Investigating Streamflow Variability of HUC-2 Regions in the Contiguous United States from Water Year 2003 to 2022

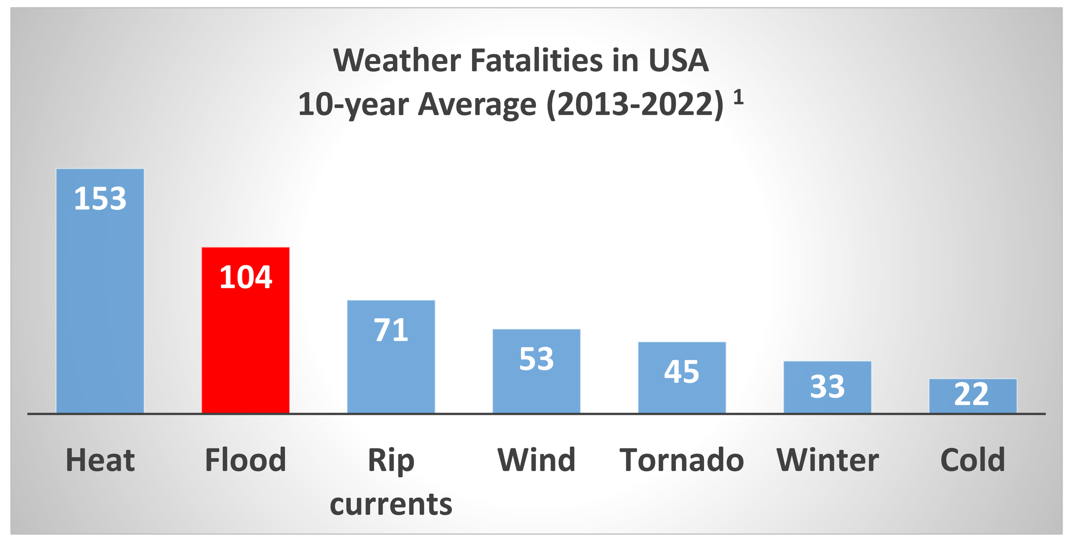
Tao Huang (huang403@pnnl.gov)

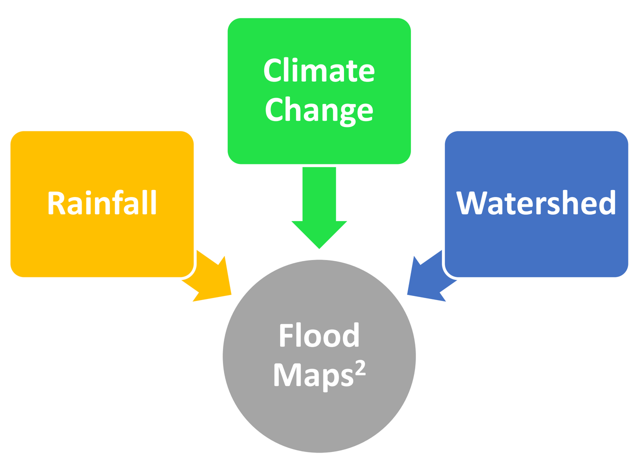
Energy and Environment Directorate, Pacific Northwest National Laboratory, Richland, WA, USA

2023 AGU Fall Meeting

EP11D-1767

Introduction





Rainfall-Runoff Relationship[3]

- The increasing trend of extreme rainfall has been widely documented over the Contiguous United States (CONUS)
- Variability of runoff in natural rivers (streamflow, Q) remains unclear

Mann-Kendall (MK) Test[4]

- **Original MK Test**
  - ❑ Used to analyze time series data for consistently increasing or decreasing trends (monotonic trends)
  - ❑ Non-parametric test, and the assumption of normality is not required
  - ❑ Insensitive to outliers

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sgn}(Q_j - Q_k)$$

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & if\ S > 0 \\ 0, & if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & if\ S < 0 \end{cases}$$

  - ❑ If $Z_{MK} > Z_{0.025}$, the null hypothesis (H_0) (no-trend) is rejected, namely, the streamflow series exhibits significant trends
  - ❑ Otherwise, the alternative hypothesis (H_1) (there exist a trend) is rejected

- **Seasonal MK Test**
  - ❑ Insensitive to the existence of seasonality (e.g., monthly data)

$$Let\ Q = (Q_1, Q_2, Q_3, \ldots Q_{12})\ \text{and}$$

$$Q_i = (Q_{i1}, Q_{i2}, Q_{i3}, \ldots Q_{i12})$$

$$S_i = \sum_{k=1}^{n_i-1} \sum_{j=k+1}^{n_i} \text{sgn}(Q_{ij} - Q_{ik})$$

Research Objectives

For 18 Hydrologic Unit Code 2-Digit (HUC-2) Regions in CONUS:

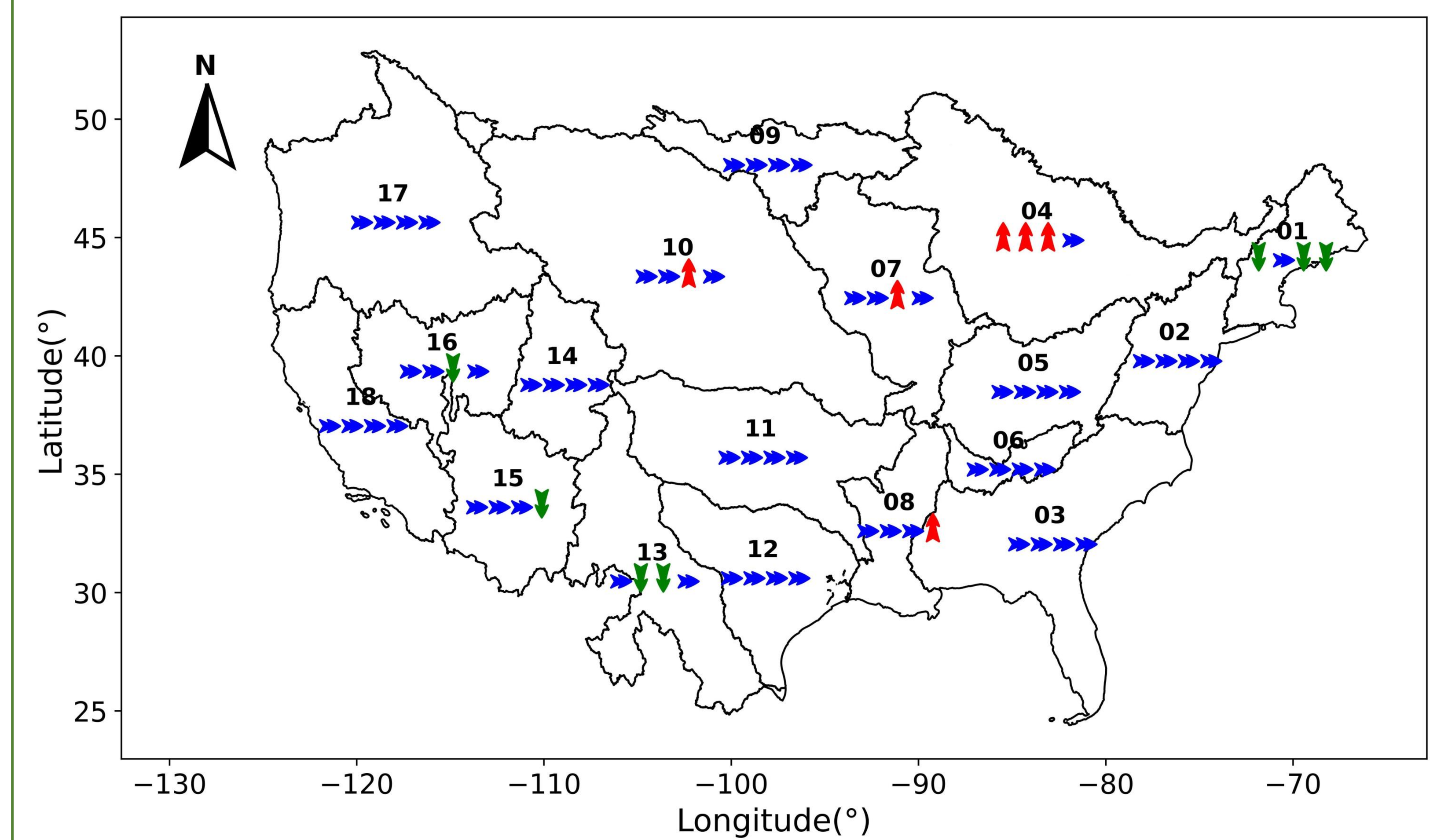
- detect the potential temporal trends of the basic statistics (max, mean, min, and standard deviation) of daily streamflow data each water year (2003-2022) using the original MK test
- assess the potential temporal trends of the same statistics (max, mean, min, and sd) of daily streamflow data each month over the water years (2003-2022) using the seasonal MK test
- compare the statistical distributions of the normalized daily streamflow within each decade (2003-2012 and 2013-2022) for each HUC-2 region

Study Area and Data

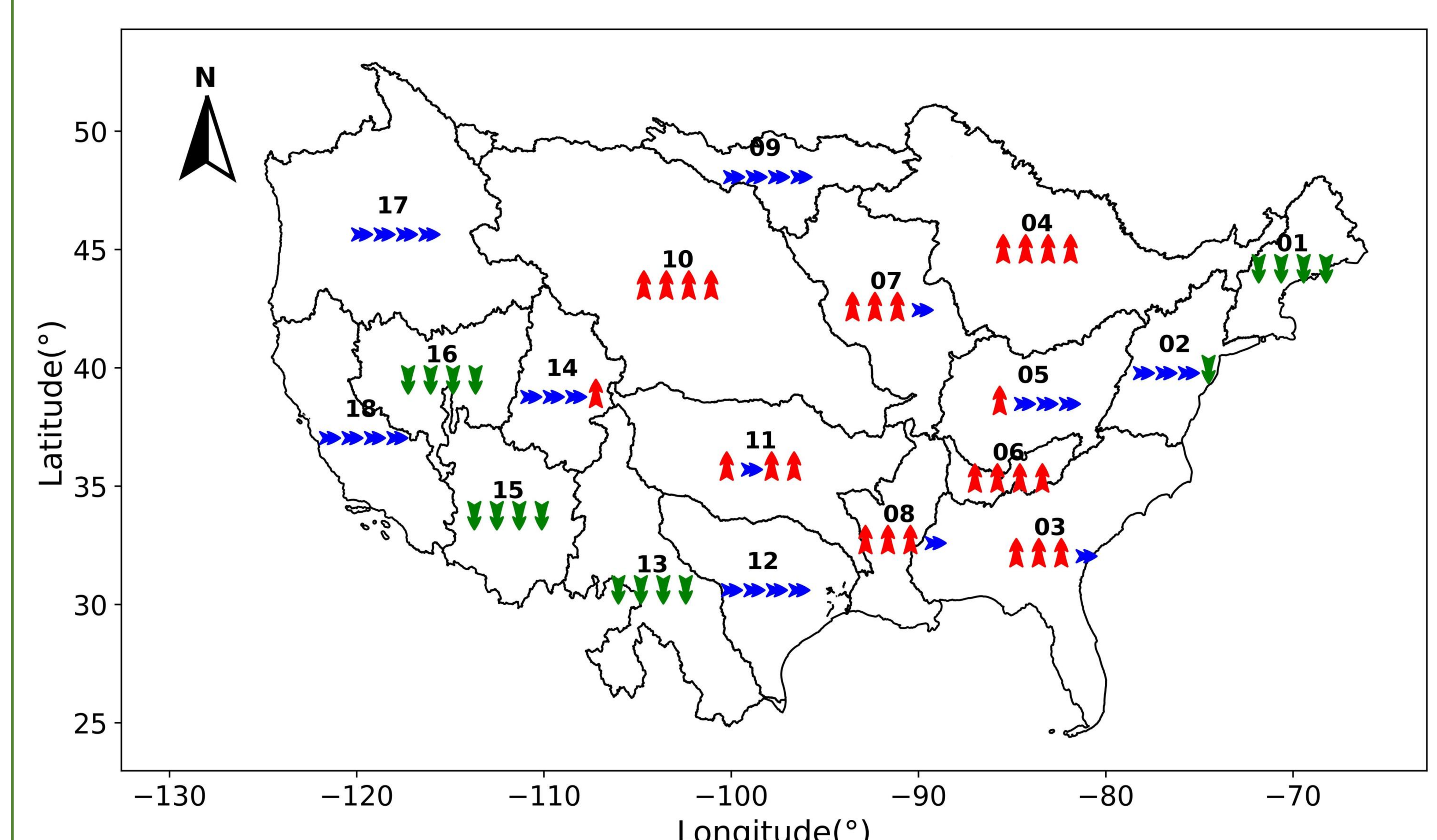
HUC-2	Region Name	USGS Gauge	Drainage Area (mile^2)	HUC-2	Region Name	USGS Gauge	Drainage Area (mile^2)
01	New England	01184000	9,660	10	Missouri	06935965	524,000
02	Mid-Atlantic	01578310	27,100	11	Arkansas-White-Red	07249455	145,940
03	South Atlantic-Gulf	02359170	19,200	12	Texas-Gulf	08116650	45,339
04	Great Lakes	04119000	4,900	13	Rio Grande	08447000	40,685
05	Ohio	03381700	141,000	14	Upper Colorado	09380000	111,800
06	Tennessee	03603000	2,557	15	Lower Colorado	09520500	57,850
07	Upper Mississippi	07022000	713,200	16	Great Basin	10333000	15,504
08	Lower Mississippi	07374000	1,125,810	17	Pacific Northwest	14246900	256,900
09	Souris-Red-Rainy	05092000	34,800	18	California	11303500	13,539

Results and Discussion

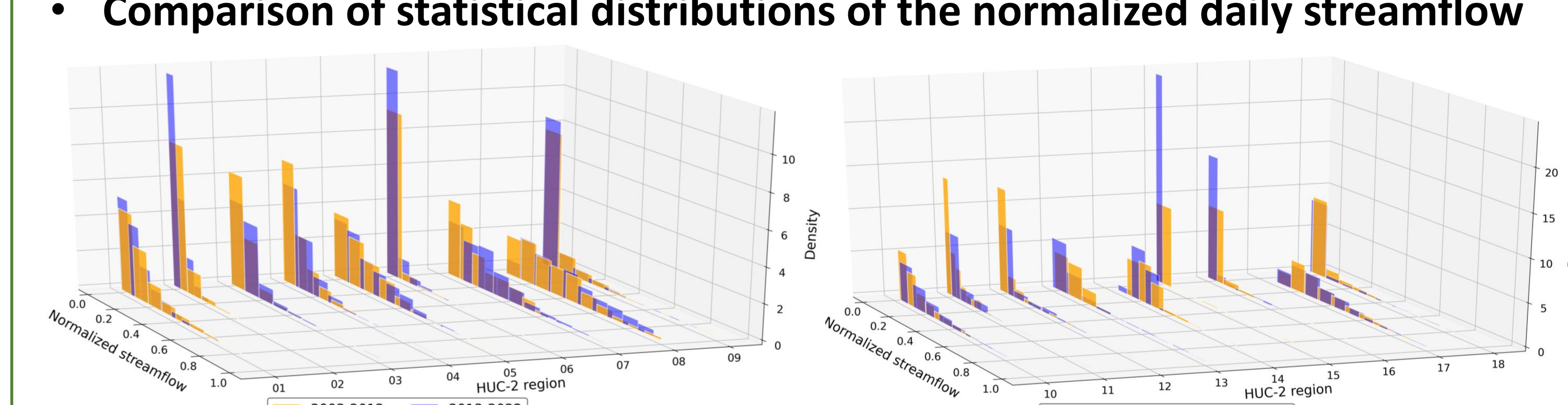
- **Results of Original MK Tests (arrows from left to right: max, mean, min, sd)**



- **Results of Seasonal MK Tests (arrows from left to right: max, mean, min, sd)**



- **Comparison of statistical distributions of the normalized daily streamflow**



Conclusions

- Original MK Tests show that there is no trend in streamflow for most of the HUC-2 regions.
- Seasonal MK Tests suggest either an increasing or decreasing trend for around 30% of the HUC-2 regions.
- Low flows demonstrate a more significant change in frequency between past two decades.
- Overall, this study demonstrates the complexity of the streamflow variability and implies the possible changes in flood or drought risk under a changing climate.

References

1. Data source: https://www.weather.gov/hazstat/
2. Huang, T., & Merwade, V. (2023). Uncertainty Analysis and Quantification in Flood Insurance Rate Maps Using Bayesian Model Averaging and Hierarchical BMA. Journal of Hydrologic Engineering, 28(2), 04022038.
3. Huang, T., & Merwade, V. (2023). Developing Customized NRCS Unit Hydrographs (Finley UHs) for Ungauged Watersheds in Indiana.
4. Hirsch, R. M., Slack, J. R., & Smith, R. A. (1982). Techniques of trend analysis for monthly water quality data. Water resources research, 18(1), 107-121.