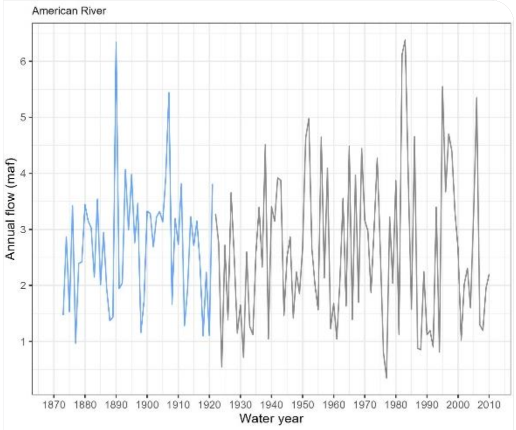
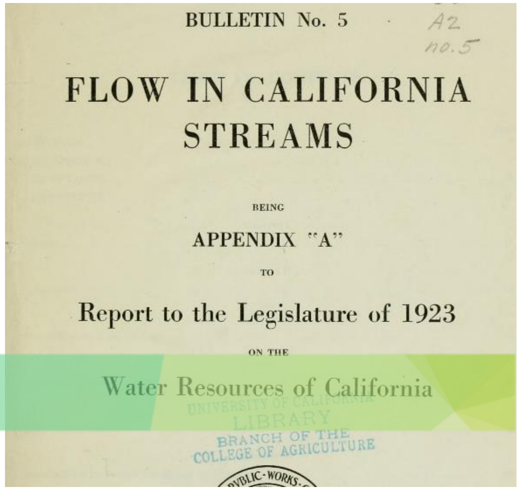



BULLETIN No. 5

FLOW IN CALIFORNIA STREAMS

BEING

APPENDIX "A"

TO

Report to the Legislature of 1923

ON THE

Water Resources of California

TETRA TECH

Digitizing and Assessing Unimpaired Flow Time Series in Bulletin 5 during Water Years 1872 to 1921

Yuchuan Lai, Paul Hutton, and Sujoy Roy

2023 CWEMF Annual Meeting

Folsom, California

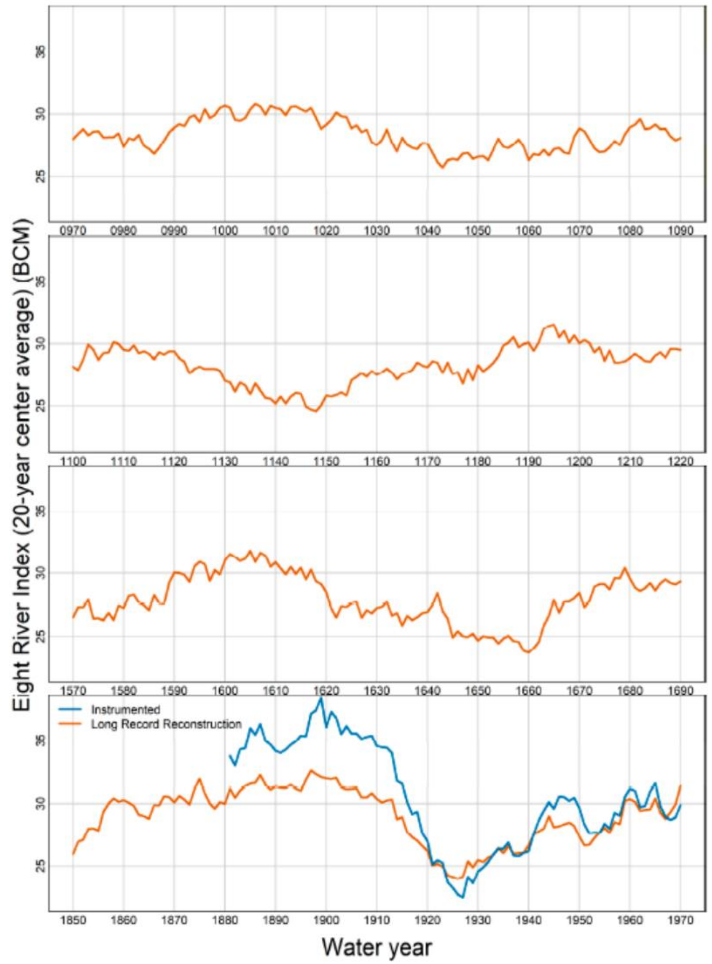
April 18, 2023

CWEMF
CALIFORNIA
Water & Environmental
Modeling Forum

Motivation

- Many of the available unimpaired flow series start from water year (WY) 1922
- Data and information for WY 1872-1921 are presented in Bulletin 5
- The period of 1870s to 1920s is of historical significance:
  - A transition from a pre-development landscape to a drained and leveed landscape
  - A transition from an extreme wet period (1870s to 1910s) to an extreme dry period (1920s to 1930s)
- Additional 50 years of runoff records can facilitate the studies of long-term climate change

Reconstructed Eight River Index (970-1970)



Hutton et al. (2021) *Water*

Objectives

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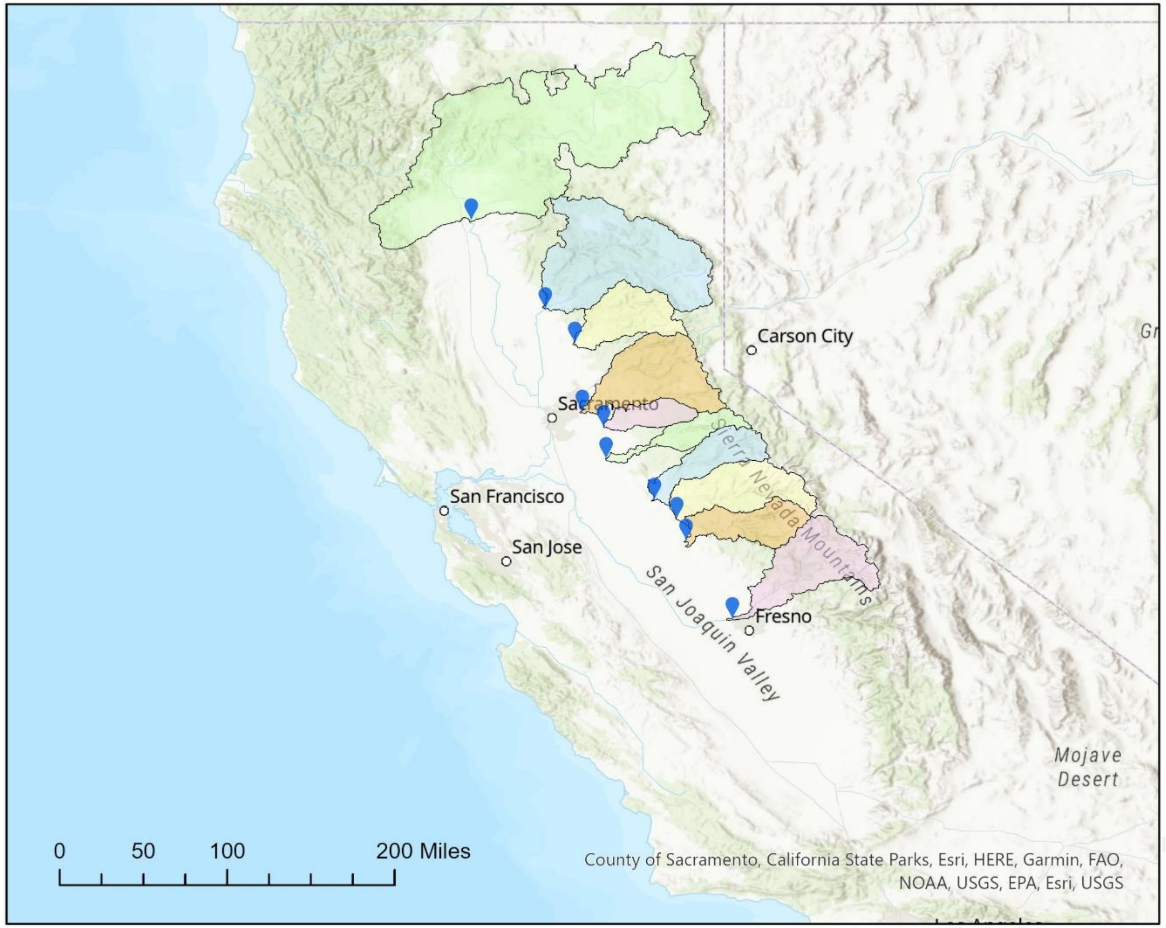
- Identify the data and information presented in Bulletin 5
- Obtain monthly unimpaired flow series during WY 1872-1921 for 10 watersheds
- Assessing long-term climate change based on the obtained time series



Raw monthly runoff data are limited for WY 1872-1921

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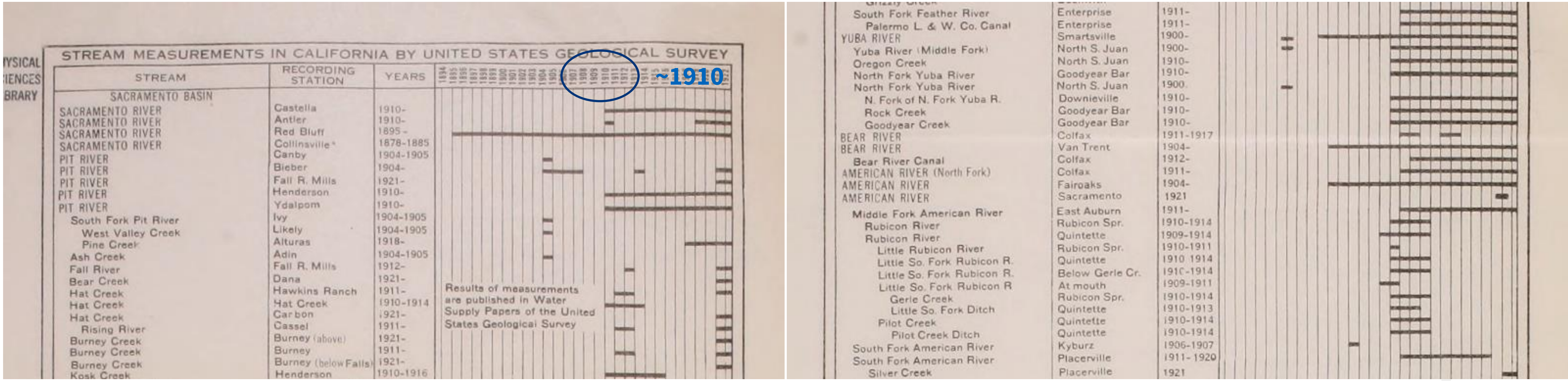
- USGS sites; start from around 1906
- Information can be found in Bulletin 5
- Raw daily data available in the USGS database

Periods of USGS station records listed in Bulletin 5



STREAM MEASUREMENTS IN CALIFORNIA BY UNITED STATES GEOLOGICAL SURVEY

STREAM	RECORDING STATION	YEARS
SACRAMENTO BASIN		
SACRAMENTO RIVER	Castella	1910-
SACRAMENTO RIVER	Antler	1910-
SACRAMENTO RIVER	Red Bluff	1895-
SACRAMENTO RIVER	Collinsville	1878-1885
PIT RIVER	Canby	1904-1905
PIT RIVER	Bieber	1904-
PIT RIVER	Fall R. Mills	1921-
PIT RIVER	Henderson	1910-
PIT RIVER	Ydalpom	1910-
South Fork Pit River	Ivy	1904-1905
West Valley Creek	Likely	1904-1905
Pine Creek	Alturas	1918-
Ash Creek	Adin	1904-1905
Fall River	Fall R. Mills	1912-
Bear Creek	Dana	1921-
Hat Creek	Hawkins Ranch	1911-
Hat Creek	Hat Creek	1910-1914
Hat Creek	Carbon	1921-
Rising River	Cassel	1911-
Burney Creek	Burney (above)	1921-
Burney Creek	Burney	1911-
Burney Creek	Burney (below Falls)	1921-
Kosk Creek	Henderson	1910-1916

Results of measurements are published in Water Supply Papers of the United States Geological Survey

STREAM	RECORDING STATION	YEARS
South Fork Feather River	Enterprise	1911-
Palermo L. & W. Co. Canal	Enterprise	1911-
YUBA RIVER	Smartsville	1900-
Yuba River (Middle Fork)	North S. Juan	1900-
Oregon Creek	North S. Juan	1910-
North Fork Yuba River	Goodyear Bar	1910-
North Fork Yuba River	North S. Juan	1900
N. Fork of N. Fork Yuba R.	Downieville	1910-
Rock Creek	Goodyear Bar	1910-
Goodyear Creek	Goodyear Bar	1910-
BEAR RIVER	Colfax	1911-1917
BEAR RIVER	Van Trent	1904-
Bear River Canal	Colfax	1912-
AMERICAN RIVER (North Fork)	Colfax	1911-
AMERICAN RIVER	Fairoaks	1904-
AMERICAN RIVER	Sacramento	1921
Middle Fork American River	East Auburn	1911-
Rubicon River	Rubicon Spr.	1910-1914
Rubicon River	Quintette	1909-1914
Little Rubicon River	Rubicon Spr.	1910-1911
Little So. Fork Rubicon R.	Quintette	1910-1914
Little So. Fork Rubicon R.	Below Gerle Cr.	1910-1914
Little So. Fork Rubicon R	At mouth	1909-1911
Gerle Creek	Rubicon Spr.	1910-1914
Little So. Fork Ditch	Quintette	1910-1913
Pilot Creek	Quintette	1910-1914
Pilot Creek Ditch	Quintette	1910-1914
South Fork American River	Kyburz	1906-1907
South Fork American River	Placerville	1911-1920
Silver Creek	Placerville	1921

Raw monthly temp and precip data available for WY 1872-1921 based on the information in Bulletin 5

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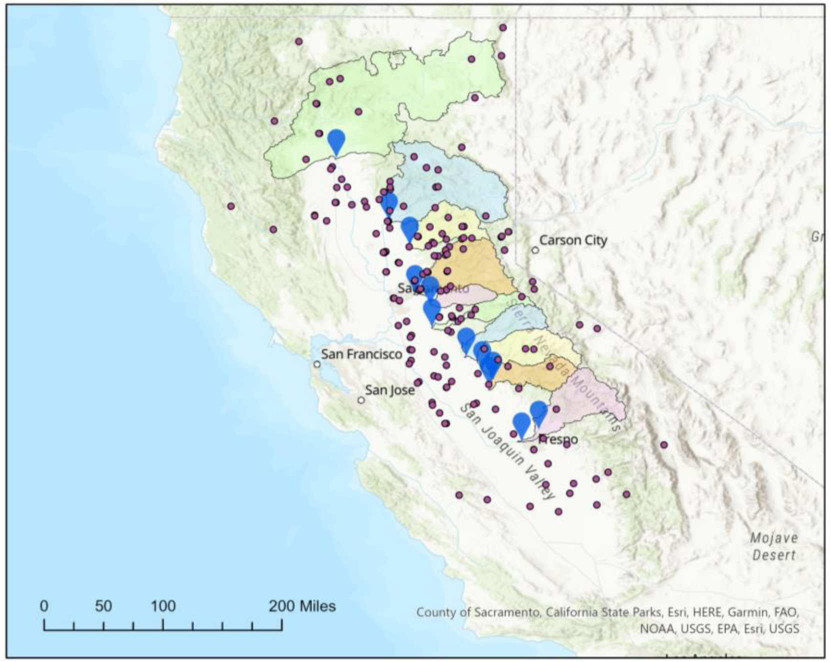
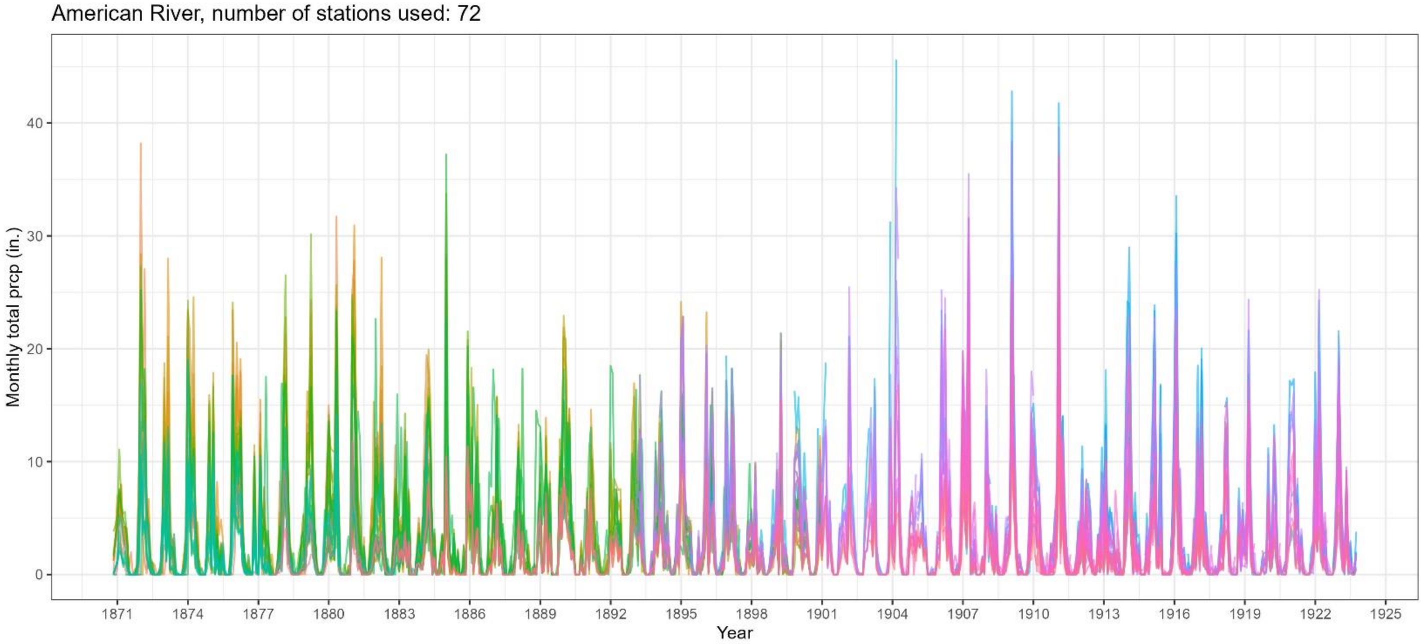
- Using National Weather Service stations (established in 1890)
- Using multiple historic documents and reports

  e.g., Physical Data and Statistics of California (1886) and Climatology of California (1903)

Locations of precipitation stations



Available precipitation records for American River Watershed



A statistical approach was used to predict monthly flow based on temperature and precipitation

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Two main components/steps:

1. Combine records of multiple stations to obtain temperature and precipitation series using a monthly decomposition method

2. Predict monthly flow using a monthly regression model and temperature and precipitation obtained from the first step

A decomposition method used to extract and preserve annual and monthly variability in station records

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Temperature of station i: $T_{t,i} = A_t + M_t + S_{t,i} + E_{t,i}$

Precipitation of station i: $P_{t,i} = A_t \times M_t \times S_{t,i} \times E_{t,i}$

At time t,

A_t: Annual variability (same for all stations)

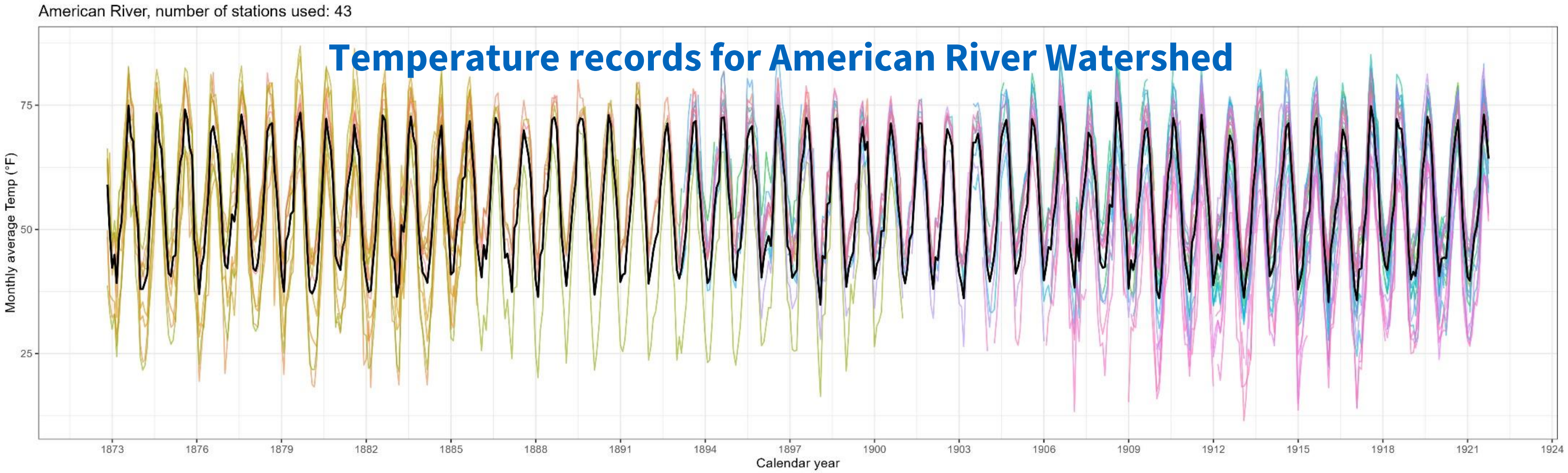
M_t: Monthly variability (same for all stations)

$S_{t,i}$: Seasonality (for station i)

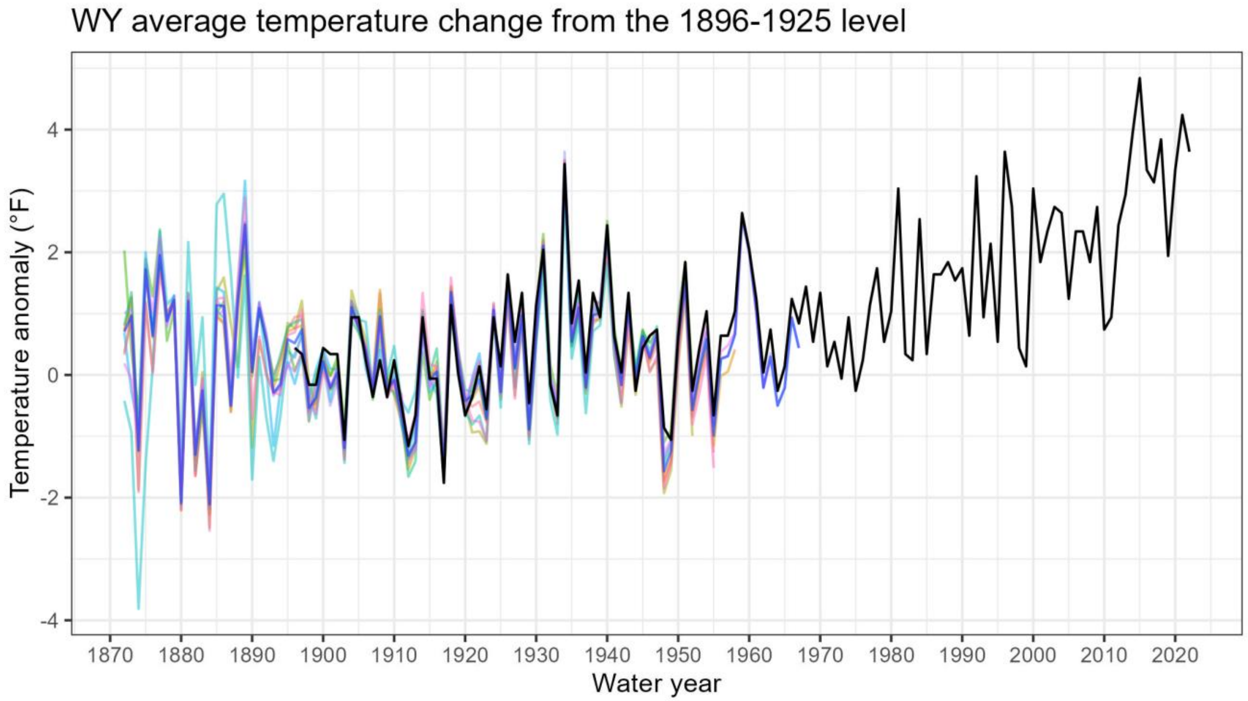
$E_{t,i}$: Monthly residuals (for station i)

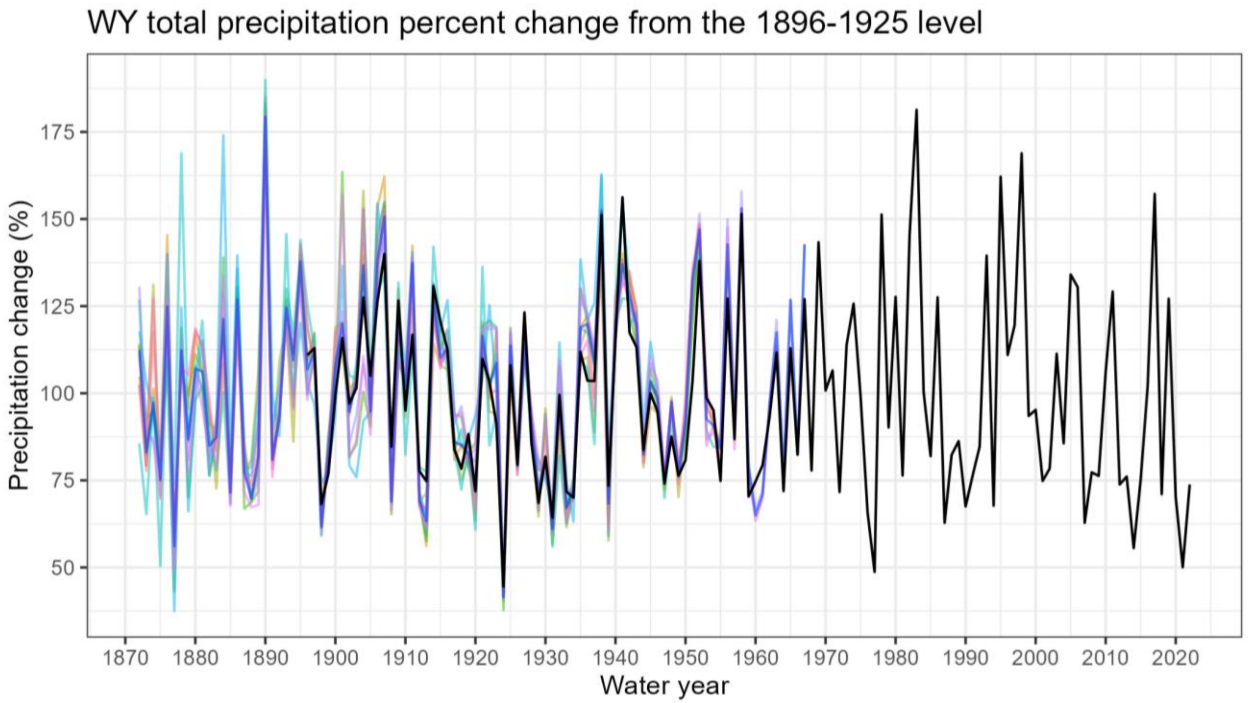
To obtain a complete temperature series: $T_t = A_t + M_t + \bar{S}_t$

To obtain a complete temperature series :$P_t = A_t \times M_t \times \bar{S}_t$



Obtained time series of temperature and precipitation are consistent with the existing NOAA records





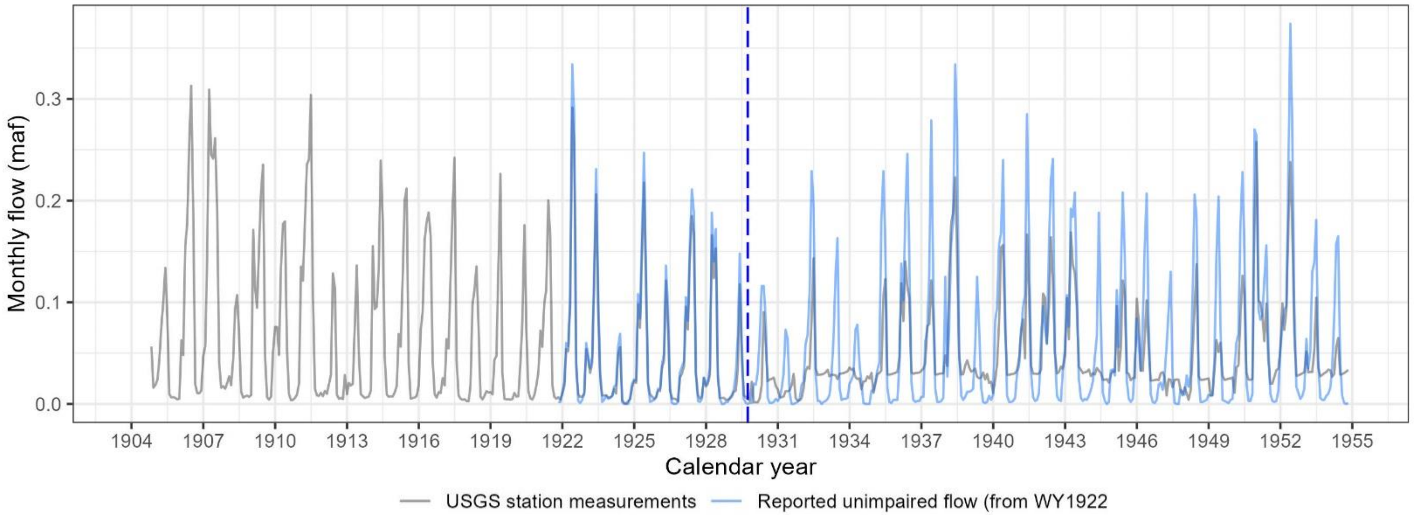
A monthly regression model used to predict monthly flow based on temperature and precipitation

$$F^{(l)}_{t(\text{when belong to month } m)} = \beta_{0,m} + \beta_{1,m}T_t + \beta_{2,m}P_t^{(l)} + \beta_{3,m}T_t^* + \beta_{4,m}P_t^{*(l)}$$

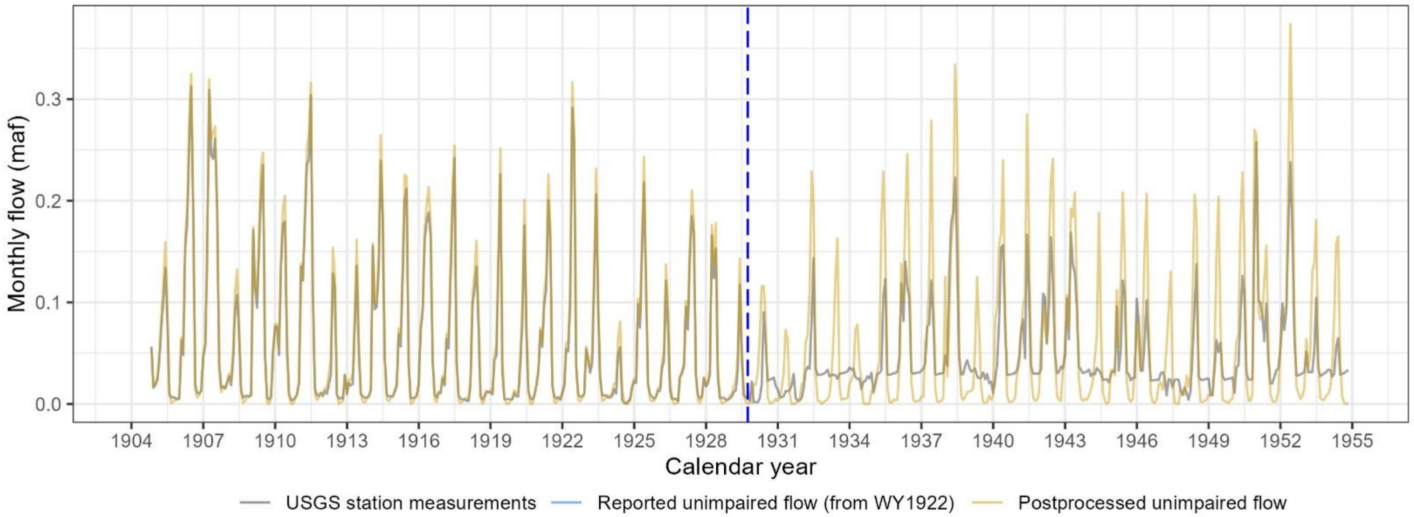
$F_t^{(l)}$:	Monthly runoff at time t with a log transformation
$\beta_{0,m}, \beta_{1,m}, \beta_{2,m}, \beta_{3,m}, \beta_{4,m}$:	Linear regression coefficients for month m
T_t:	Temperature at time t
$P_t^{(l)}$:	Precipitation at time t with a log transformation
T_t^*:	Average temperature from the previous 12 months
$P_t^{*(l)}$:	Average precipitation from the previous 12 months (transformed)

Available runoff measurements were postprocessed by using the reported unimpaired flow series from WY 1922

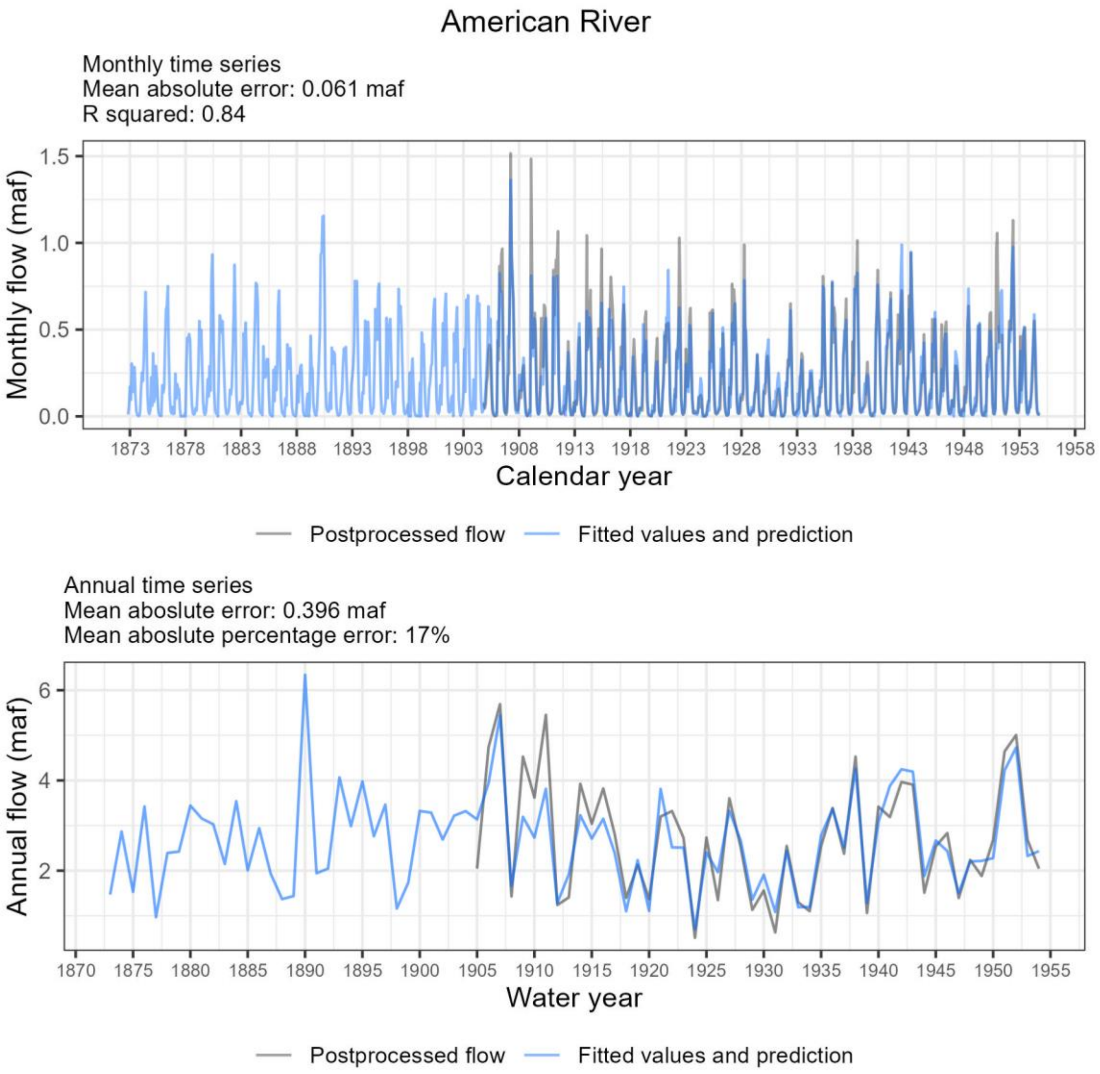
Comparing the reported unimpaired flow with the obtained measurements − Mokelumne River

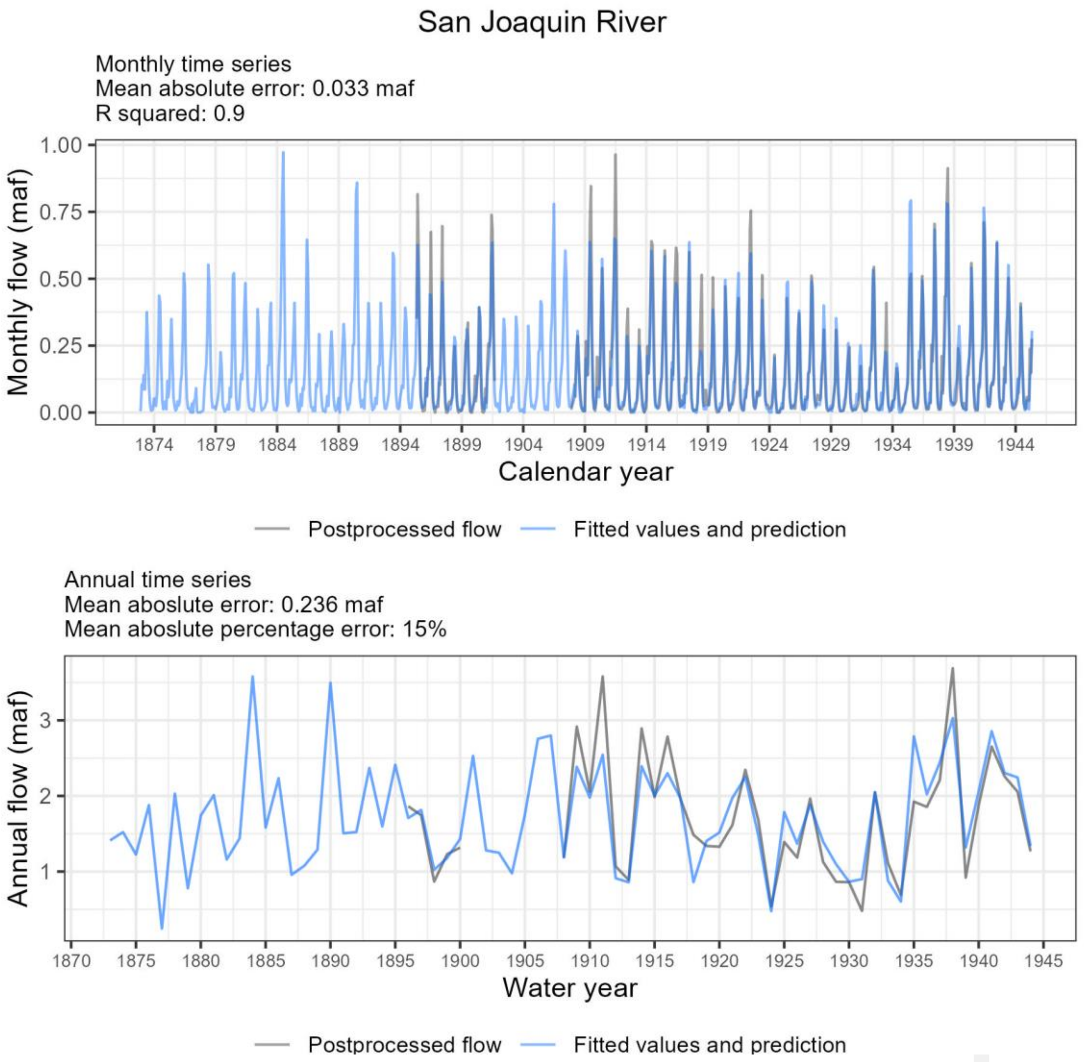


Comparing the postprocessed flow series with the obtained measurements − Mokelumne River



The monthly regression model provided accurate results





No significant changes in annual total flow

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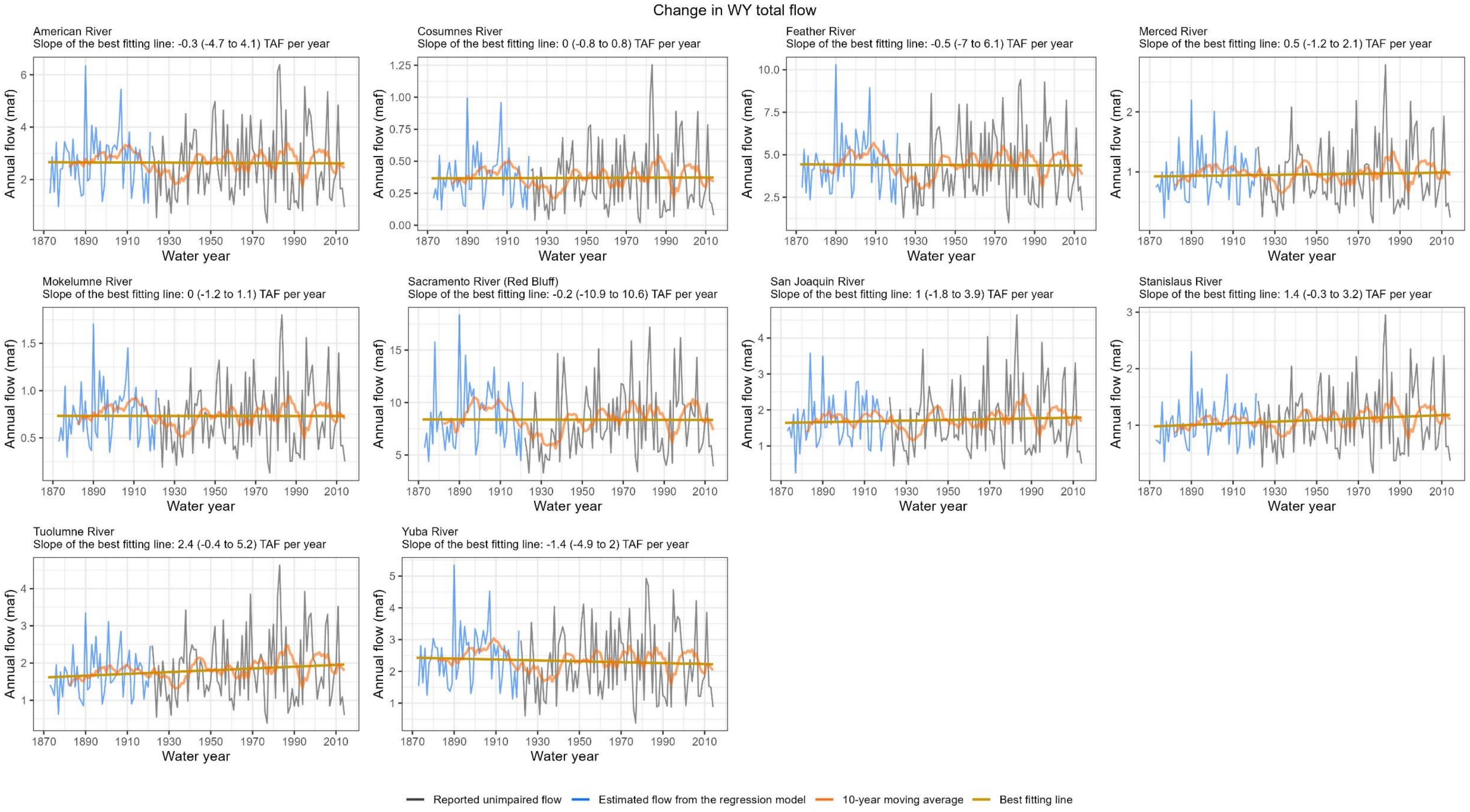

Significant decreases of April to July total flow identified for some watersheds

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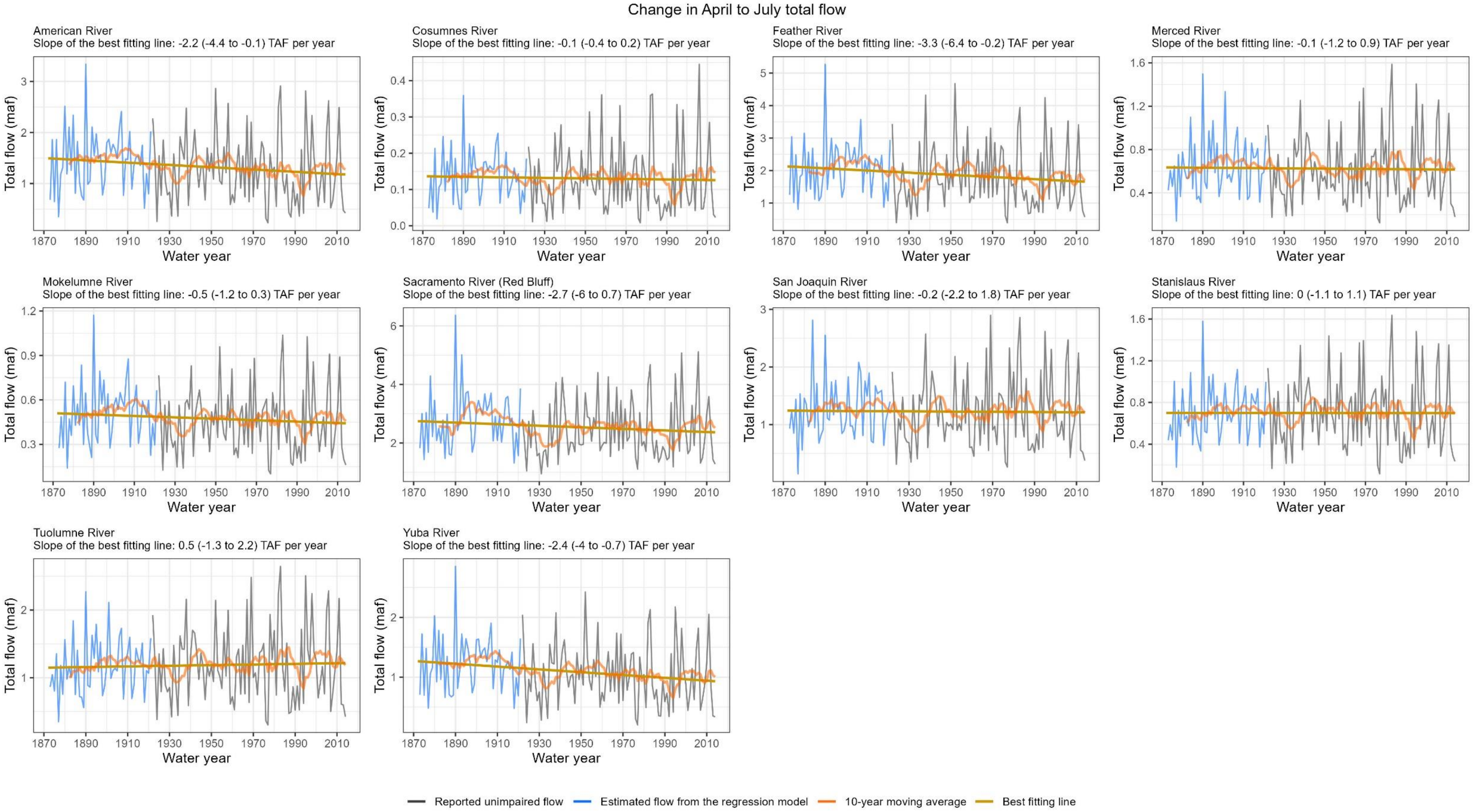
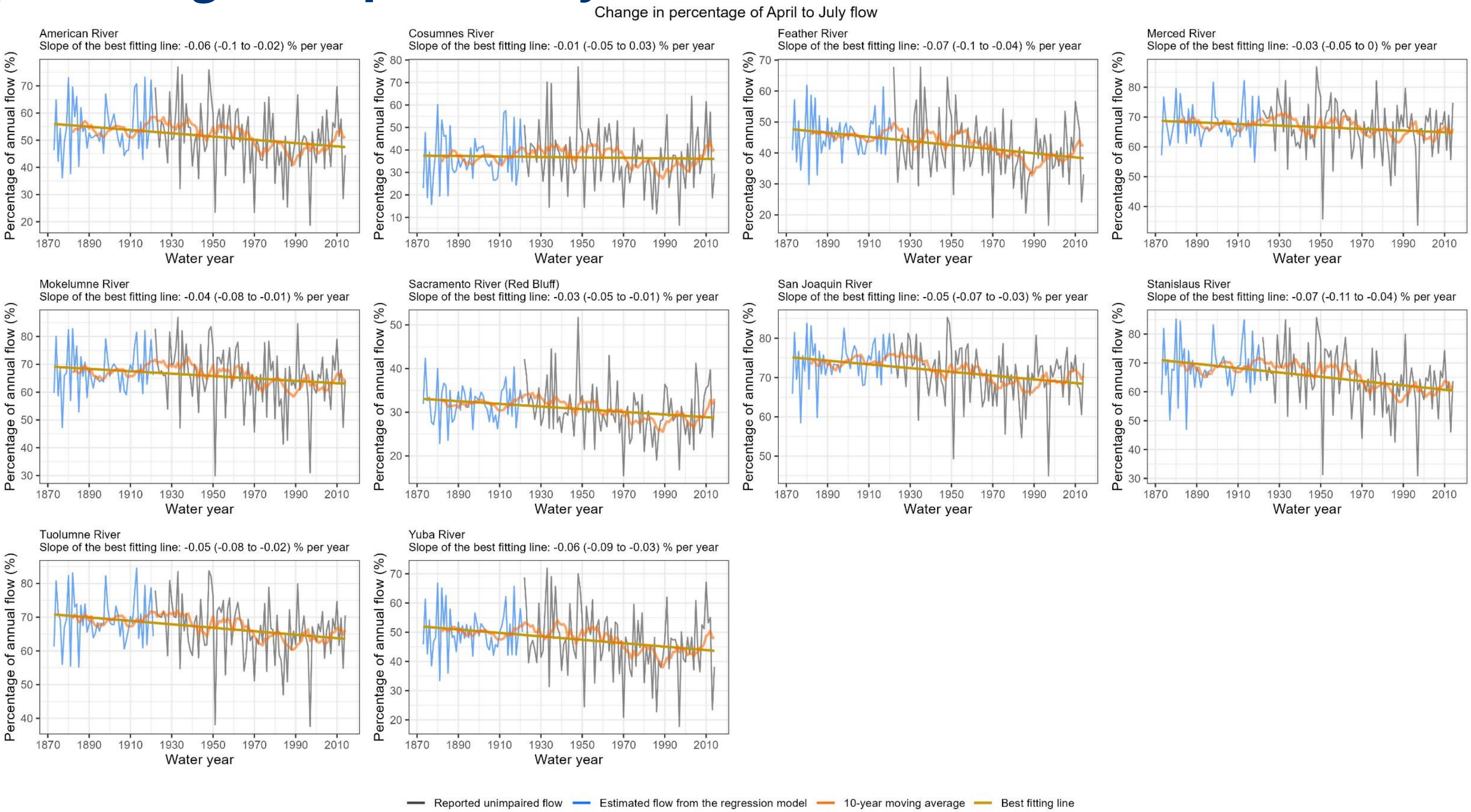


More watersheds exhibit significant decreases in annual percentages of April to July total flow



Summary and conclusions

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- Bulletin 5 serves as an important document – providing valuable data and information on historical climate and hydrology
- Monthly unimpaired flow series were obtained for WY 1872-1921 using empirical, statistical methods, i.e., a monthly decomposition method and a regression model
- Time series analyses on the obtained unimpaired flow series confirmed the decadal variability and long-term climate change trend
- Results are expected to facilitate various regional applications such as studies related to water supply and water quality