



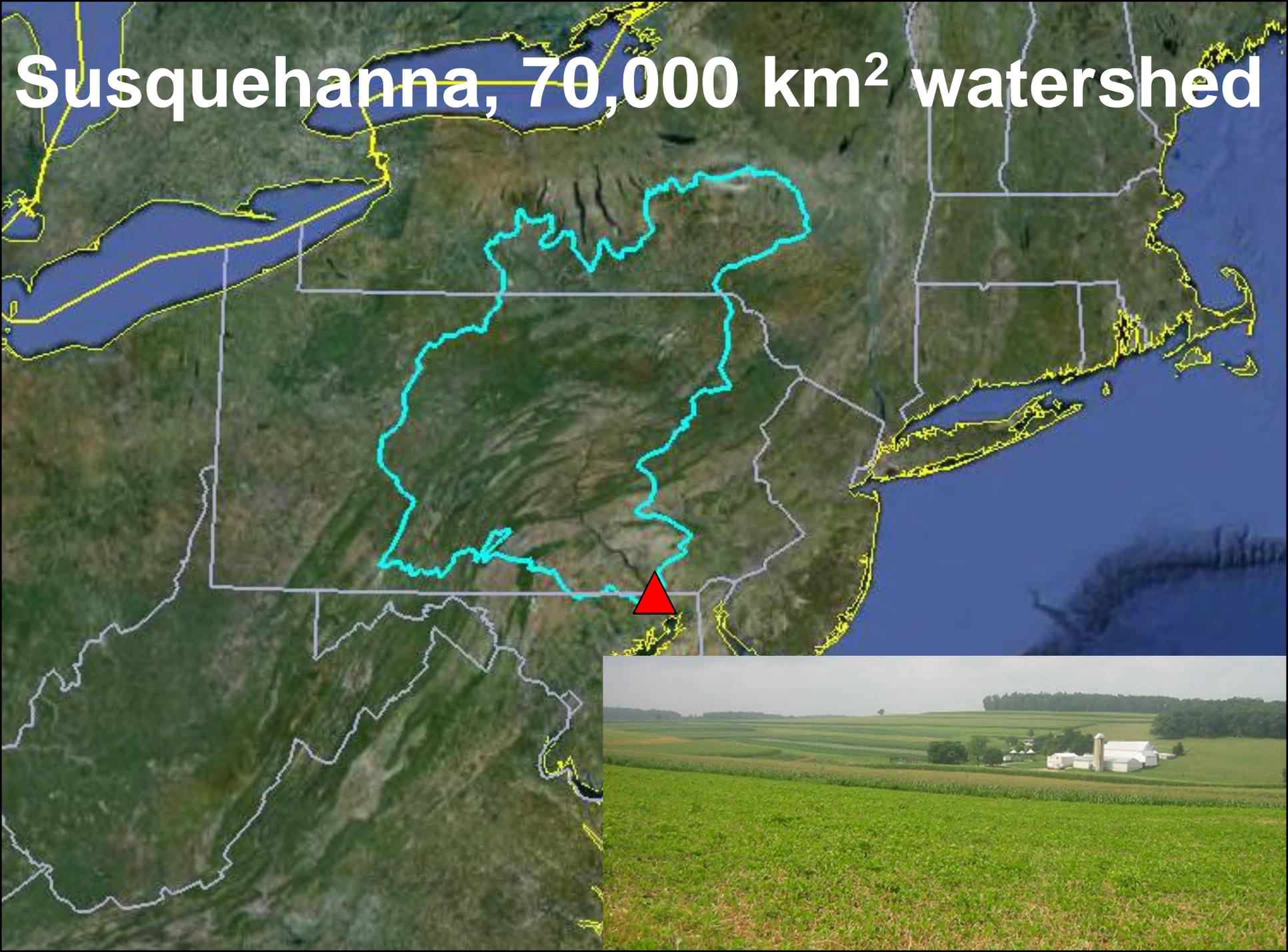
Importance of extreme events

Robert M. Hirsch
U.S. Geological Survey
30 April, 2014

My main points

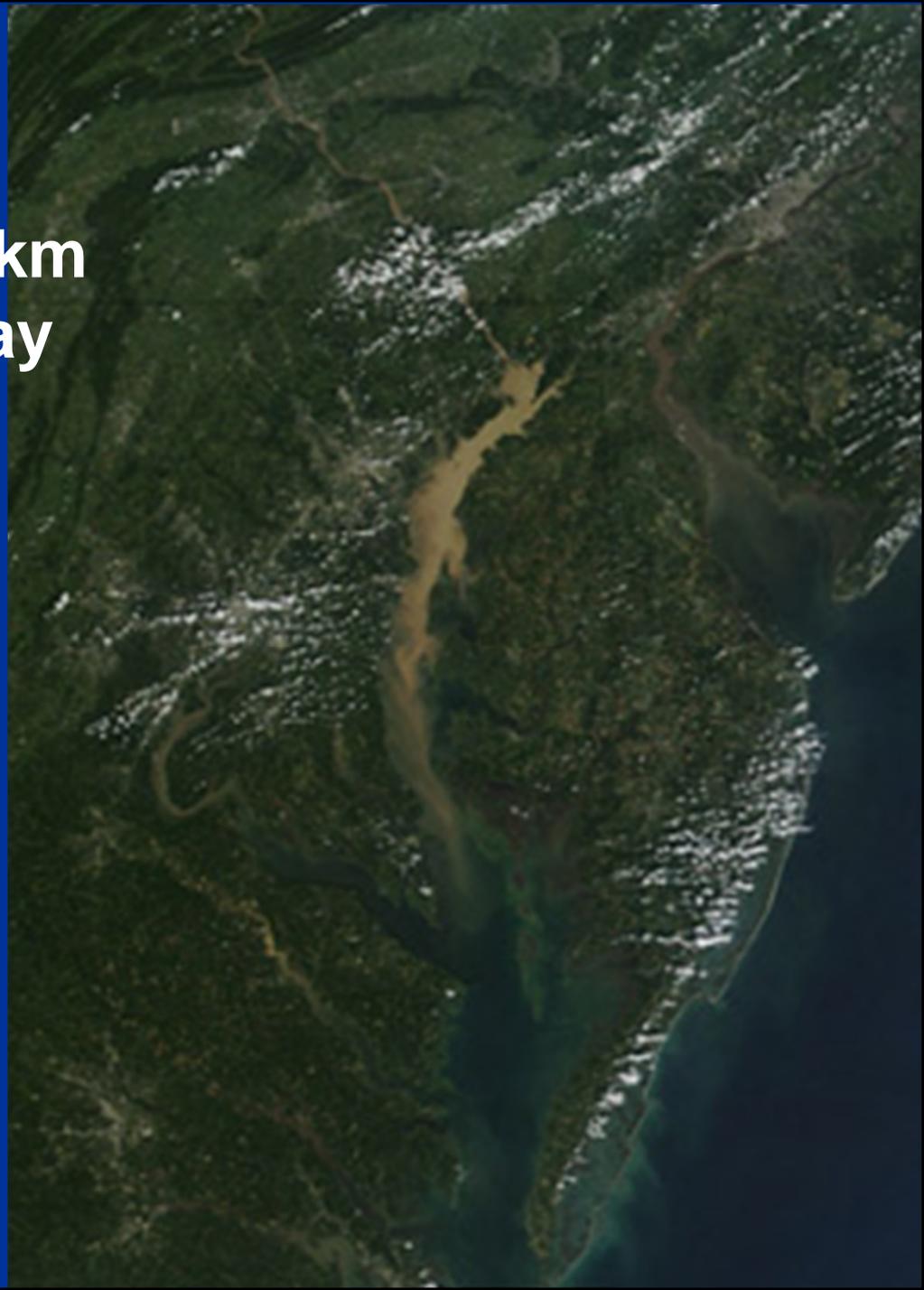
- Extreme events are natural experiments, they can tell us a lot about how things work
- The high flow events are critical to estimating fluxes
- Be very skeptical about statements about the consequences of enhanced greenhouse forcing on hydrologic extremes

Susquehanna, 70,000 km² watershed

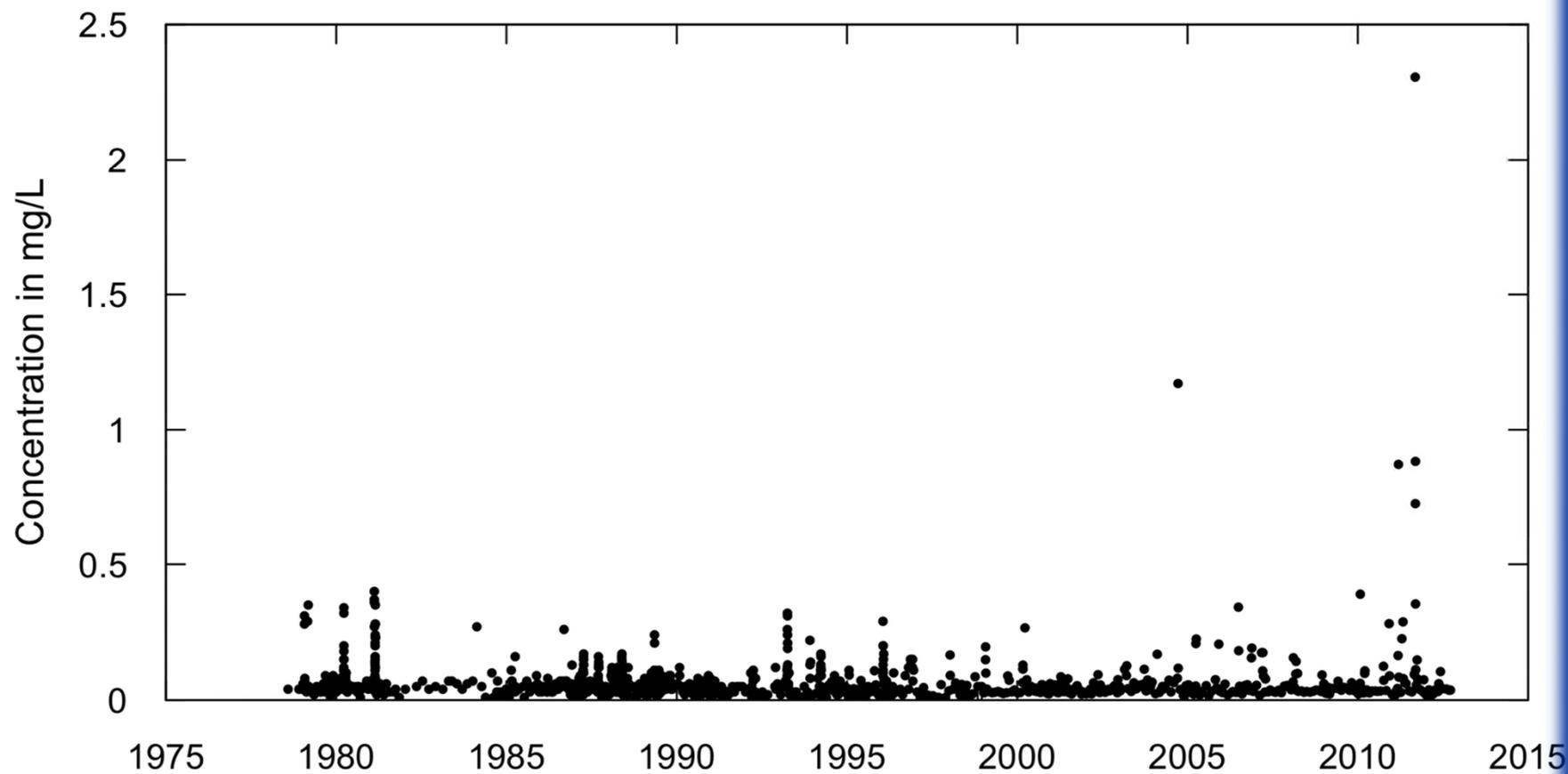


**Sediment plume from
Susquehanna watershed
Plume extends over 150 km
down the Chesapeake Bay
Carrying:
Sediment,
Phosphorus,
Nitrogen**

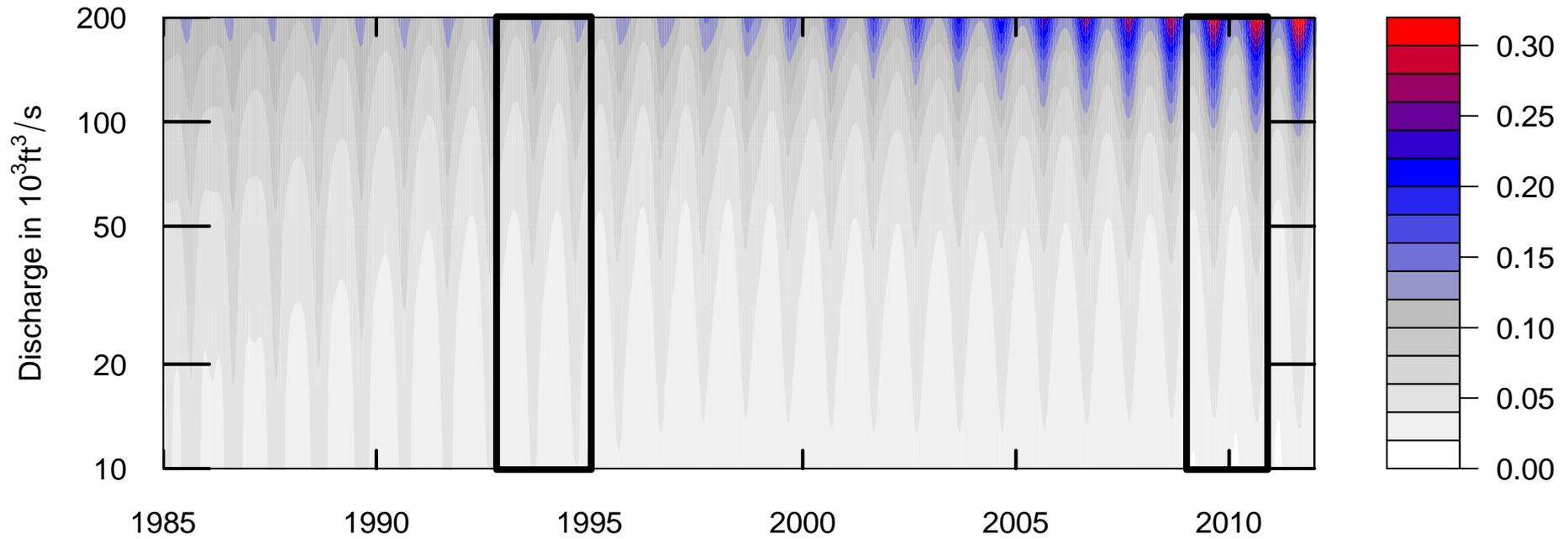
**From the watershed and
from storage in
Conowingo Reservoir**



Susquehanna River at Conowingo, MD , Total Phosphorus



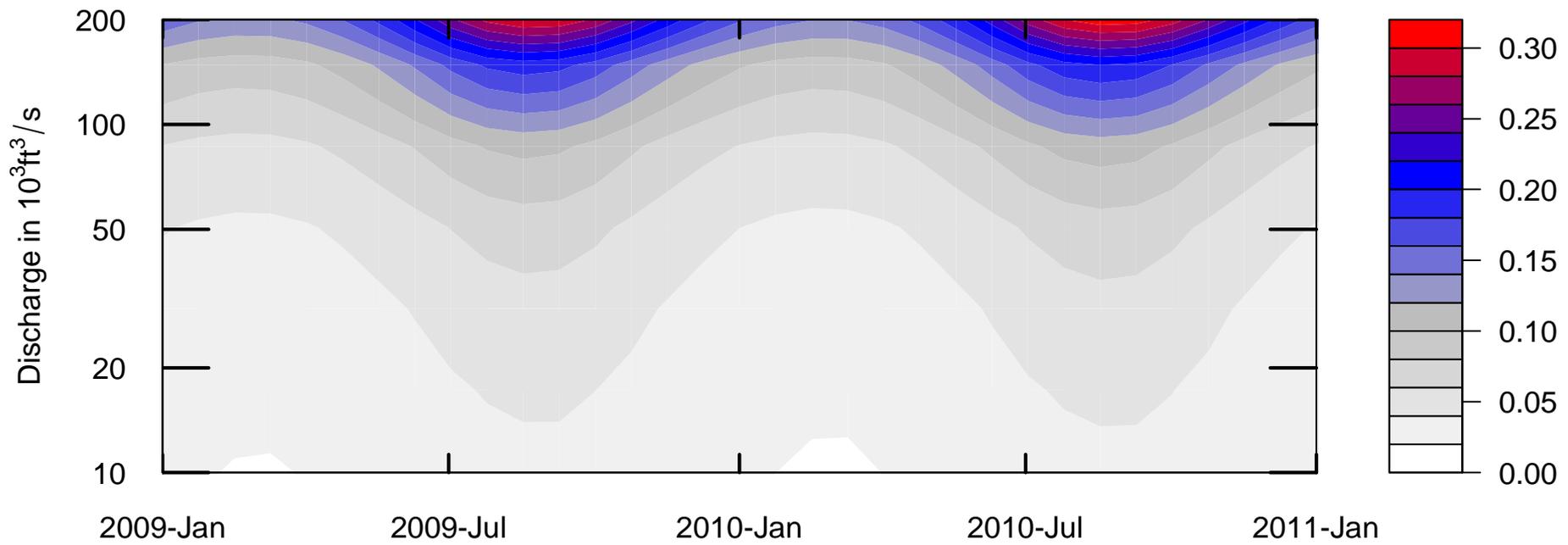
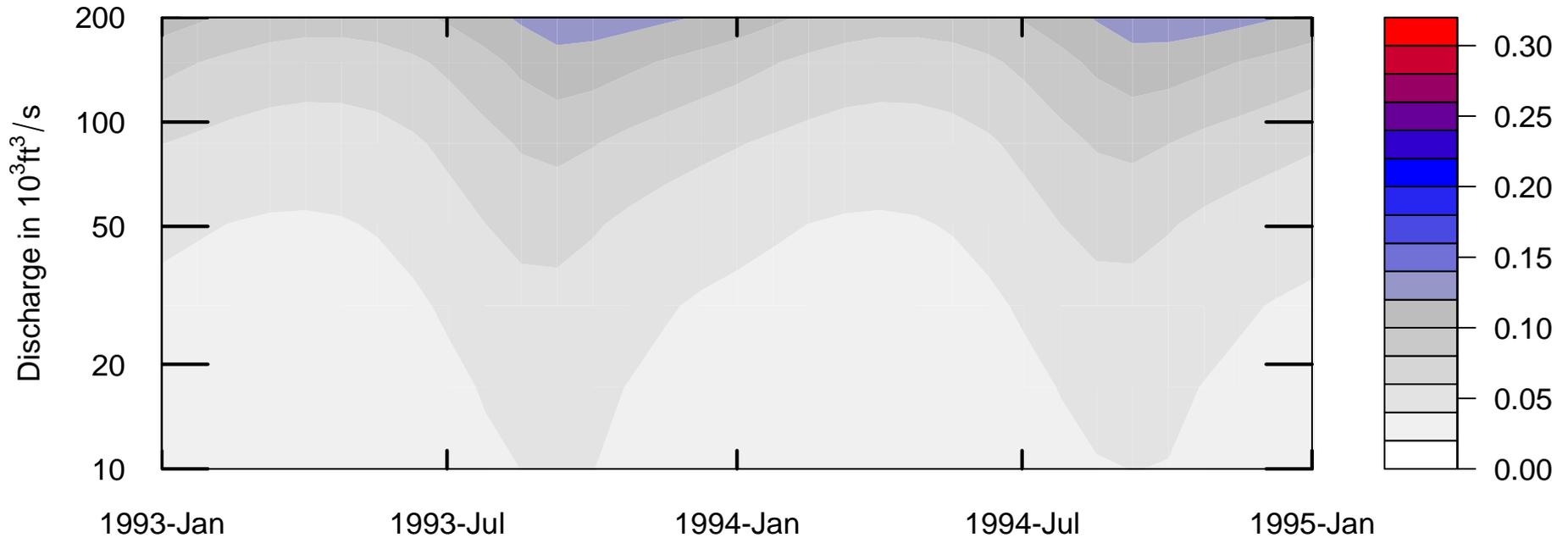
Susquehanna River at Conowingo, MD Total Phosphorus Estimated Concentration Surface in Color



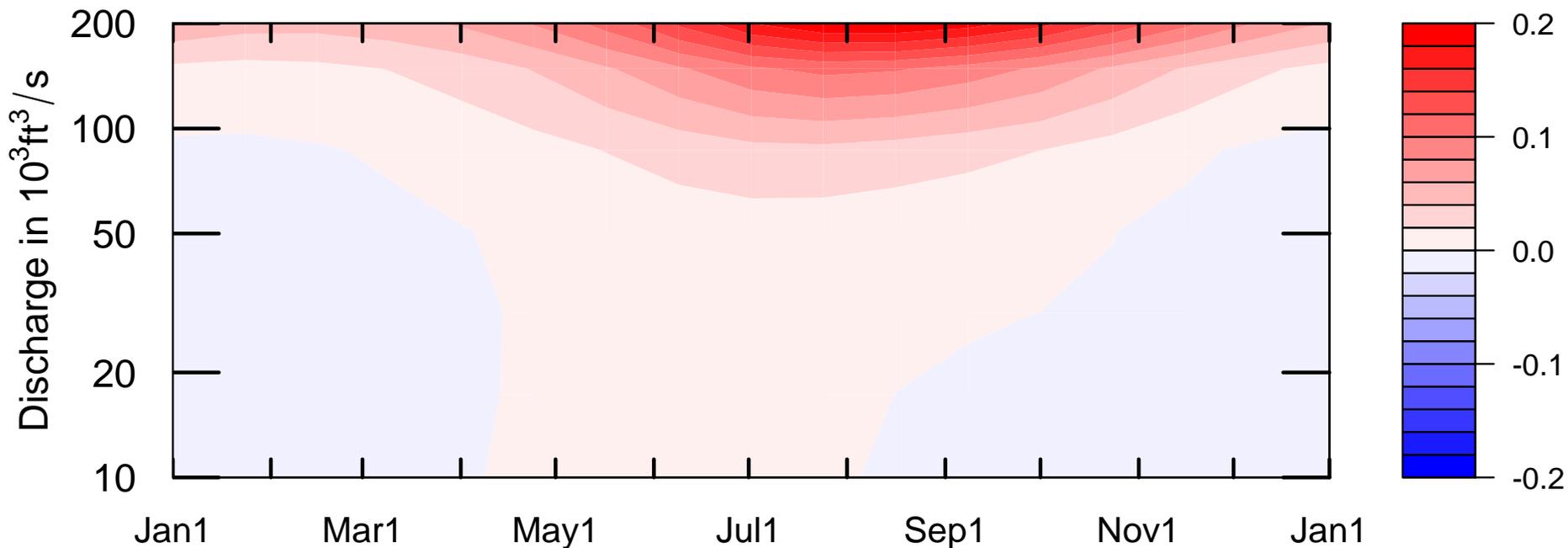
Conowingo Dam during
Tropical Storm Lee,
September 2011,
Reservoir is rapidly filling,
Trap efficiency in decline



Susquehanna River at Conowingo, MD Total Phosphorus Estimated Concentration Surface in Color

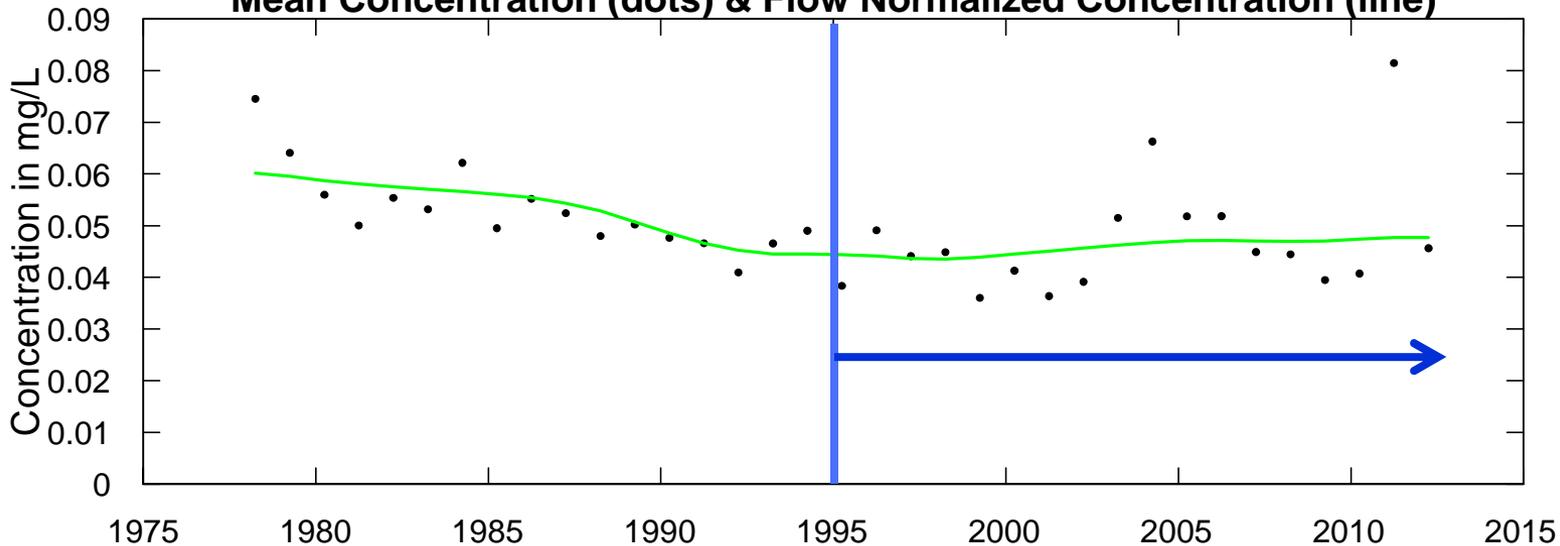


Susquehanna River at Conowingo, MD Total Phosphorus Estimated Concentration change from 1995 to 2011



Susquehanna River at Conowingo, MD Total Phosphorus Water Year

Mean Concentration (dots) & Flow Normalized Concentration (line)

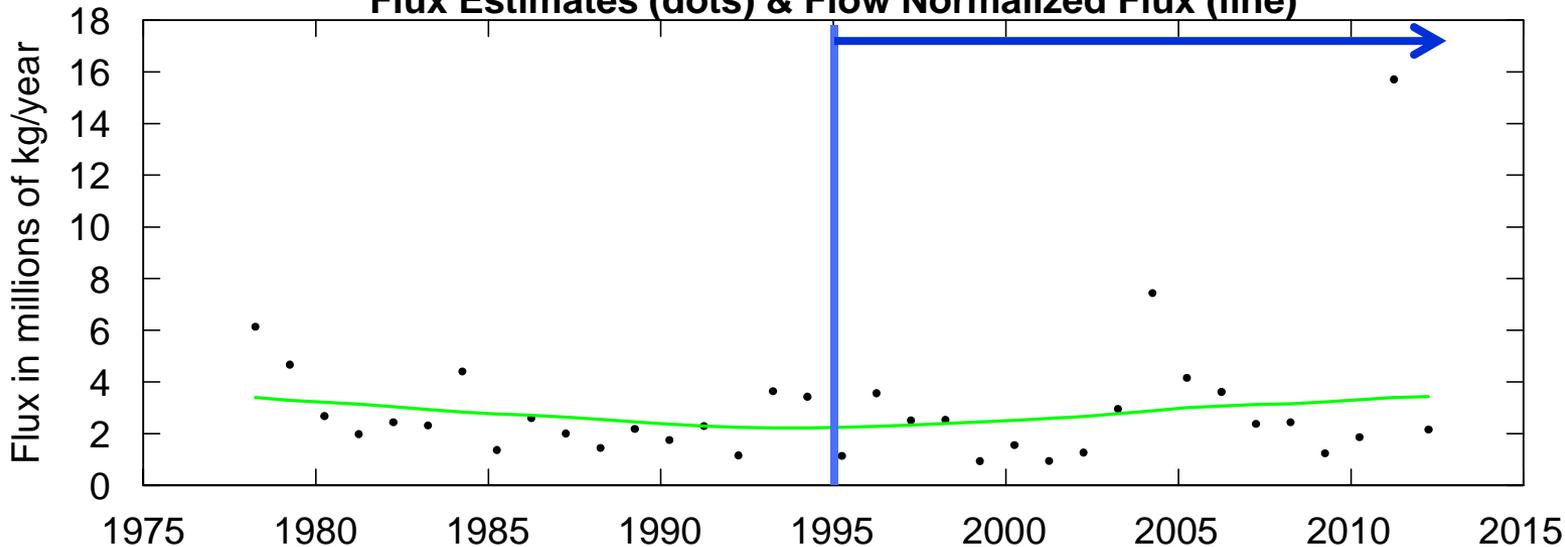


**Change
from
1995-2012**

0.4%/yr

Susquehanna River at Conowingo, MD Total Phosphorus Water Year

Flux Estimates (dots) & Flow Normalized Flux (line)



3.1%/yr

My Hypothesis:

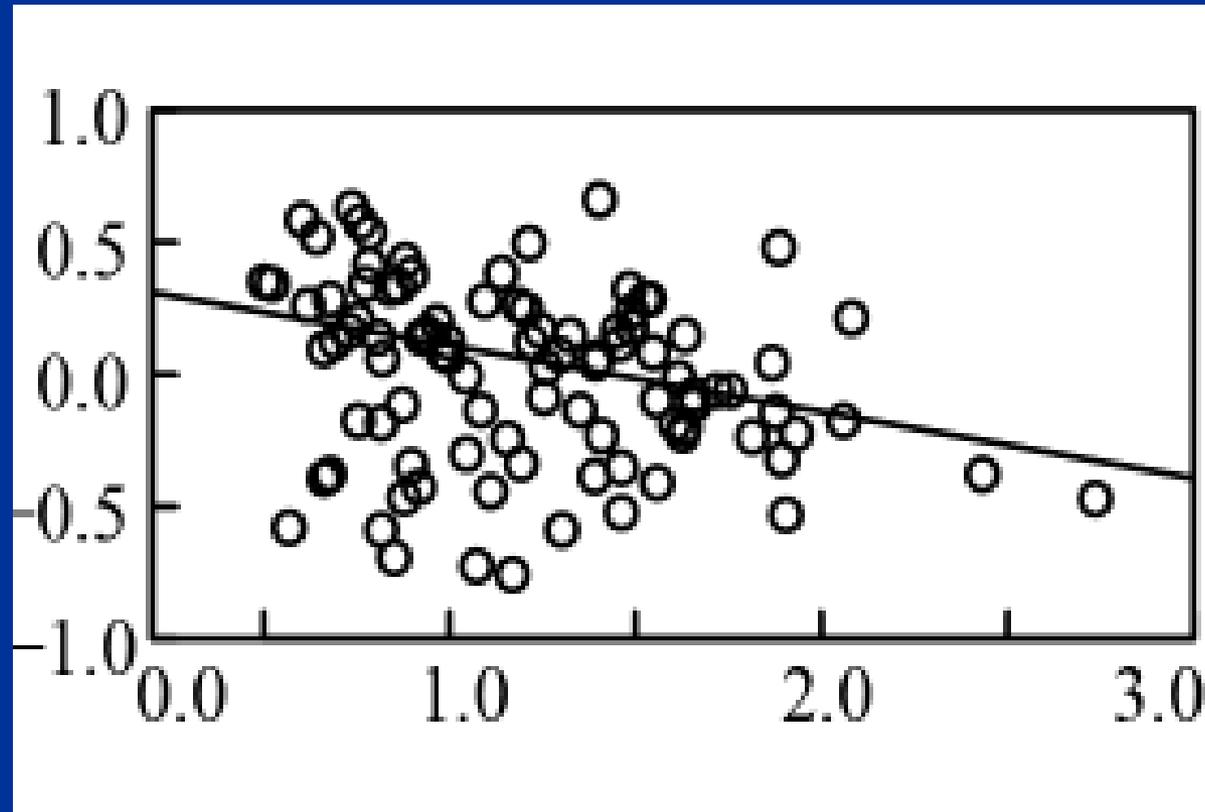
- As the reservoirs fill: for any given discharge, there is less cross-sectional area, resulting in greater velocity.
- Result: a decrease in the scour threshold (more frequent scour) and greater amount of scour for a given discharge.
- Also results in a decrease in the amount of deposition at moderately high discharge.
- For most of the last 80 years, output has been less than input. **Ultimately, average output must equal average input.**
- **Unless there is a dramatic decrease in the inputs, the outputs of particulate N and P, and of SS must rise: Either naturally or by engineered removal.**

High flows right after drought

- Example: Iowa River at Wapello, IA
- Published in: Murphy, Hirsch, and Sprague, HESS, 2014, “Antecedent flow conditions and nitrate concentrations in the Mississippi River basin”

Iowa River at Wapello, IA

**Nitrate
anomaly**



Flow anomaly

(flow over last 365 days)/(long-term mean flow)

Nitrate anomaly is the error in natural log space
For example: if the flow anomaly is 0.7, the actual
will be 2x the expected value

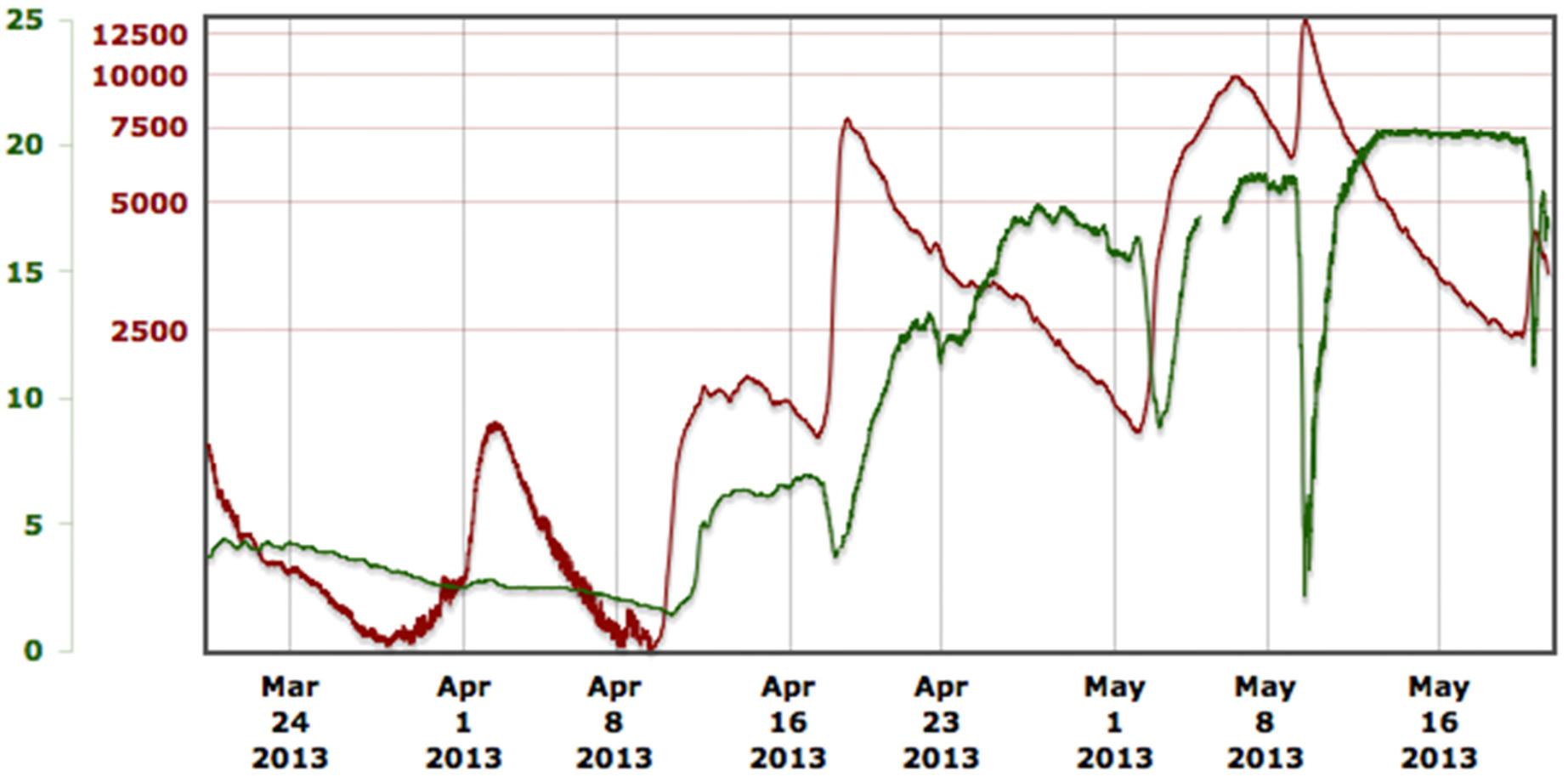
Optical Nitrate sensor: Data on the web in real time

NO_3
in
mg/L

USGS 05484500 Raccoon River at Van Meter, IA

Q in ft^3/s

Zoom period plot

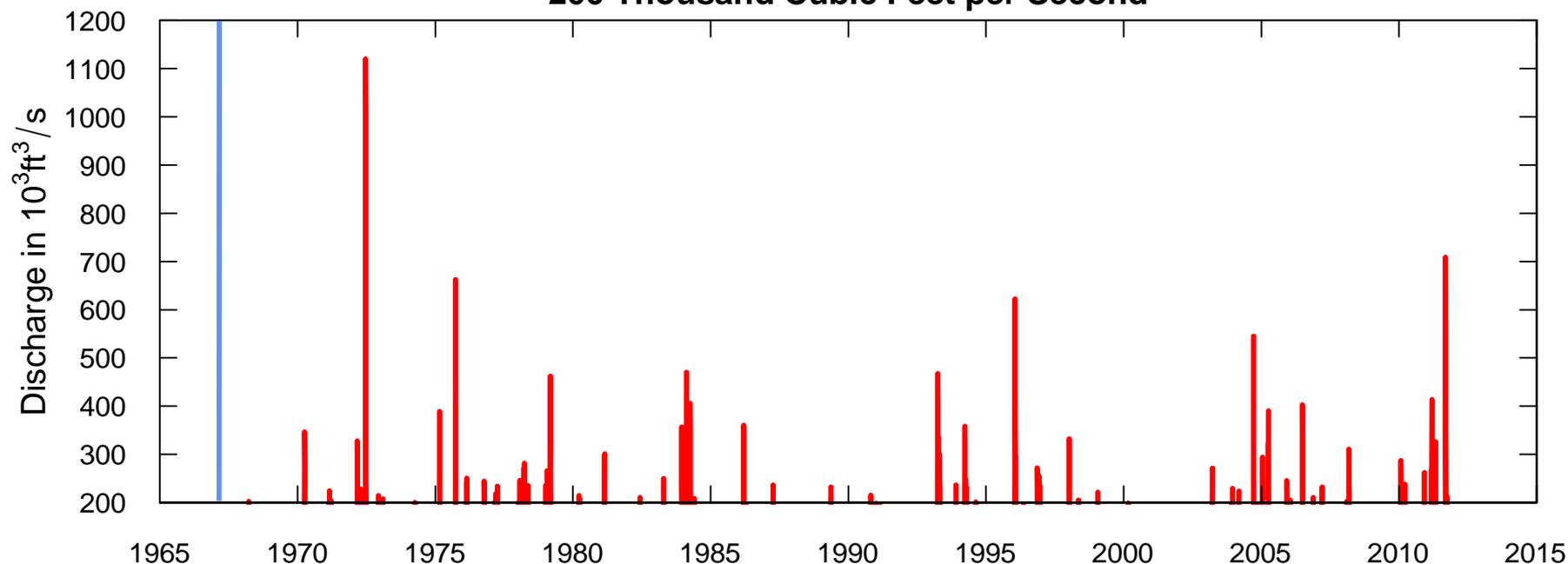


Thoughts about climate change and high flows

- High flows are serially correlated
- Needs to be a lot more work done to understand past and future changes in high flows associated with enhanced greenhouse forcing

The fact is, floods tend to cluster. It is very hard make a case for a real trend in floods

**Susquehanna River at Conowingo, MD
Daily discharge above a threshold of
200 Thousand Cubic Feet per Second**



Relationship of streamflow & greenhouse forcing

Approaches to the issue:

- 1) Use climate models to drive hydrologic models and simulate future hydrologic change.**
- 2) Use the past century as an unplanned global experiment. Streamflow records in many watersheds are “experimental subjects.”**
- 3) Use climate models in hindcast mode to create multiple realizations of the past century. Then ask: Do the actual hydrologic records fall within the envelope of the climate model hindcasts?**

An example of approach 2

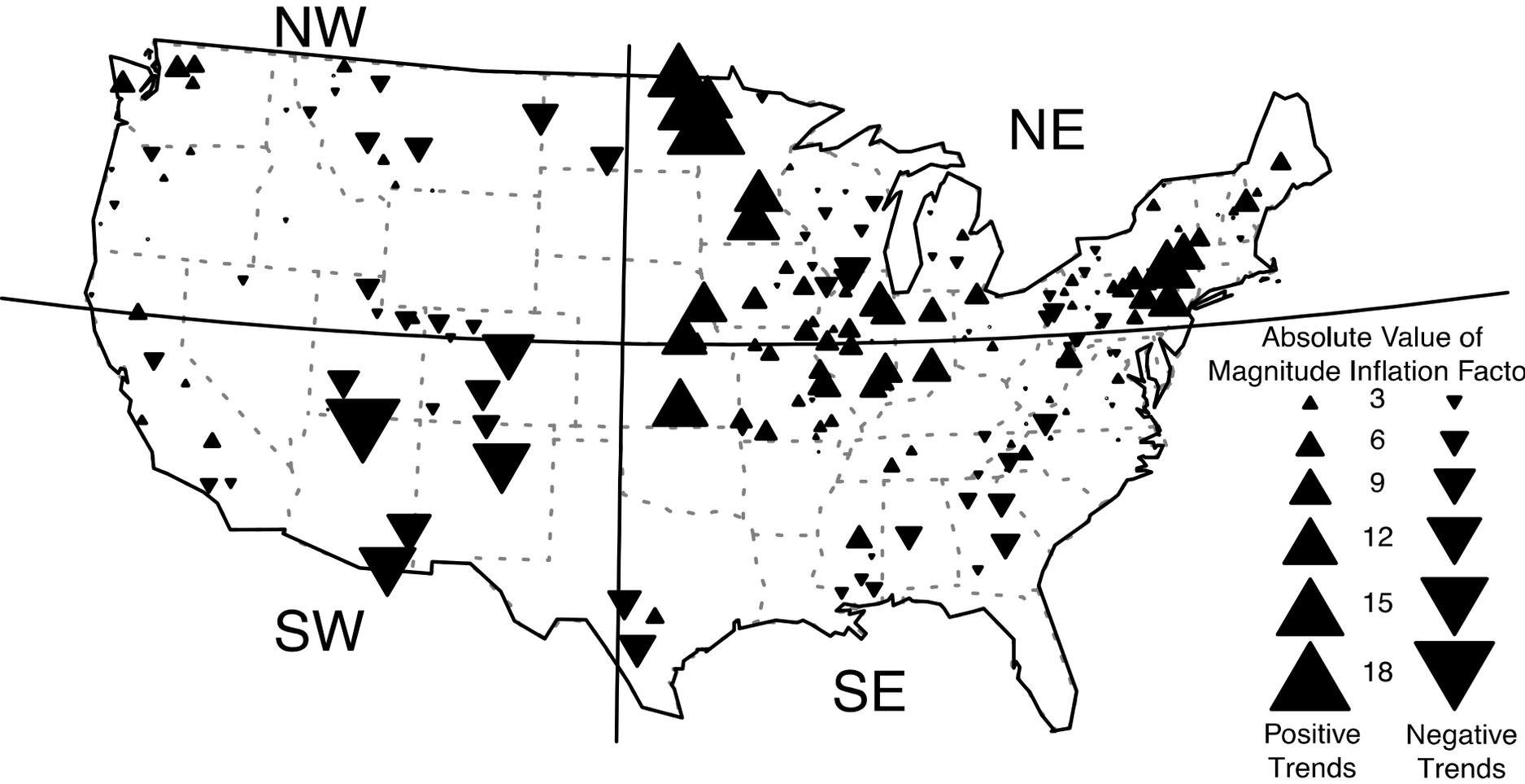
Hirsch and Ryberg, 2011, Hydrologic Sciences Journal

Picked 200 very long streamflow records with limited human intervention. Through 2008.

Regress $\log(\text{annual peak discharge})$ on global mean CO_2 for that year and take the regression slope as a measure of “effect” without regard to “statistical significance”

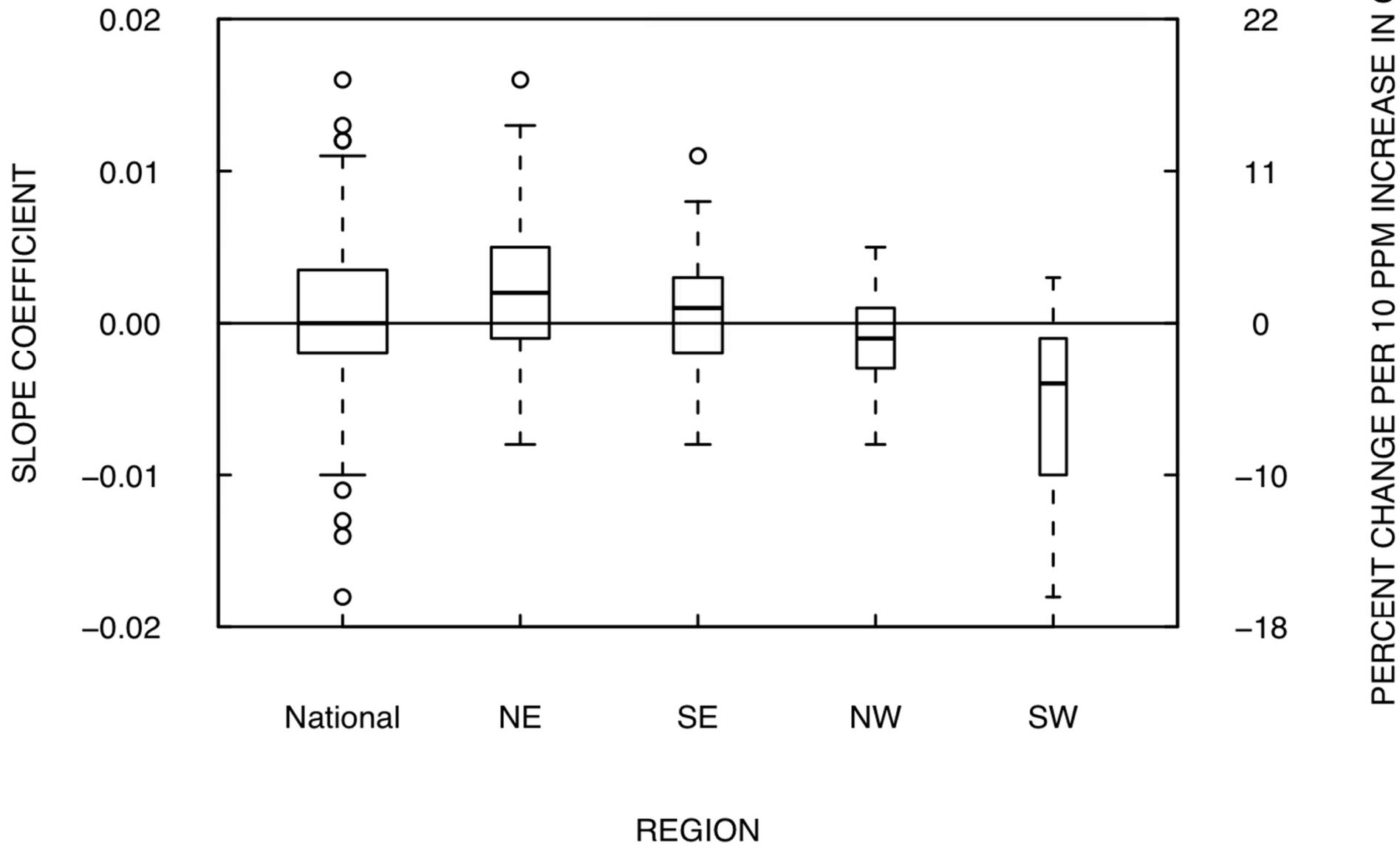
What’s the pattern, nationally, regionally, by drainage area?

National results: 200 streamgauge records



Units are % change per 10 ppm change in CO₂
(current increase is about 10 ppm every 5 years)

CARBON DIOXIDE REGRESSION RESULTS



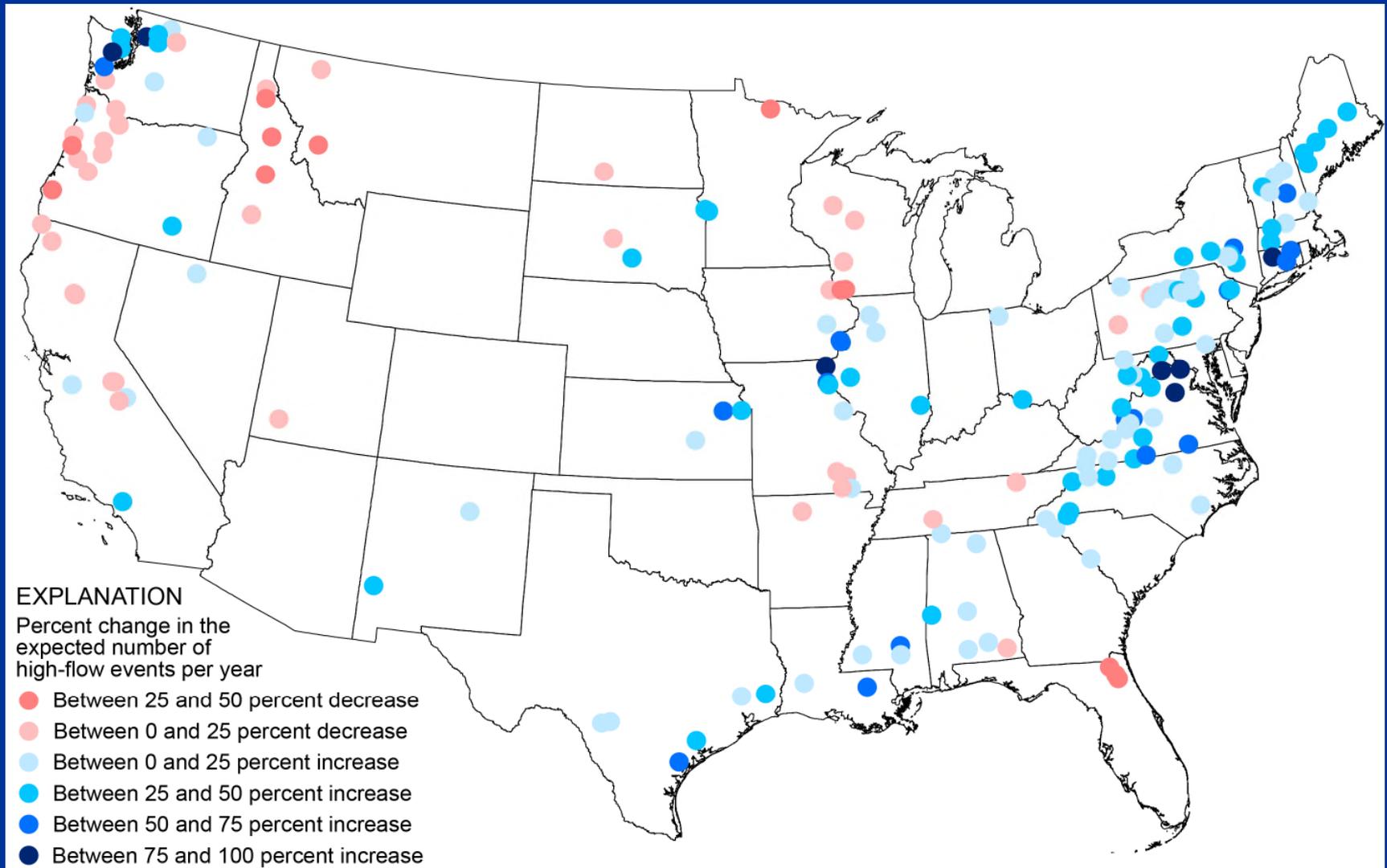
Take away messages:

- The only region with strong statistical evidence of an association between floods & global CO₂ is in the southwest, and the relationship there is negative.
- All approaches to understanding the streamflow/greenhouse gas connection have flaws. But we need to **look at the data regularly and with diverse approaches** to see what might be emerging.

So, here's another approach:

- Consider the frequency of events that had a twice per year average frequency from 1941 – 1970.
- Use the daily flow record to find the threshold discharge to get 60 events in those 30 years.
- Now, see how often the threshold was exceeded in the years 1971-2012
- This work is just starting.

Ratio of frequency 1971-2012 to frequency 1941-1970



Archfield and Hirsch, 2014, unpublished