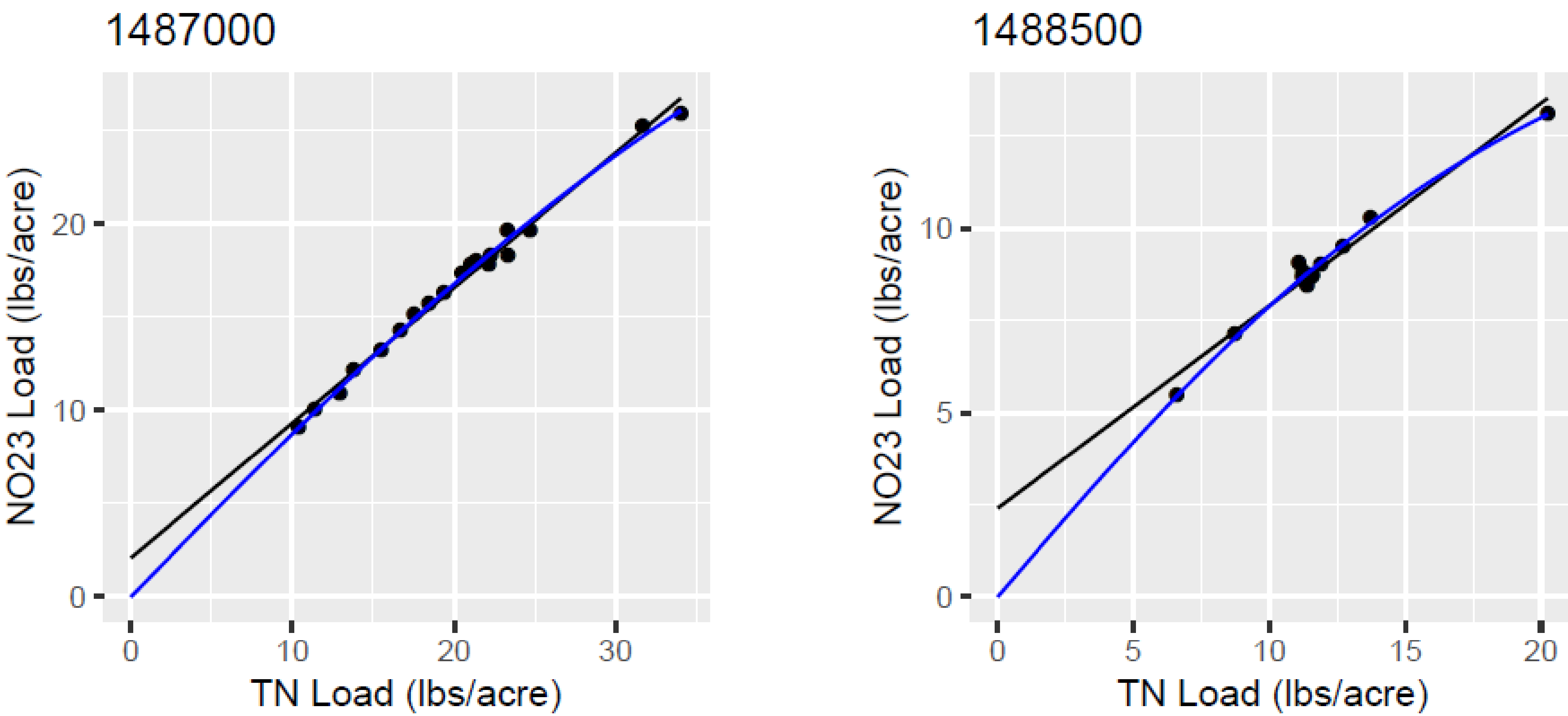
Three example stations



Linear vs non-linear fit at individual stations

Black line: $$NO23_i = b0 + b1 * TN_i + error_i$$

Blue line: $$NO23_{i,j} = \frac{b0_j * TN_{i,j}}{\sqrt{b1_j^2 + TN_{i,j}^2}} + error_{i,j}$$



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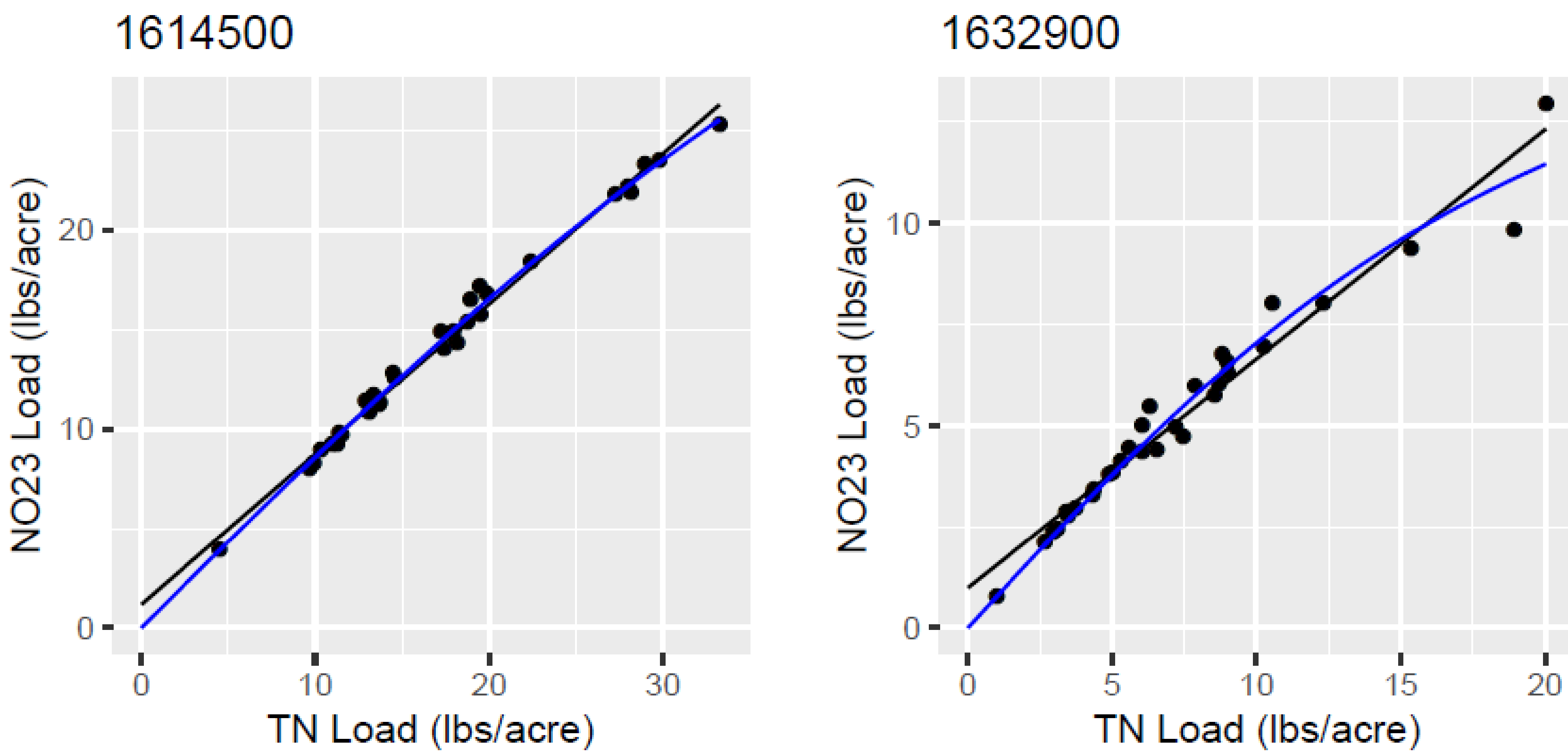

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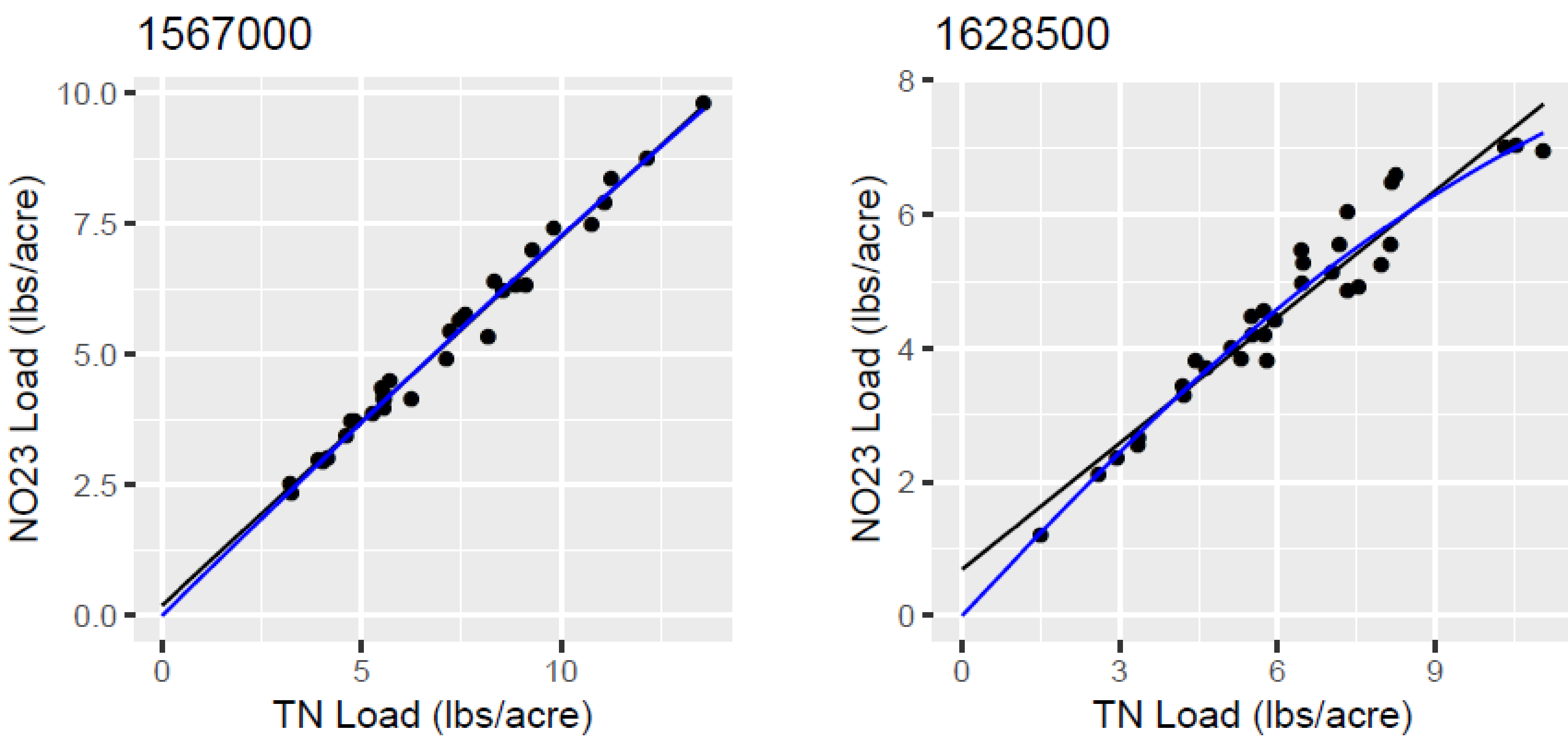
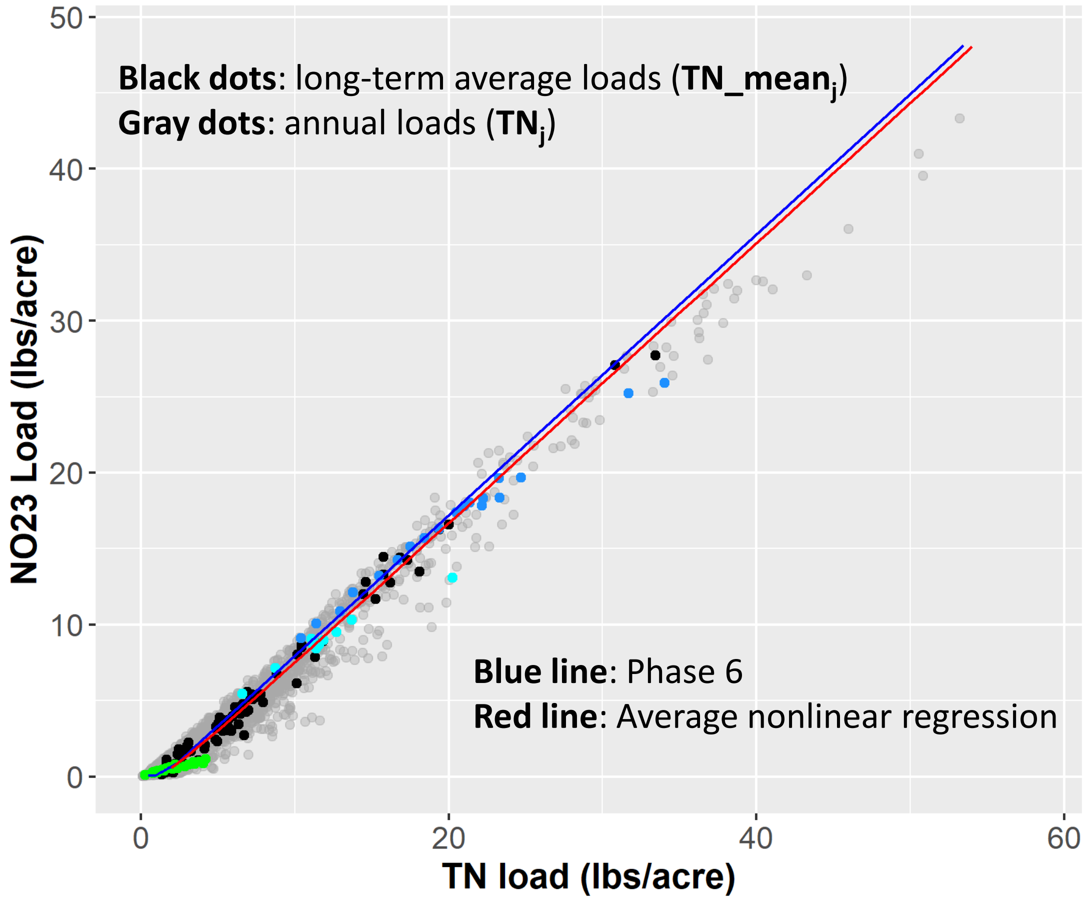


Nonlinear Regression with parameters varying by WRTDS station

$$NO23_{i,j} = \frac{b0_j * TN_{i,j}}{\sqrt{b1_j^2 + TN_{i,j}^2}} + error_{i,j}$$ i = Year, j = WRTDS Station

$\mathbf{b0_j}$ = -3.26+ 3.16*TN_mean_j

$\mathbf{b1_j}$ = 3.56 + 3.27*TN_mean_j



Phase 6 vs Revised regression

$$NO23_{i,j} = \frac{b0_j * TNi_{,j}}{\sqrt{b1_j^2 + TN_{i,j}^2}} + error_{i,j}$$ i = Year, j = WRTDS Station

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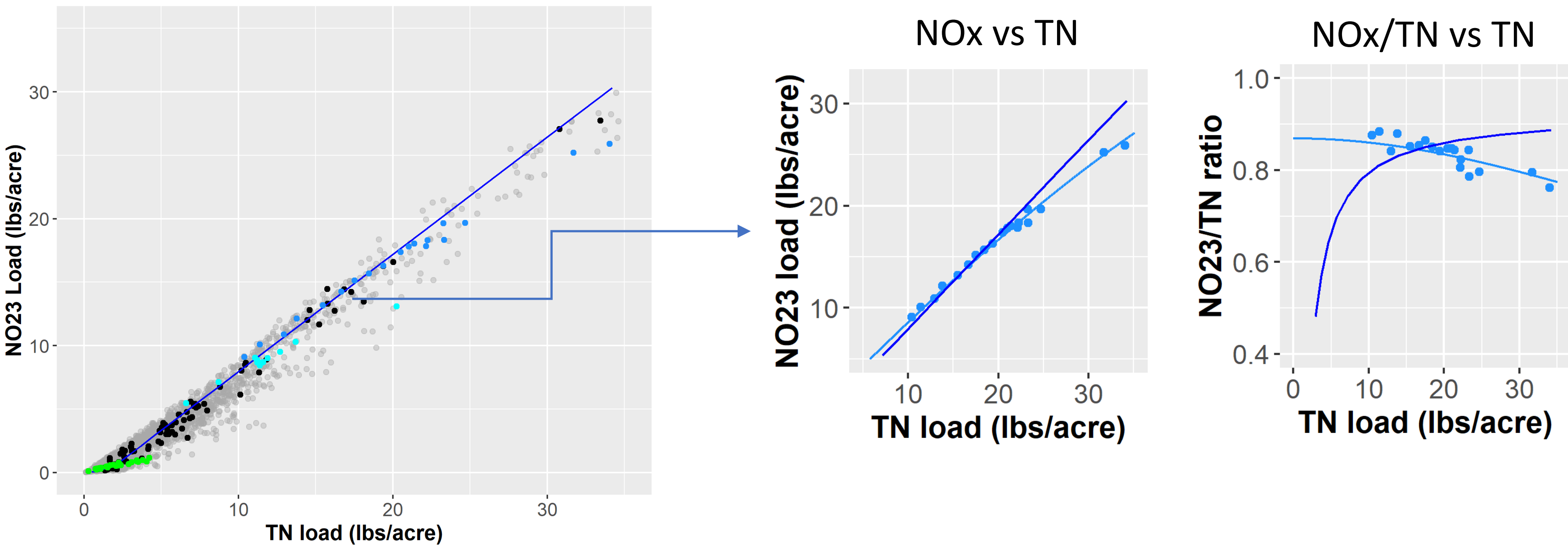
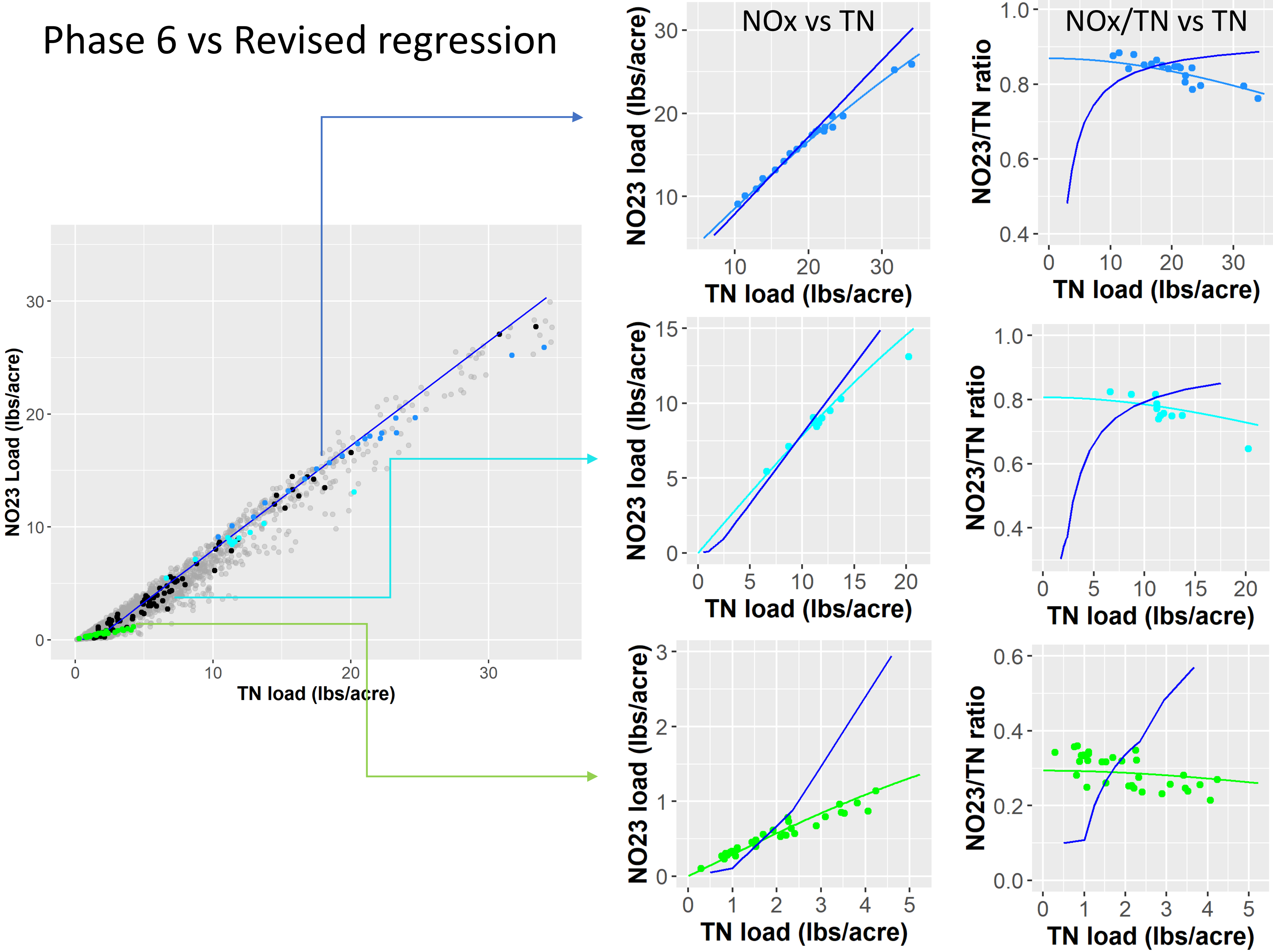
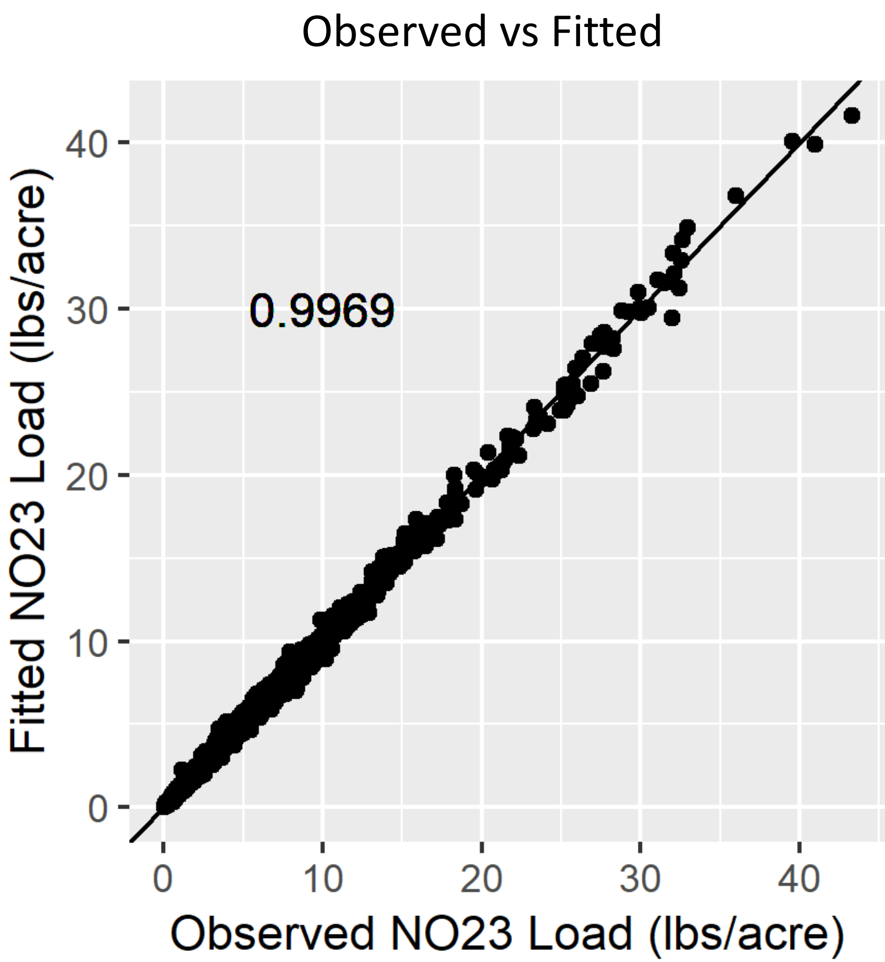
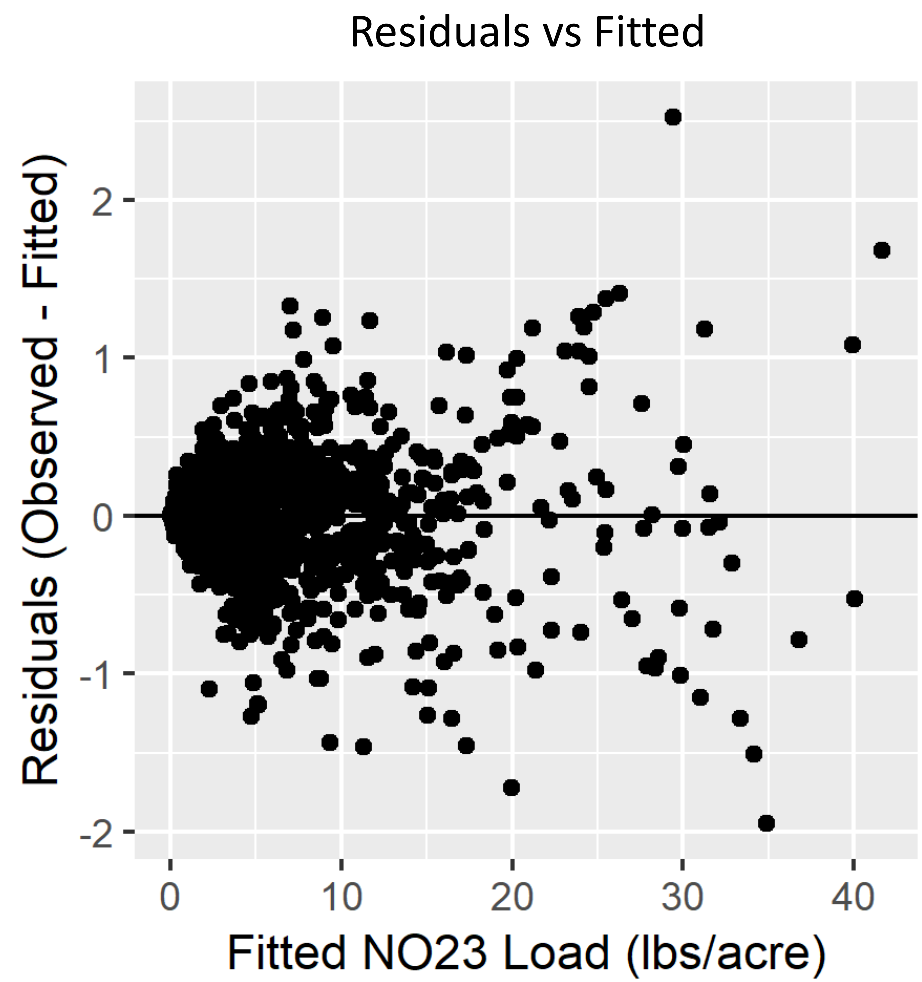


Phase 6 vs Revised regression



Revised regression model performance





Conclusions

- A revised nonlinear hierarchical regression provides a means to better capture changes in NOx/TN observed at WRTDS sites as a result of inter-annual changes in hydrology

- We propose using this revised regression to approximate changes in NOx/TN expected due to climate-change driven in hydrology