Understanding Trends in Load

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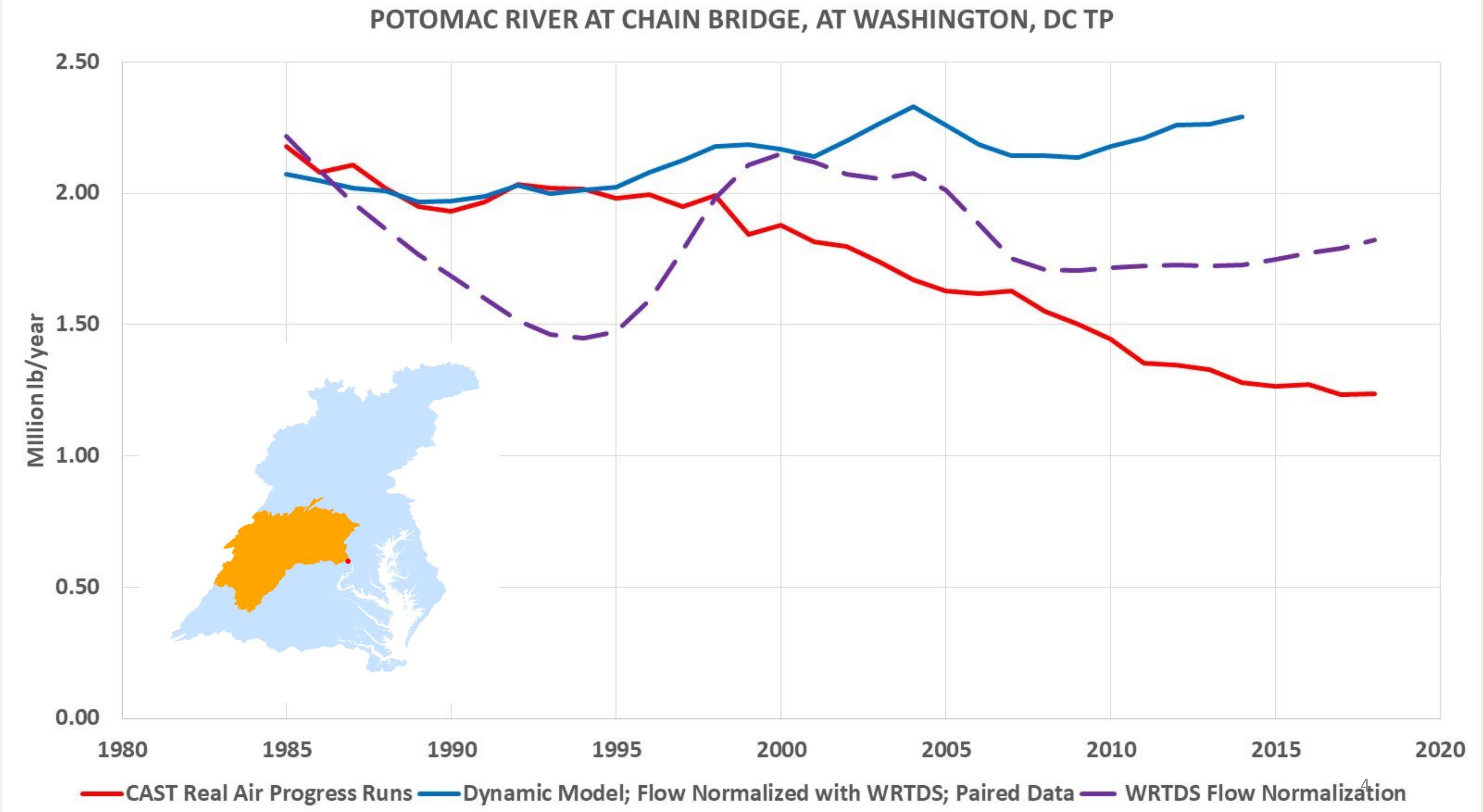
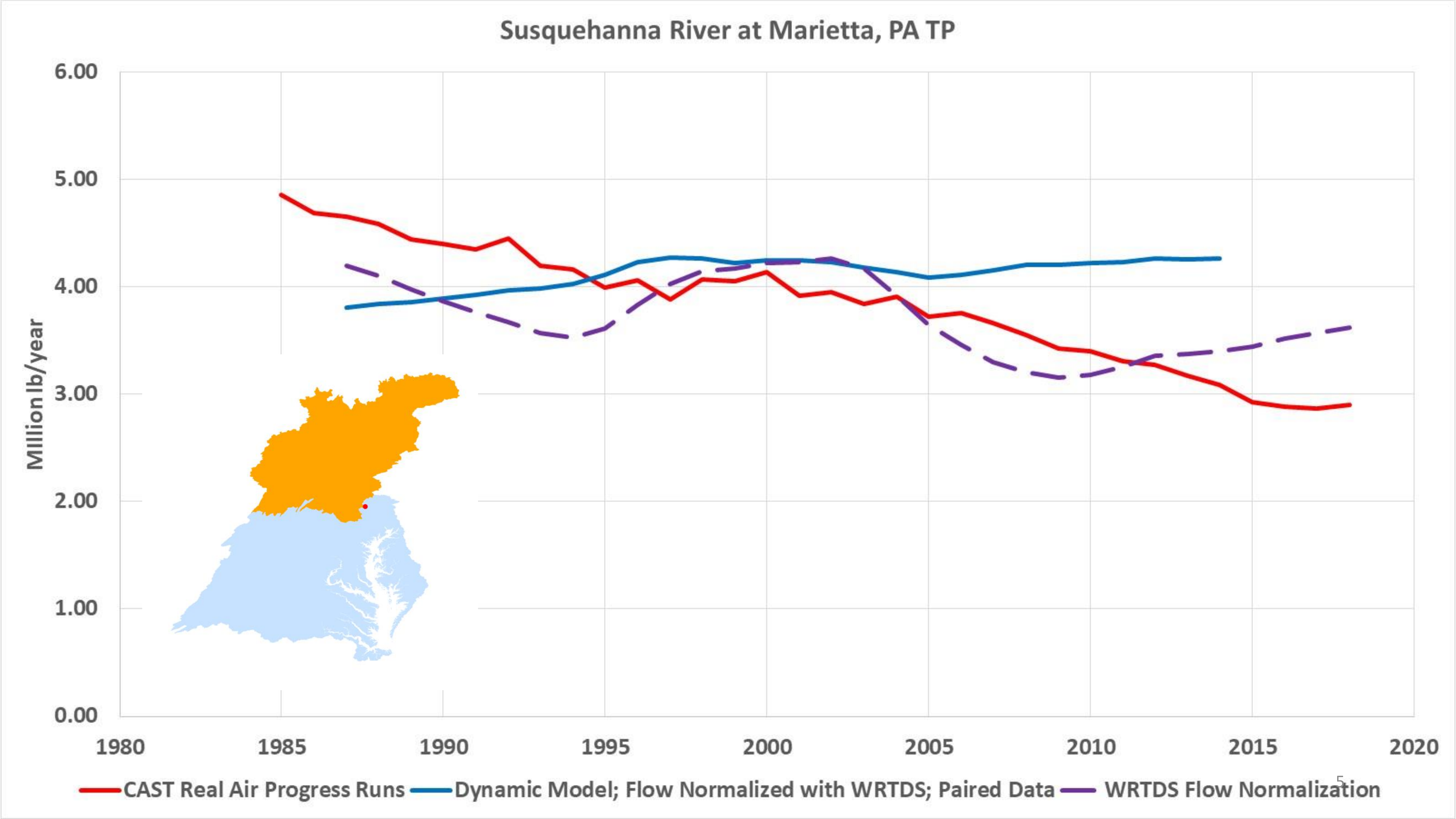
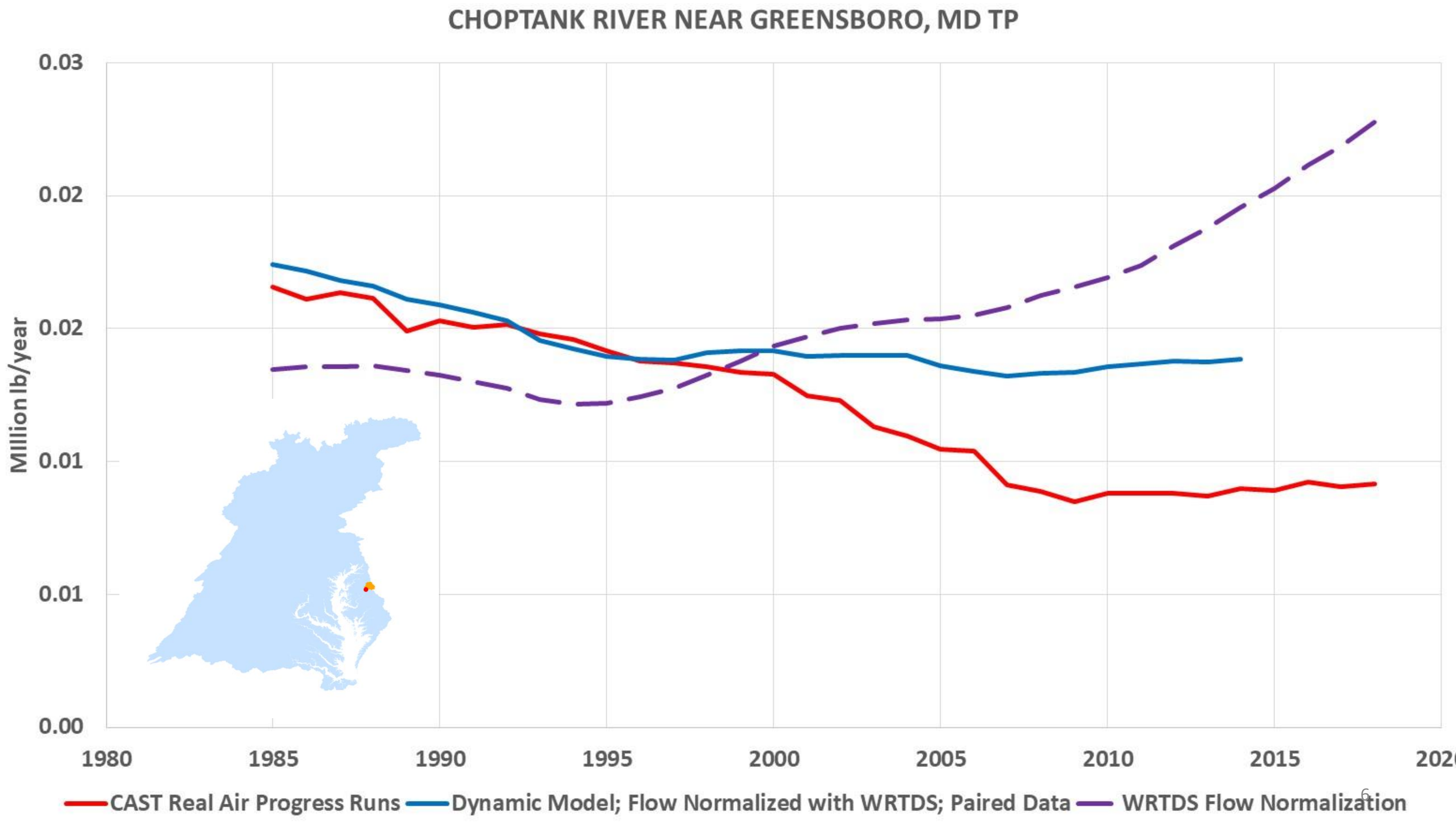
Understanding “humps” in TP loads

- WRTDS flow-normalized TP loads exhibit ‘humps’ around the late 90s – early 00s at several stations across the watershed. These “humps” are only partially captured by the Dynamic Model.
- What may be causing these “humps”?
- Understanding whether/which watershed processes may be causing these “humps” may help us reconcile differences between WRTDS and Dynamic Model flow-normalized trends in TP loads.

Some examples of TP “humps”


POTOMAC RIVER AT CHAIN BRIDGE, AT WASHINGTON, DC TP
Million lb/year
2.50
2.00
1.50
1.00
0.50
0.00
1980
1985
1990
1995
2000
2005
2010
2015
2020
CAST Real Air Progress Runs
Dynamic Model; Flow Normalized with WRTDS; Paired Data
WRTDS Flow Normalization


Susquehanna River at Marietta, PA TP
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Million lb/year
1980
1985
1990
1995
2000
2005
2010
2015
2020
CAST Real Air Progress Runs
Dynamic Model; Flow Normalized with WRTDS; Paired Data
WRTDS Flow Normalization


CHOPTANK RIVER NEAR GREENSBORO, MD TP
0.03
0.02
0.02
0.01
0.01
0.00
Million lb/year
1980
1985
1990
1995
2000
2005
2010
2015
2020
CAST Real Air Progress Runs
Dynamic Model; Flow Normalized with WRTDS; Paired Data
WRTDS Flow Normalization

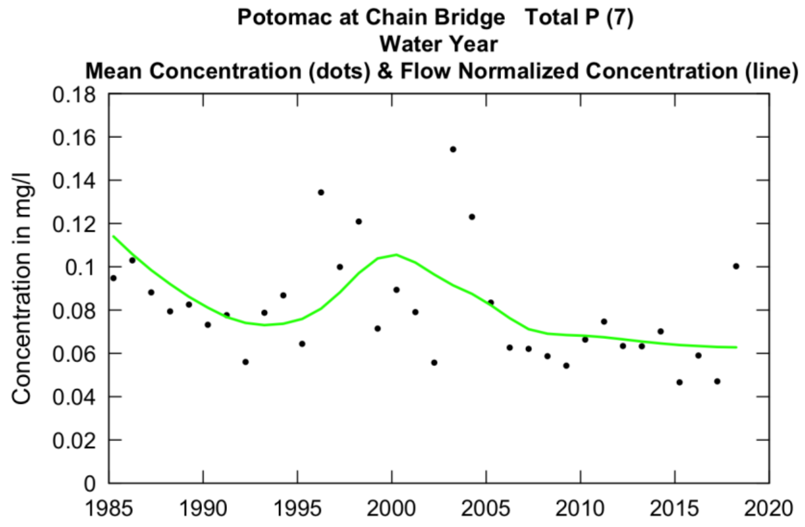
The “Drought Hypothesis”

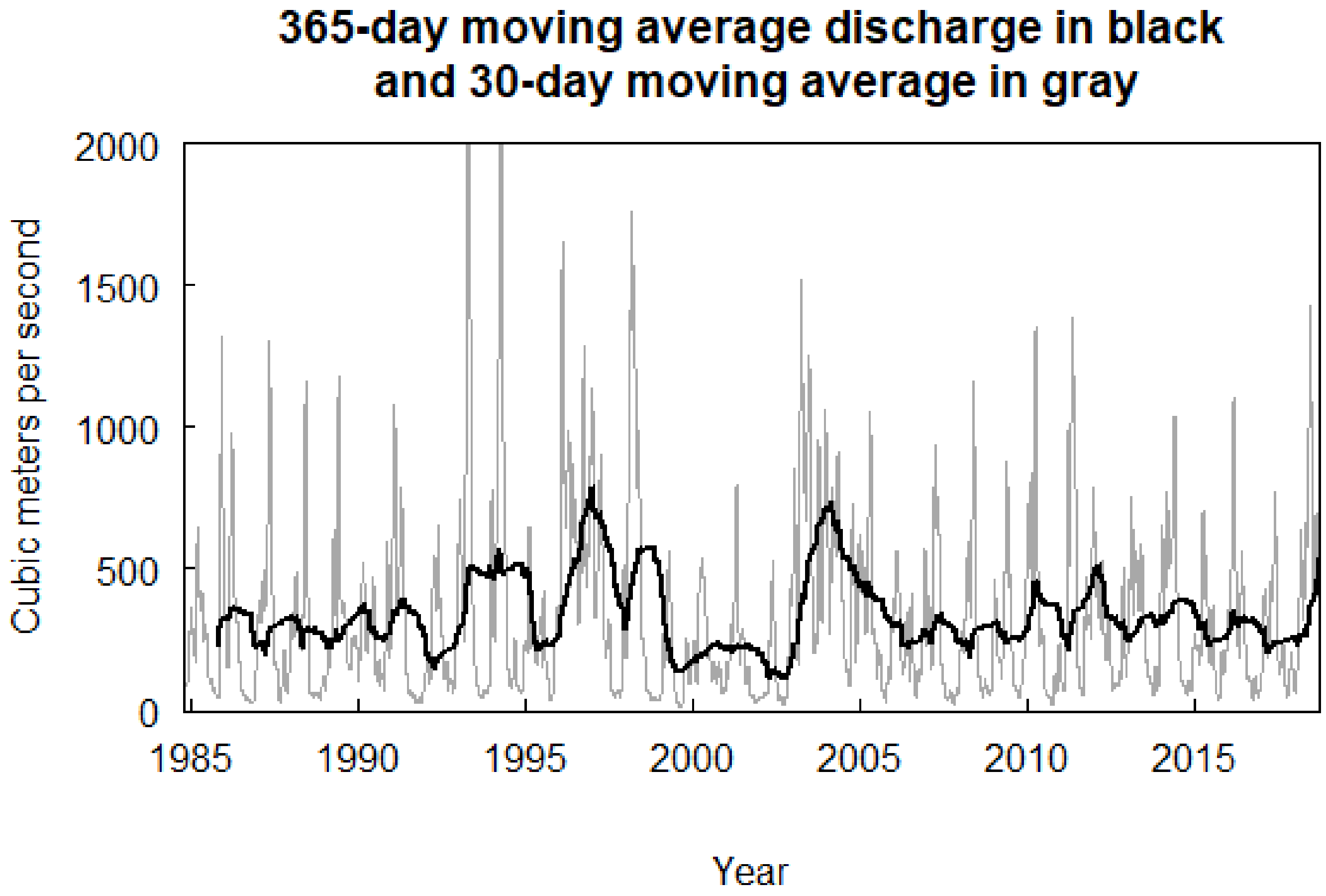
- TP “humps” appear to roughly coincide with a stretch of prolonged dry conditions (1999-2002) across the watershed

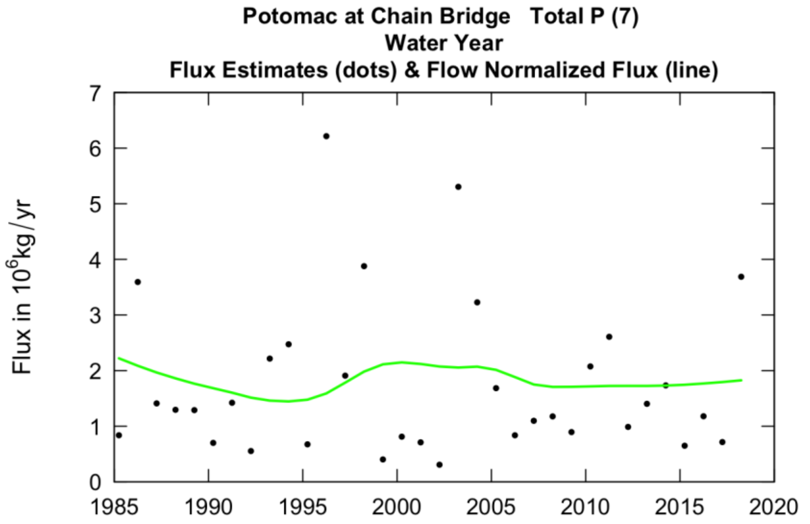
- Is this prolonged drought associated with changes in the C-Q relationship that may have resulted in the observed “humps”?

- The Potomac River at Chain Bridge was chosen as an initial case study to answer this question (**Hirsch, unpublished**)

Potomac River at Chain Bridge

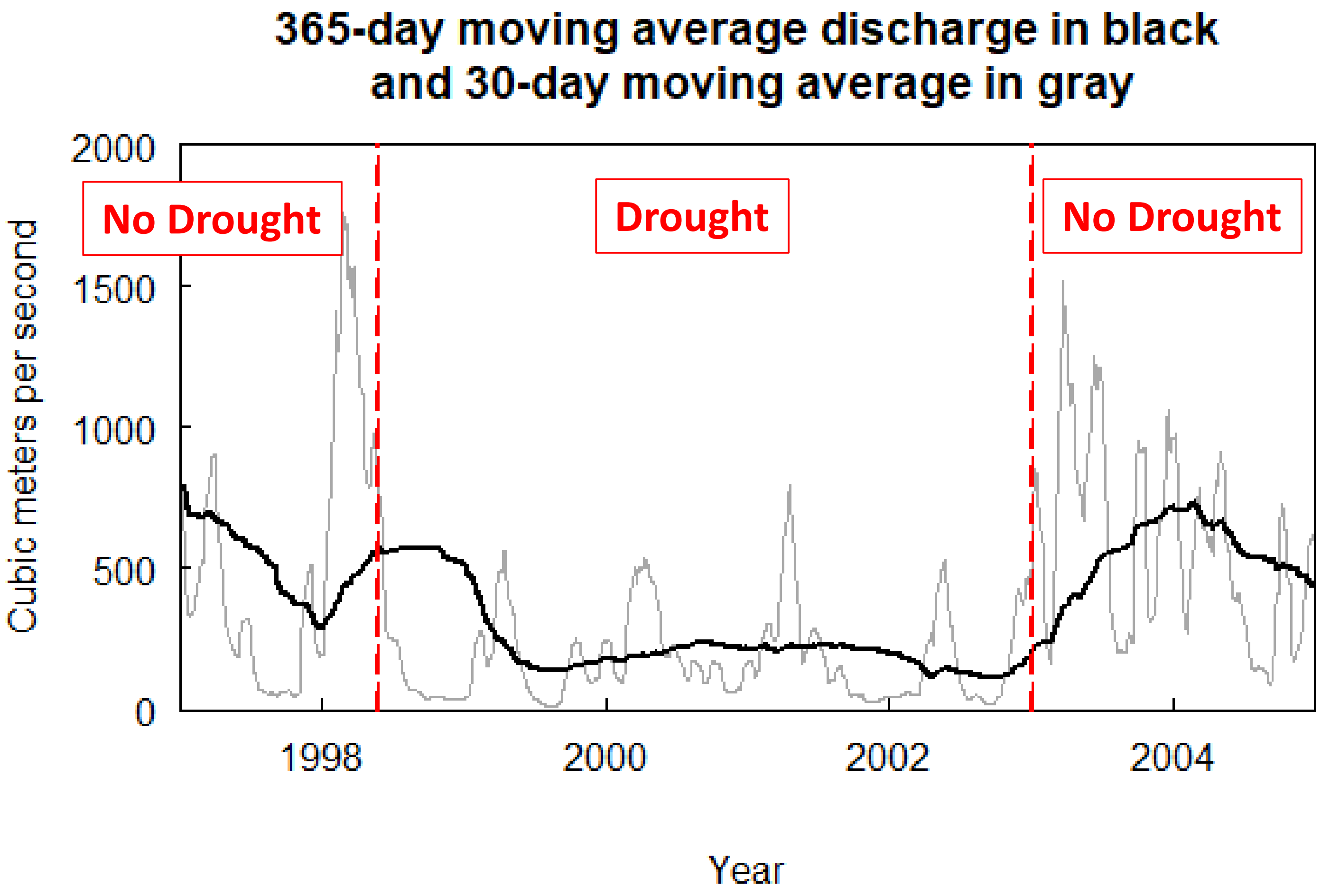






Hirsch, unpublished

Potomac River at Chain Bridge



After accounting for flow (Q) and season (DY), are TP concentrations systematically different in the "Drought" vs. "No Drought" period?

The following regression was fit:

$\log[TP] \sim \log Q + \log Q^2 + \sin DY + \cos DY + D$

D: Binary Drought/No Drought variable

Hirsch, unpublished

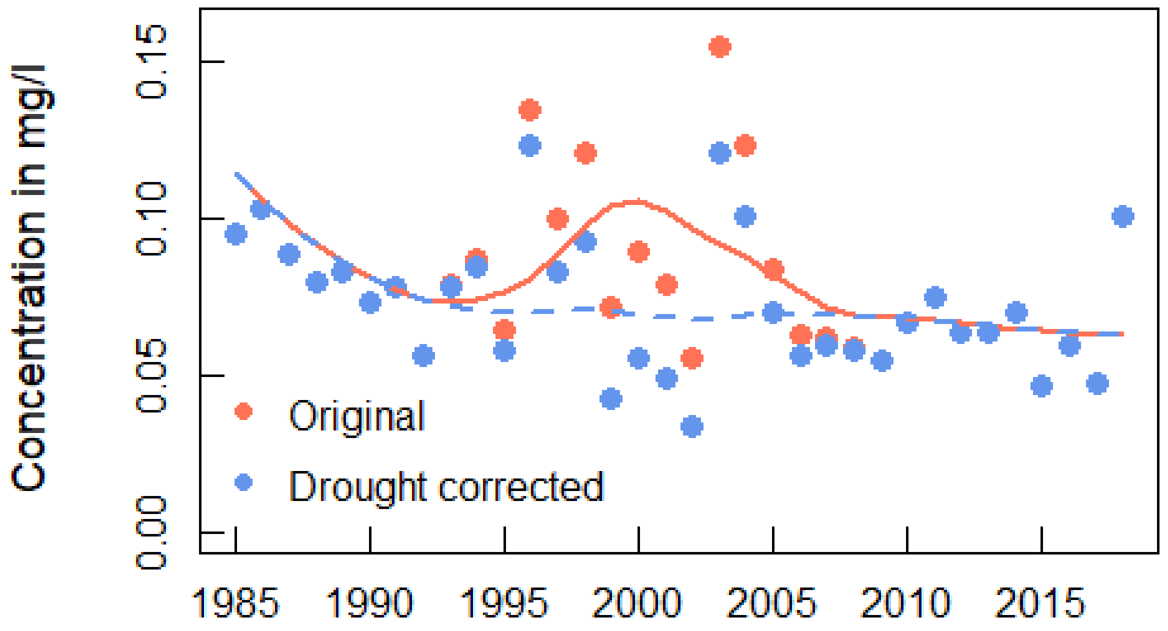
Potomac River at Chain Bridge

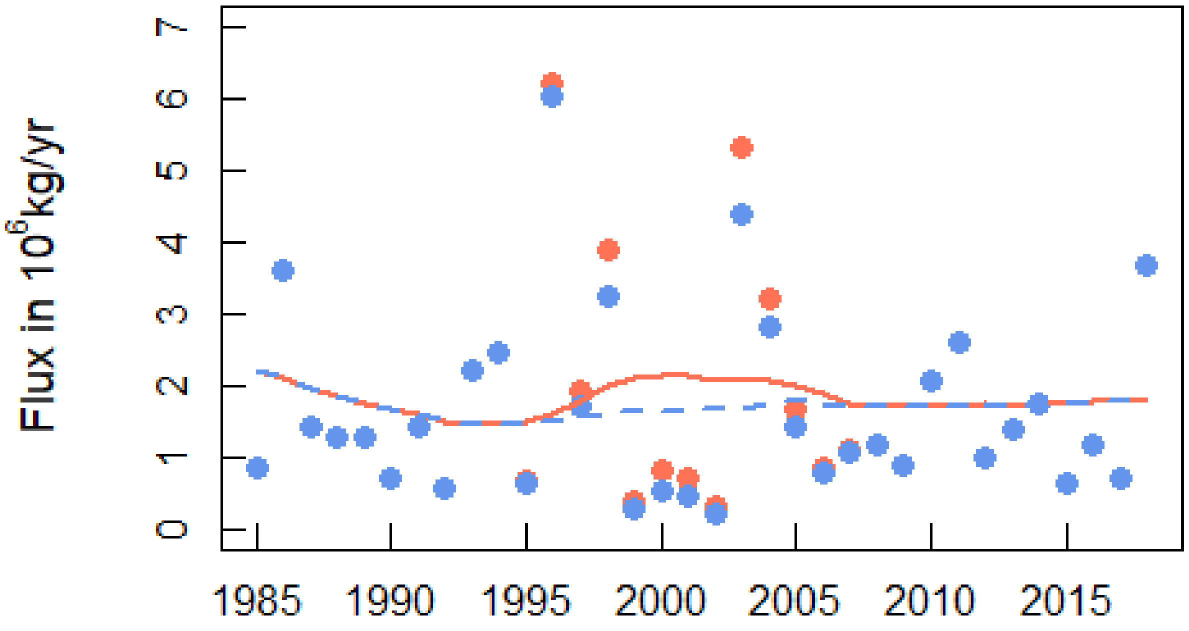
Regression results show a positive relationship between [TP] and the Drought variable. That is, **[TP]** tends to be **higher** than expected **during the "Drought"** compared to the "No Drought" period.

How does the "hump" change when the effect of the Drought variable is accounted for?

Potomac River at Chain Bridge

After accounting for dry conditions by removing the “excess” TP concentration associated with the drought, the “hump” in flow-normalized concentrations and loads disappears





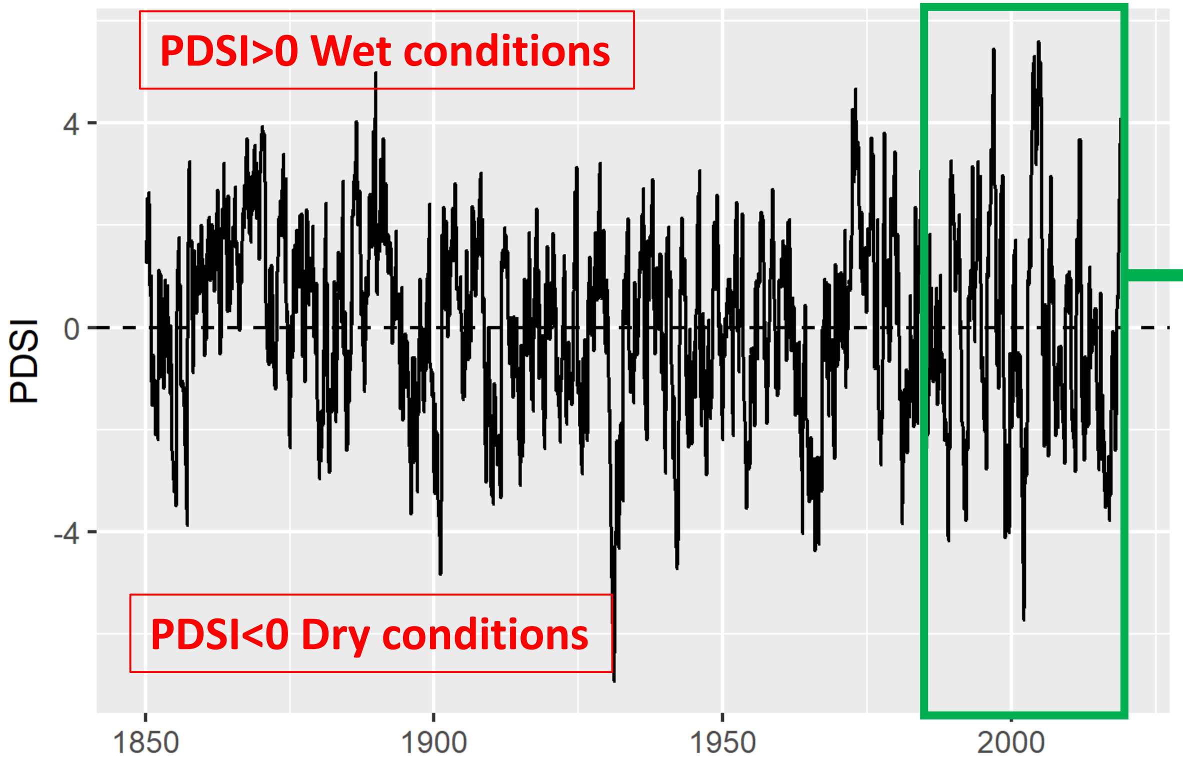
Hirsch, unpublished

Potomac River at Chain Bridge

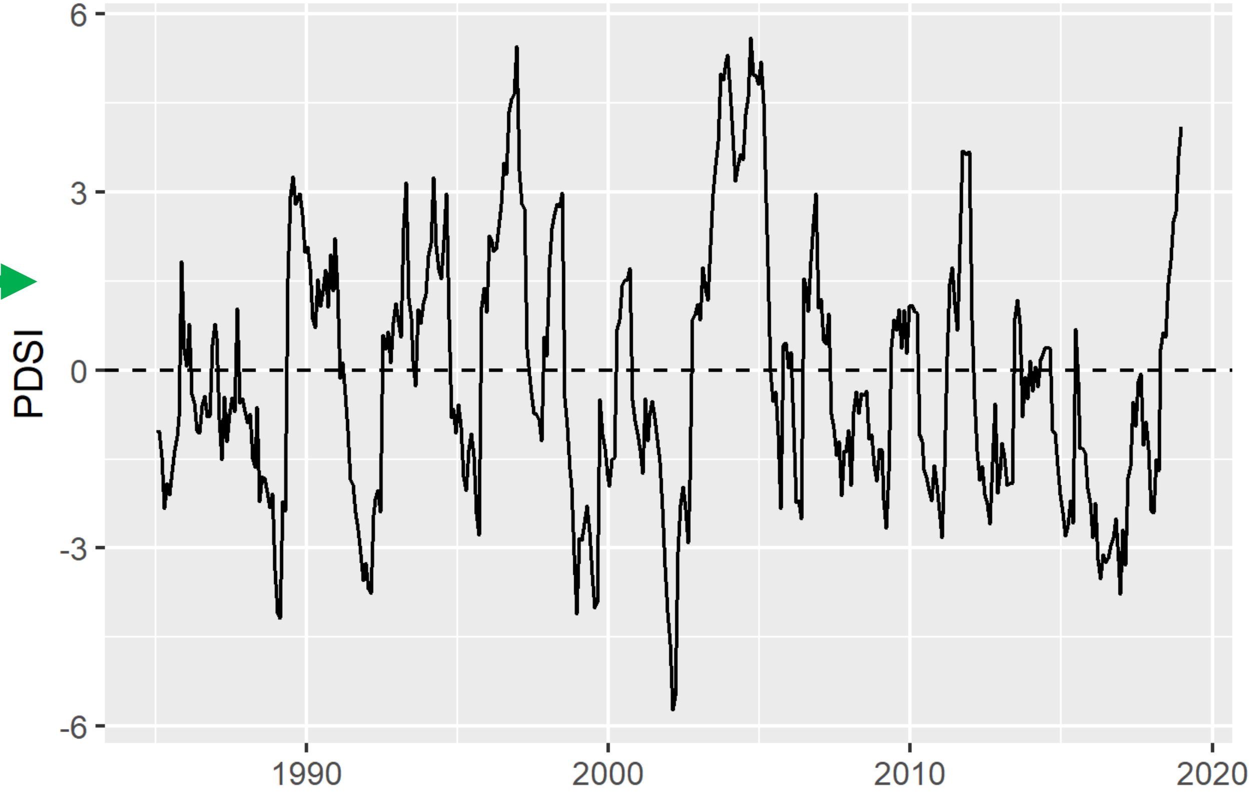
What happens if we replace the binary Drought/No Drought variable with a continuous variable that quantifies Drought Severity and extend the analysis over the whole period of record (1985-2018)?

Palmer Drought Severity Index (PDSI)

Monthly PDSI in the CB Watershed



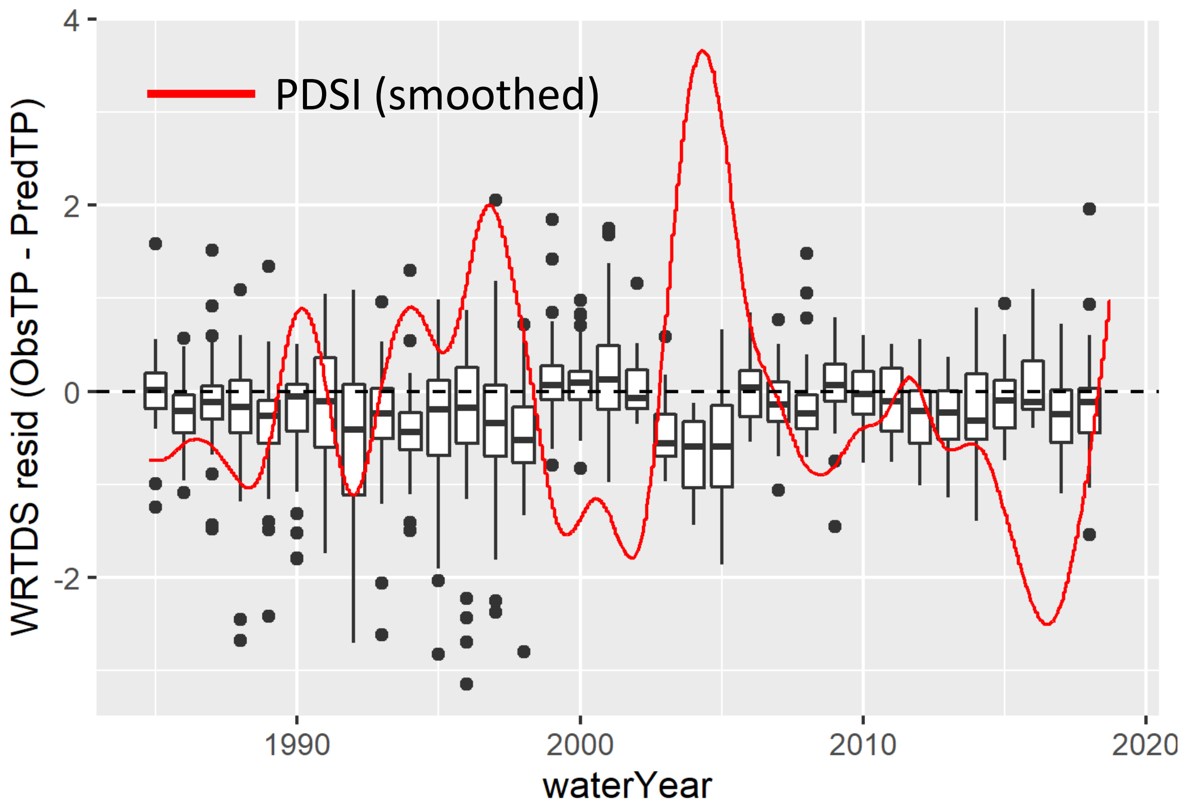
Monthly PDSI in the CB Watershed – 1985-2018



https://rda.ucar.edu/datasets/ds299.0/

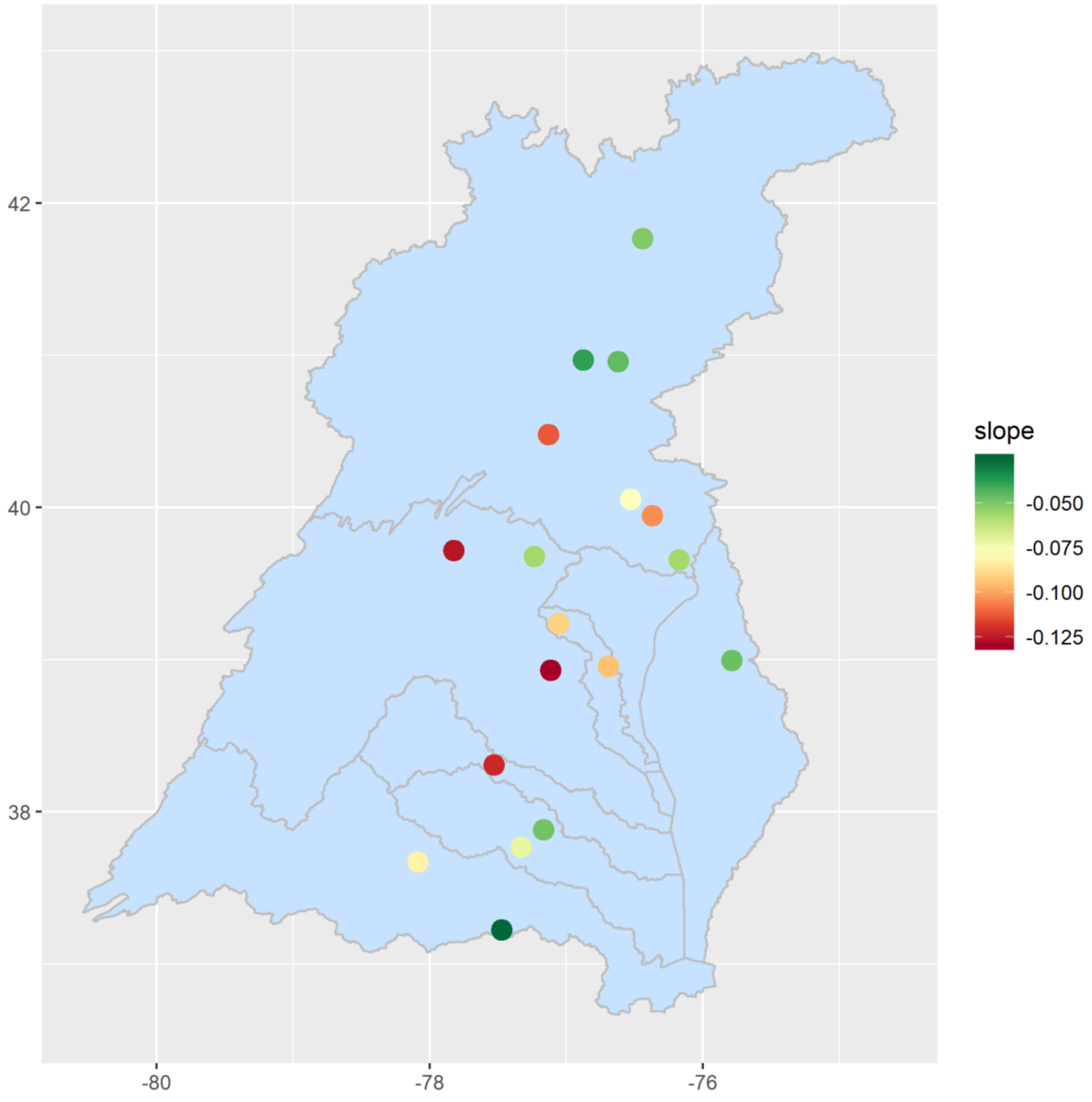
Potomac River at Chain Bridge

There is a **negative relationship between [TP] and PDSI** after accounting for the effect of discharge, seasonality, and long-term trend through WRTDS. That is, **[TP]** tends to be **higher** than expected during **dry conditions** (negative PDSI).



Is this pattern generalizable beyond the Potomac?

Distribution of slopes of WRTDS Residuals vs. PDSI



WRTDS Residual [TP] ~ PDSI

All stations exhibit a negative relationship between WRTDS residual [TP] and PDSI

TP concentrations tend to be **higher** than expected during **dry spells** across the watershed

Conclusions

- Although still a **preliminary hypothesis**, there are indications that prolonged (multi-year) dry spells may result in changes in the C-Q relationship. This change is in the direction of higher concentrations during the dry spell, for any given combination of river discharge and time of year, as compared to concentrations expected under more normal conditions. Changes in the C-Q relationship can create short-term trends in flow-normalized loads, which then vanish in the years after the dry spell.

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- More in-depth analyses are needed to **confirm** this hypothesis and elucidate the potential mechanisms involved. The effects seen in the Potomac and Susquehanna suggest that during prolonged dry spells there may be a build-up of available P on the land surface, river beds, and riparian zones because there are no large flow events to transport this available P. As a result, more P is available for transport at low/moderate flows than would normally be the case.

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- These types of analyses have the potential to help us understand and **reconcile differences** in trends in loads across modeling products (e.g., WRTDS vs. Dynamic Model).

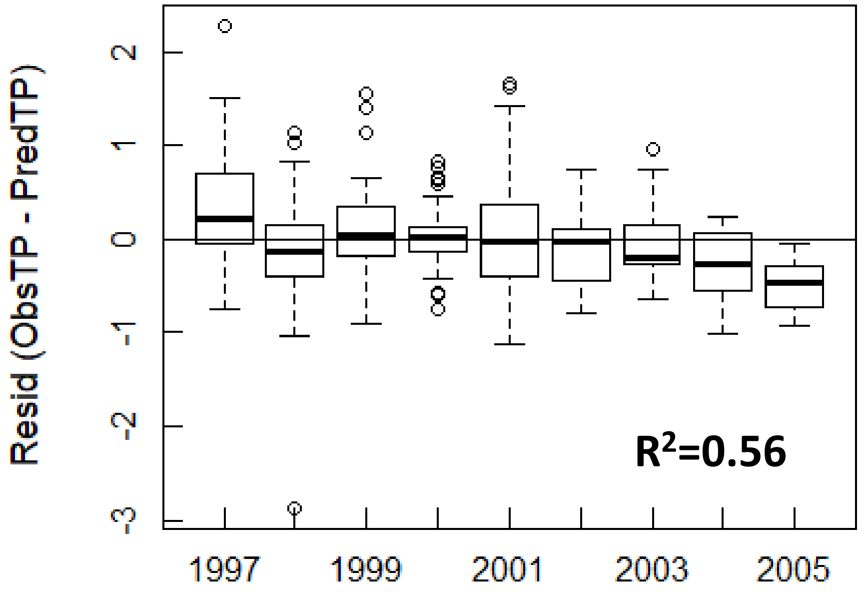
Extra Slides

Potomac River at Chain Bridge

Log[TP] ~ LogQ + LogQ^2 + SinDY + CosDY + D

	Estimate	Std. Err.	P value
Intercept	-2.33	0.39	4.56e-09 ***
LogQ	-0.88	0.15	3.56e-09 ***
LogQ2	0.14	0.01	< 2e-16 ***
SinDY	-0.41	0.04	< 2e-16 ***
CosDY	-0.35	0.04	< 2e-16 ***
D	**0.72**	**0.06**	**< 2e-16 *** **

Log[TP] is 0.72 higher during the drought on average (after accounting for discharge and season)



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Potomac River at Chain Bridge

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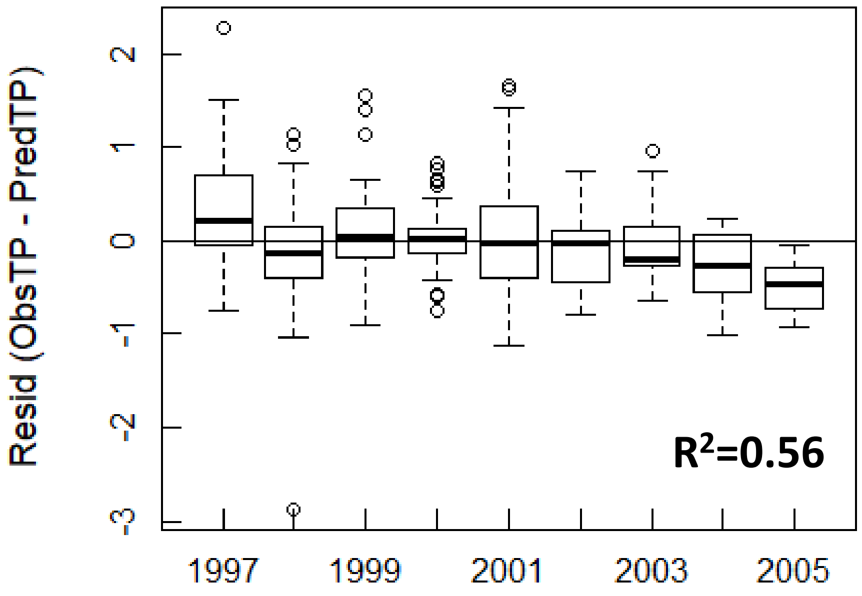
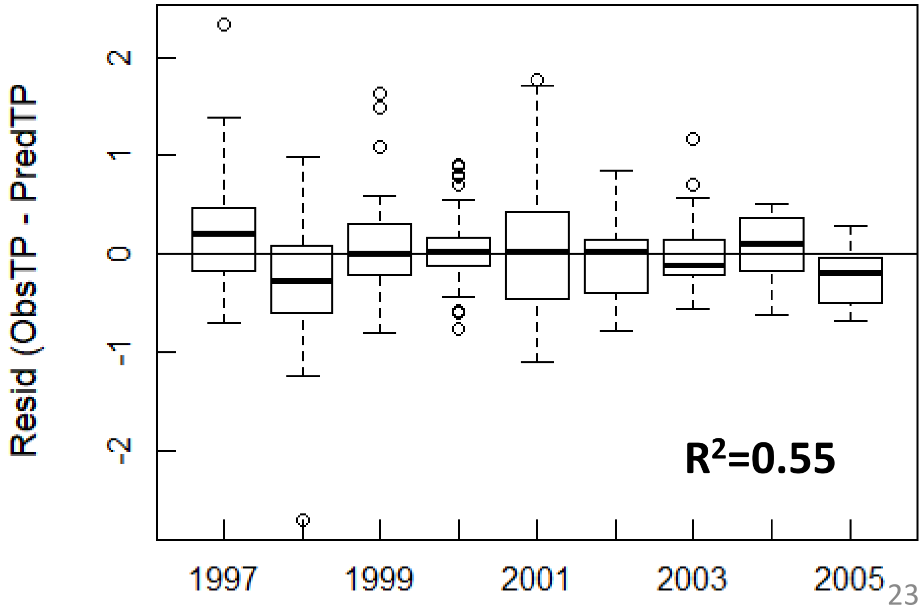
Log[TP] ~ LogQ + LogQ^2 + SinDY + CosDY + PDSI

	Estimate	Std. Err.	P value
Intercept	-2.36	0.39	4.34e-09 ***
LogQ	-0.69	0.15	3.84e-06 ***
LogQ2	0.12	0.01	4.42e-16 ***
SinDY	-0.45	0.04	< 2e-16 ***
CosDY	-0.41	0.04	< 2e-16 ***
PDSI	**-0.21**	**0.02**	**< 2e-16 *** **



Replacing the binary Drought/No Drought variable with PDSI gives very similar results



Potomac River at Chain Bridge

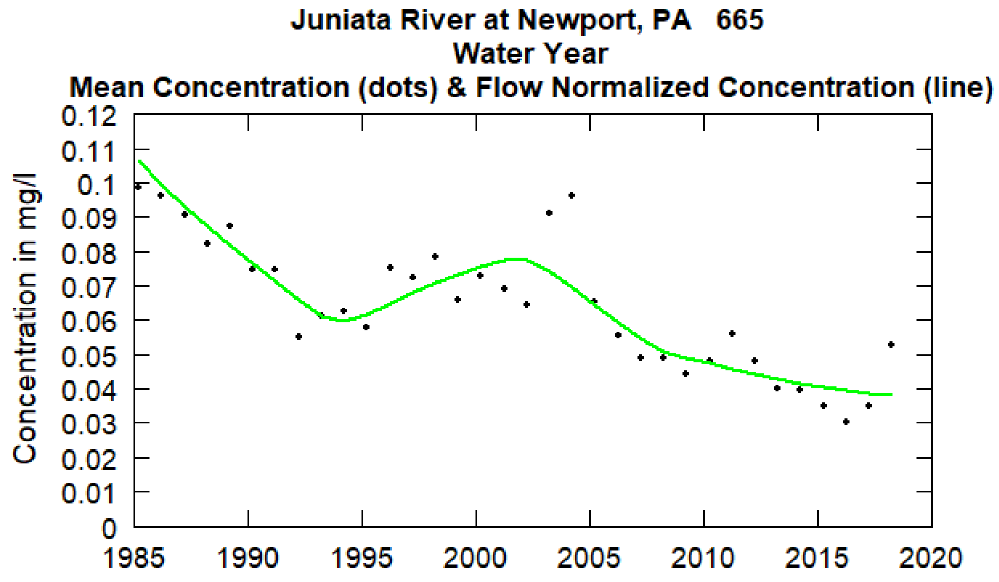
Instead of fitting the regression model used above to account for **discharge and seasonality**, we took the time series of WRTDS residual TP concentrations:

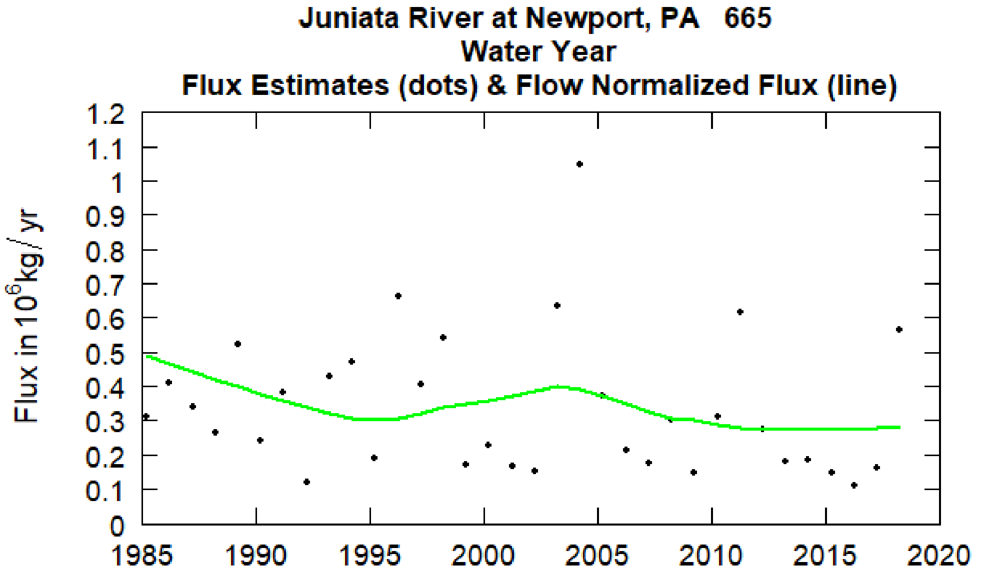
WRTDS Residuals = Log(Observed [TP]) – Log(WRTDS-Predicted [TP])

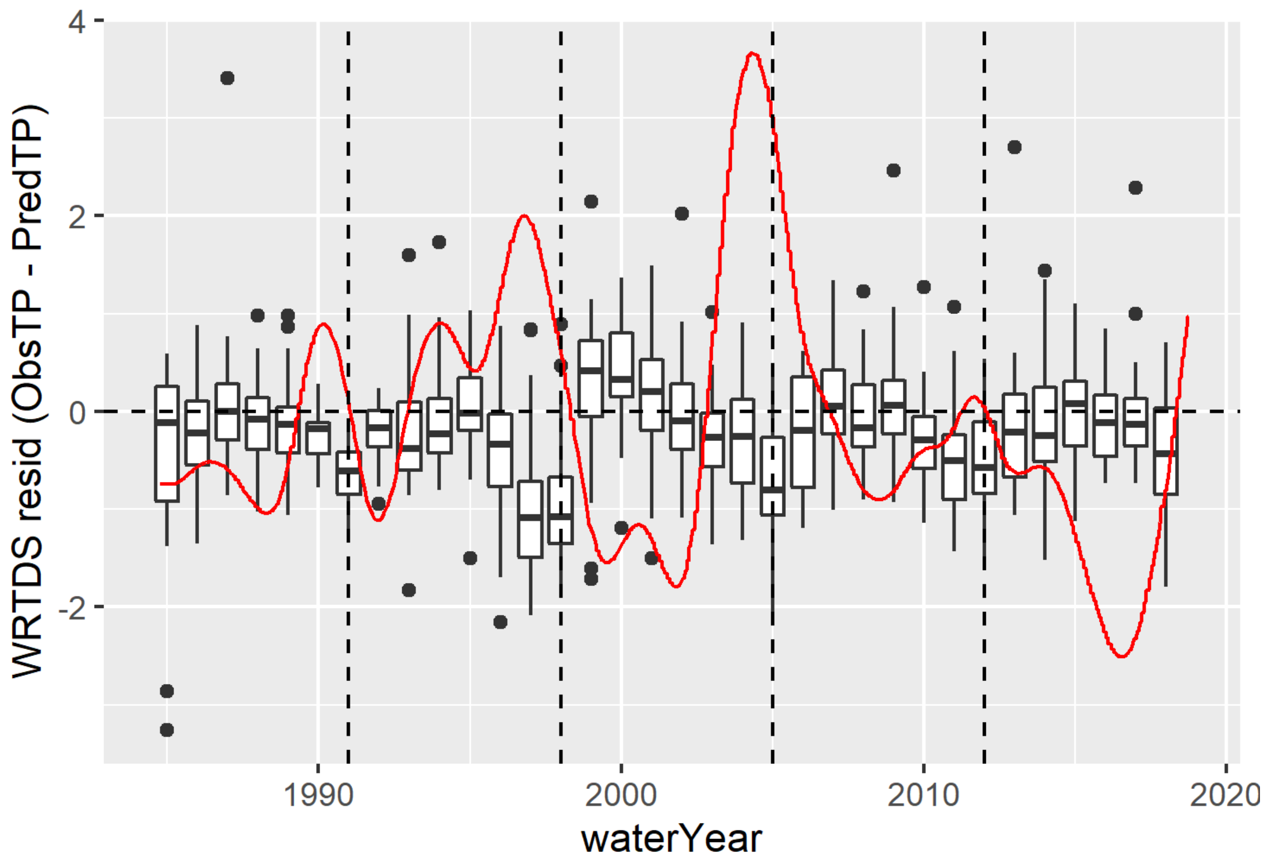
WRTDS residuals represent the amount of variability in TP concentrations that is not explained by WRTDS predictors (**discharge, seasonality, long-term trend**)

Is there any relationship between WRTDS residuals and PDSI? E.g., do residuals tend to be positive (i.e., TP concentrations are higher than expected) in relatively dry periods, similar to what was observed for the Potomac in 1998-2002?

Example: Juniata River at Newport

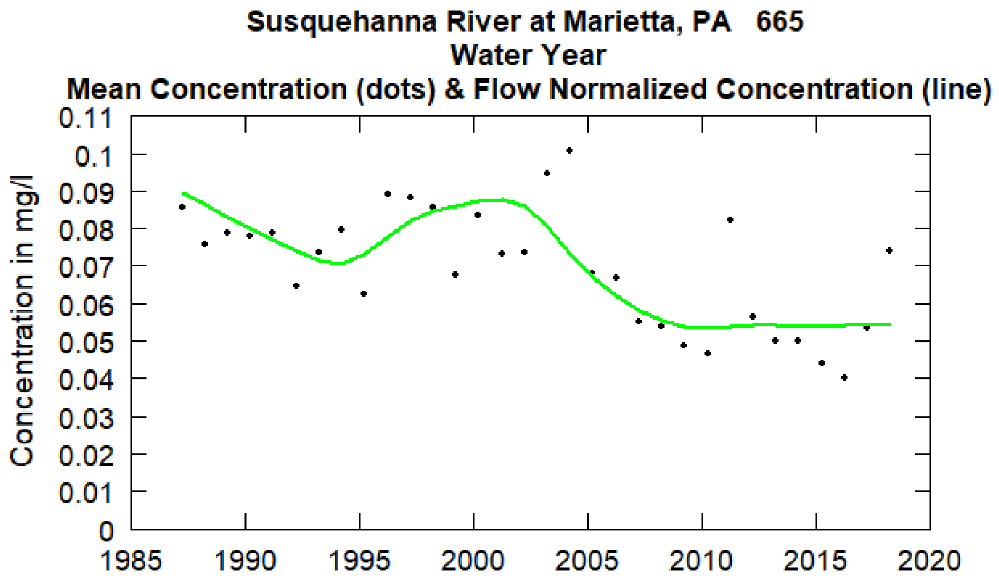


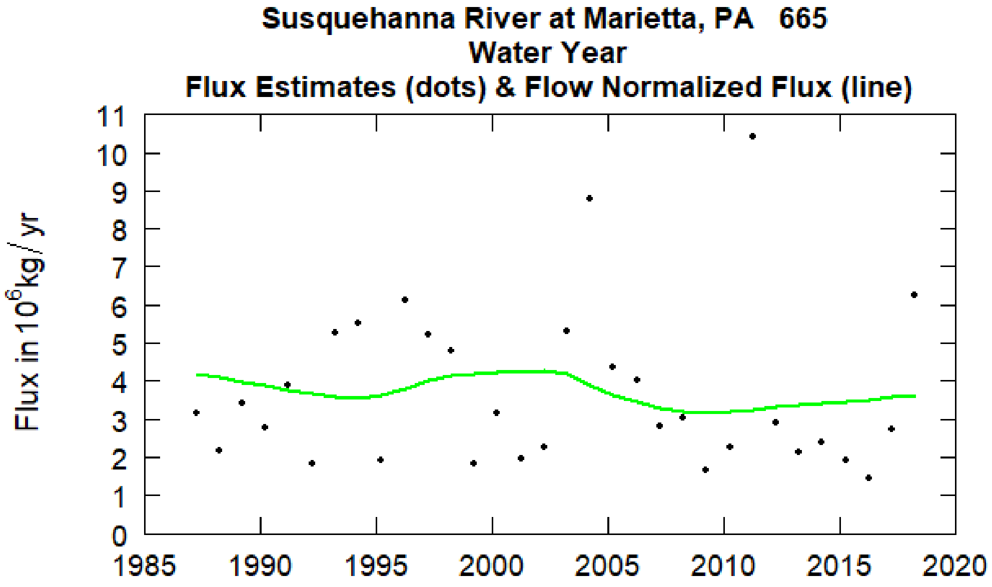


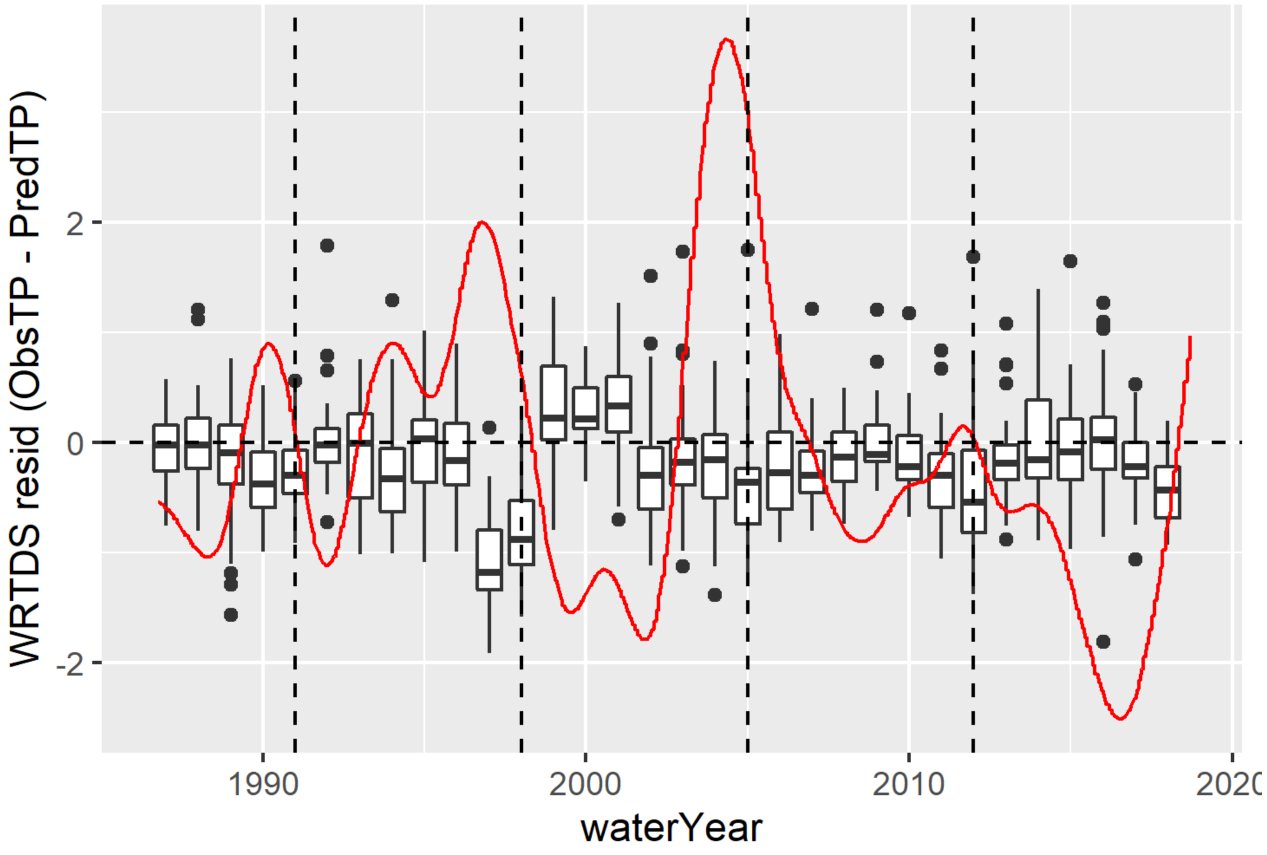


Similar negative relationship between WRTDS residual [TP] and PDSI

Example: Susquehanna River at Marietta







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