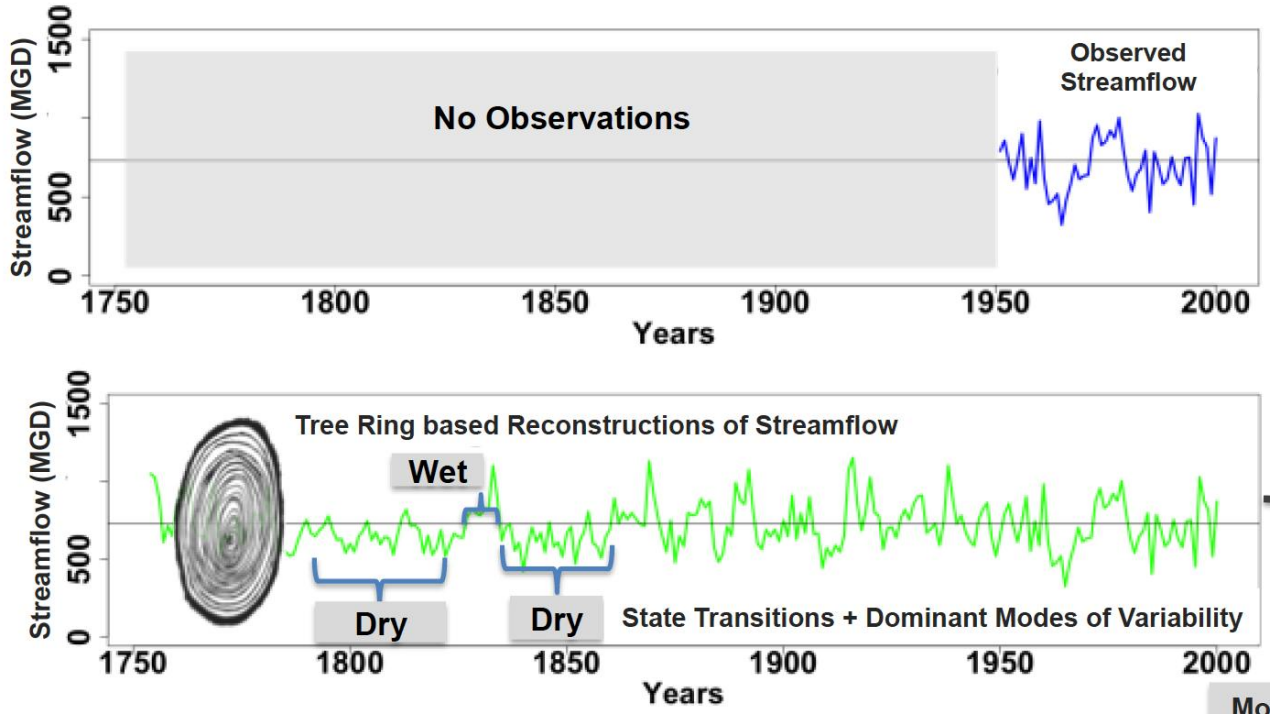
Hazen



Estimated New York City Water Supply Reliability over the Years 1450 to 2020 using Paleohydrologic Reconstructions Derived from Tree Ring Sample Data

John Clayton, Hazen and Sawyer

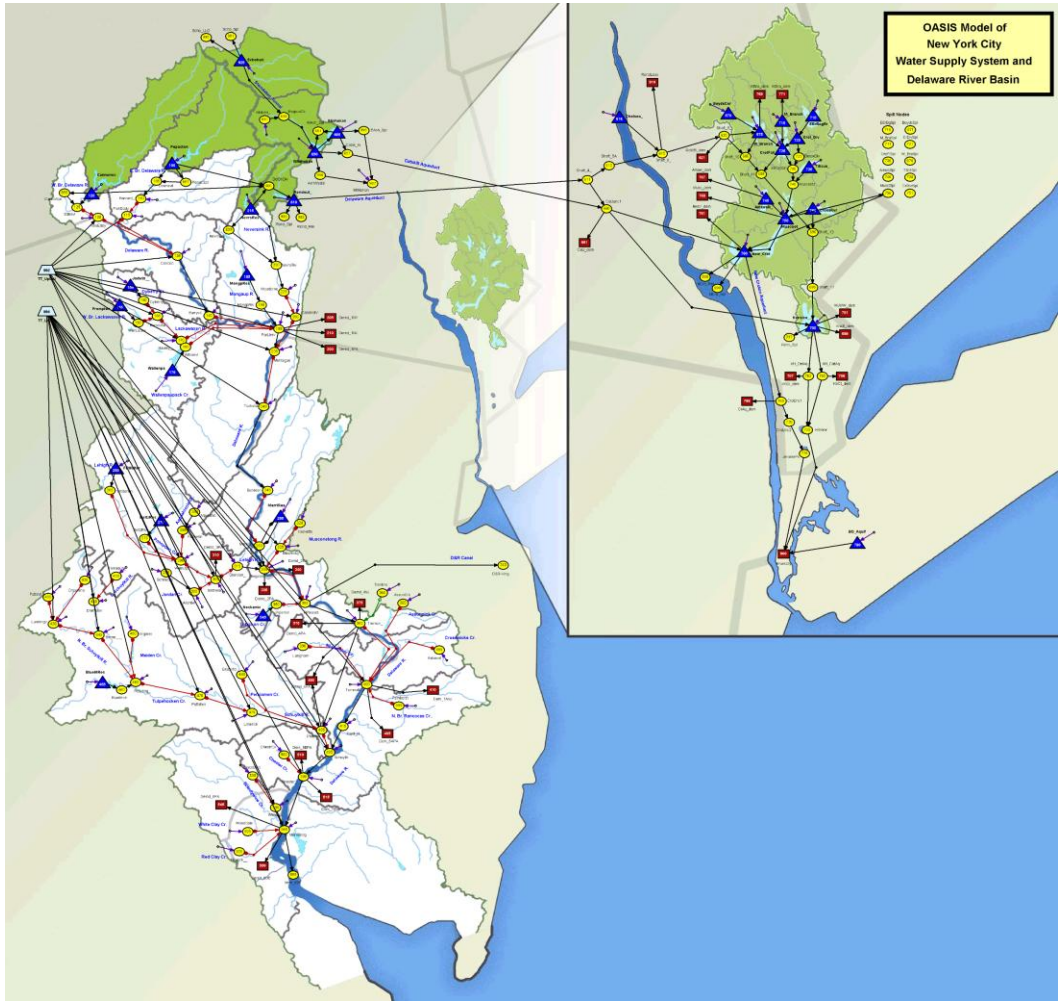
Naresh Devineni, City University of New York

Catskill Environmental Research and Monitoring Conference 2025

Motivation

NYCDEP's Operational Support Tool (OST): Hydrologic record extension into past

- NYCDEP's Operational Support Tool (OST): Daily inflows and operations
- River flow also varies at decadal and longer time scales
  - **Critical for planning future water supplies / management**
  - **OST: Limited historical hydrologic data for decadal-scale analyses (1927-present)**
- NYCDEP is concerned with the threat of the recurrence of the 1960s drought and the likelihood of an even more extensive drought.

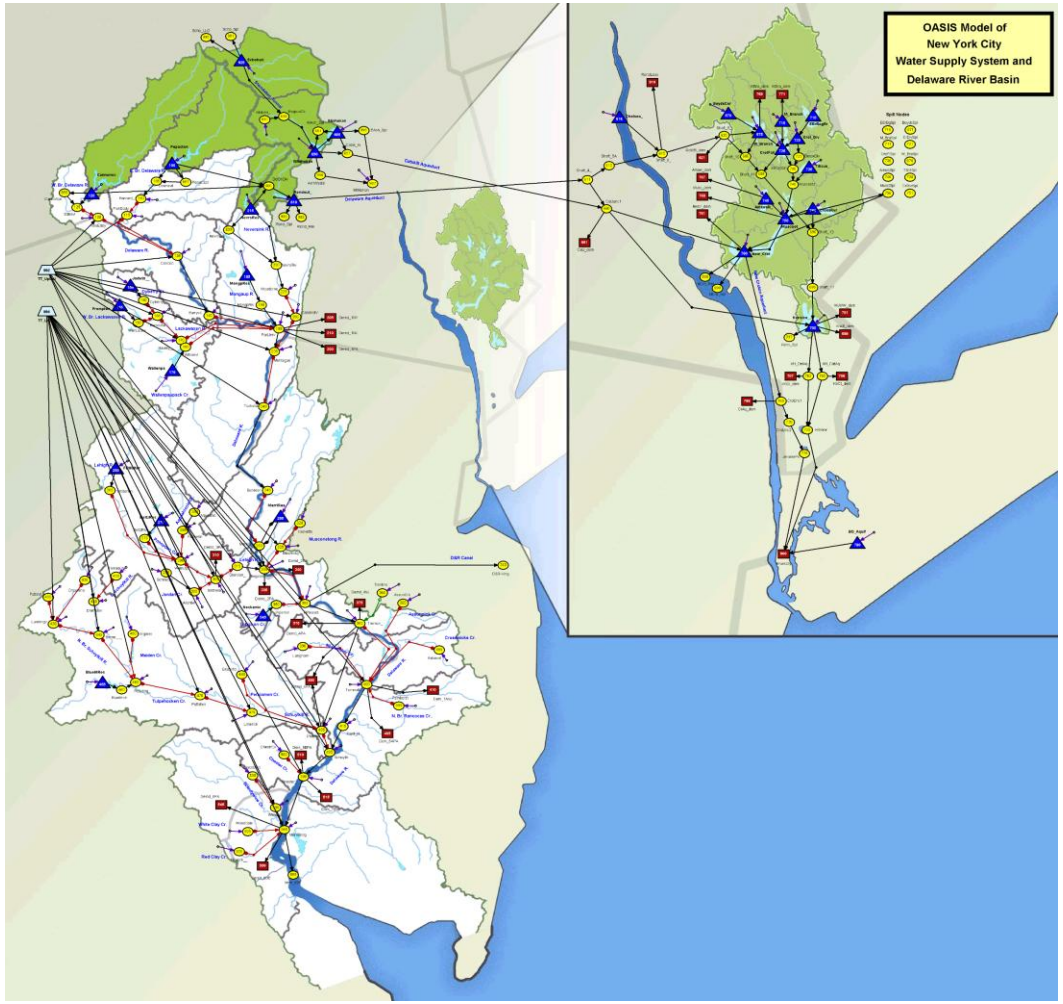


Approach

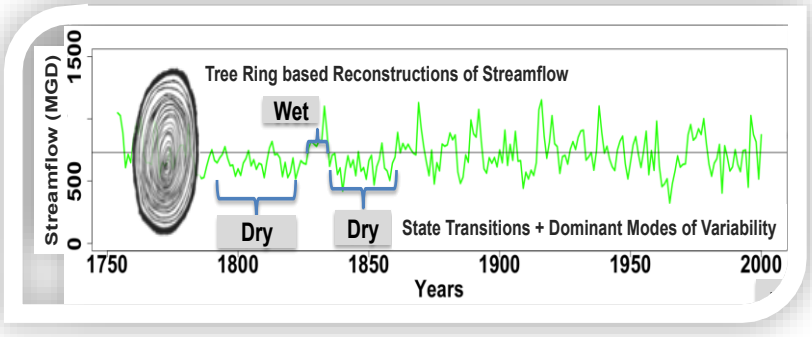
Tree Ring/Stream Flow Regression

- This study uses regional tree-ring chronologies to develop five centuries of basin-wide (upper and lower Delaware River Basin and the Croton water system) streamflow reconstructions.
  - **Annual paleoclimate flows at USGS gages**
  - **Break down to monthly and then daily flows at OST inflow points**

- These streamflow reconstructions can better assess the likelihood of the 1960s drought conditions and inform and test existing reservoir rules.

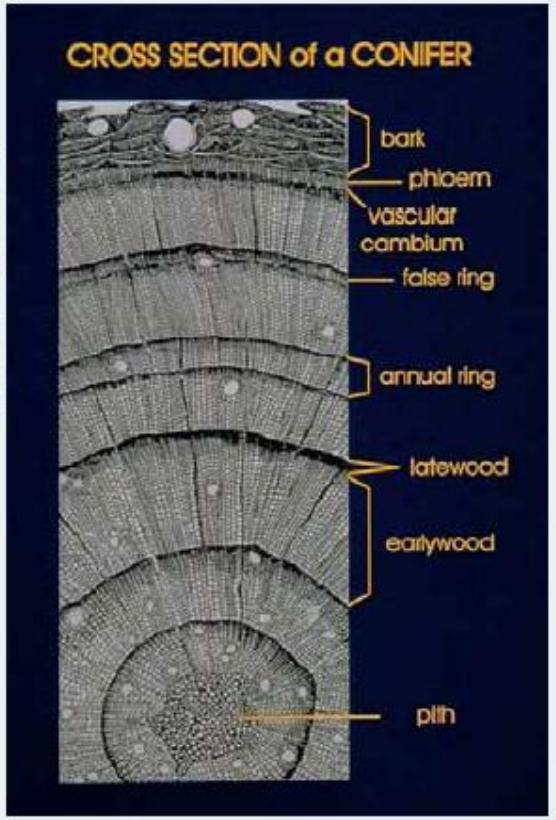


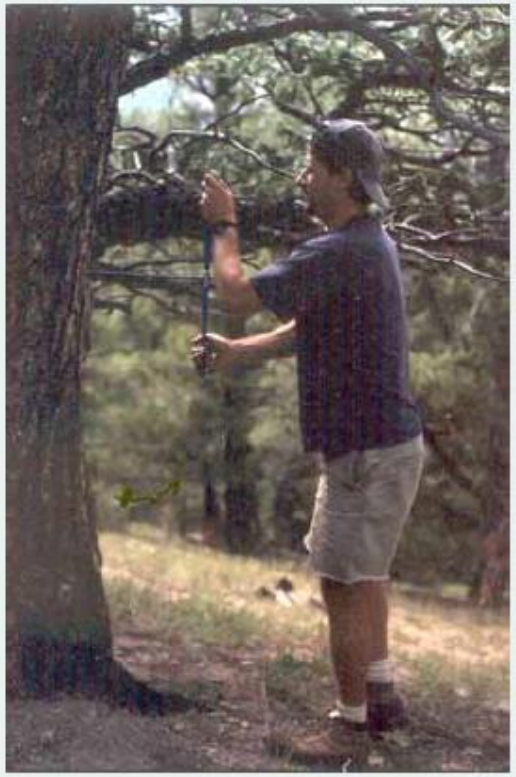
Streamflow reconstruction principles



How is past streamflow reconstructed from tree rings?

Moisture-sensitive tree species growing on open, well drained sites reflect moisture variability in their ring widths and are targeted for collection.





Cores collected from about 20 trees are dated, measured, and averaged into site tree-ring chronologies.

Tree Ring Chronologies → Streamflow

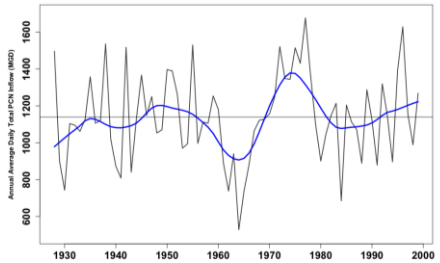
Each chronology is an aggregate index from ~ **20 similar trees** in the region with ~ **20 cores** per tree.

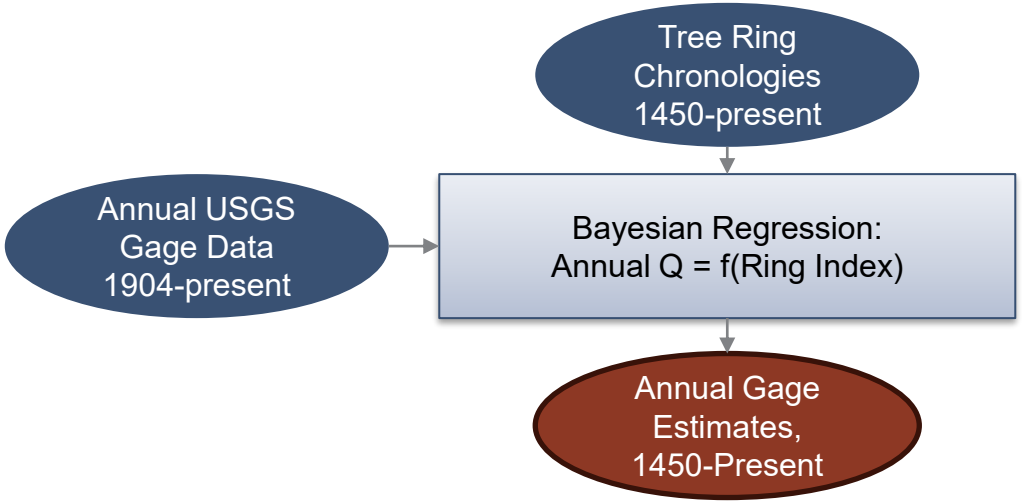
Up to 553 years chronology ($\mathbf{X_t}$)
(40 tree ring chronologies of varying time records)

1450 2002

1904 2023

~120 year gage streamflow record ($\mathbf{Y_t}$)
(27 sites)





Geo-locations of the 27 Streamflow and the 40 Tree Ring Chronology Sites

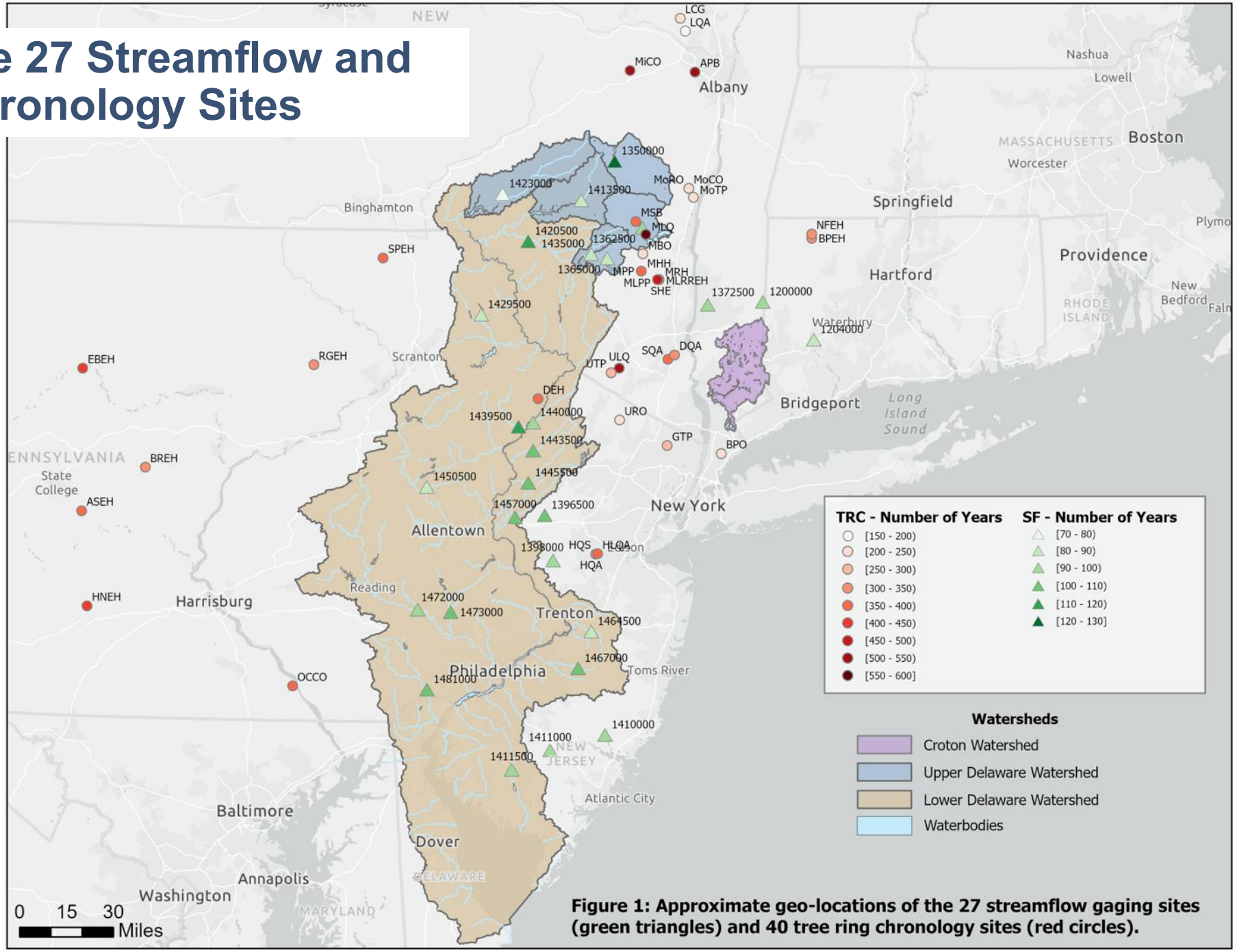
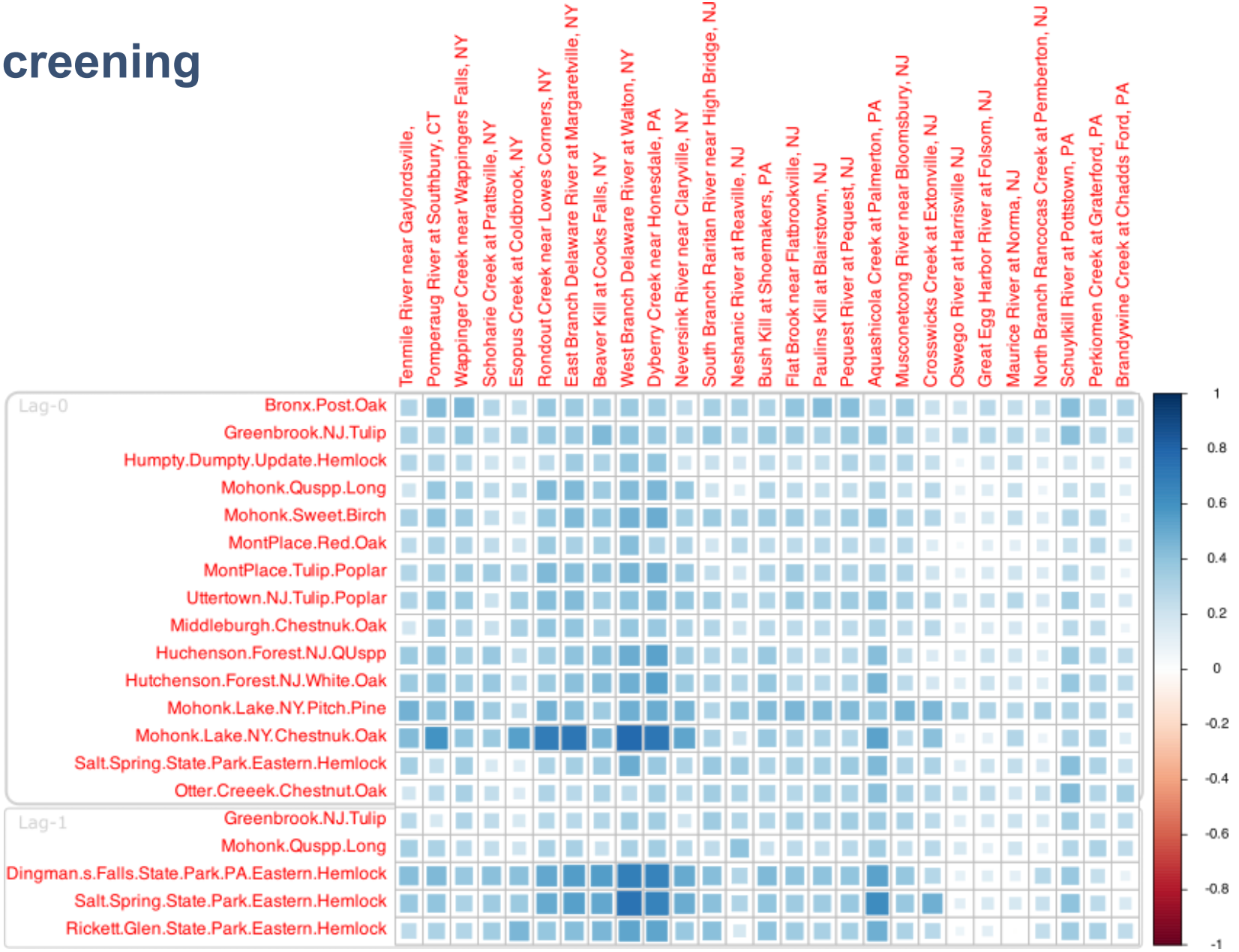


Figure 1: Approximate geo-locations of the 27 streamflow gaging sites (green triangles) and 40 tree ring chronology sites (red circles).

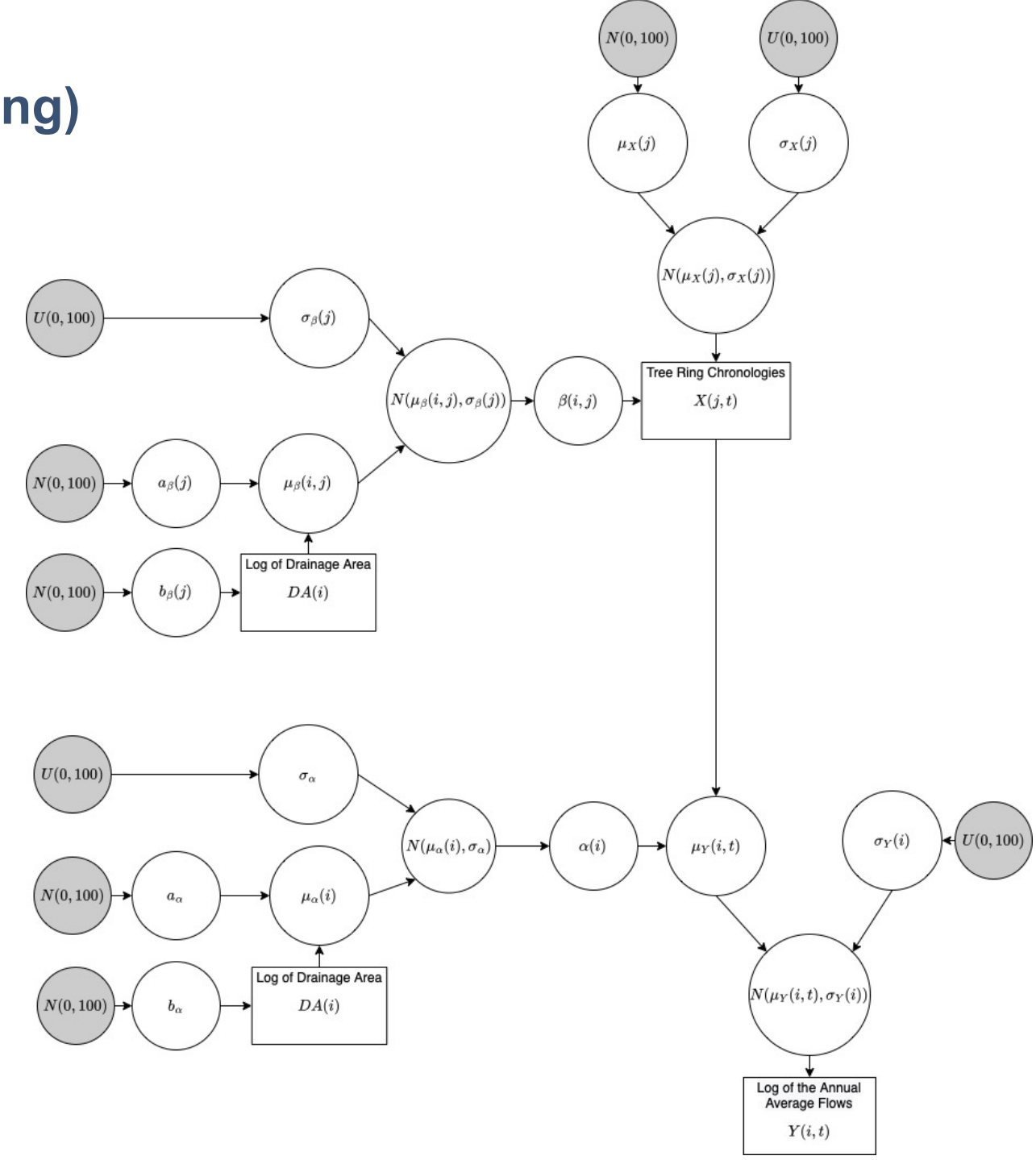
Tree Ring Chronology Screening

- One-sided hypothesis test rejection level: 5%
- A TRC should be statistically significantly correlated with at least 21 gages (~77% sites) at lag-0 and lag-1
- Min leverage



Bayesian multilevel model (auto-nesting)

- Fits ring-to-flow relationship over 1904-2022 water years
- Simultaneously performs Markov Chain Monte Carlo simulation of annual flows over 1450-present
- Uses as many trees for each year as there are available records
- Outcome: 3000 traces of 500-yr annual streamflow
- Uncertainty varies with time
- Scaling across gages is tied to Drainage Are

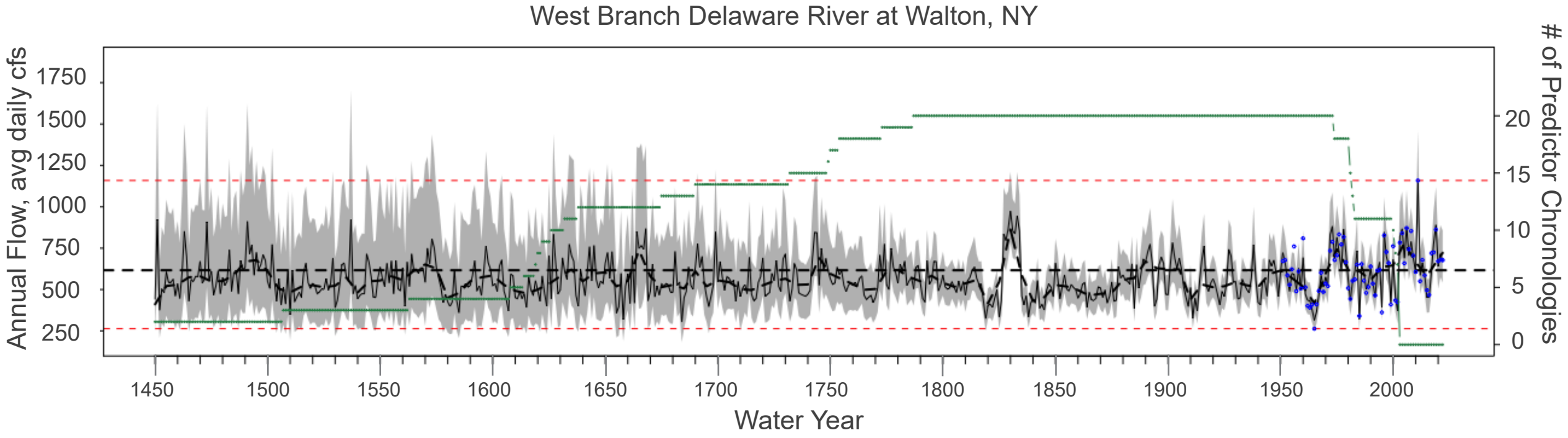


Example Reconstructions

USGS 01423000 – West Branch Delaware @ Walton NY
(Main tributary to Cannonsville Reservoir)

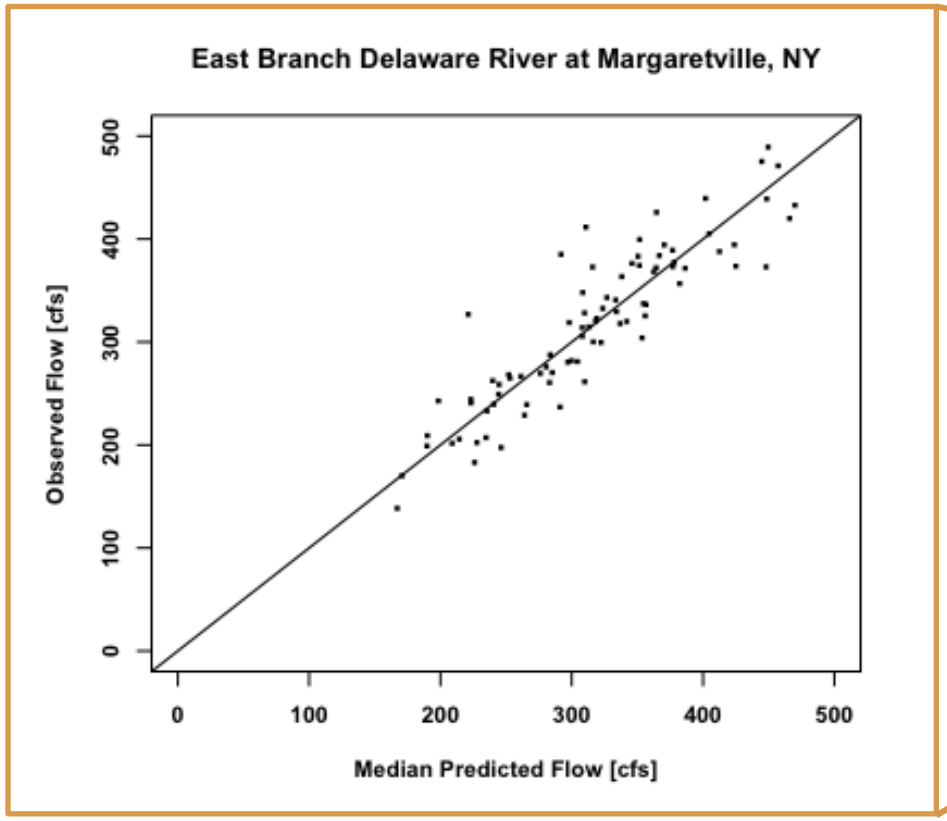
Grey band: uncertainty interval
Black line: median flow per year
Dashed line: 11-year lowess avg
Green lines: Number of TRCs
Blue dots: observed flow values
Red dashed lines: min/max historical values

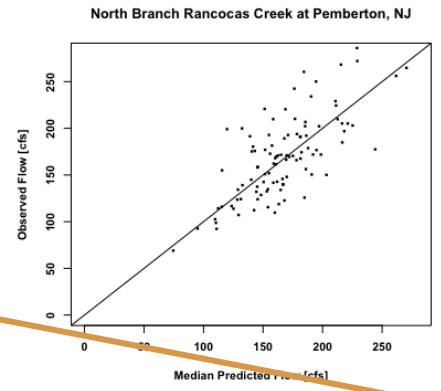
Note auto-nesting: Only a few trees go back as far as 1450. As the number of TRCs decrease, uncertainty in reconstructions increases

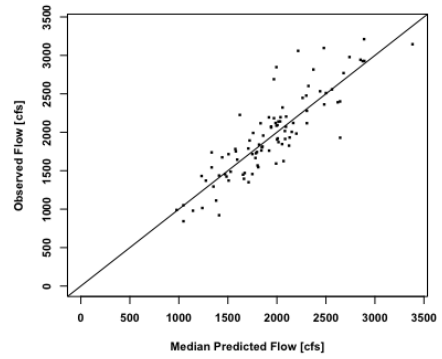


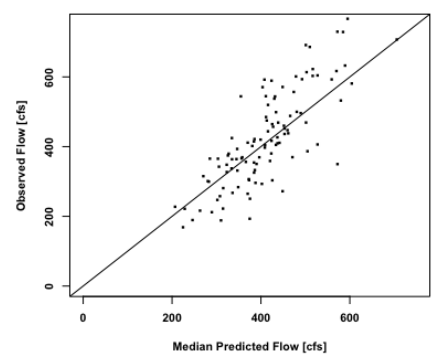
Reconstruction Model skill

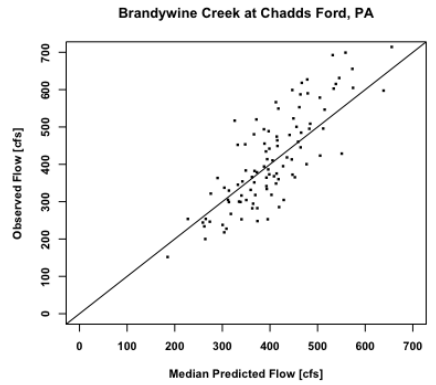
Observed vs Median Estimate
over 19XX-Present
for nine of the gages

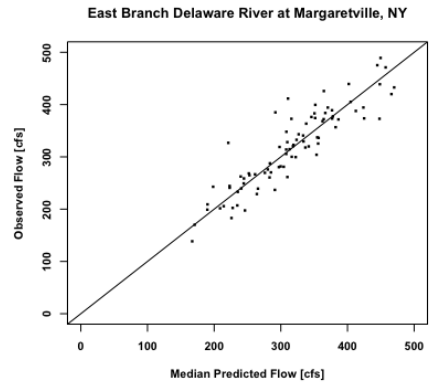


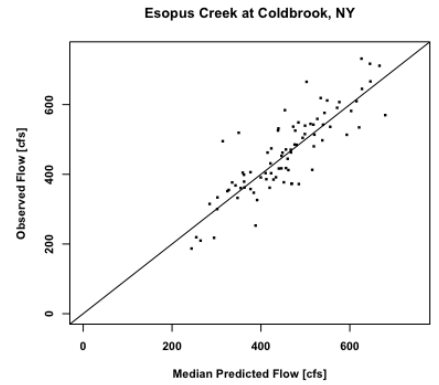


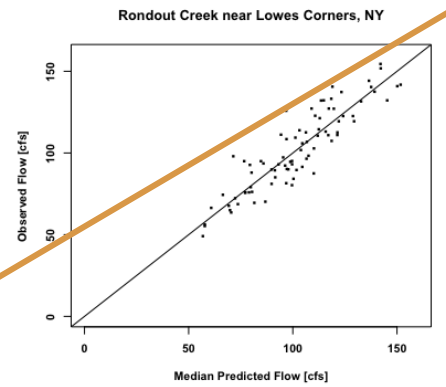


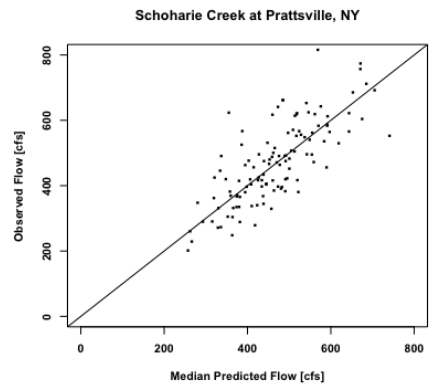


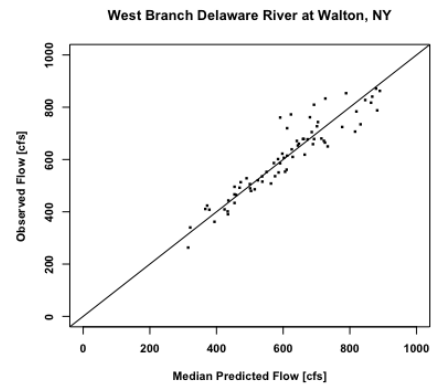








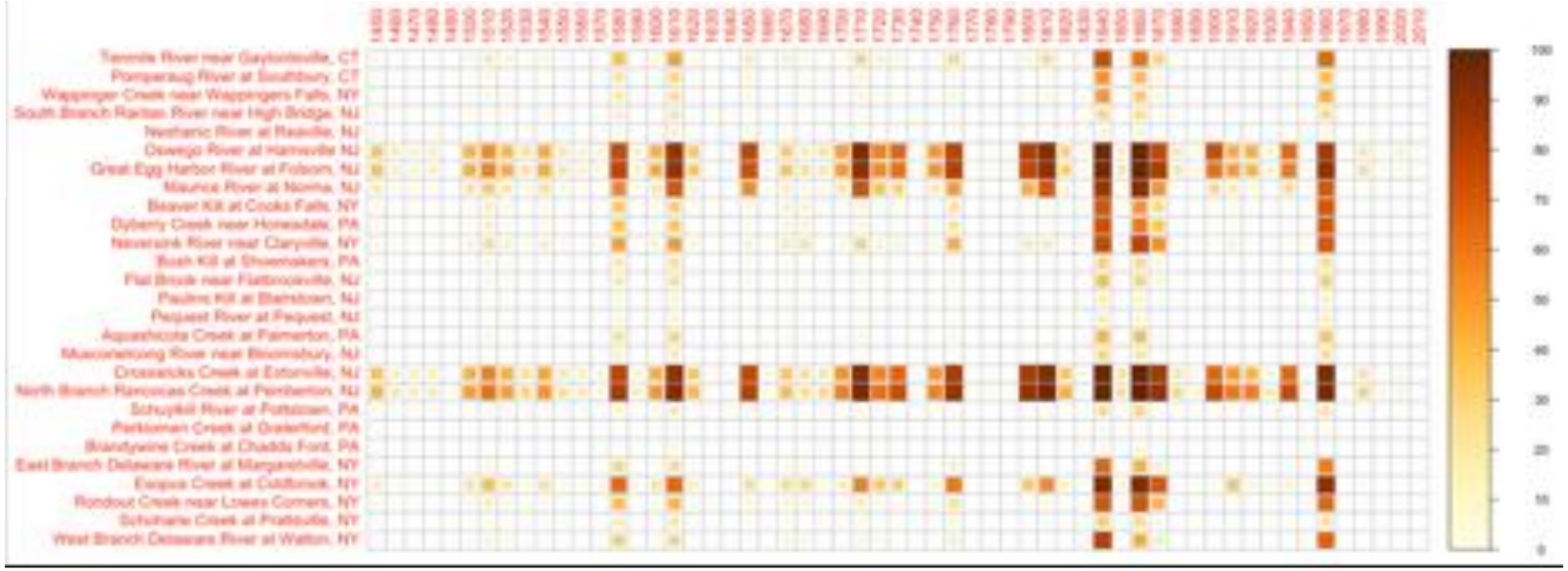




Basin-wide Decadal Drought analysis

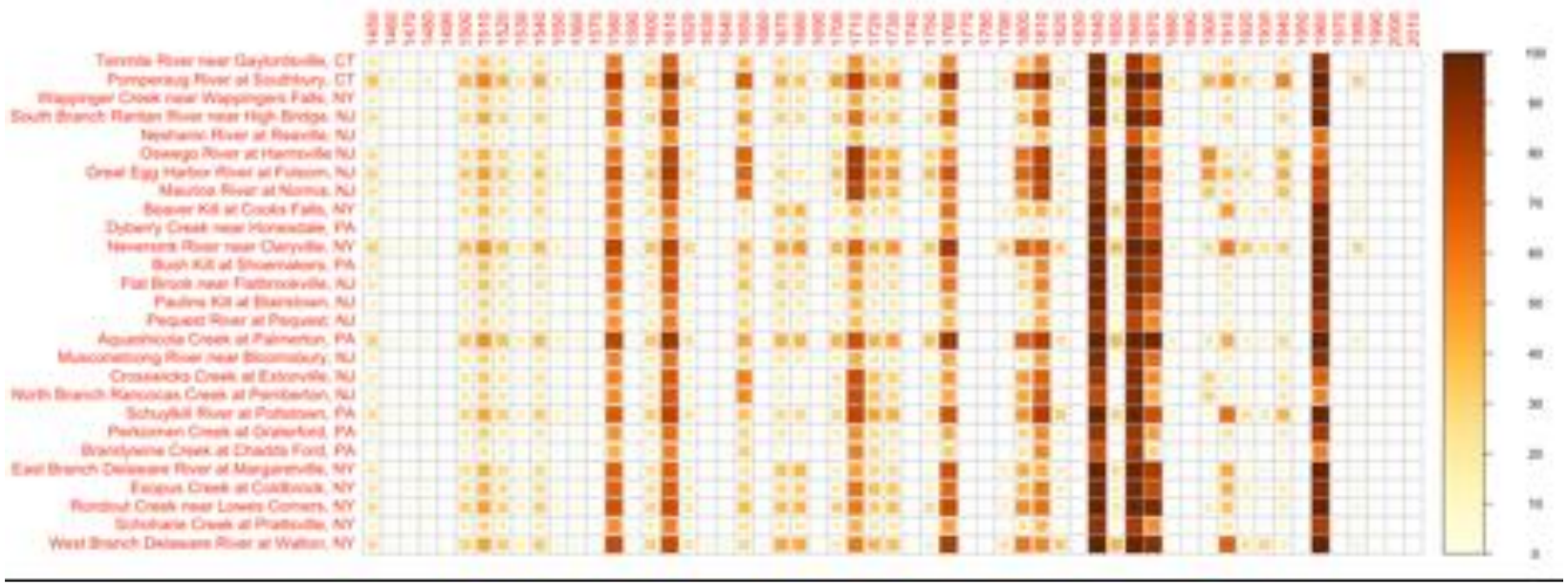
$$P\left(Q_d^{paleo} < Q_{[1960\ decade]}^{obs}\right)$$

Drought Threshold = 1960's average flow



$$P\left(Q_d^{paleo} < Q_{[33]}^{obs}\right)$$

Drought Threshold = 33rd percentile average decadal flow



Takeaways

- Five centuries of basin-wide (upper and lower Delaware River Basin and the Croton water system) streamflow reconstructions are now available for the New York City DEP
- In process of translating those reconstructions to daily OST inflows
- The Bayesian multilevel strategy made this prediction task seamless
  - **handling multiple tree-ring proxies and flow records**
  - **unequal data lengths**
  - **scaling of flows across the entire basin.**
- The 1960s drought was likely exceeded in 1840s.
- The 1840's to 1870s were persistently dry for a duration not seen in current observations…a "mega drought"
- Many more plausible drought scenarios to stress-test the system

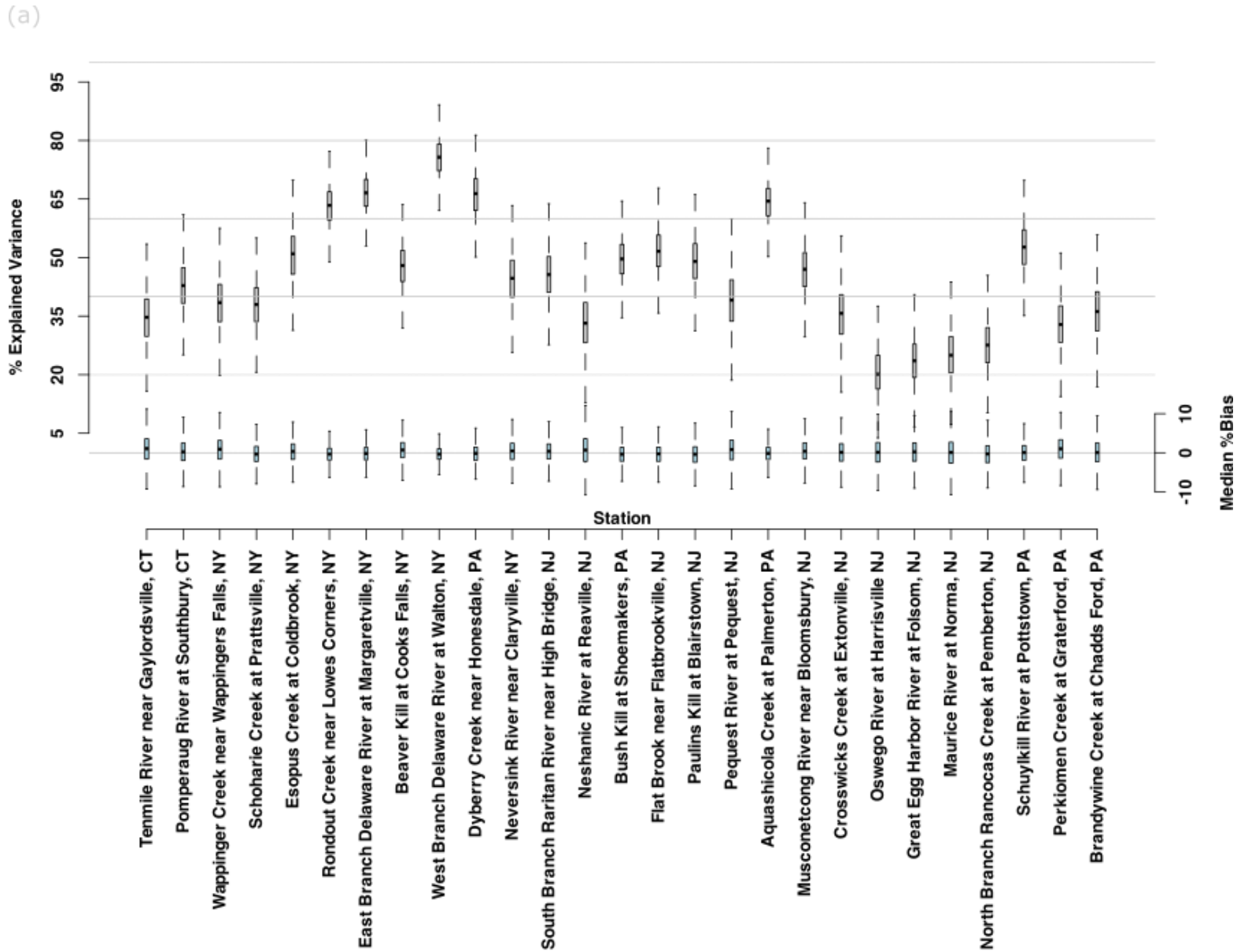
Questions?

RECONSTRUCTION MODEL SKILL

Good skill in explaining streamflow variability

Explained variance ranges from 20% to 80% with several sites around 50%

Median % Bias between observed and predicted flows is centered on 0 and within 10%



Decadal Drought analysis

Blue line: 67th percentile of annual average flow

Pink line: 33rd percentile of annual average flow

Red line: 1960s decadal average observed flow