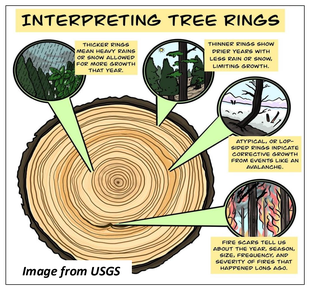
From Tree Rings to Streamflow: Reconstructing the Hydroclimatic History of the Mississippi River Basin Over the Past Millennia

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Introduction

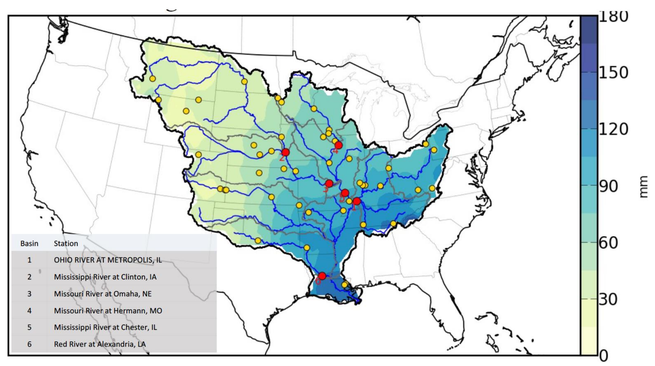
The **Mississippi River Basin (MRB)**, the largest watershed in the United States, plays a crucial role in shaping the country's hydroclimate. This research reconstructs streamflow in the MRB over the past millennium to enhance understanding of historical hydroclimate variability. To achieve this, we utilized the North American Drought Atlas (NADA), which reconstructs the Palmer Drought Severity Index (PDSI) across North America on a 0.5° grid, serving as a proxy for past hydroclimate variability. Streamflow data from 51 stations across the MRB were analyzed, and streamflow was successfully reconstructed for the period 1200–2005 using a principal components regression program. Verification statistics for each station demonstrated significant reconstruction skill across the entire domain.

Methodology



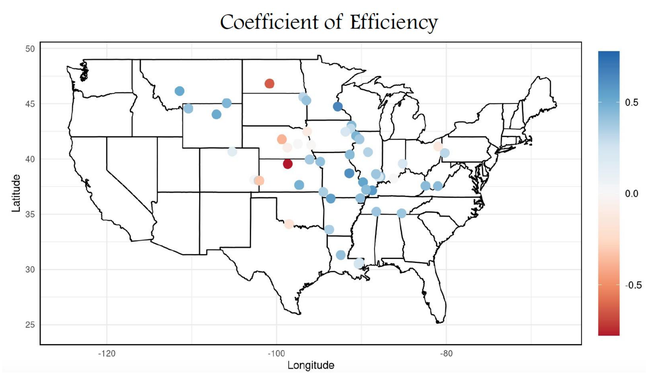
Why tree rings and NADA? Tree rings provide long-term hydroclimate records, and drought atlases like NADA improve their spatial and temporal consistency, making them ideal for large-scale streamflow studies.

We selected records with a minimum of 40 years and less than 3% missing values to ensure data quality. Stations near reservoirs that might disrupt natural flow patterns were also excluded. NADA grid points were selected based on hydroclimatic similarity to each streamflow station in terms of aridity, seasonality, and snow influence. Principal Component Analysis (PCA)was applied to reduce data dimensionality, highlighting dominant climate patterns influencing streamflow variability. Streamflow variability was then modeled using a Linear Dynamical System (LDS) approach, which captures seasonal patterns and extreme events by iteratively linking NADA-derived climate data with observed streamflow.

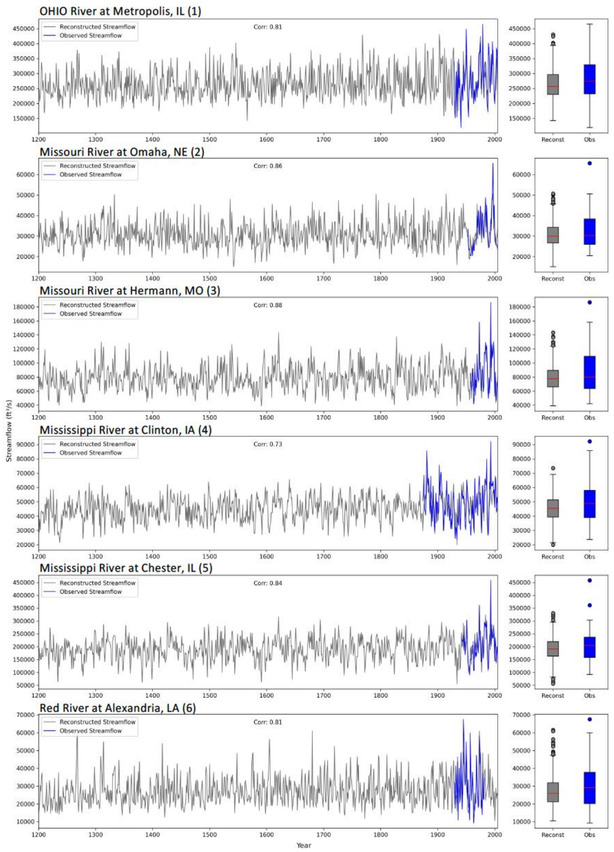


Geographical Focus of the Study: The Mississippi River Basin (MRB). The yellow circles are the locations of the selected 51 streamflow stations. The larger red circles are the most downstream river gauges on the six selected sub-basins in the MRB.

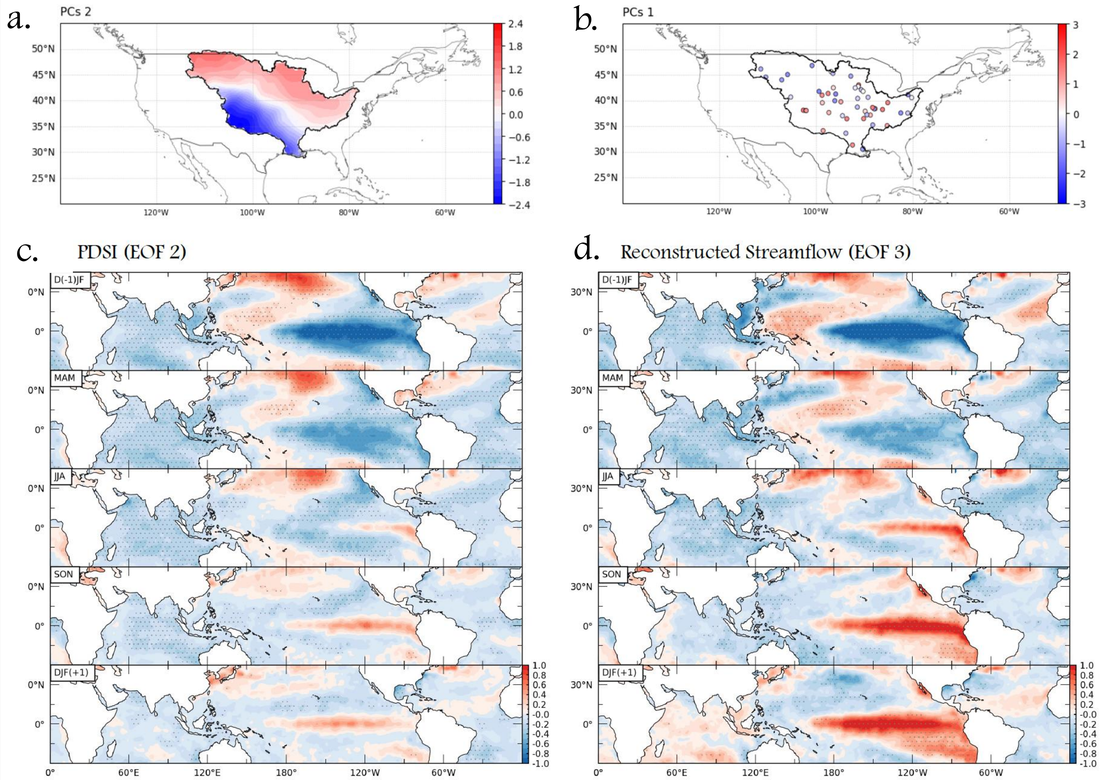
Results



Validation: Coefficient of Efficiency (CE) for reconstructed streamflow at each of the 51 stations. A value of 1 indicates a perfect prediction. 0 indicates model predictions are as accurate as using the mean of the observations, and negative values indicate the model performs worse than simply using the mean value.



Reconstructed Streamflow: The detrended time series (left) and boxplots (right) of observed (blue lines) and reconstructed streamflow (grey lines) for six selected sub-basins within the MRB from 1200 to 2005. R scores are calculated based on the length of the observed record at each station.



Large-Scale Climate Drivers: a) Shows EOFs (eigenvectors) and PCs (principal component) based on the temporal covariance matrix of NADA PDSI over the Mississippi River watershed. **b)** shows EOF analysis based on the temporal covariance matrix of the 51 reconstructed streamflow stations. Lead lagged regression of **(c)** EOF PC 2 for PDSI and **(d)** EOF PC3 for streamflow on SST. EOFs are based on yearly averaged summer (JJA) PDSI and streamflow, from 1900 ~ 2005.

Summary

Using tree-rings data, we reconstructed streamflow from 1200 to 2005, demonstrating the effectiveness of a PDSI–streamflow reconstruction approach in the Mississippi River Basin. The resulting dataset provides a valuable resource for understanding hydroclimate conditions over the past millennium. Verification statistics, including cross-correlation and the CE, indicate significant reconstruction skill, underscoring the reliability of the PCA model. Correlations between observed and reconstructed streamflow over overlapping periods range from 0.56 to 0.90 across the 51 gauges. The reconstruction reveals periods of extreme droughts and floods, with some historical events comparable in severity to 20th-century droughts, although the model slightly underestimates the range of variability. This highlights the role of river basins as "low-pass filters," which amplify longer-term trends while dampening high-frequency fluctuations. This research can be leveraged to constrain future hydroclimate projections, thus using the past as a key to unlocking insights for the future.

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