Estimated Nitrogen Speciation Changes Under Future Climate Hydrology

Modeling Workgroup Quarterly Review
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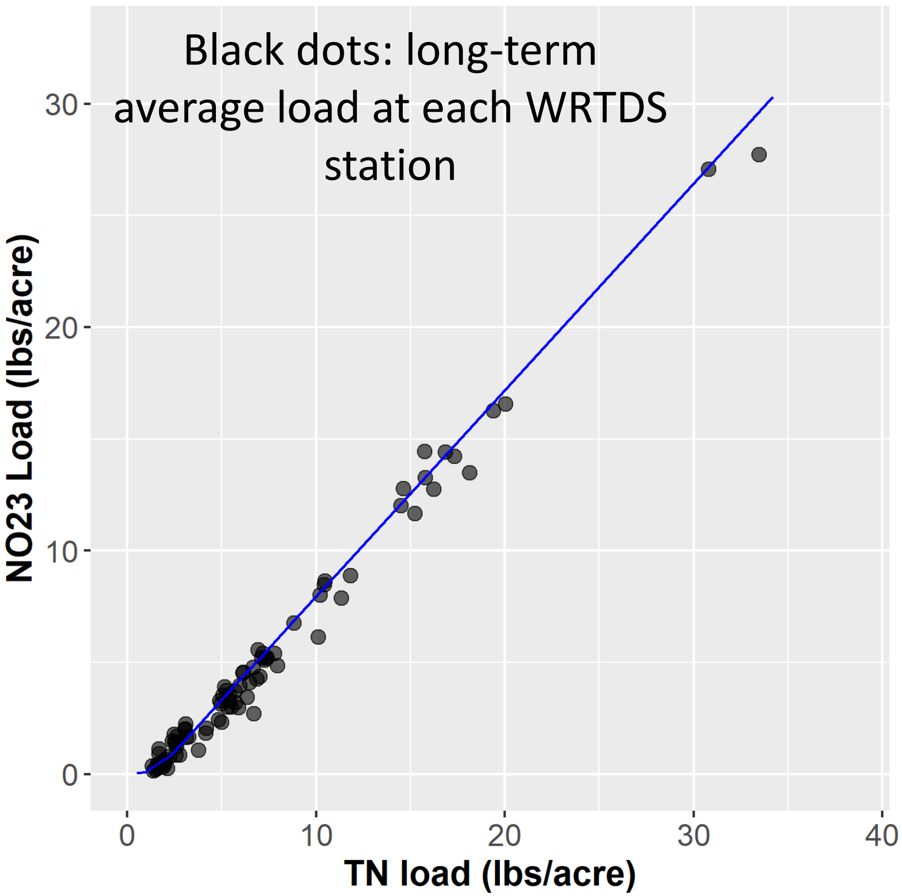
2019 Climate Change Documentation:

Section **4.7.1** – Changes in speciation

Estimated Nitrogen Speciation Changes Under Future Climate Hydrology

Regression model Used in 2017 Climate Assessment



- Used to estimate the fraction of EOR TN that is NO_3
- Used to estimate NO_3 fraction as TN loads are modified by climate change
- **2018 STAC CC Workshop**: Relationship likely confounded/driven by spatial differences in land use rather than climate/hydrology

Estimated Nitrogen Speciation Changes Under Future Climate Hydrology

1. Literature review

2. Analysis of WRTDS data from Chesapeake Bay Nontidal stations

Estimated Nitrogen Speciation Changes Under Future Climate Hydrology

1. Literature review

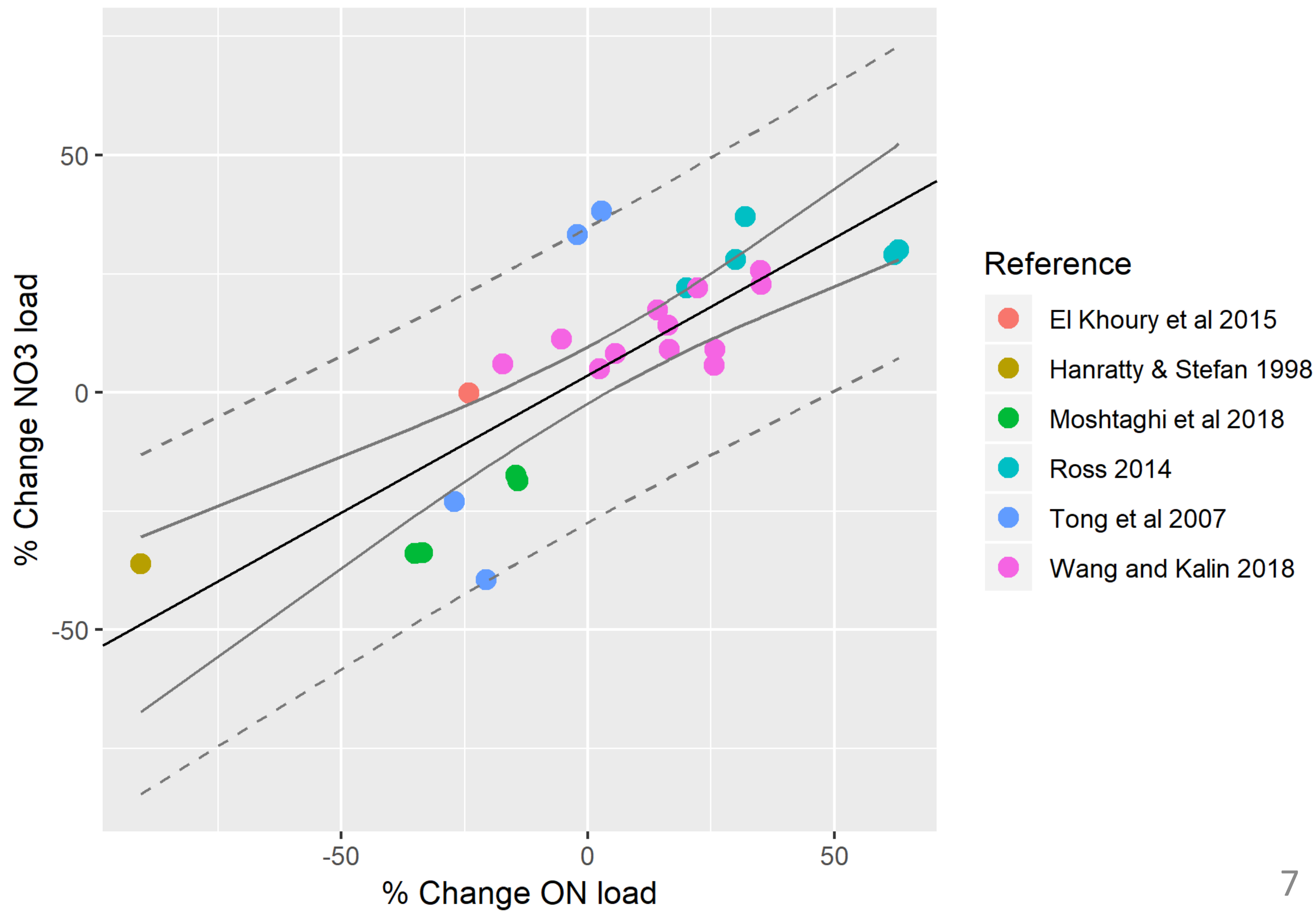
Estimated Nitrogen Speciation Changes Under Future Climate Hydrology – Literature review

6 Studies in 10 watersheds – All SWAT models

Reference	**River**	**State/ Country**	**Watershed Area (km^2)**	**Land use**
El Khoury et al 2015	South Nation	Ontario, Canada	3858	57.8% agricultural; 41.03% forest
Hanratty & Stefan 1998	Cottonwood	MN	3400	52% rangeland; 46% crop
Moshtaghi et al 2018	Golgol	Iran	280	27% cultivated
Ross 2014	Woonasquatucket-Moshassuck	RI/MA	192.6	38.2% developed; 49.1% forest; 4.5% agricultural; 2% water; 6.2% wetland
Ross 2014	Ten Mile	RI/MA	143.6	40.9 developed; 46.2% forest; 4.5% agricultural; 2% water; 6.3% wetland
Ross 2014	Taunton	RI/MA	1250.2	Upper Taunton: 36% developed; 50.5% forest; 1.1% agricultural; 2.9% water; 9.5% wetland; Mid Taunton: 17.6% developed; 62.8% forest; 4.7% agricultural; 6.3% water; 8.7% wetland; Lower Taunton: 24.6% developed; 56.4% forest; 3.4% agricultural; 7.5% water; 8.0% wetland
Ross 2014	Pawtuxet	RI/MA	599.6	18.2% developed; 67% forest; 4.4% agricultural; 4.6% water; 5.6% wetland; 0.2% bare rock
Ross 2014	Blackstone	RI/MA	1228.5	Upper Blackstone: 28.7% developed; 53.1% forest; 6.1% agricultural; 4.7% water; 7.3% wetland; 0.1% bare rock; Lower Blackstone: 14.6% developed; 70.2% forest; 6.5% agricultural; 2.3% water; 6.3% wetland
Tong et al 2007	Little Miami	OH	5840	56.2% agricultural; 23.7% forest; 17.8% urban; 0.97% water; 0.38% other
Wang and Kalin 2018	Wolf Bay	AL	126	1.2% water; 26.4% urban; 20.9% forest; 9.7% pasture; 29.9% cropland; 11.9% wetland

Estimated Nitrogen Speciation Changes Under Future Climate Hydrology – Literature review

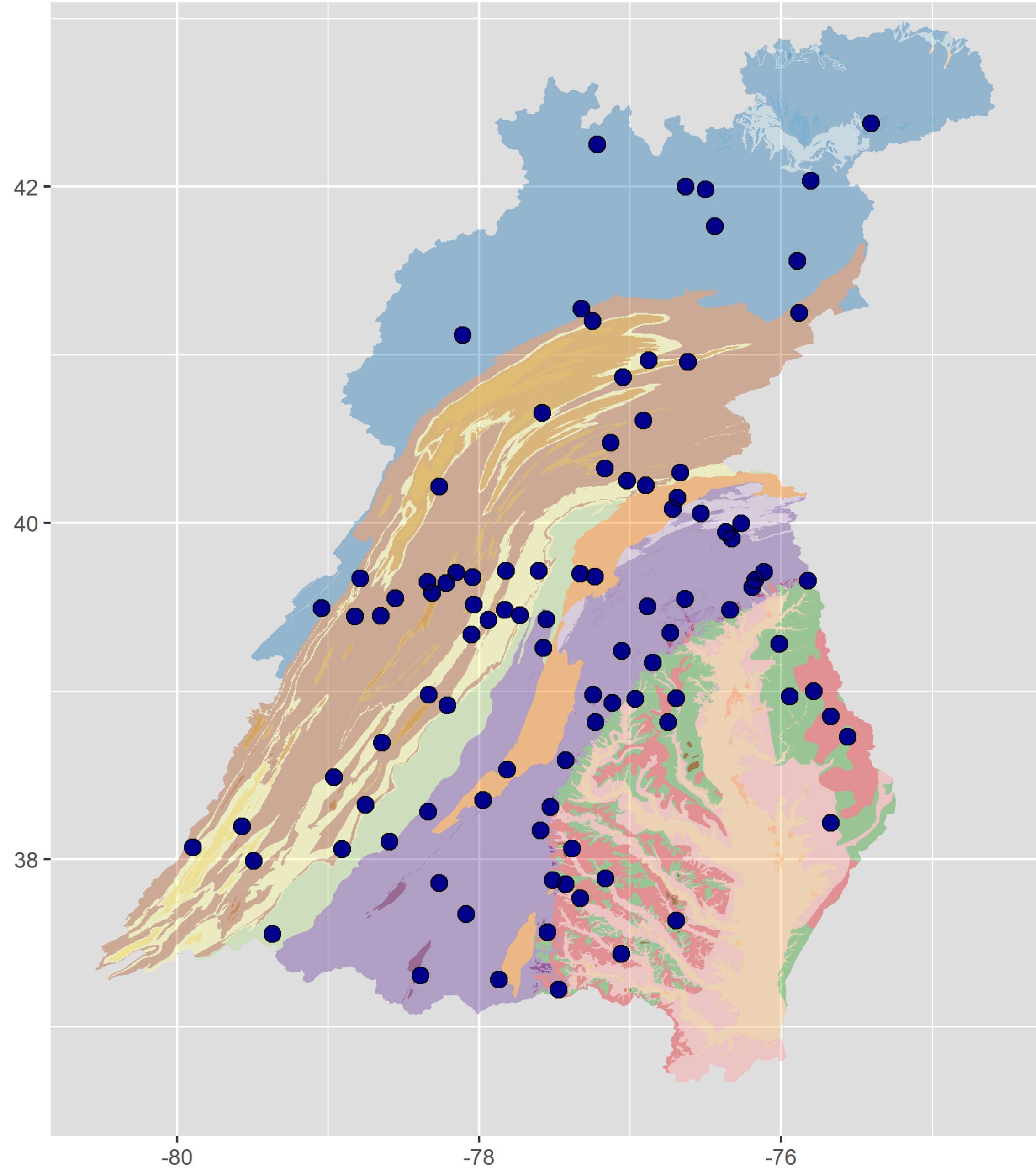
$\%NO3 = 3.67 + 0.58 * \%ON \quad (R^2 = 0.61)$



Estimated Nitrogen Speciation Changes Under Future Climate Hydrology

2. Analysis of WRTDS data from Chesapeake Bay Nontidal stations

Chesapeake Bay Nontidal Network

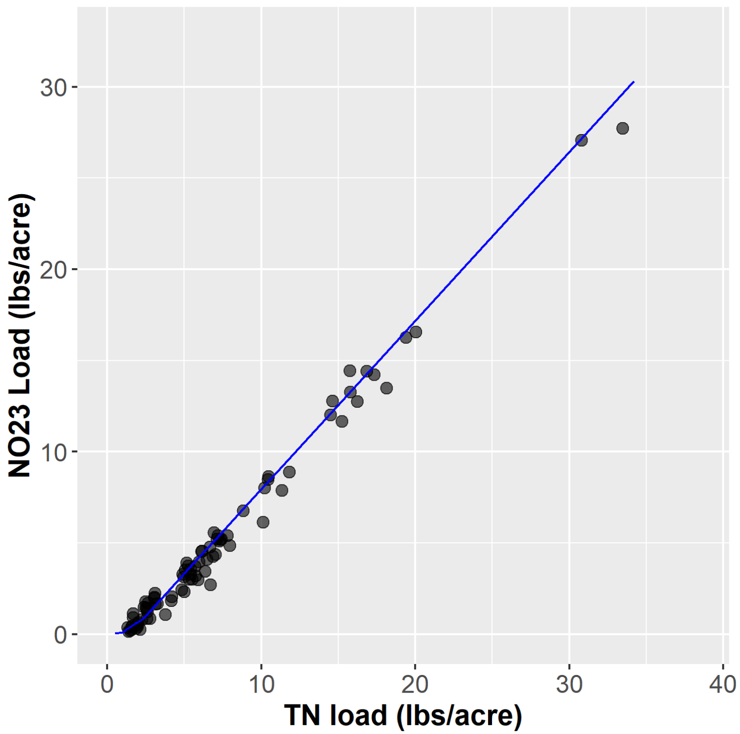


WRTDS-estimated **NO_3** and **TN loads** from Chesapeake Bay Nontidal Network stations

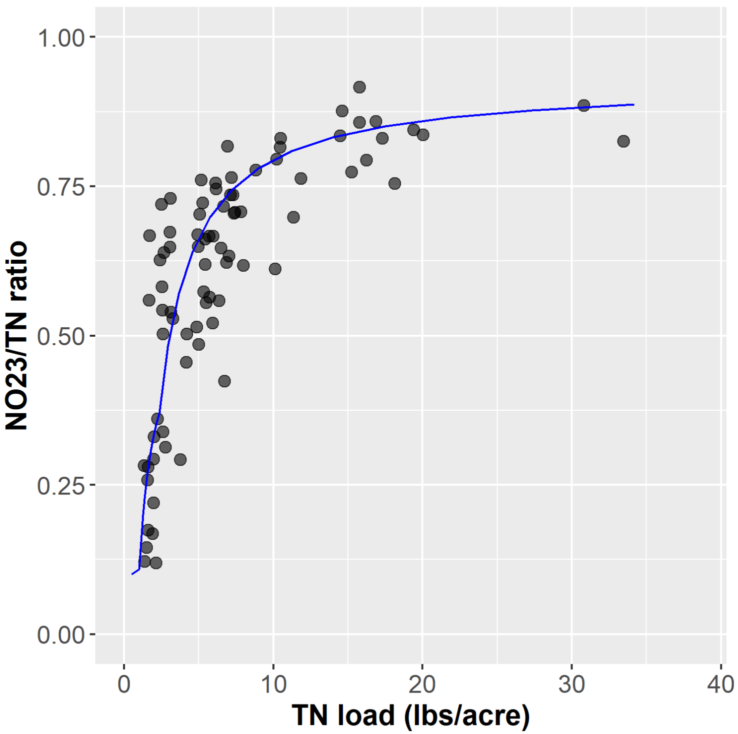
(https://doi.org/10.5066/F7RR1X68)

Phase 6 NO_3 vs TN regression

NO_3 vs TN

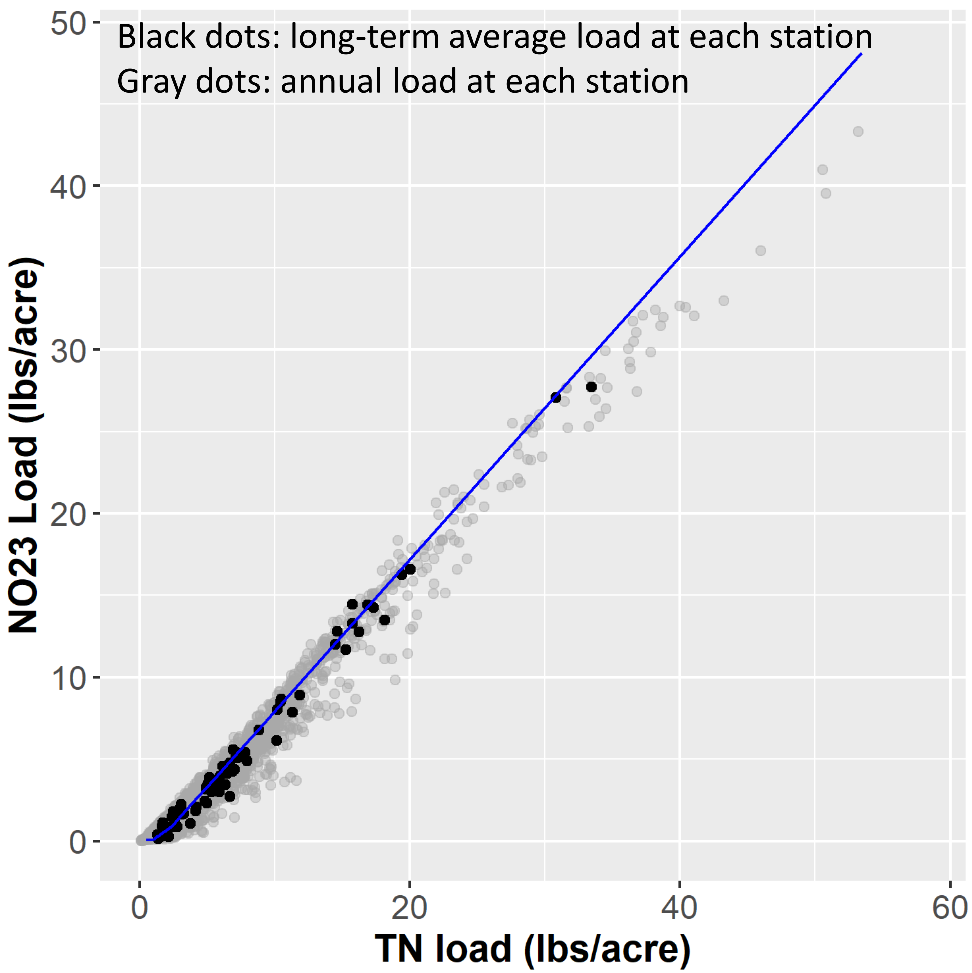


NO_3/TN vs TN



Increase in TN load -> Increase in NO_3/TN ratio

Annual WRTDS data – NO_3 vs TN



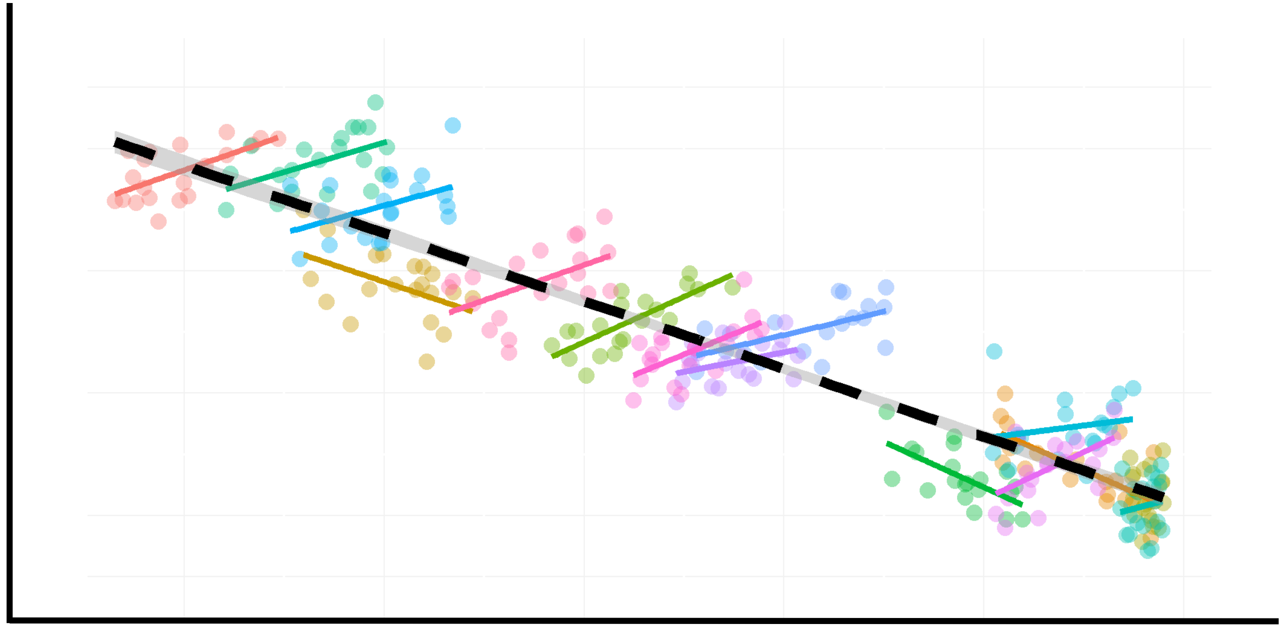
Two modifications of previous EOR regression:

1. **Hierarchical** model formulation (instead of estimating only one intercept and one slope for the whole dataset, each WRTDS station is allowed to have its own intercept and slope)

2. Linear formulation replaced by **non-linear** formula

Hierarchical Regression: parameters varying by WRTDS station

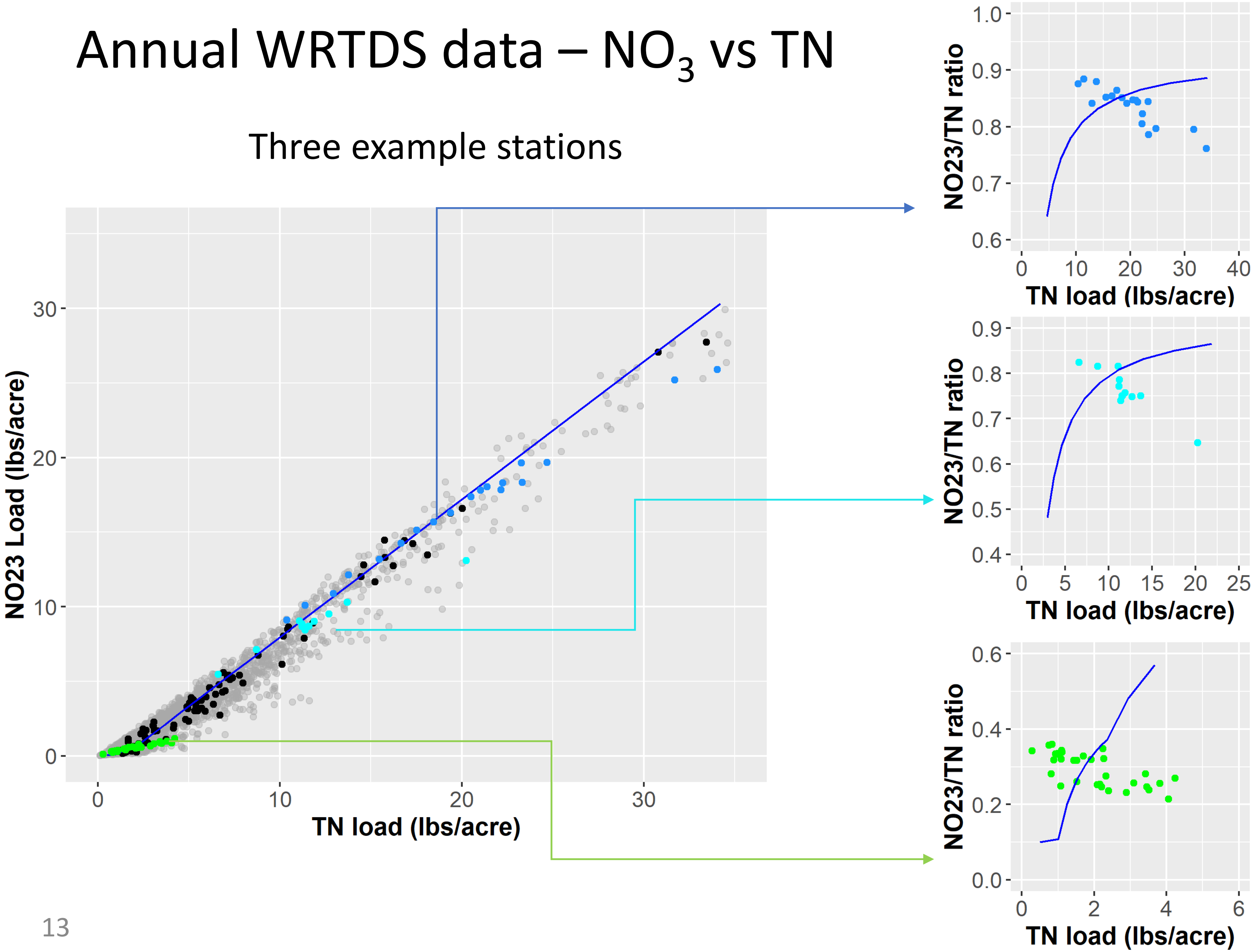
Goal: Separate the relationship between NO_3 and TN into two components: **within-station** (largely - although not exclusively - influenced by hydrology) and **between-station** (largely influenced by spatial differences in land use, watershed characteristics, etc..)



https://hlplab.files.wordpress.com/2011/05/simpsons-paradox.png

Annual WRTDS data – NO_3 vs TN

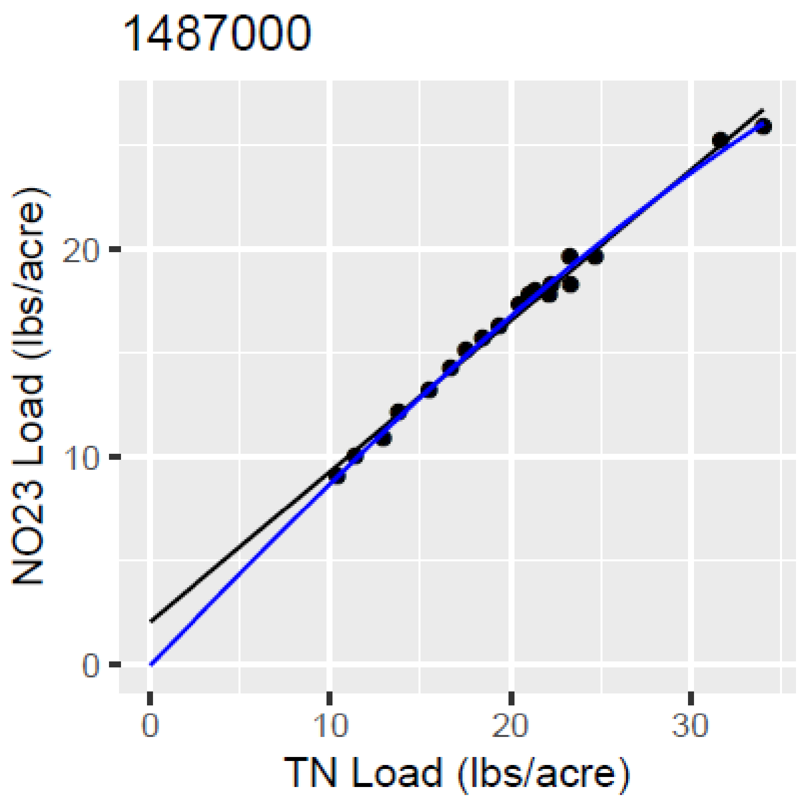
Three example stations

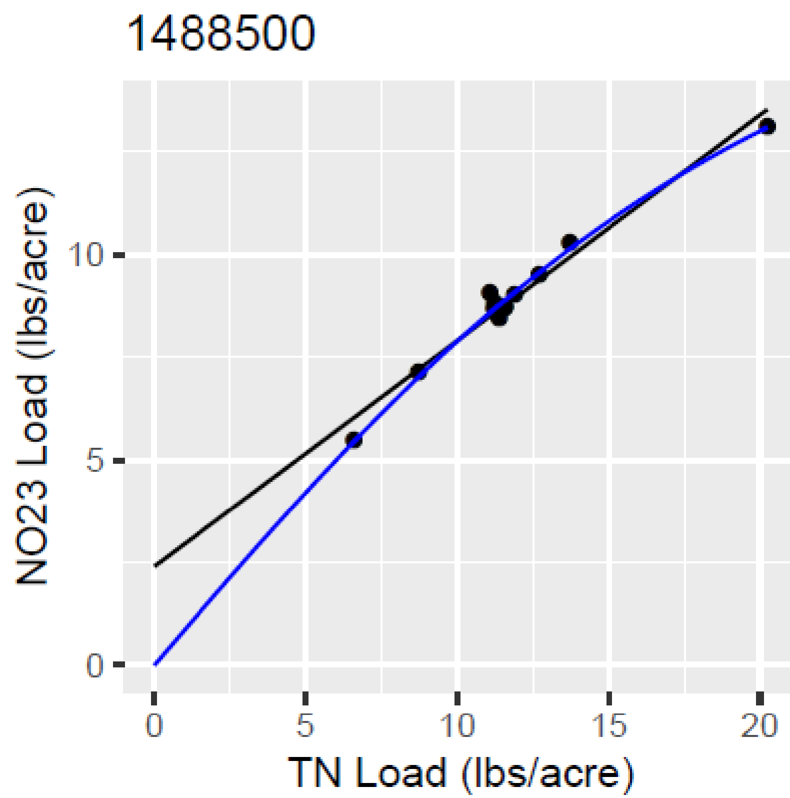


Linear vs non-linear fit at individual stations

Black line: $$NO3_i = \alpha + \beta * TN_i + error_i$$

Blue line: $$NO3_i = \frac{\alpha * TN_i}{\sqrt{\beta^2 + {TN_i}^2}} + error_i$$





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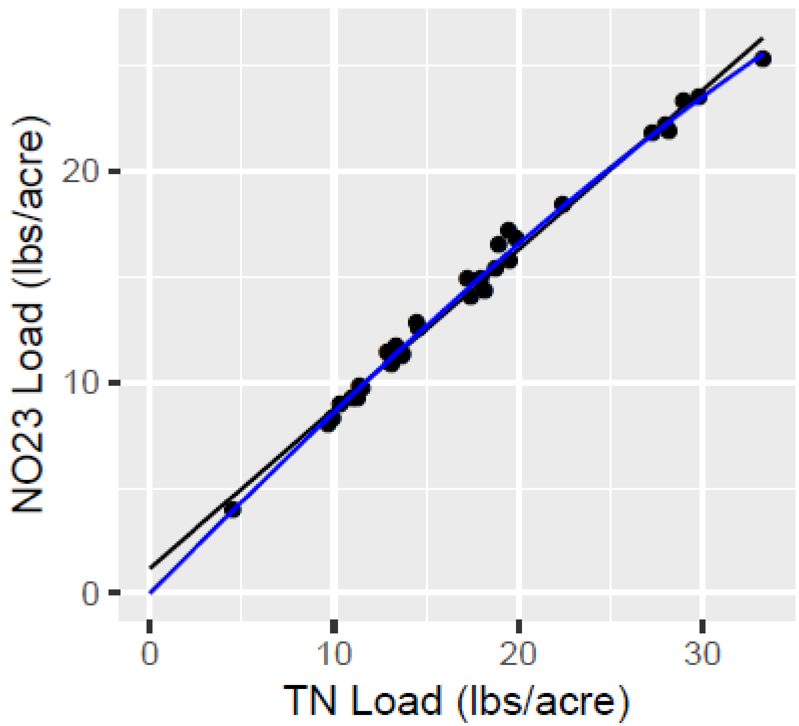

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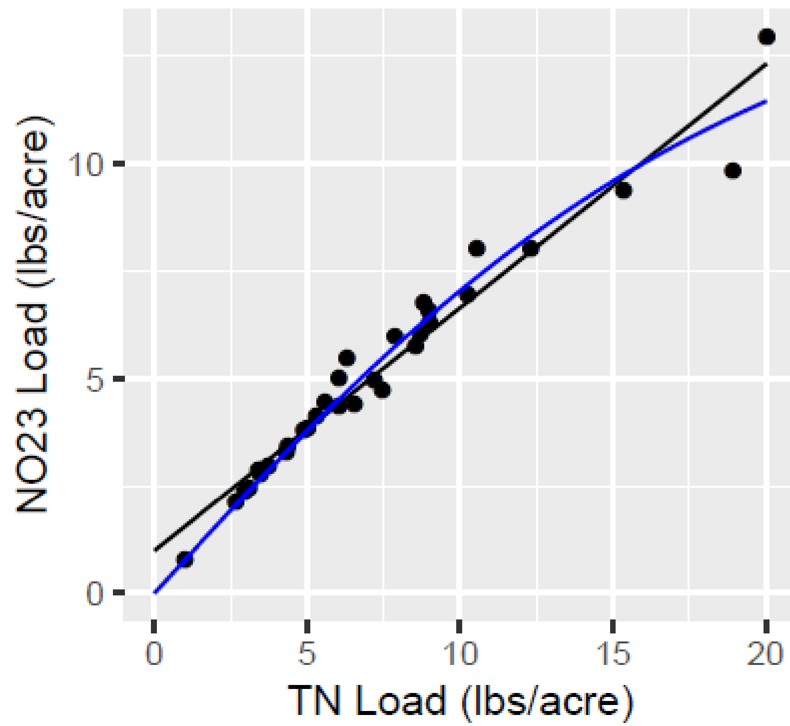

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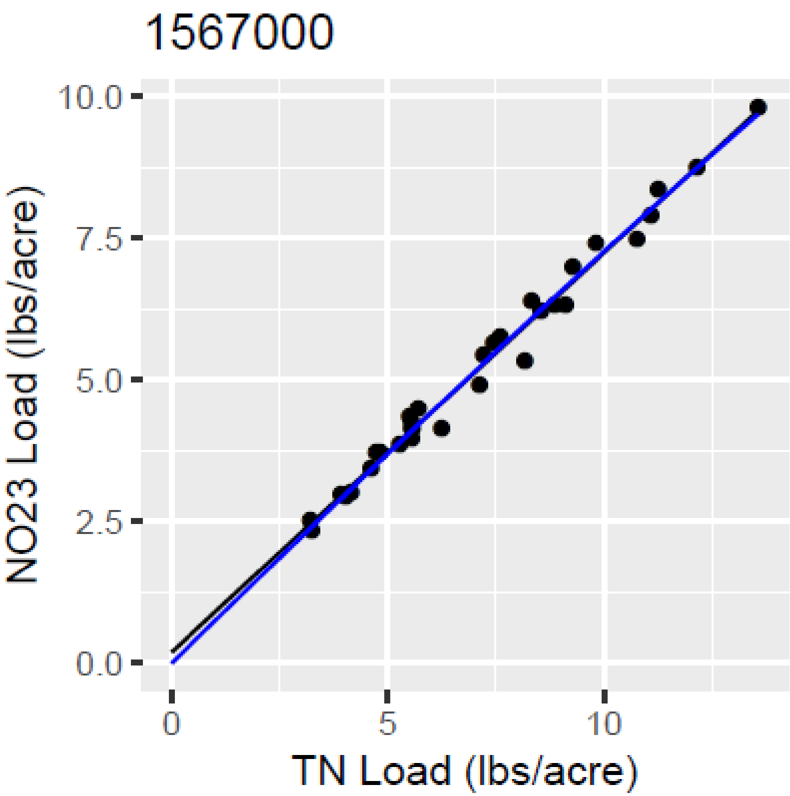
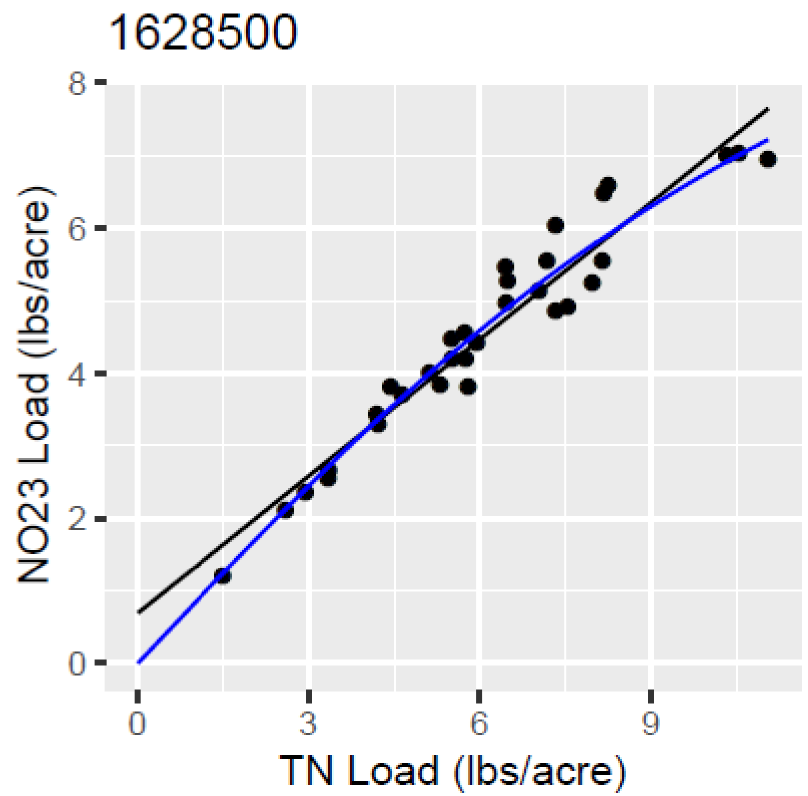




Nonlinear Hierarchical Regression with parameters varying by WRTDS station

1st Level

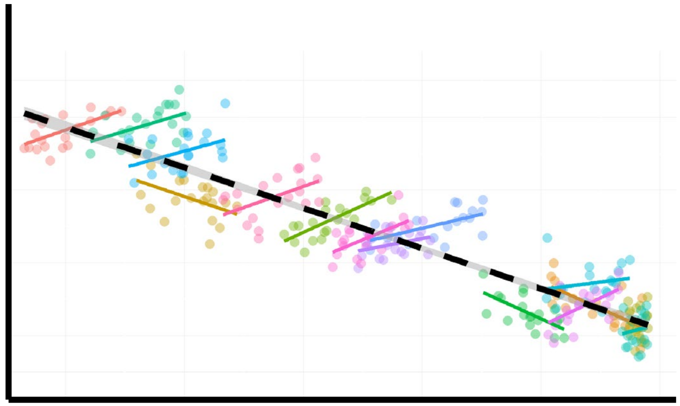
$NO3_{i,j} \sim Normal(\hat{y}_{i,j}, \sigma)$ (Eq. 1)

$\hat{y}_{i,j} = \frac{\alpha_j * TN_{i,j}}{\sqrt{\beta_j{}^2 + TN_{i,j}{}^2}}$ (Eq. 2)

2nd Level

$\alpha_j \sim Normal(a_0 + a_1 * \overline{TN}_j, \sigma_\alpha)$ (Eq. 3)

$\beta_j \sim Normal(b_0 + b_1 * \overline{TN}_j, \sigma_\beta)$ (Eq. 4)



1st Level + 2nd Level combined:

$$NO3_{i,j=J} = \frac{\left(a_o + a_1\overline{TN}_{j=J}\right) \times TN_{i,j=J}}{\sqrt{\left(b_o + b_1\overline{TN}_{j=J}\right)^2 + TN_{i,j=J}{}^2}}$$

$NO3_{i,j}$: NO3 load in **year i** at **station j**

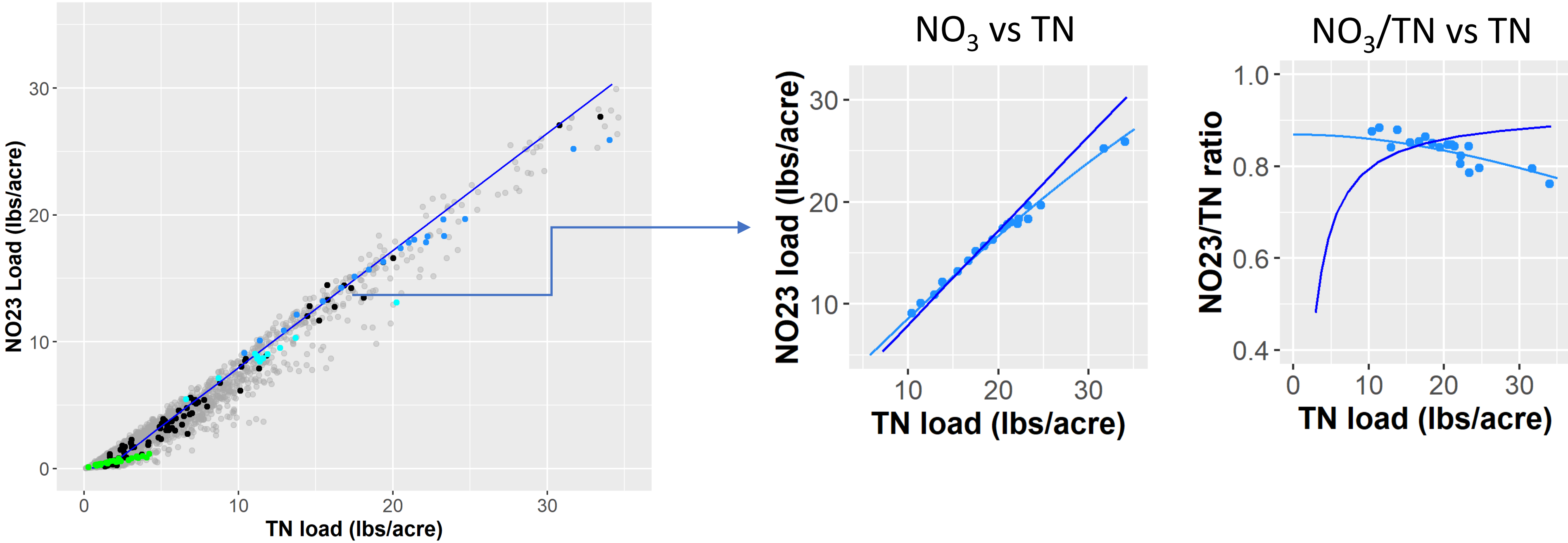
$\hat{y}_{i,j}$: mean deterministic model prediction for $NO3_{i,j}$

$TN_{i,j}$: TN load in year i at station j

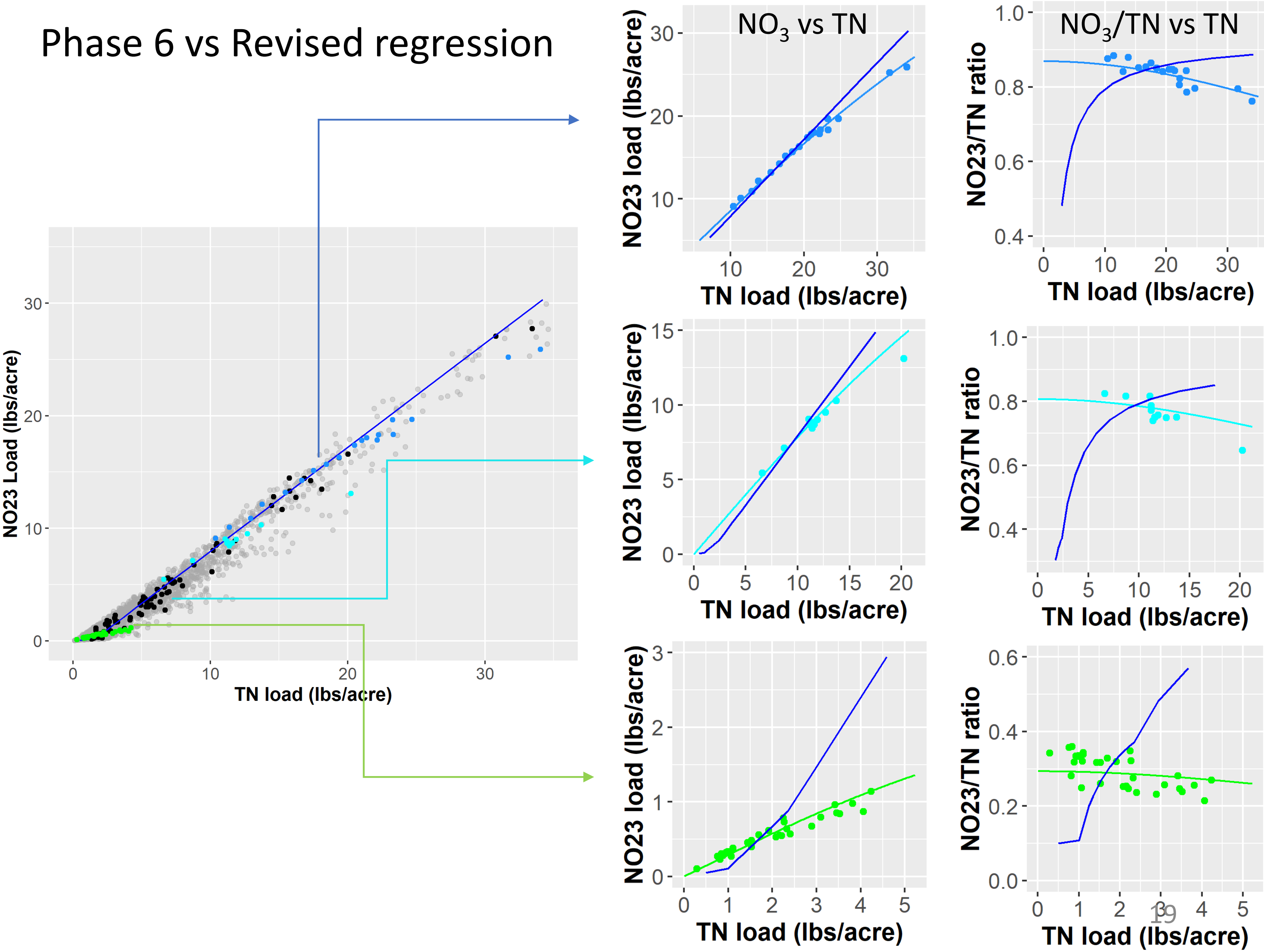
$\overline{TN}_j$: long-term average TN load at station j

Phase 6 vs Revised regression

$$NO3_{i,j=J} = \frac{\left(-3.26 + 3.16 \times \overline{TN}_{j=J}\right) \times TN_{i,j=J}}{\sqrt{\left(3.56 + 3.27 \times \overline{TN}_{j=J}\right)^2 + {TN_{i,j=J}}^2}}$$



Phase 6 vs Revised regression



Phase 6 vs Revised regression

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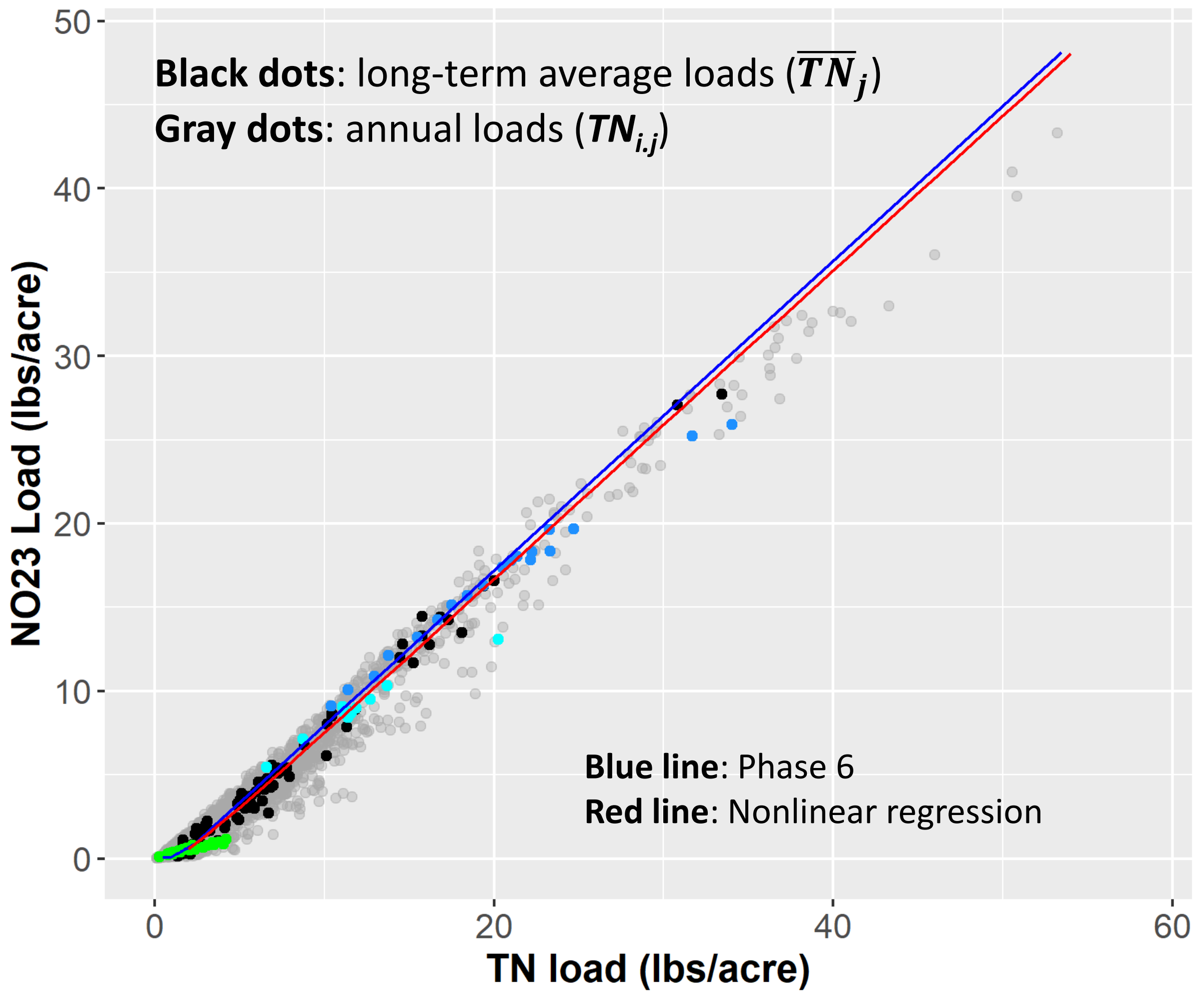
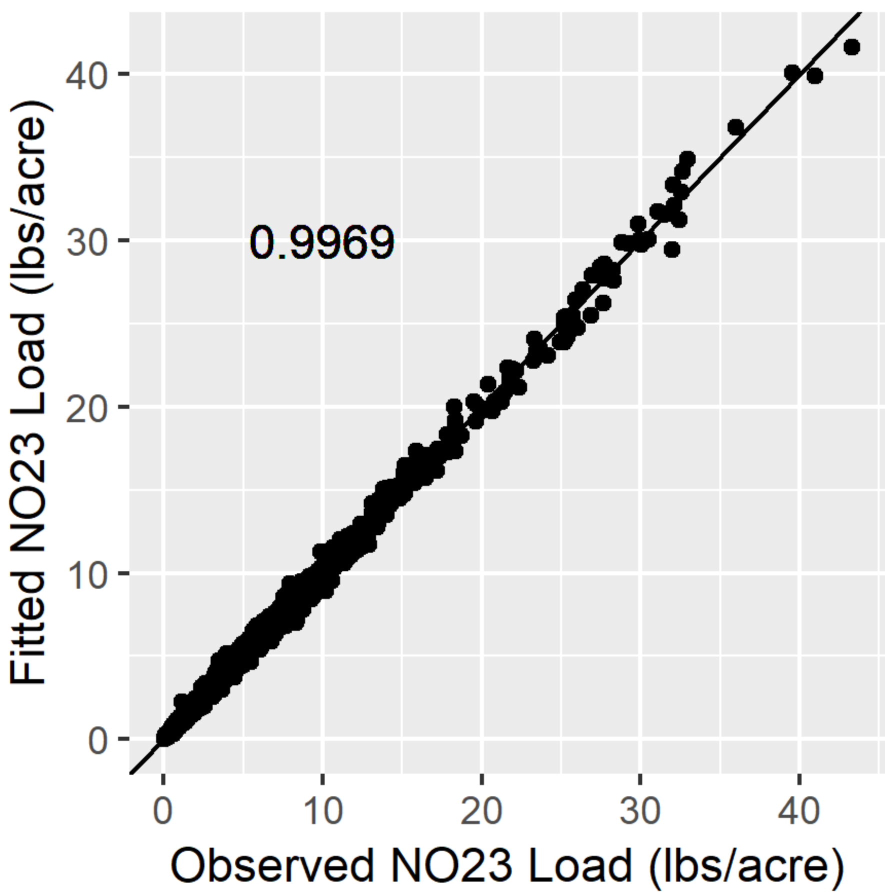
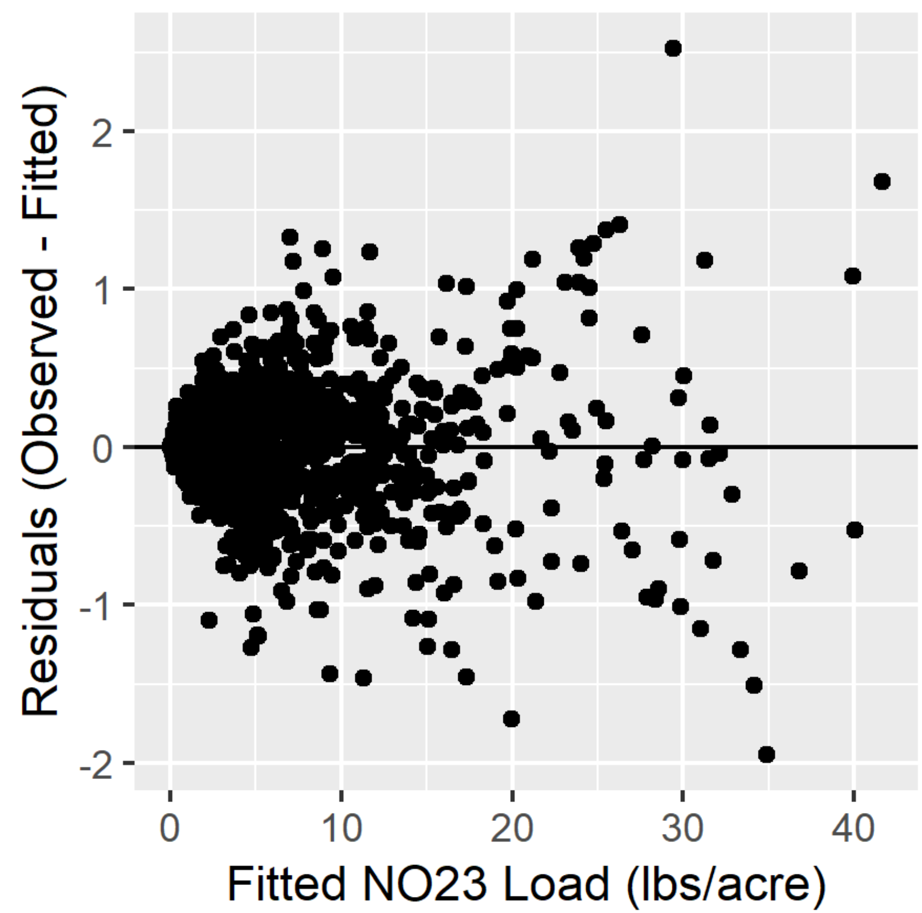


Revised regression model performance

Observed vs Fitted



Residuals vs Fitted



Conclusions

- A revised nonlinear hierarchical regression provides a means to better capture changes in NO_3/TN observed at WRTDS sites as a result of inter-annual changes in hydrology

- We propose using this revised regression to estimate edge-of-river N speciation response

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Seeking approval of

Section 4.7.1 – Changes in speciation

of 2019 Climate Change Documentation

Main outcome: Revise regression model used to estimate EOR fraction of TN that is NO_3 in P6 Watershed Model