



Evaluating Changes in the Seasonality of Peak Streamflow Caused by Hydroclimatic Variability in Montana Using Circular Statistics

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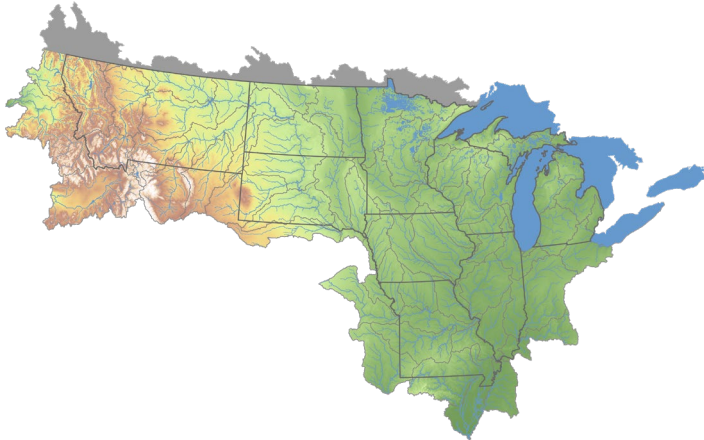
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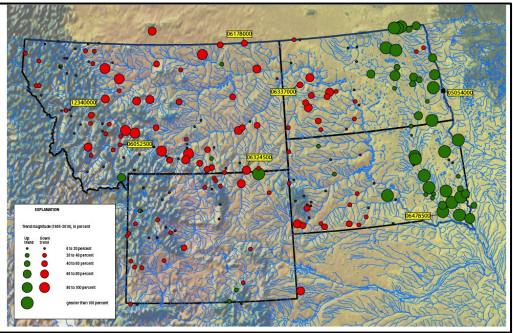
Transportation Pooled Fund Project

TPF-5(460) <https://www.pooledfund.org/Details/Study/687>

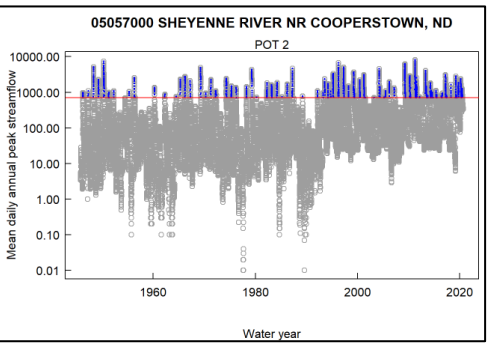
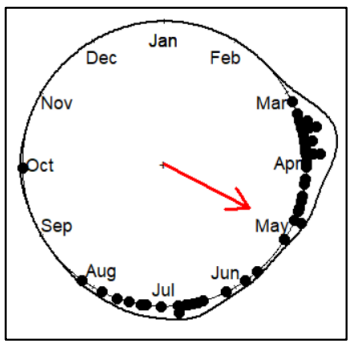
Motivation and objectives



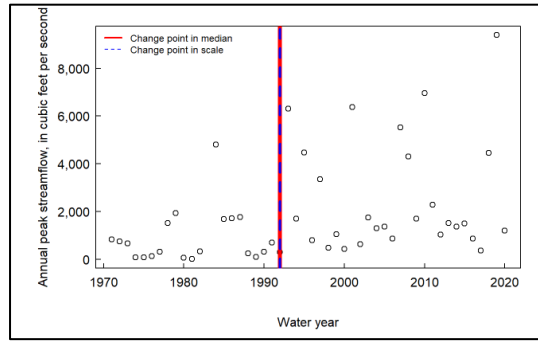
Hydroclimatic variability and multidecadal persistence



Seasonal properties of annual maximum series among three discrete trend periods



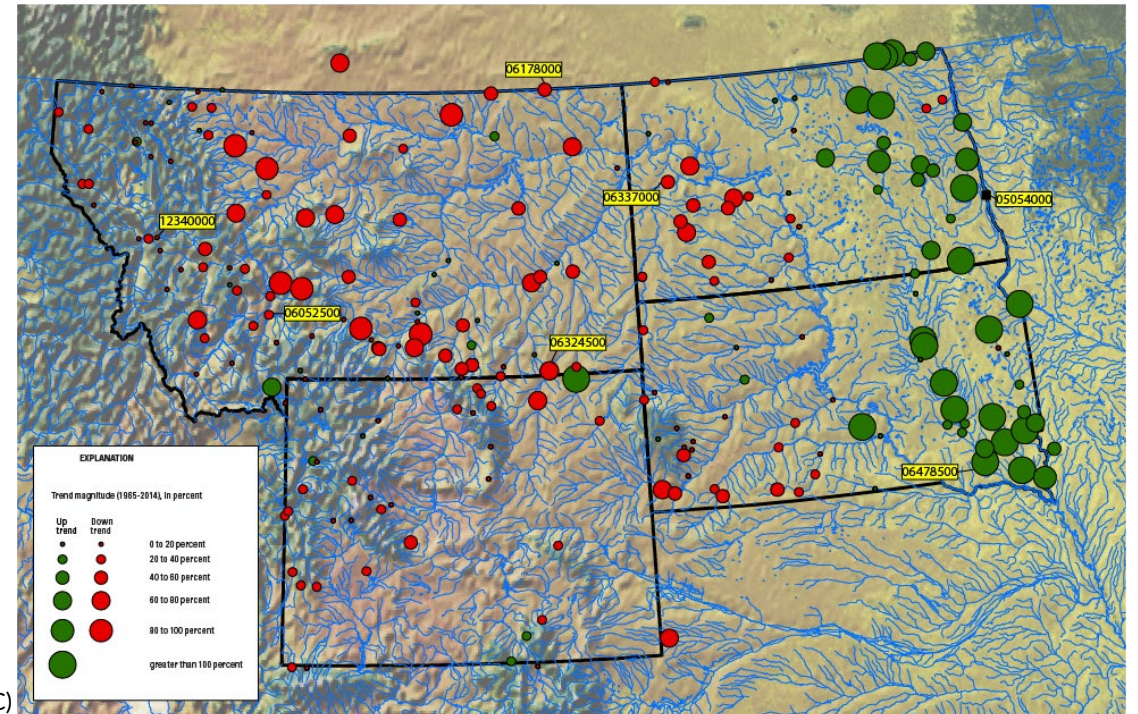
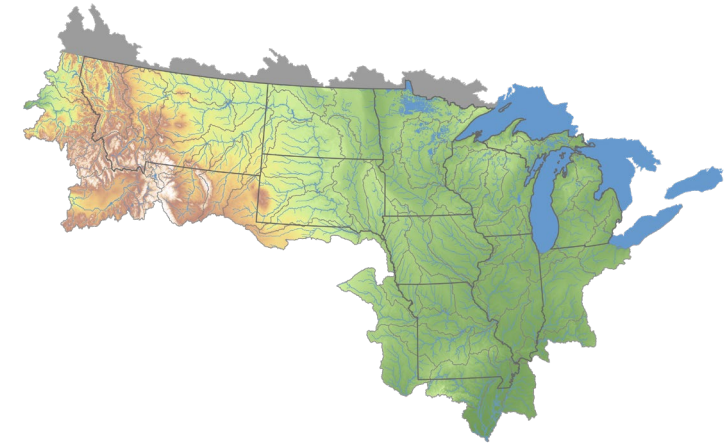
Evaluating changes in seasonality due to detected change points in median and/or scale in annual peak streamflow



Project objective

<https://www.pooledfund.org/Details/Study/687>

- Evaluate the combined effects of hydroclimatic shifts, gradual climate change, multidecadal climatic persistence, seasonality and land-use change on peak-flow frequency analyses in the study region.
- Provide a framework for addressing potential nonstationarity issues in statewide peak-flow frequency updates



(Courtesy of Steve Sando, WY-MT WSC)

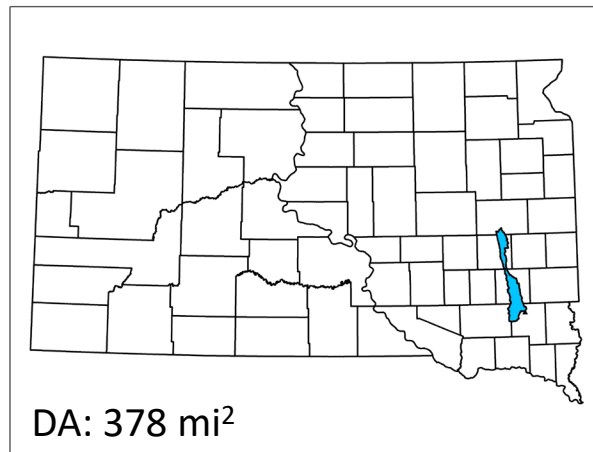
Peak flow magnitude trends



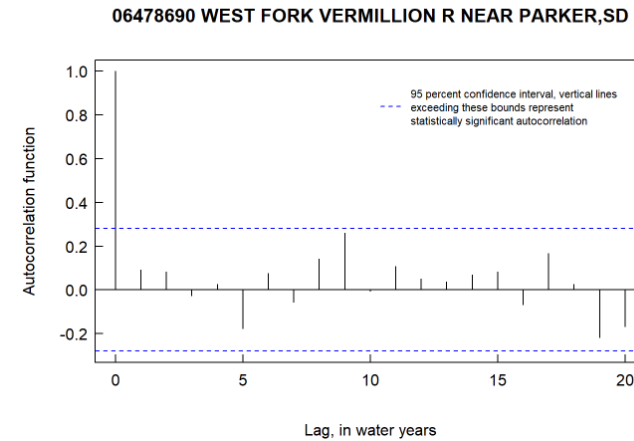
Candidate site with multiple lines of evidence for stationarity violations: USGS streamgauge with 50-year record (1971-2020)

Revisit conventional assumptions for flood frequency analysis

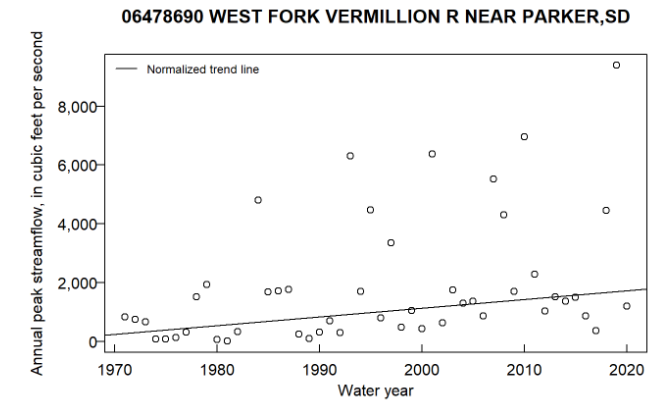
- The stochastic process that generates floods is assumed:
 - (i) stationary or invariant in time and
 - (ii) generated by a single flood-generating mechanism
- However, the period of record may include “flood rich” and “flood poor” flow regimes. They represent another type of “temporal mixed population” — a two-state system



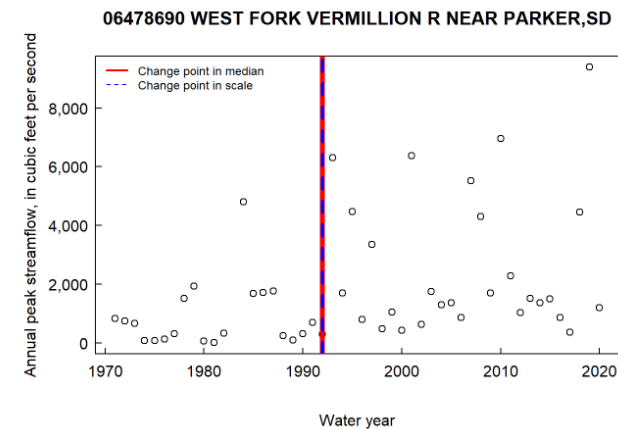
Autocorrelation



Monotonic Trends



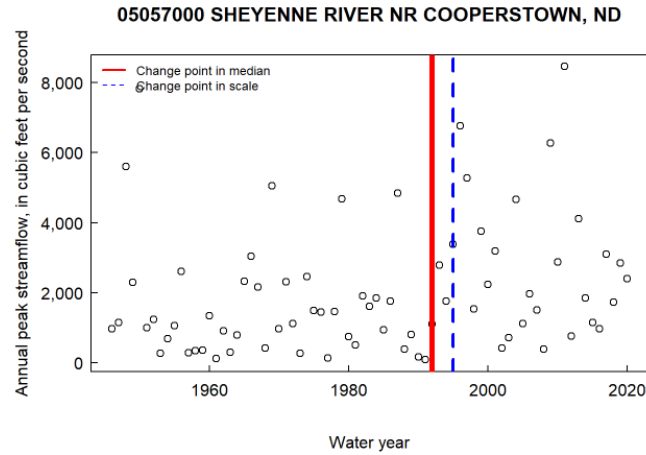
Change Points



Candidate site with multiple lines of evidence for stationarity violations: USGS streamgage with 75-year record (1946-2020)

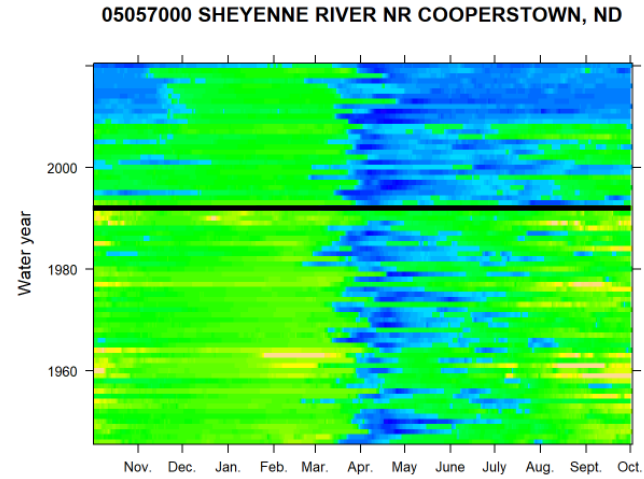
Change Points

A



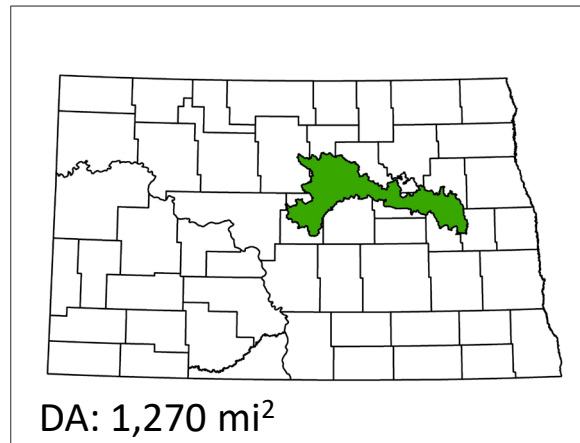
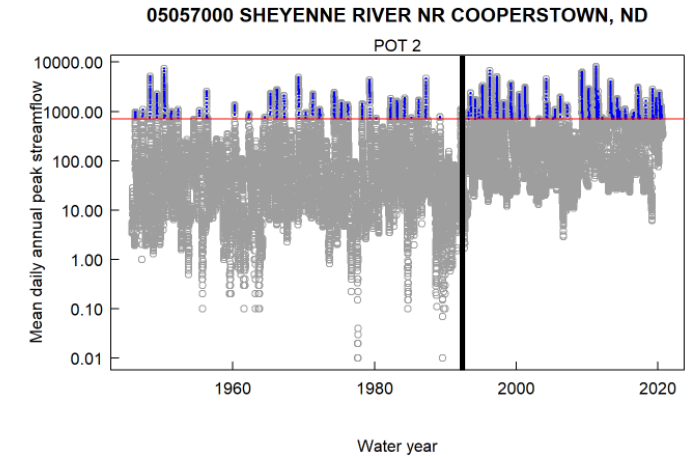
Raster-Seasonality Plot

B



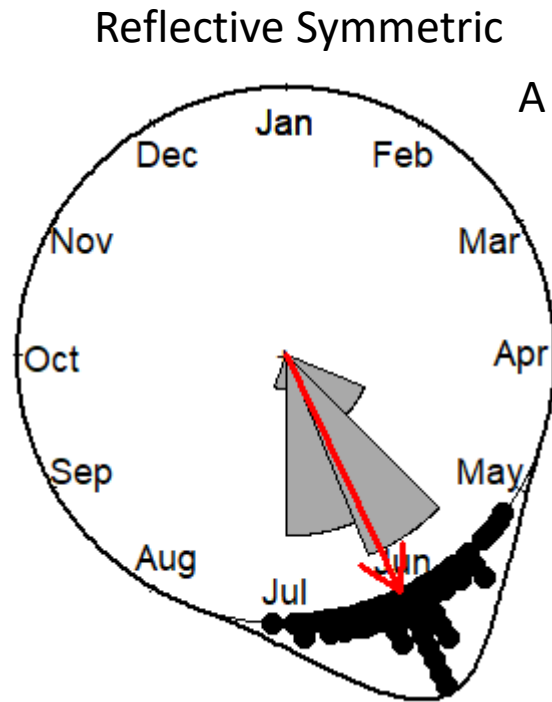
Peaks-Over-Threshold Analysis

C

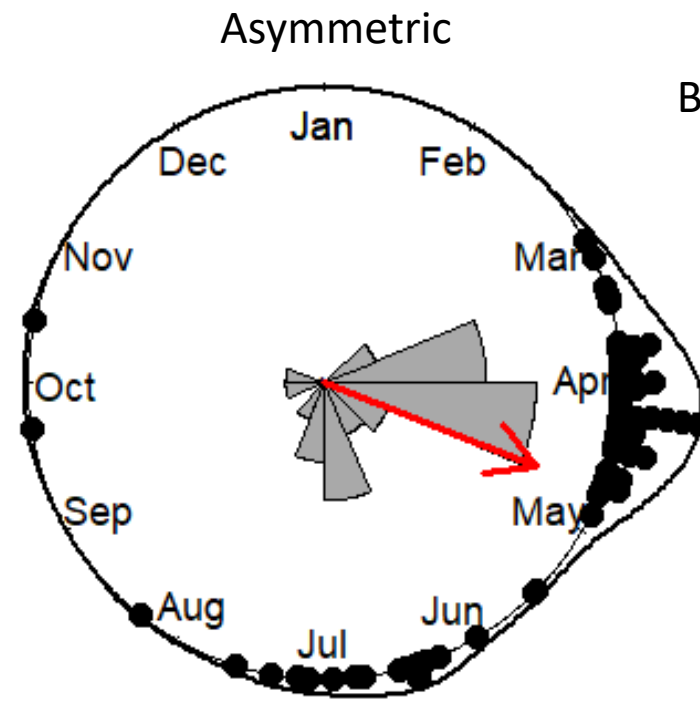


Seasonality of annual peak streamflow and evaluating changes in their timing: a circular statistics approach

“The concept of seasonality refers to *recurring events or processes* that are correlated with seasons...” (EPA, 2021)

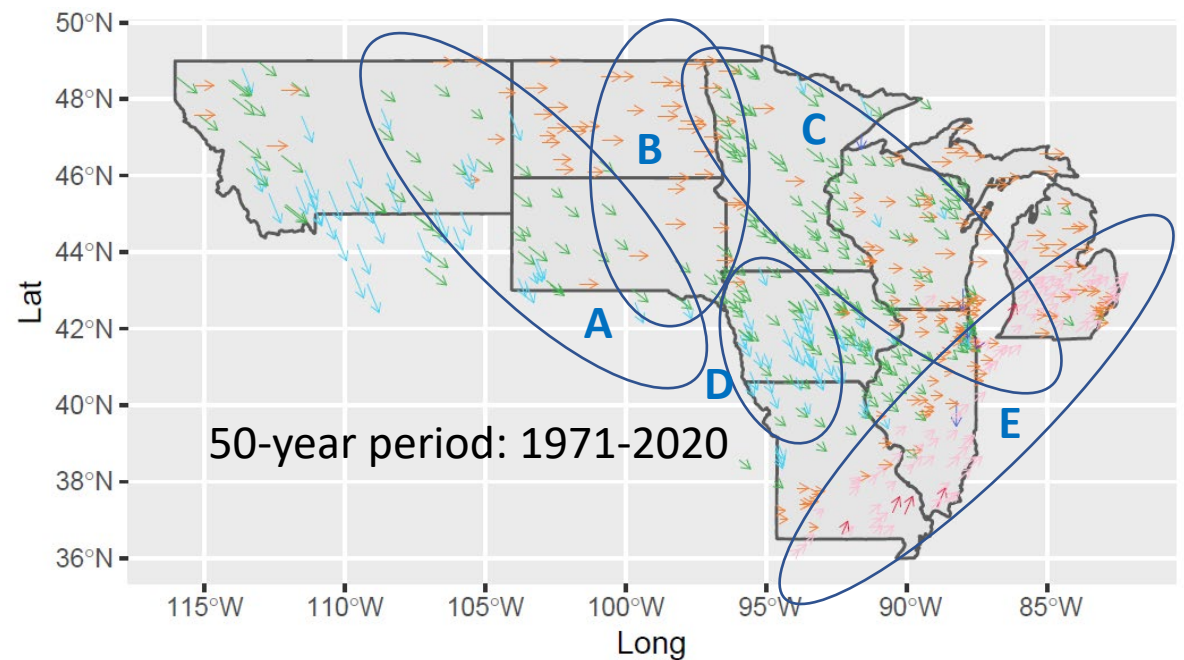
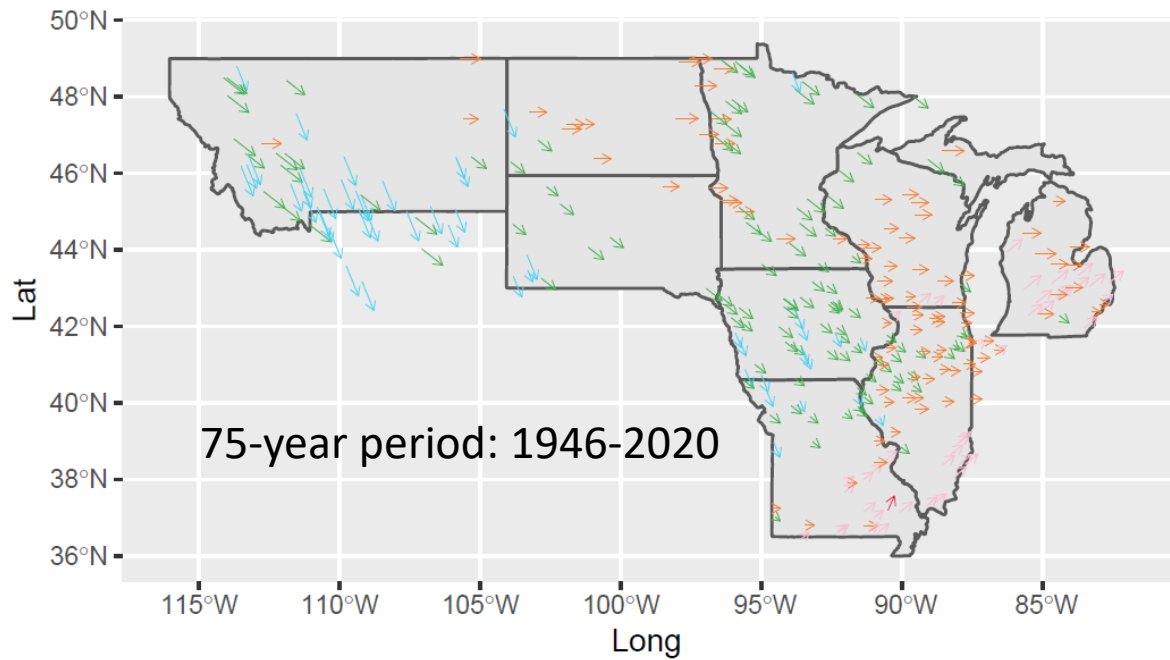


Station 06191500
Yellowstone River at Corwin Springs, Montana

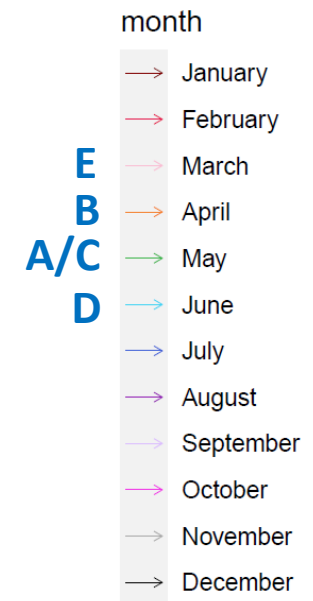
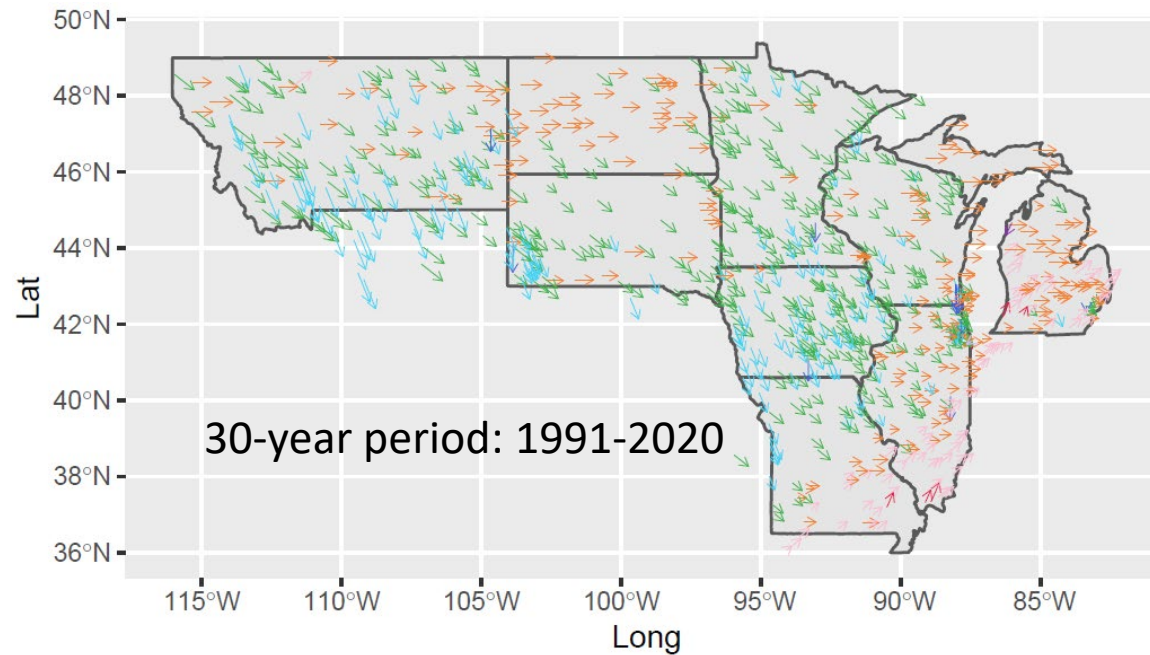
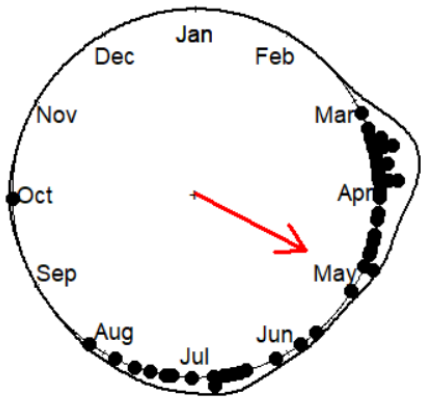


Station 05094000
South Branch Two Rivers at Lake Bronson, Minnesota





Annual Maximum Series (AMS)



Results of evaluating changes in seasonality between POR1 and POR2 based on detected change points

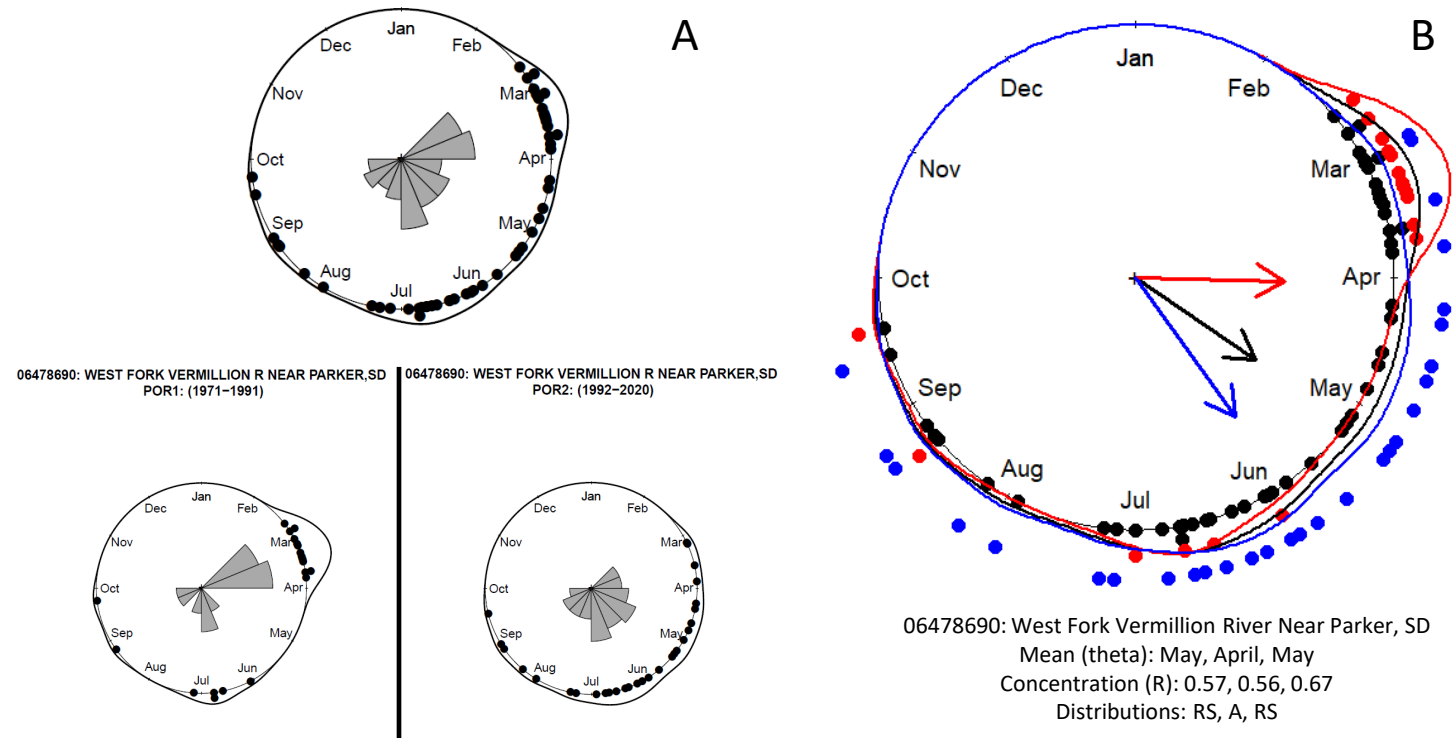
Statistically significant changes in the:

- Mean (theta)
- Distributions
 - Asymmetric (POR1)
 - Reflective symmetric (POR2)

(*at p -value 0.05)

- Not in the dispersion (R)

06478690: West Fork Vermillion River near Parker, SD
POR: (1971-2020)



Putting it all together: seasonality of peak-flow timing and changes in seasonal characteristics

TIMING: changes in when a seasonal event occurs during the year

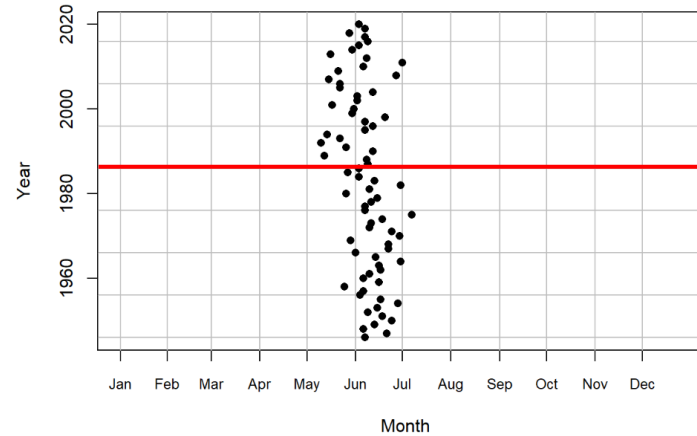
Diminished snowpack and earlier melting in higher mountain elevations

Leading to shifts in water availability

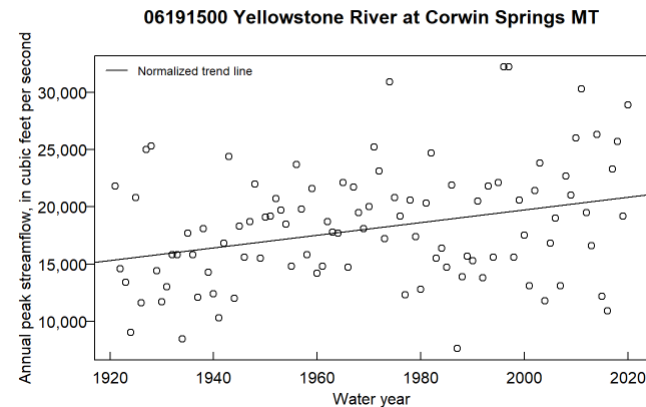
Modified from: EPA (2021)



06191500: Yellowstone River at Corwin Springs MT
POR: (1946-2020)

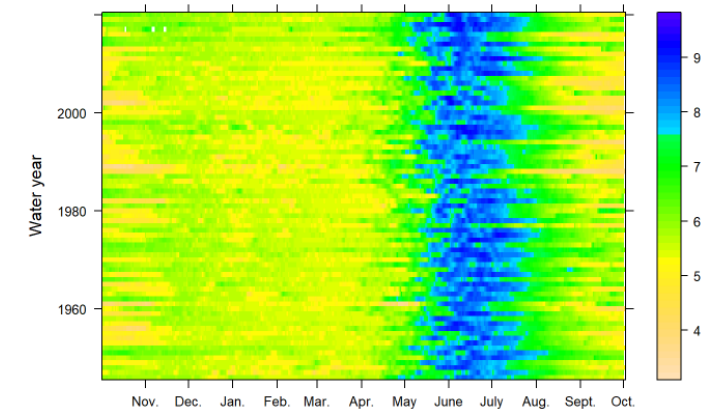


Monotonic Trends

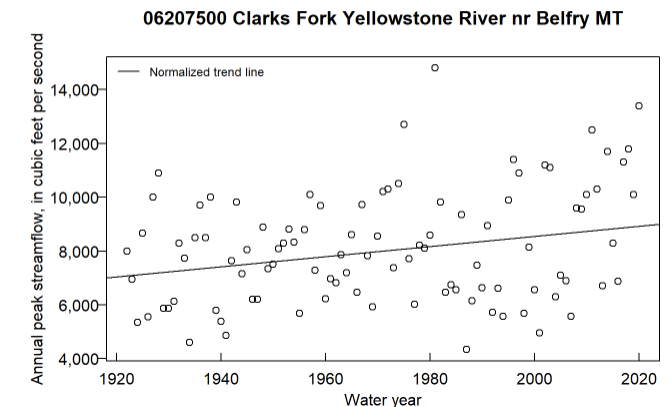


Raster-Seasonality Plot

06207500 Clarks Fork Yellowstone River nr Belfry MT



Monotonic Trends



Putting it all together: seasonality of peak-flow timing and changes in seasonal characteristics

TIMING: changes in when a seasonal event occurs during the year

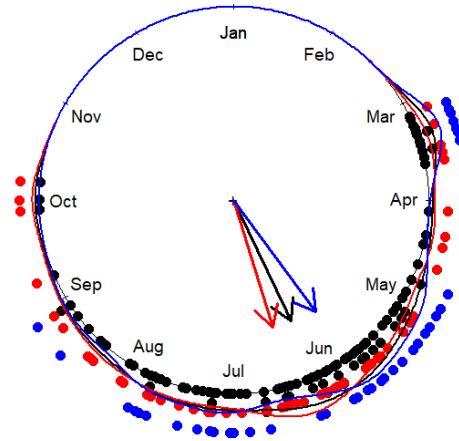
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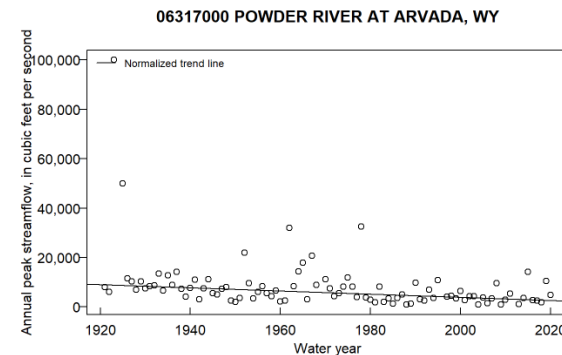
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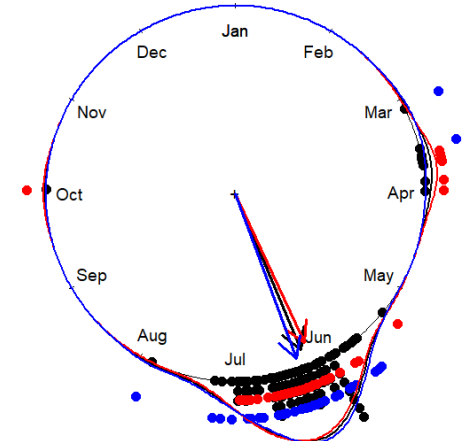
06317000: POWDER RIVER AT ARVADA, WY
POR: (1921-2020)



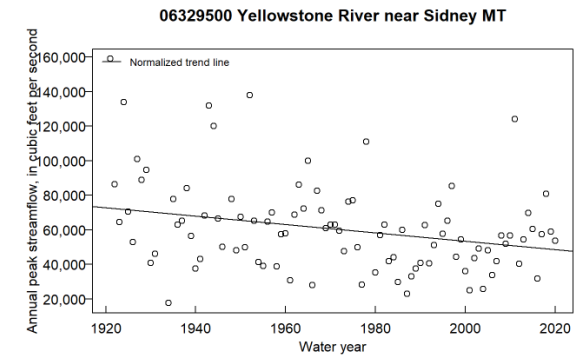
Monotonic Trends



06329500: Yellowstone River near Sidney MT
POR: (1921-2020)



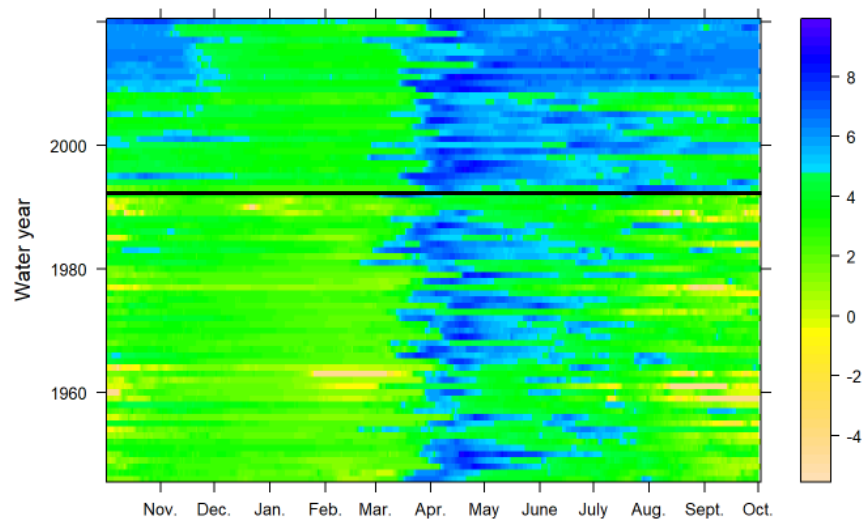
Monotonic Trends



Putting it all together: seasonality of peak-flow timing and changes in seasonal characteristics

Raster-Seasonality Plot

05057000 SHEYENNE RIVER NR COOPERSTOWN, ND



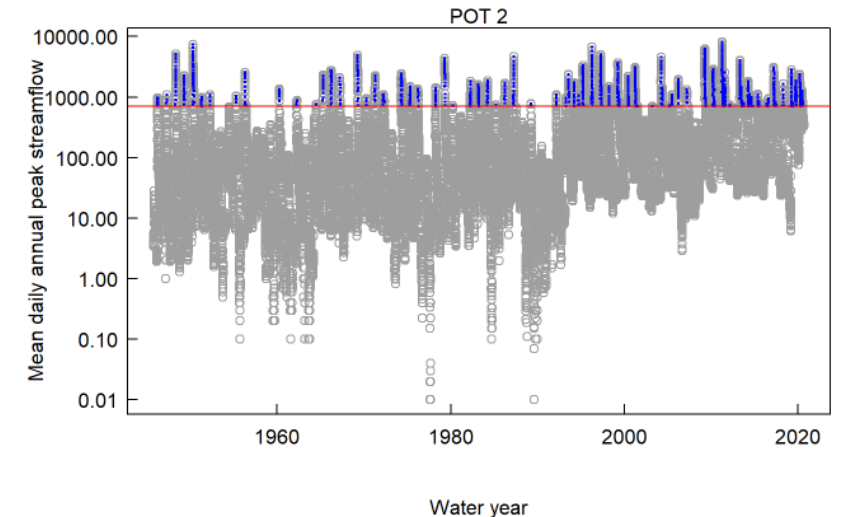
DURATION: changes in how long a seasonal event lasts during the year

Earlier springtime snowmelt and later warmer season rainfall events

Leading to longer periods of high flow events

Peaks-Over-Threshold Analysis

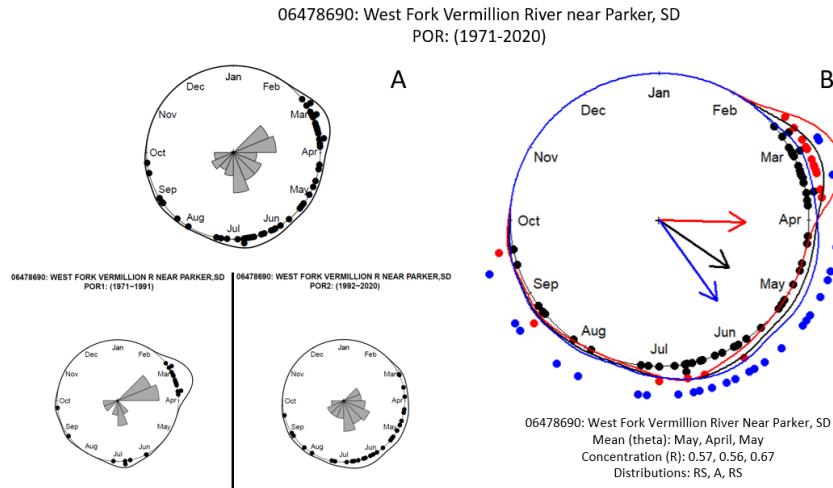
05057000 SHEYENNE RIVER NR COOPERSTOWN, ND



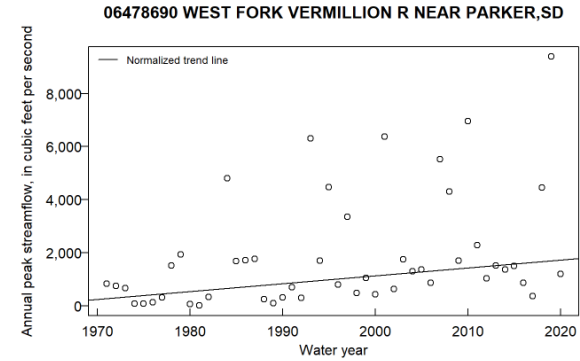
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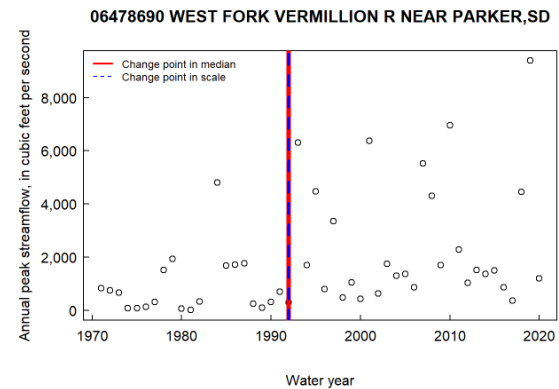
Putting it all together: seasonality of peak-flow timing and changes in seasonal characteristics



Monotonic Trends



Change Points



VARIABILITY: changes in intensity and frequency of seasonal events

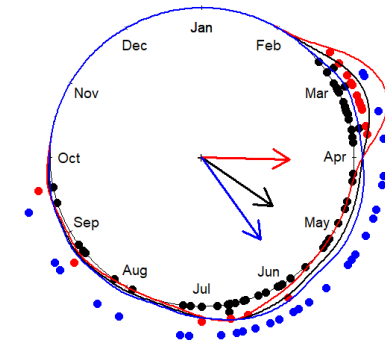
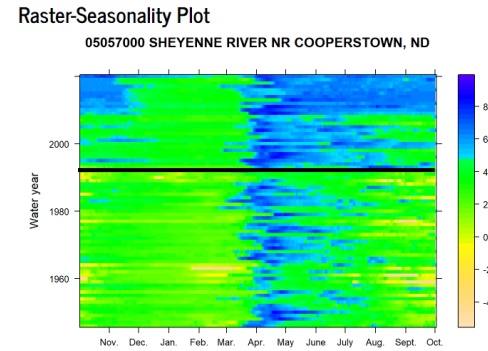
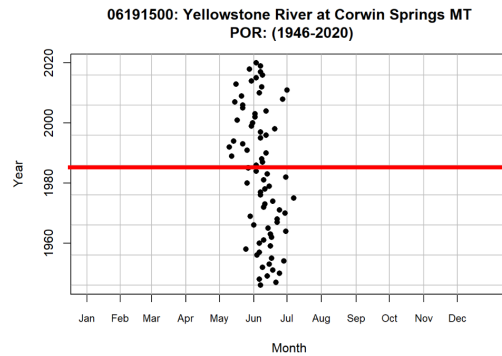
Longer duration of higher streamflow events

Leading to increasing frequency of high flow events

Modified from: EPA (2021)



Putting it all together: multiple lines of evidence for candidate attributions for nonstationarity due to hydroclimatic variability



TIMING: changes in when a seasonal event occurs during the year

Diminished snowpack and earlier melting in higher mountain elevations

Leading to shifts in water availability

DURATION: changes in how long a seasonal event lasts during the year

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VARIABILITY: changes in intensity and frequency of seasonal events

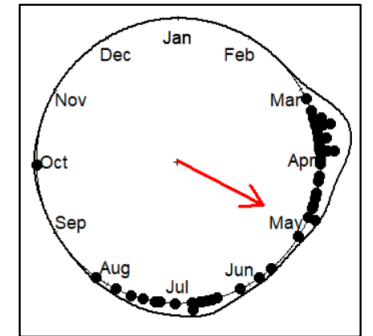
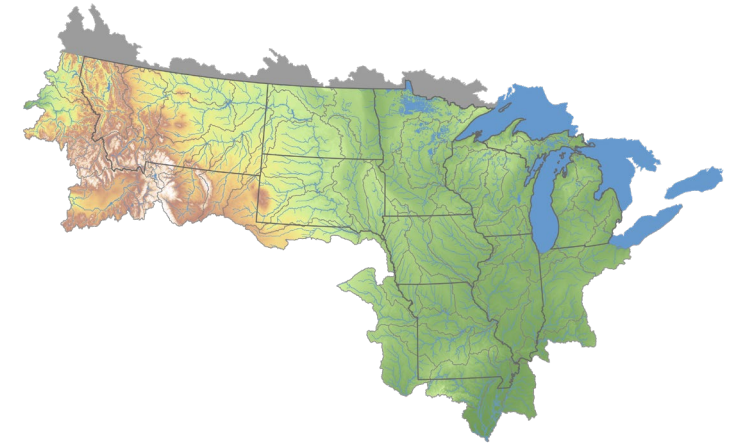
Longer duration of higher streamflow events

Leading to increasing frequency of high flow events

Annual time scale

Inter-annual time scale





Questions?
 (nabarth@usgs.gov)

