Monthly Paleostreamflow Reconstruction from Annual Tree-Ring Chronologies

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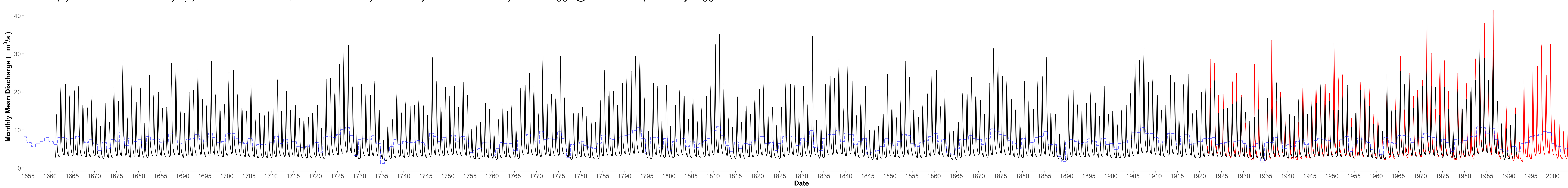


Figure 1 - Reconstructed streamflow time series at the Logan river site using the full APR model (black). Former annual reconstruction shown in blue, while observed monthly flow shown in red.

I. Objectives and Approach

Paleoclimate reconstructions are increasingly used to characterize annual climate variability prior to the instrumental record, to improve estimates of climate extremes, and to provide a baseline for climate-change projections. To date, paleoclimate records have seen limited engineering use to estimate hydrologic risks because water systems models and managers usually require streamflow input at the monthly scale.

This study presents a **novel approach** to **reconstruct monthly streamflow** by **regressing annual flow reconstructions, regional tree-ring chronologies, and global climate indices** against monthly flow.

Research Approach
- Develop conceptual reconstruction models
- Reconstruct flow at two sites in northern Utah
- Evaluate skill during the instrumental period

II. Study Location and Data Preparation

Study Location
▪ Two sites in the Bear river watershed, which spans Utah, Wyoming, Idaho
▪ Bear river is the largest tributary to the Great Salt Lake, providing appoximately 60% of annual inflow

Mean Annual Flow (MAF) Reconstructions
▪ Logan river (554 km^2)
1605-2010 AD (Allen et al. 2013)
▪ Bear river headwaters (445 km^2)
800-2010 AD (DeRose et al. 2015)

Regional tree-ring chronologies
▪ 49 chronologies from 7 species
▪ Iterative PCA with imputation to reduce dataset dimensions and correct differing chronology lengths

Global climate index reconstructions
▪ El Nino-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO)
▪ ENSO reconstructions use two base datasets: North American or Pacific Ocean tree-rings

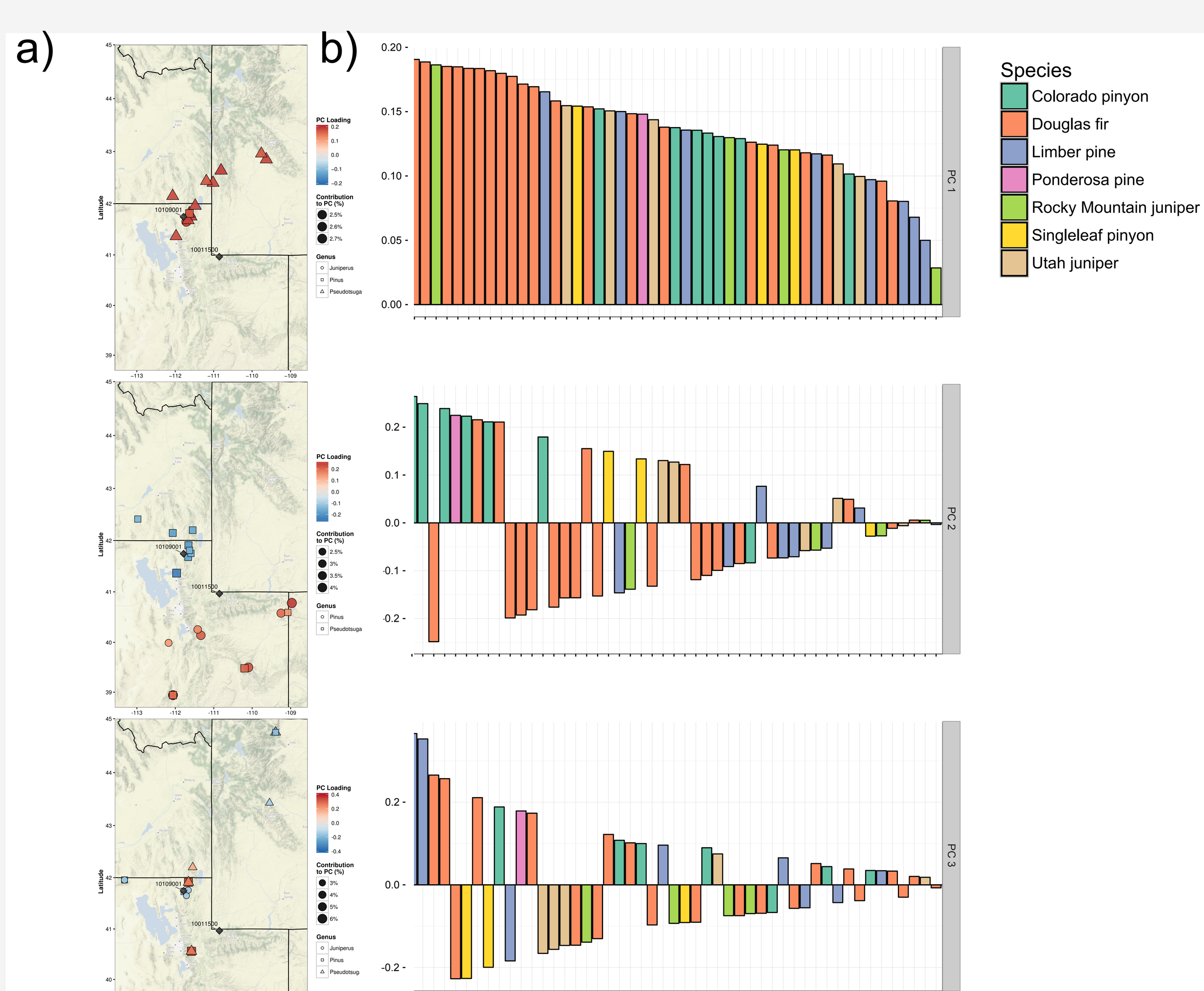


Figure 2 - Tree-ring chronology loading of first 3 PCs, by location (a) and species (b)

III. Models

Monthly Fraction (MF): Multiply annual reconstructed flow by monthly historical mean fraction of annual flow

Annual Percentile (AP): Normalized annual flow percentile is equal to monthly percentile

Annual Percentile Regression (APR): Monthly normalized percentile is estimated using linear regression
1. Normalized MAF (-1, 0, +1 year lags)
2. Normalized MAF + climate indices (ENSO, PDO)
3. Normalized MAF + climate indices + regional tree-ring PCs

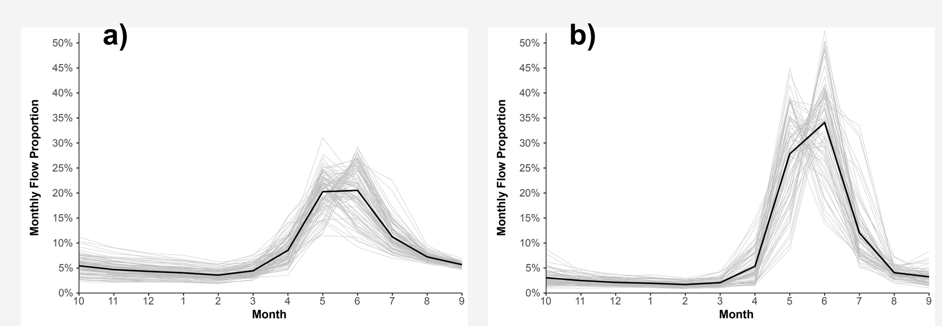


Figure 3 - Monthly flow proportion for MF model.

IV. Results - Predictors

Lagged Annual Reconstructions
▪ Normalized MAF importance transitions smoothly between the previous and concurrent water year
▪ Crossover occurs during snow melt season (annual peak flow)
▪ Removes the need to specify water year *a priori*

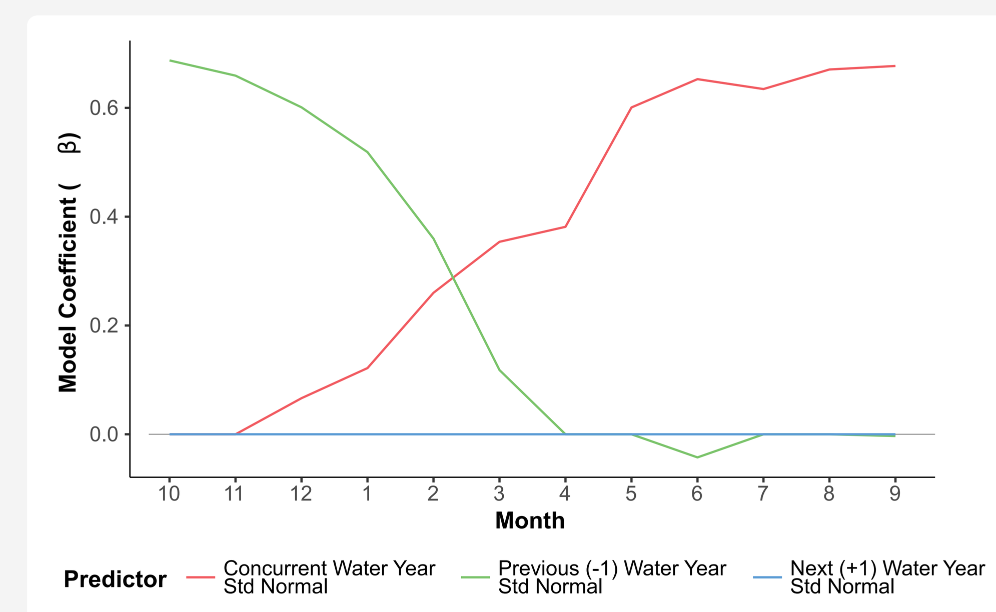


Figure 4 - Model coefficients for concurrent and lagged MAF reconstruction at the Logan river site.

Global Climate Teleconnections
▪ ENSO was a significant predictor for the Logan river during winter and spring (Jan - May)
▪ The best ENSO index shifts from the Pacific proxies (Winter) to North American proxies (Spring)
▪ PDO was a significant predictor for the Bear river (Aug - Dec)

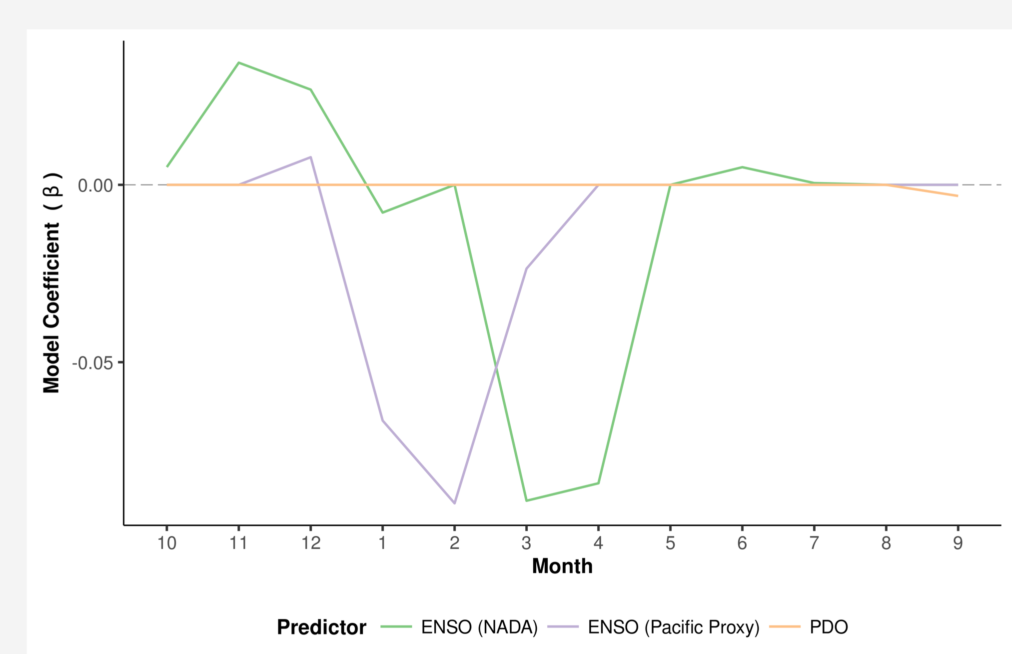


Figure 5 - Model coefficients for global climate teleconnections at the Logan river site.

IV. Results - Goodness of Fit

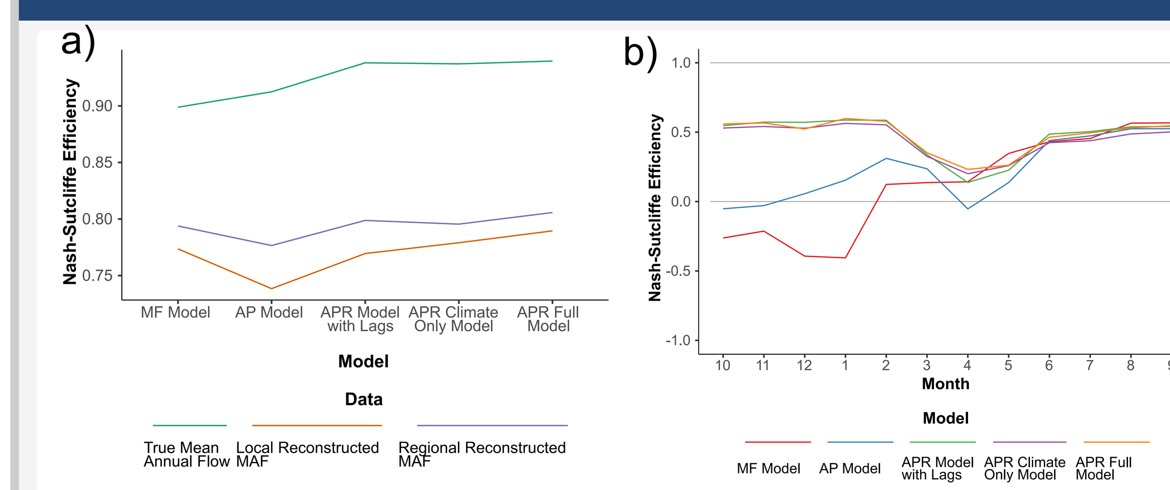


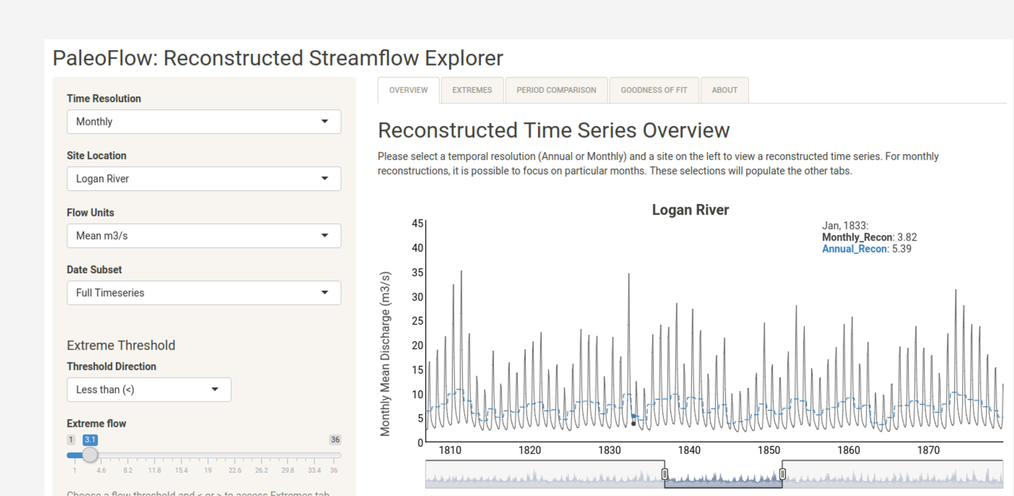
Figure 6 - Goodness of fit measured by Nash-Sutcliffe Efficiency (NSE) for the overall time series (a) and on a monthly scale (b).

Overall Goodness of Fit
▪ Greatest model improvement from flexible water year transition
▪ Including climate indices and regional tree-rings PCs provide smaller, but significant improvements

Monthly Goodness of Fit
▪ APR model improvement is most significant between Oct-Feb, when the MF and AP models have no predictive skill
▪ Inclusion of climate indices and regional tree-rings greatly improves the hydrograph visually, smoothing transitions in the recession curve, which is not captured by NSE

V. Conclusions and Implications

▪ The APR model **successfully reconstructs monthly flows**, while also reproducing seasonal hydrographs
▪ Allows use of paleoclimate data in water management applications, **exanding scenarios for simulation and optimization**
▪ Paper currently in review.
▪ Visualization tool at **https://jstagge.shinyapps.io/paleo_flow/** for greater public acces to paleoclimate data.



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