Peak-flow Frequency and Nonstationarity in Illinois

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IAFSM
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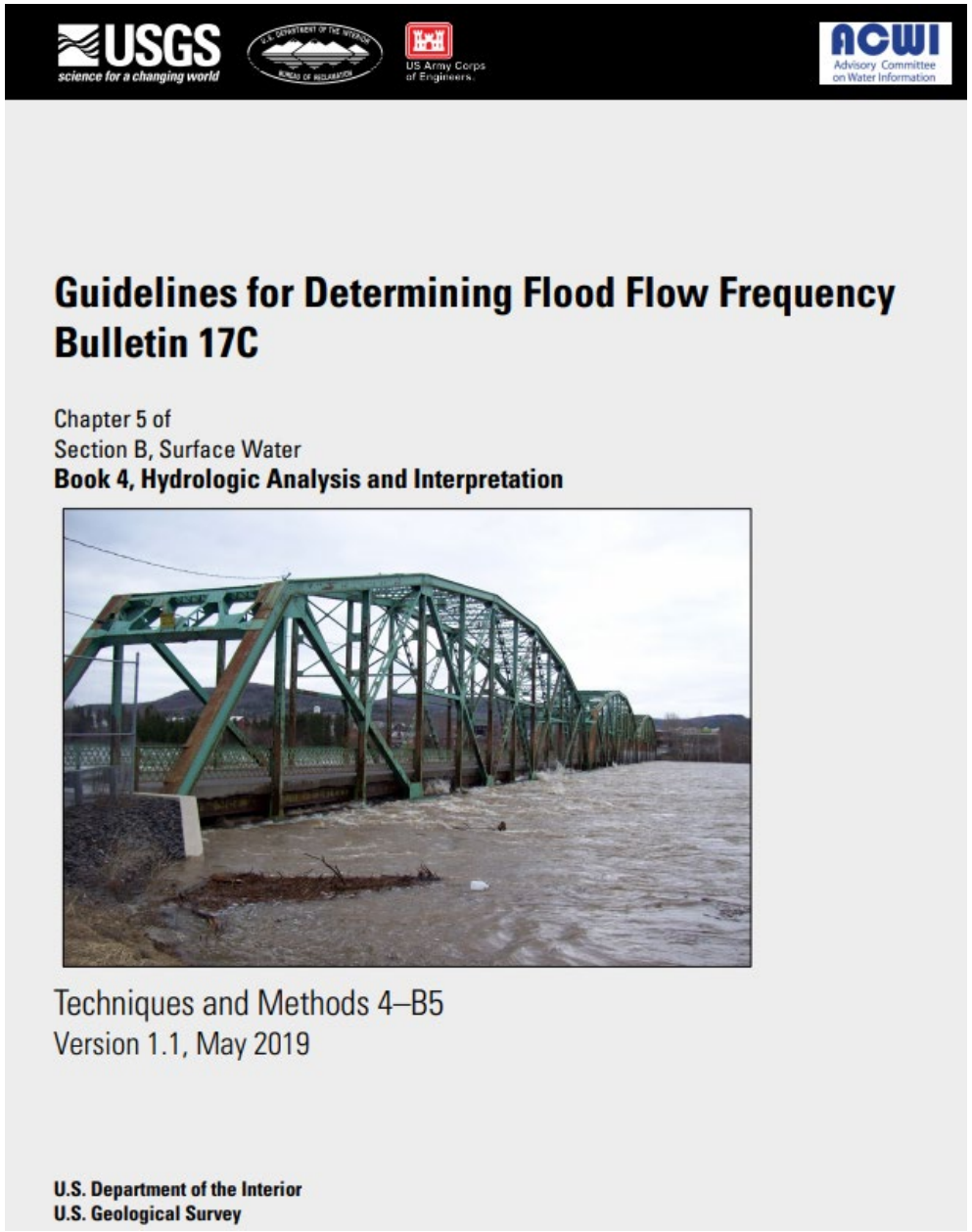
Background

- Peak-flow frequency (PFF) analysis is critical in water-resource management applications

- Federal guidelines (Bulletin 17C) for PFF analyses assume no trend in annual peak flow—stationary peak flows



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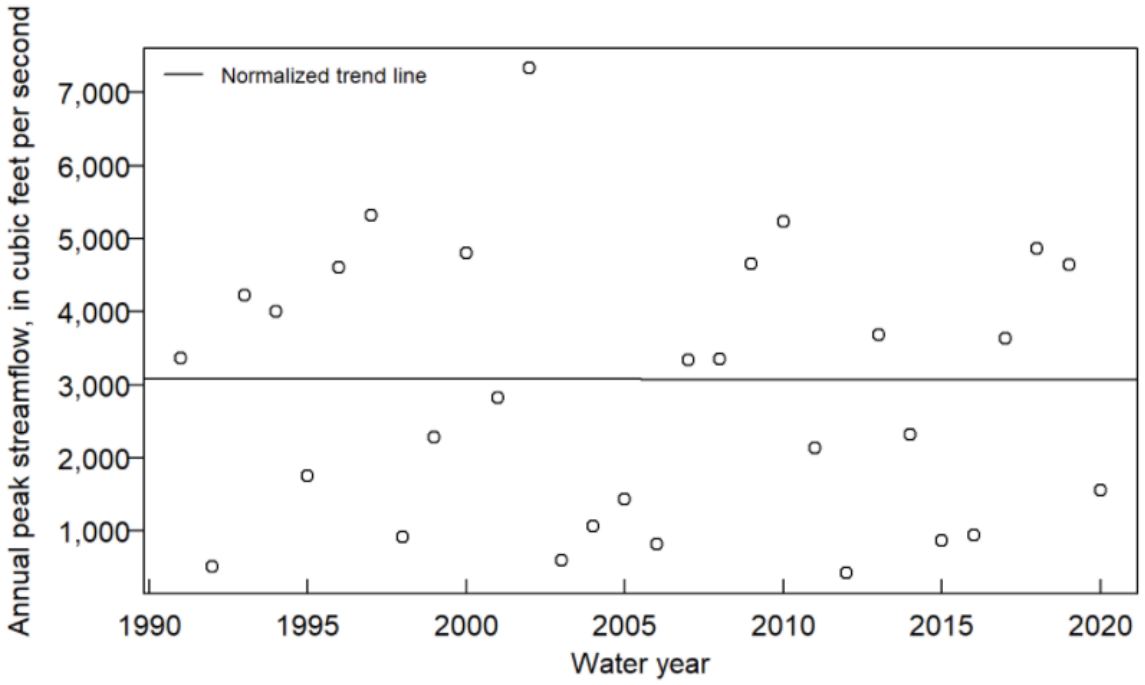
05444000 Elkhorn Creek near Penrose, Illinois



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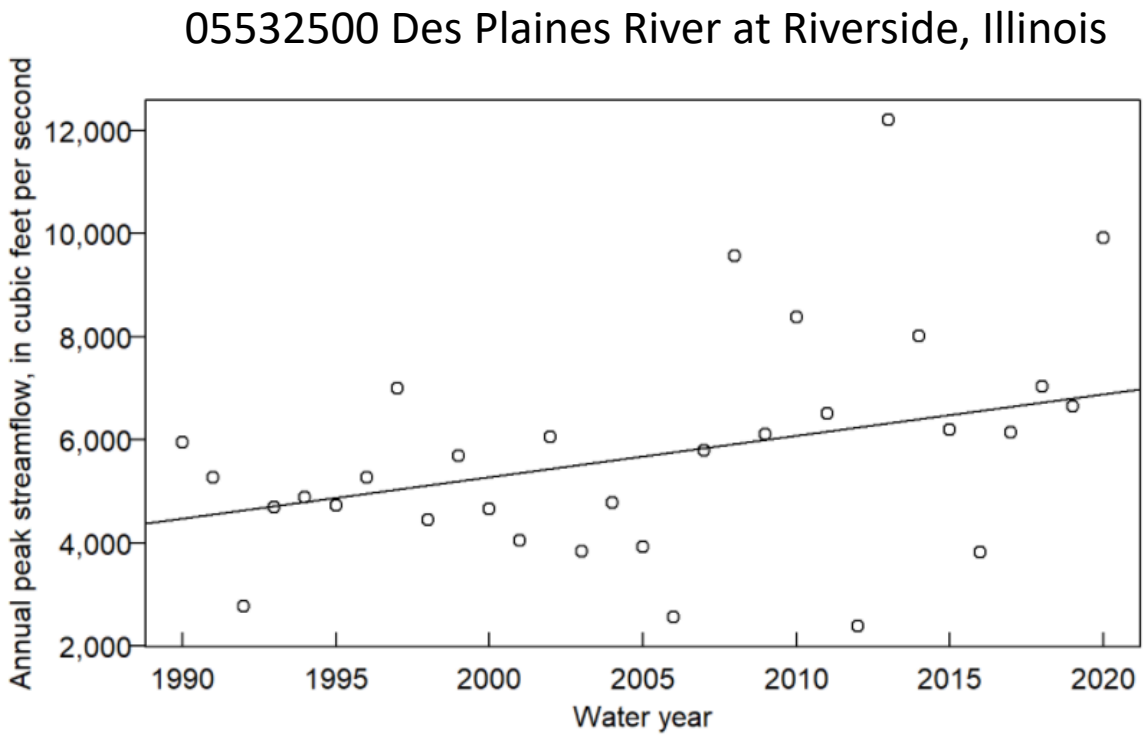
Background

- Increasing understanding about persistent climate patterns, potential climate change, and land-use change have caused the stationarity assumption to be reexamined

- Failing to incorporate **nonstationarity** into PFF analysis may result in a poor representation of the true flood risk at present and into the future

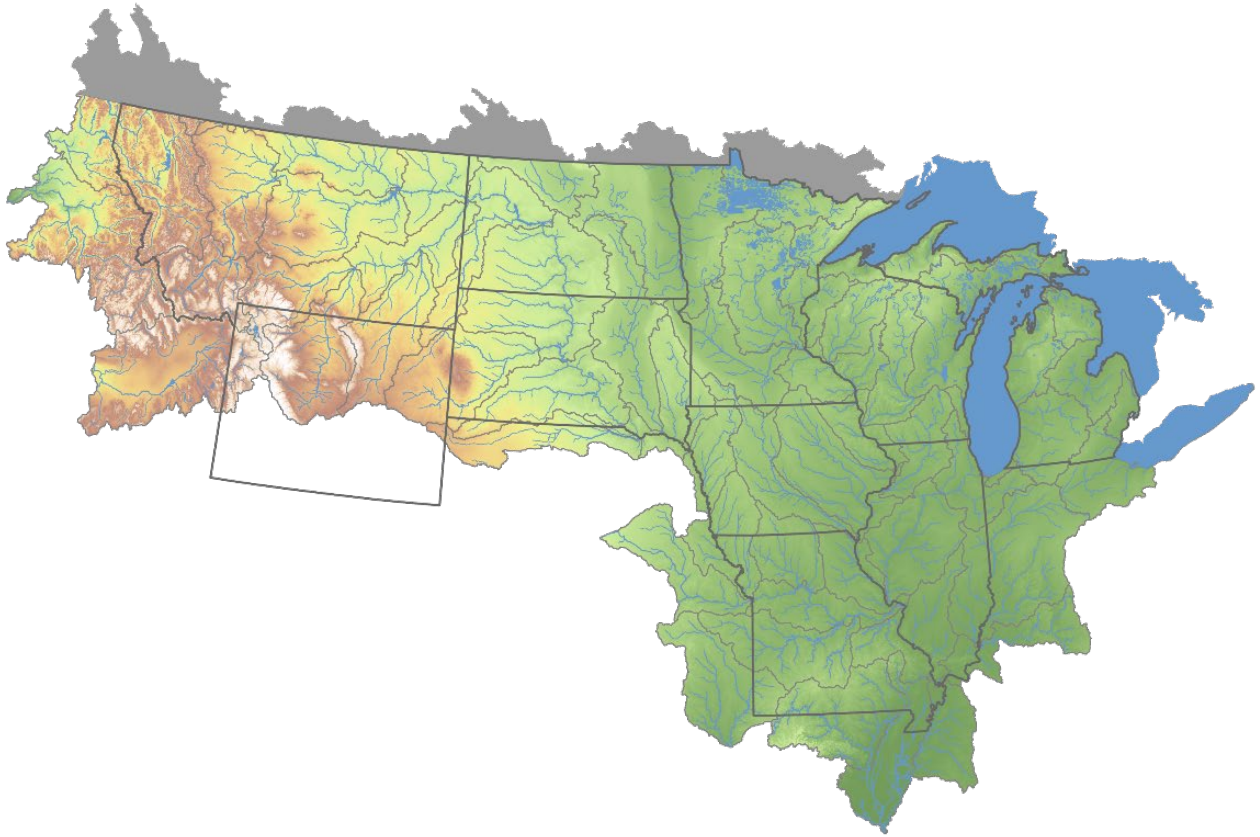


Project scope

- Goal: analyze historical trends in peak flows in relation to climate, land use, and other drivers of change and to investigate methods to incorporate these trends into peak-flow frequency analyses
- Phase 1: investigate peak streamflow (trends, change points, timing) and relation to climate metrics
- Phase 2: investigate seasonality of peak streamflow
- Phase 3: investigate effects of urbanization on peak streamflow
- Phase 4: investigate effects of tile drainage on peak streamflow
- Phase 5: investigate methods for incorporating drivers of trends into PFF

Cooperators and study area

- Illinois Department of Transportation
- Iowa Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Missouri Department of Transportation
- Montana Department of Natural Resources and Conservation
- North Dakota Department of Water Resources
- South Dakota Department of Transportation
- Wisconsin Department of Transportation



USGS

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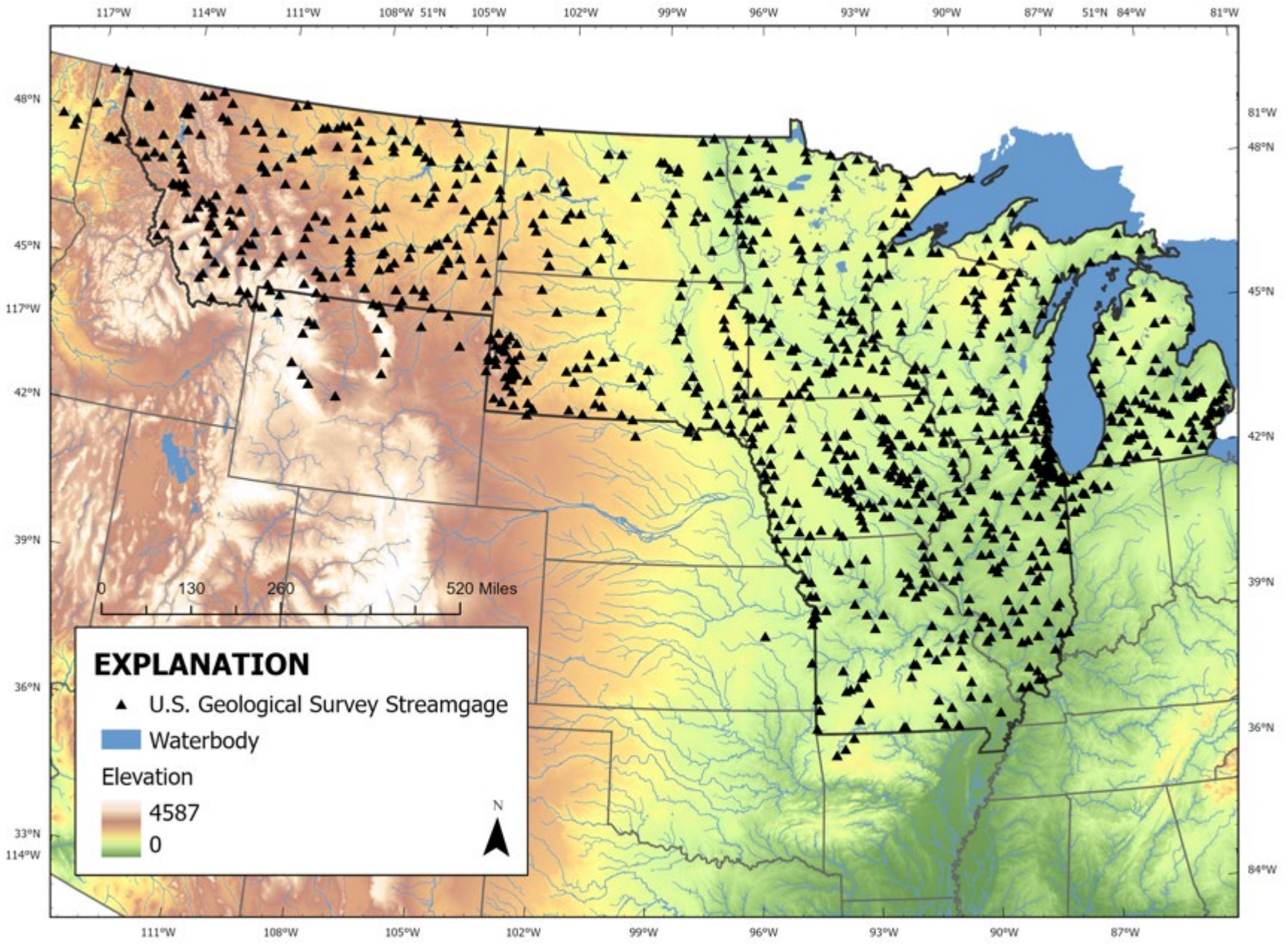
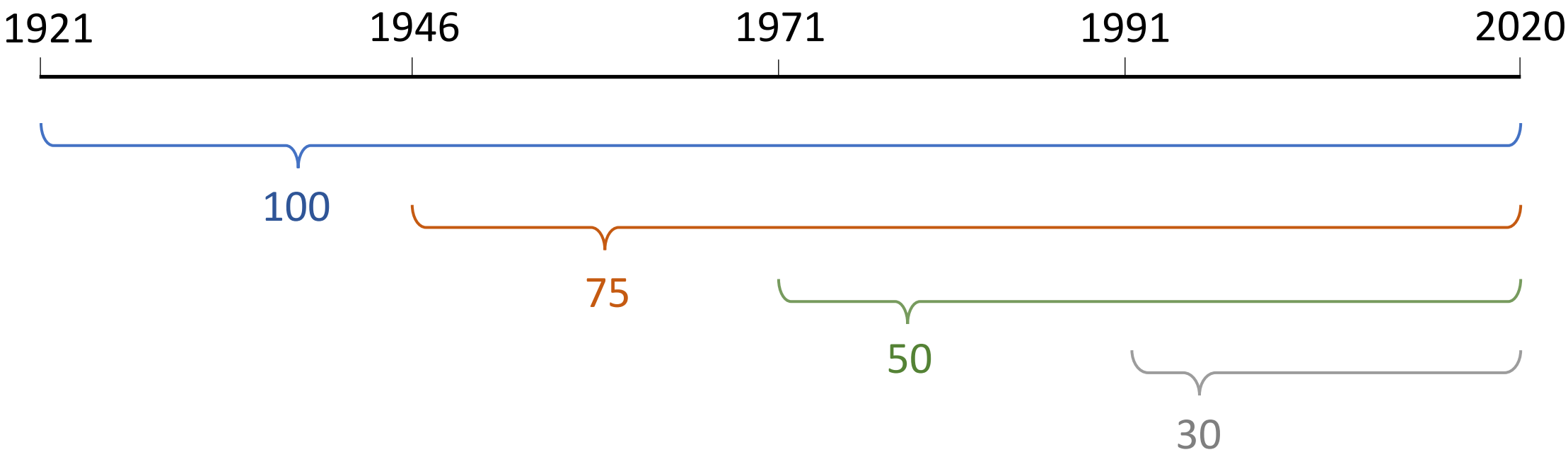


National Hydrography Dataset, https://apps.nationalmap.gov/viewer/
Elevation data, https://apps.nationalmap.gov/viewer/
Milan Liu, Upper Midwest Water Science Center

Trend periods



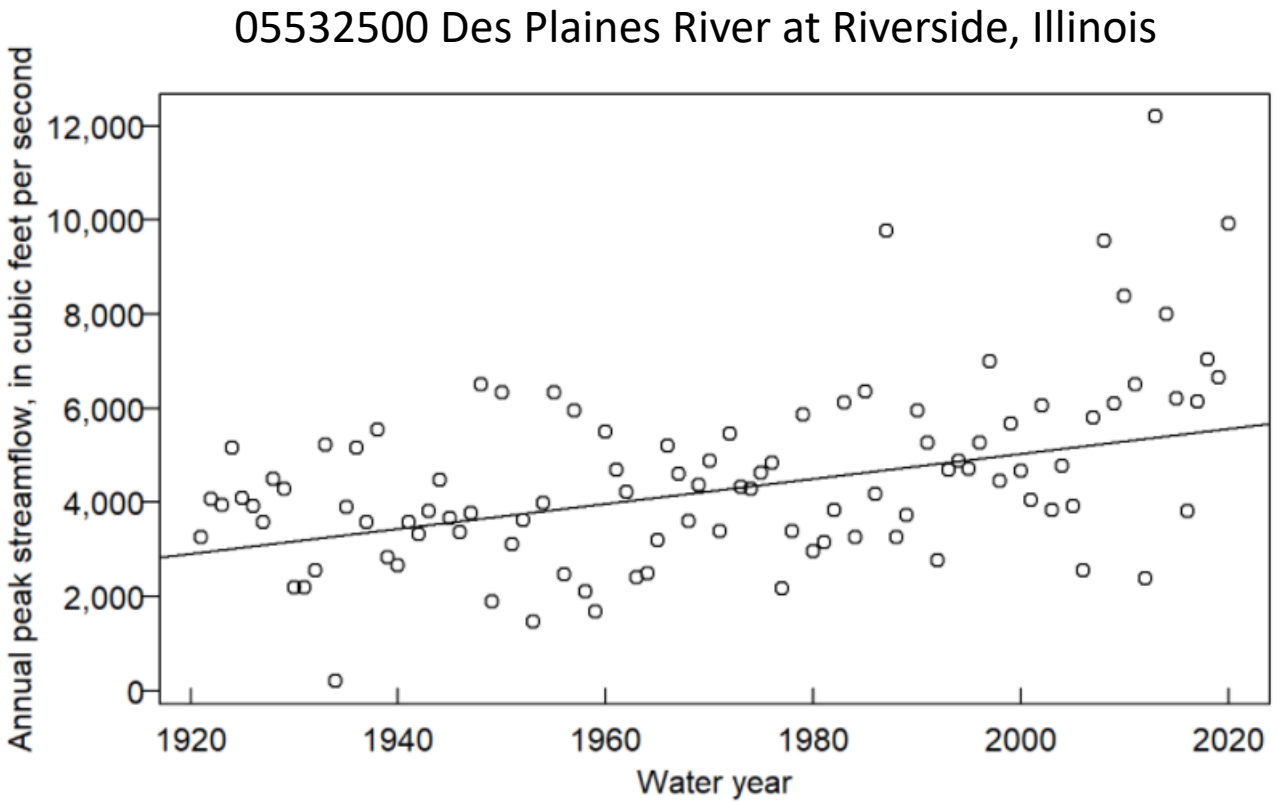
Statistical Significance

- Mapped trends are presented using a likelihood approach (Hirsch and others, 2015)
- Trend likelihood value = $1 - \left(\frac{p-value}{2}\right)$

- **0.85 – 1.0:** “likely” upward or downward
- **0.70 – 0.85:** “somewhat likely” upward or downward
- **< 0.70:** “about as likely as not”

Hirsch and others, 2015: A bootstrap method for estimating uncertainty of water quality trends, https://doi.org/10.1016/j.envsoft.2015.07.017

Annual peak streamflow trends

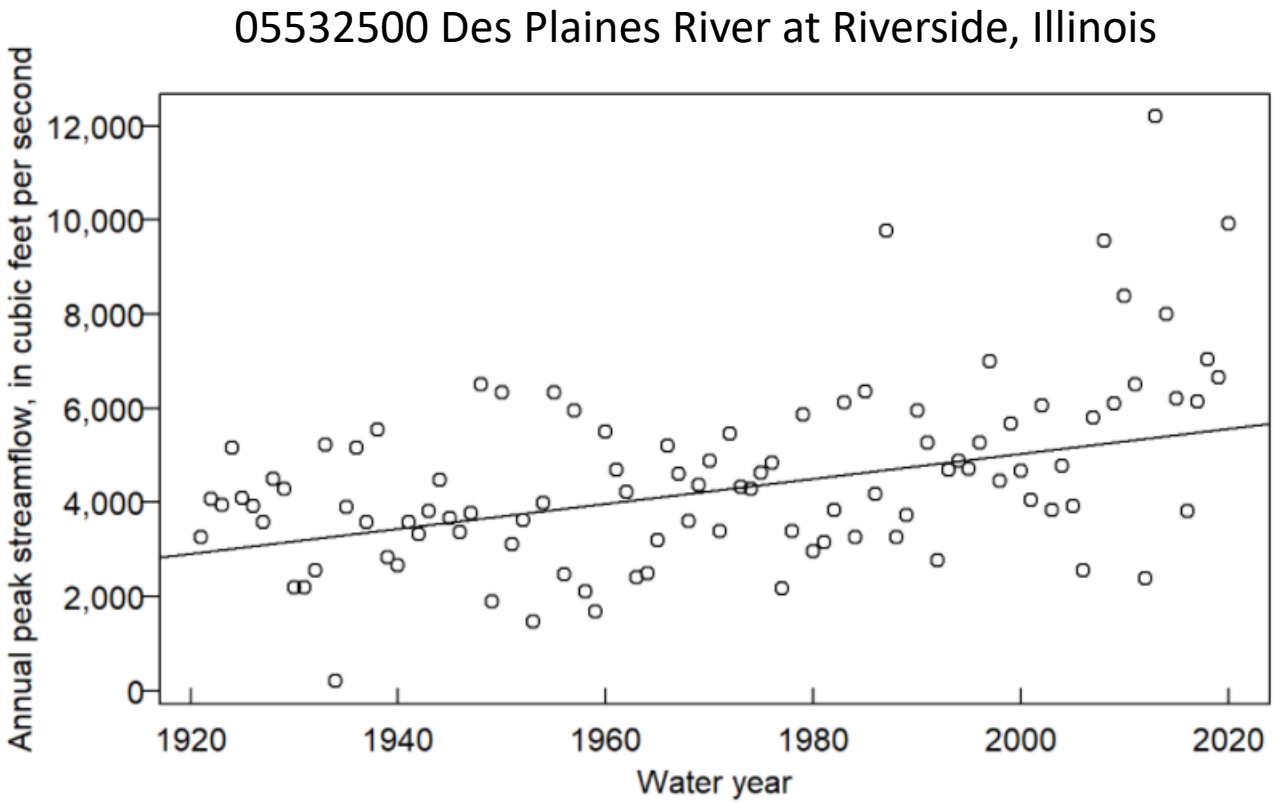


Slope = 26.7 cfs

p-value < 0.001

Trend likelihood value = $1 - \left(\frac{p-value}{2}\right)$

Annual peak streamflow trends



Slope = 26.7 cfs

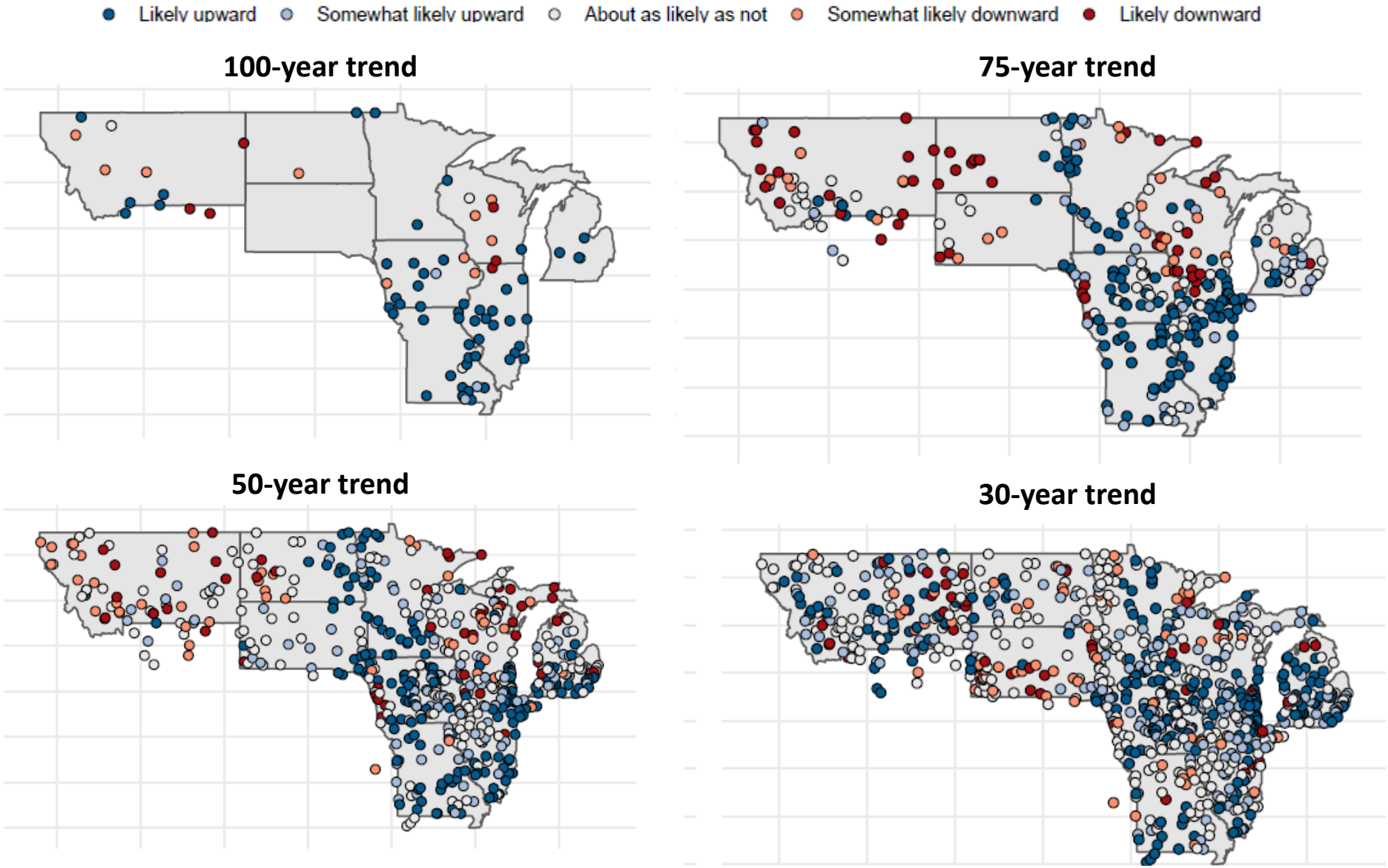
p-value < 0.001

Trend likelihood value = ~1

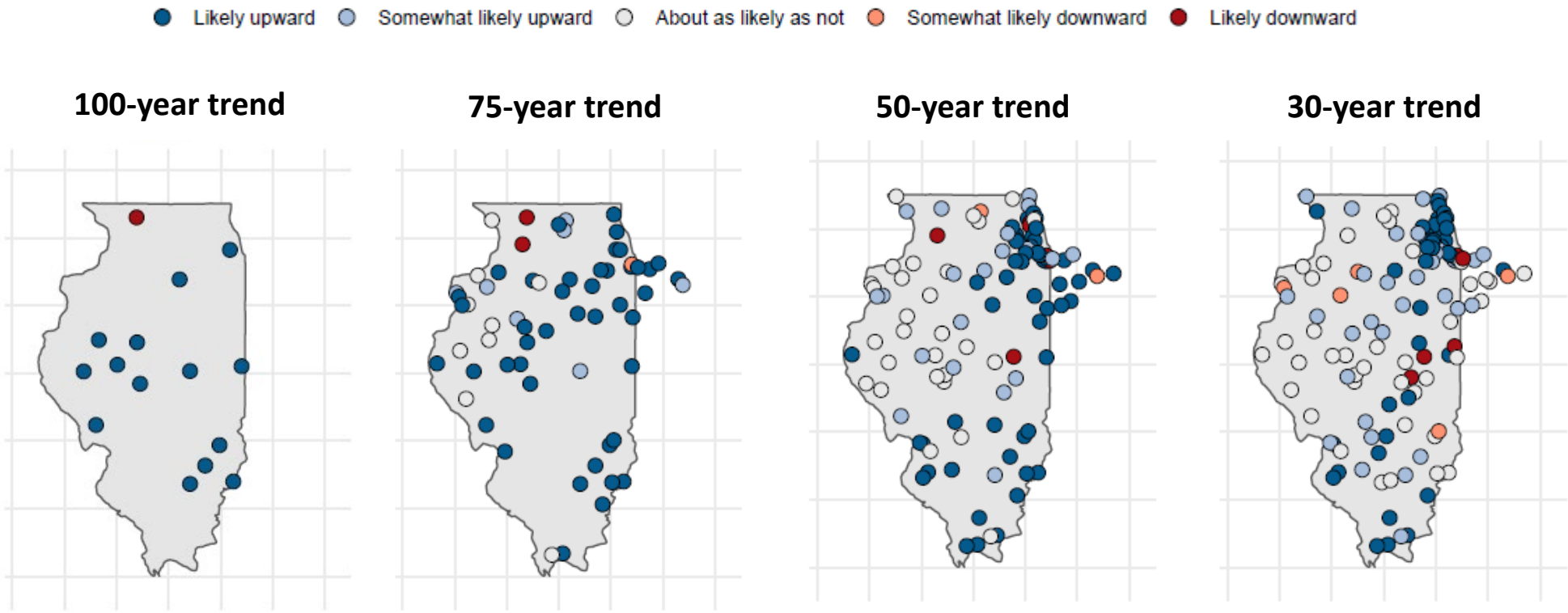
=

likely upward

Annual peak streamflow trends



Annual peak streamflow trends

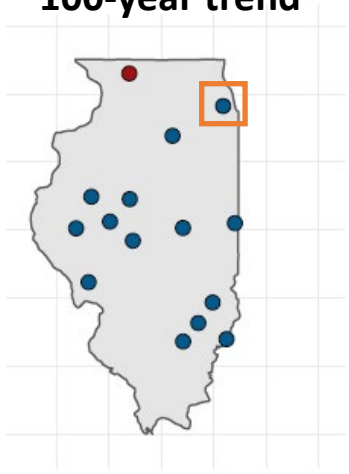


	100-year trend	75-year trend	50-year trend	30-year trend
Total stations	15	62	111	132
"Likely" or "somewhat likely" upward	93%	81%	68%	59%
"Likely" or "somewhat likely" downward	7%	5%	7%	9%

USGS

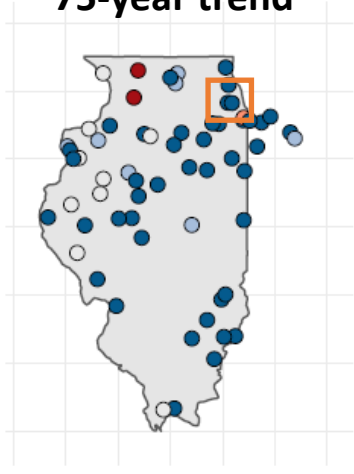
Annual peak streamflow trends, 05532500 Des Plaines River at Riverside, Illinois

100-year trend



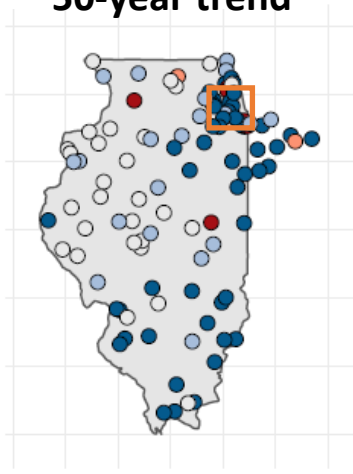
Likely upward

75-year trend



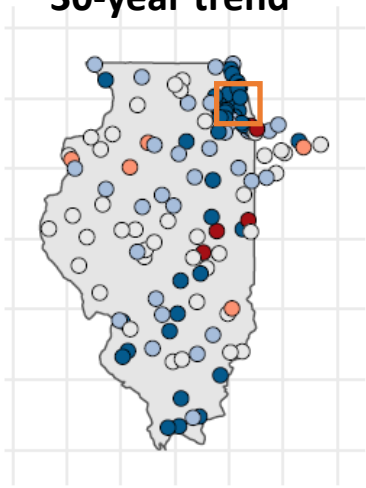
Likely upward

50-year trend



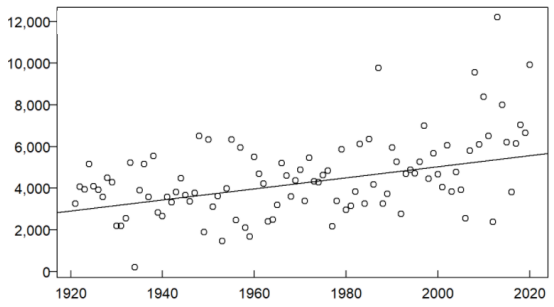
Likely upward

30-year trend

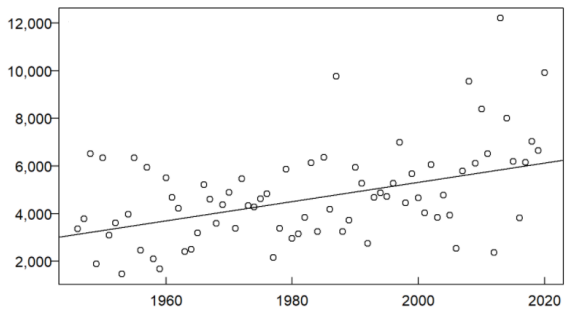


Likely upward

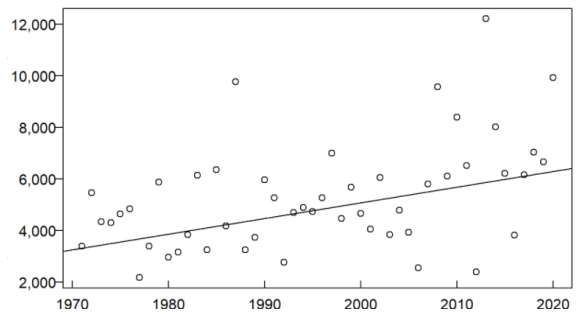
Annual peak streamflow, cfs



Water Year



Water Year



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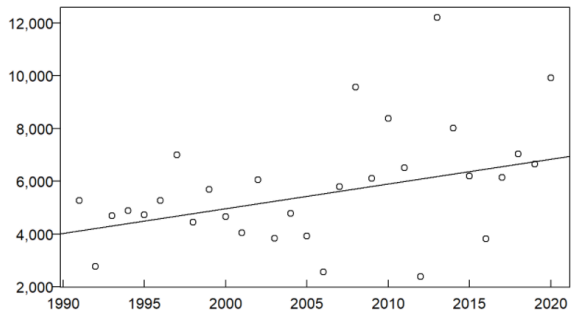

Water Year

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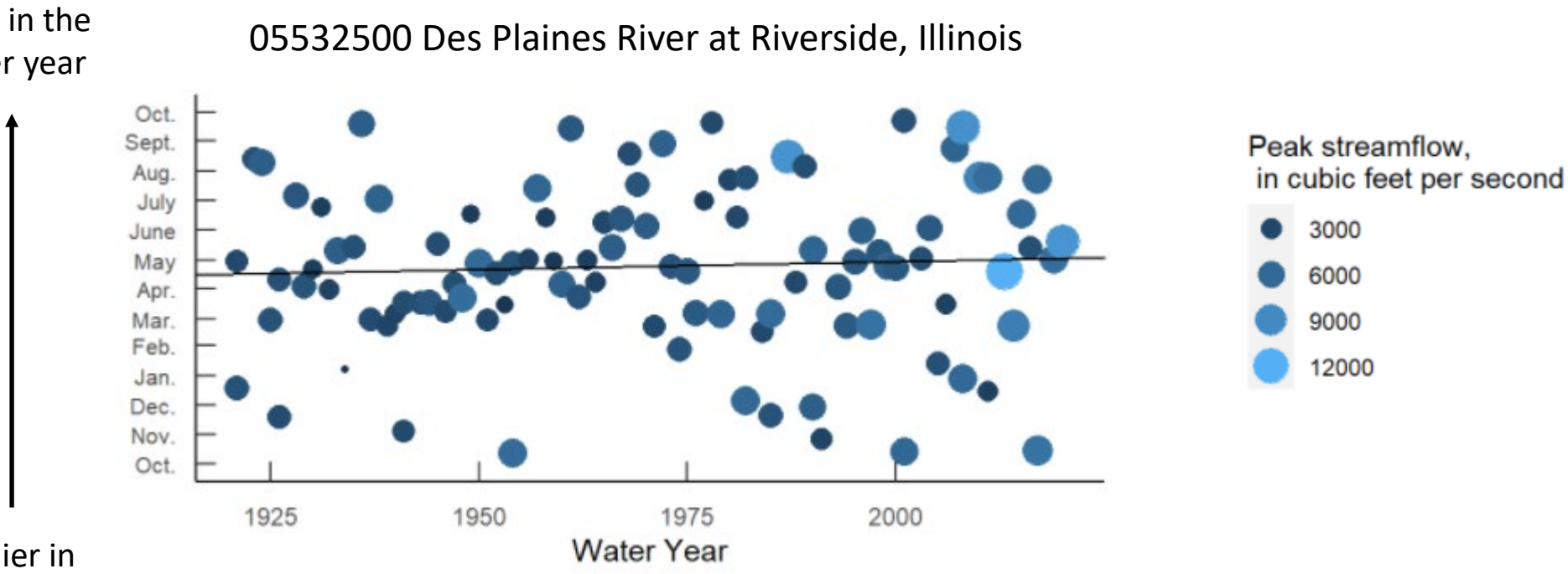
Annual peak flow timing

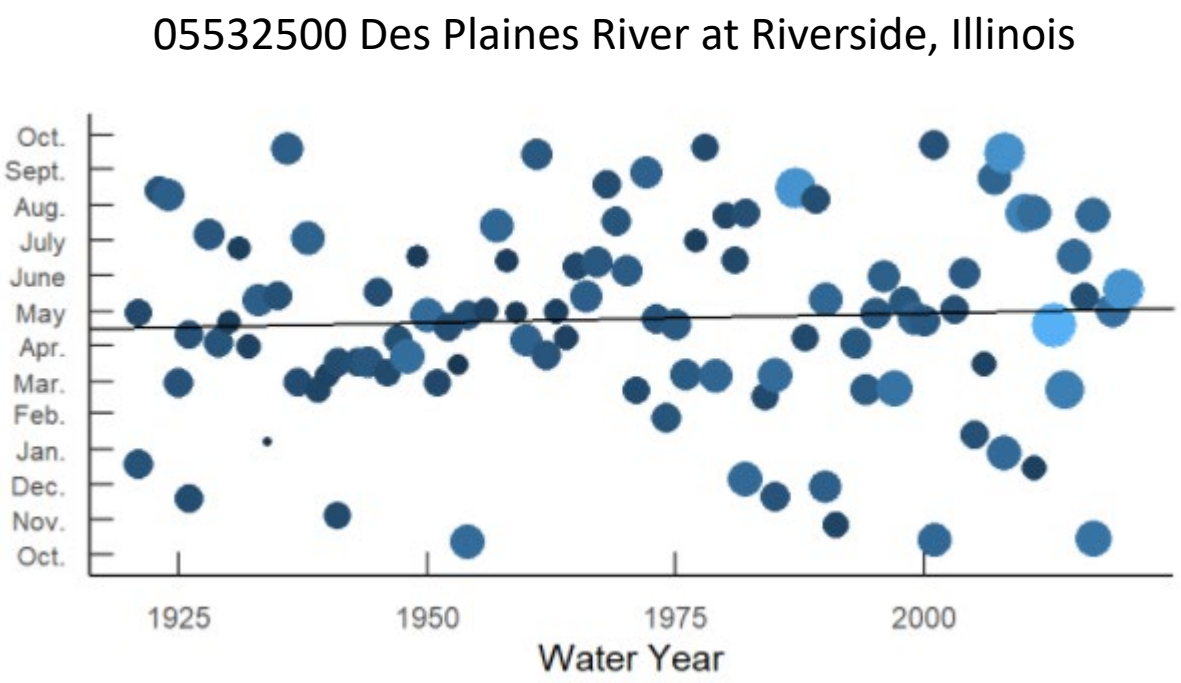
Later in the water year



Earlier in the water year

Annual peak flow timing

Later in the water year



Earlier in the water year

Upward trend: peaks shifting to **later** in the water year

Downward trend: peaks shifting to **earlier** in the water year

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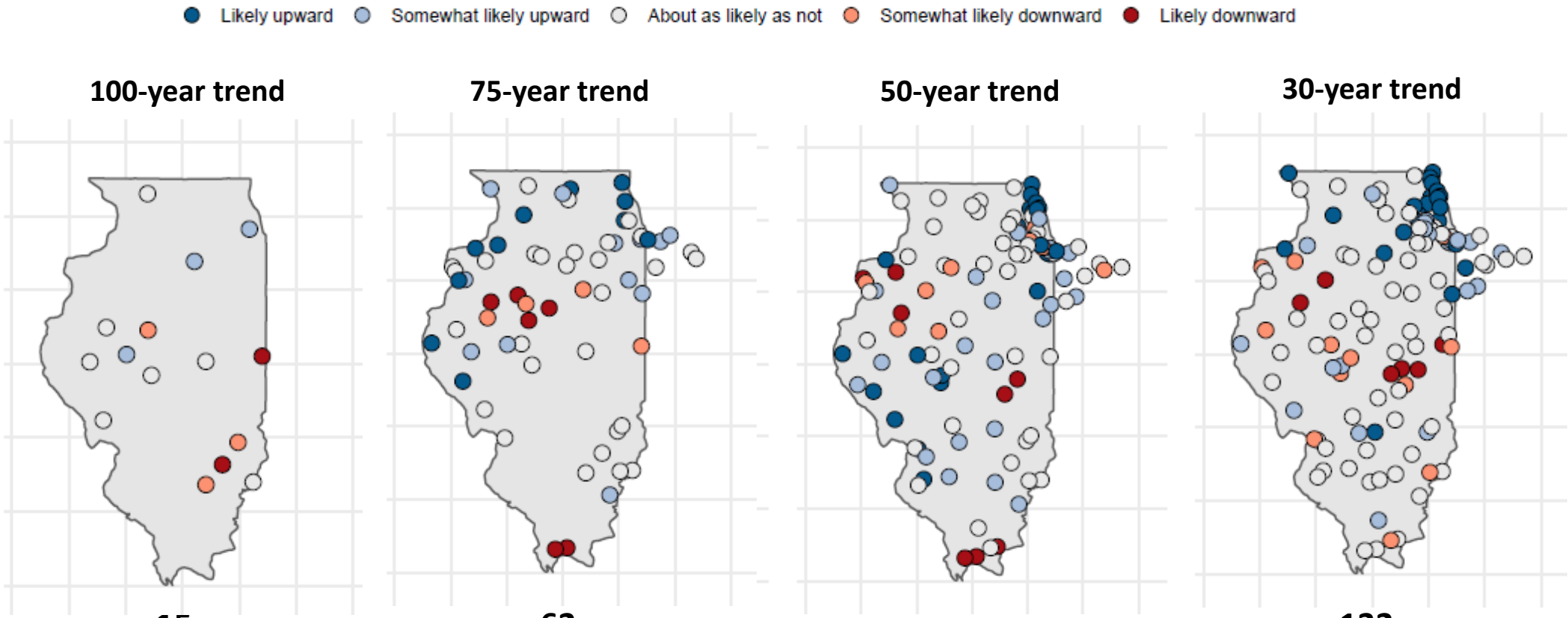
Annual peak flow timing



	100-year trend	75-year trend	50-year trend	30-year trend
Total stations	15	62	111	132
"Likely" or "somewhat likely" later	20%	37%	45%	36%
"Likely" or "somewhat likely" earlier	33%	16%	15%	14%

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Climate trends

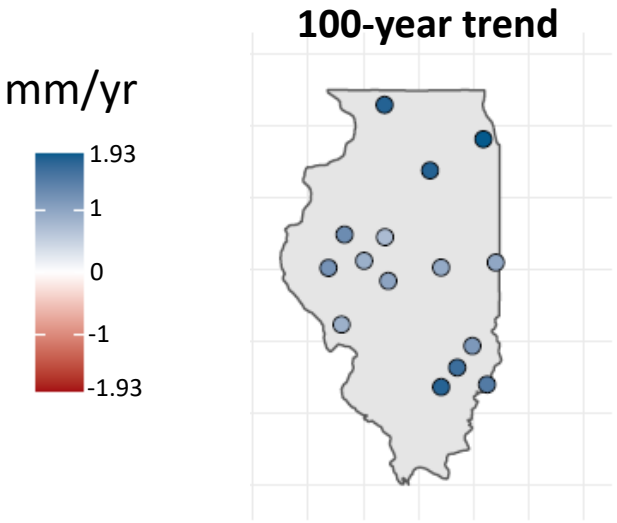
- Monthly water balance model (MWBM) (McCabe and Wolock, 2011) for 1900-2020

- Monthly time series estimates of **temperature**, **precipitation**, potential and actual evapotranspiration, rainfall, snowfall, soil moisture storage, snow water equivalent, and runoff on 4 km x 4 km grid for entire conterminous United States
  - **Observed variable sourced from NOAA's NClimGrid (Vose and others, 2015)**
  - Modeled variable

- Modeled runoff incorporates trends in climate as mediated by watershed storage in a more hydrologically relevant way than statistical analyses can easily model

McCabe and Wolock , 2011, Independent effects of temperature and precipitation on modeled runoff in the conterminous, https://doi.org/10.1029/2011WR010630
Vose and others, 2015, Gridded 5km GHCN-daily temperature and precipitation dataset, https://doi.org/10.7289/V5SX6B56

Observed annual precipitation vs water year

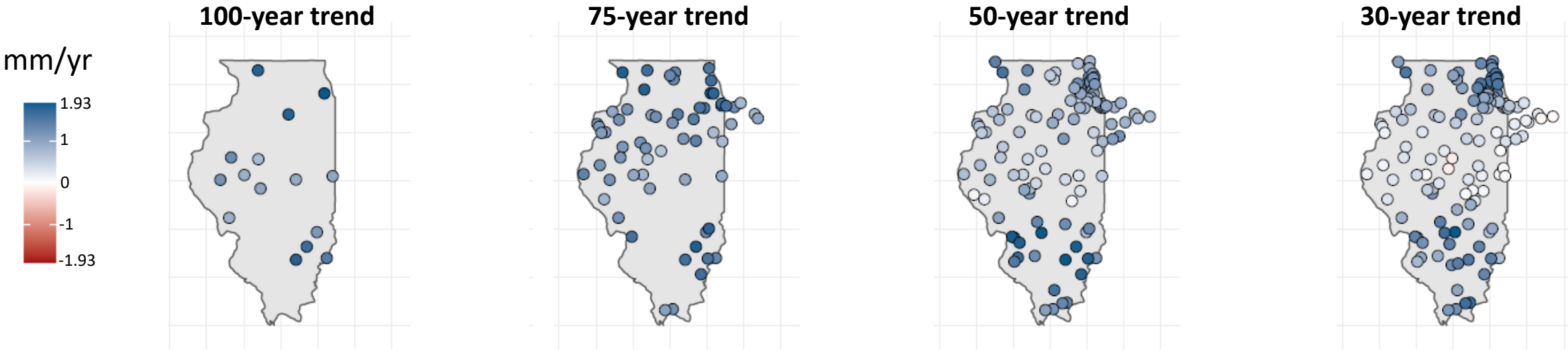


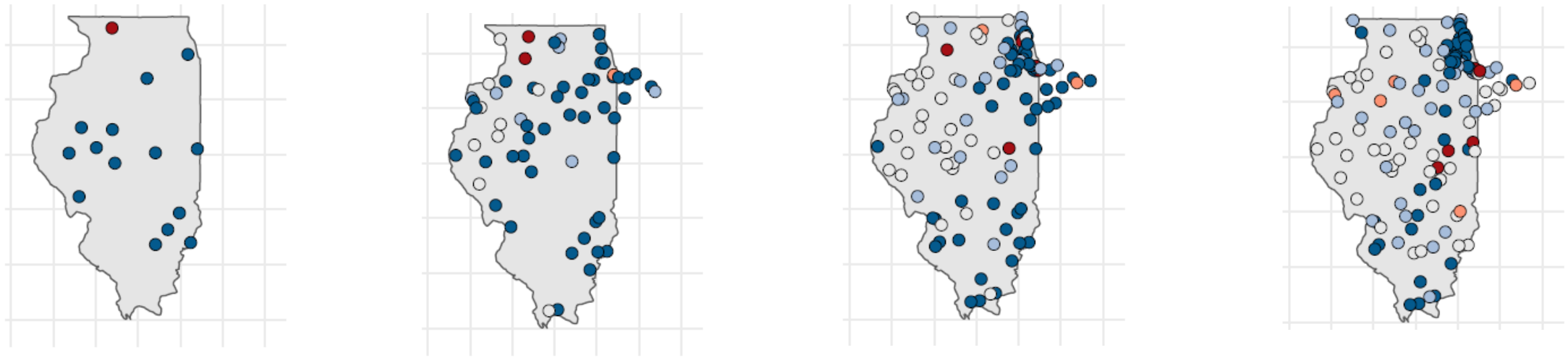
Each point represents the observed trend in annual precipitation over the trend period in mm/year

Blue = increase

Red = decrease

Observed annual precipitation vs water year



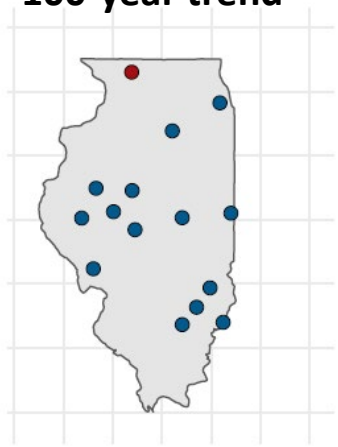


Annual peak streamflow

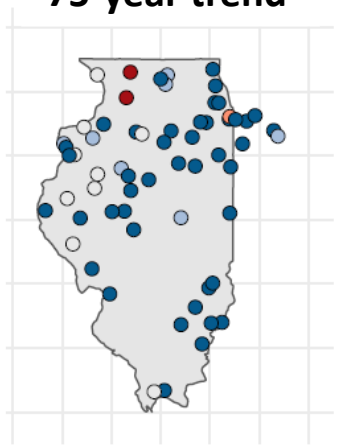
Summary

Annual peak streamflow trends

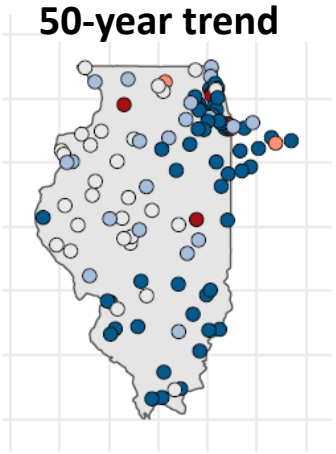
100-year trend



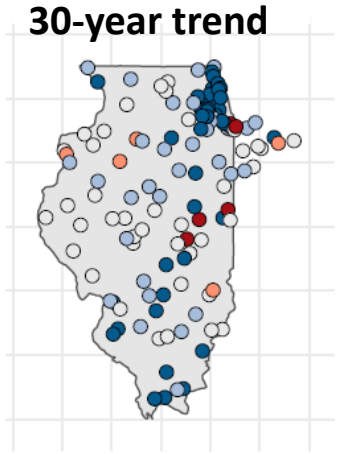
75-year trend



50-year trend



30-year trend



- Majority of streamgages show increasing peak streamflow trends over all trend periods in Illinois
  - Trends in precipitation likely large driver of increasing peak streamflow trends
- Trends in timing of peak flows less consistent both spatially and across trend periods
- Results for all states in the study area will be published in state chapters in 2023

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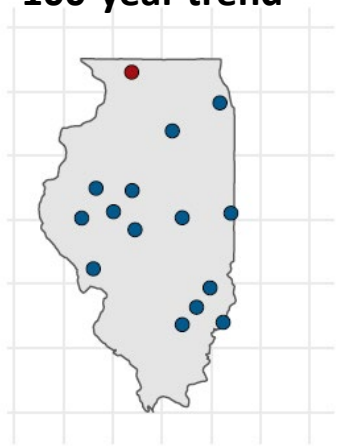
Summary

Annual peak streamflow trends

100-year trend



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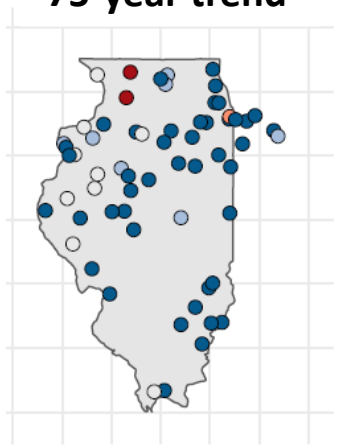

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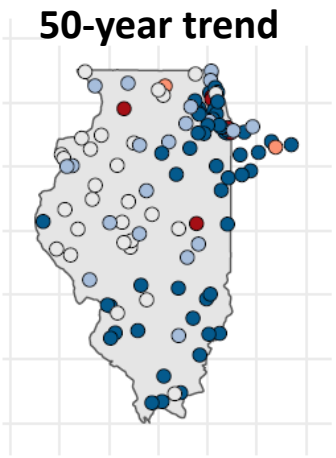

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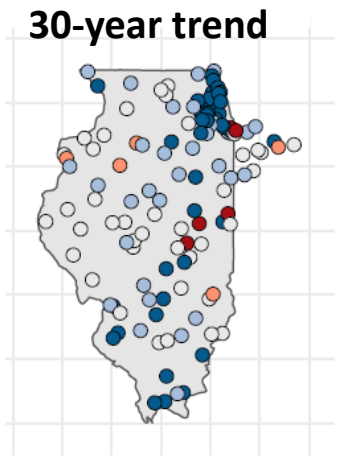

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Questions?