Impacts of Period of Record on the Uncertainty of Estimates of Precipitation Extremes

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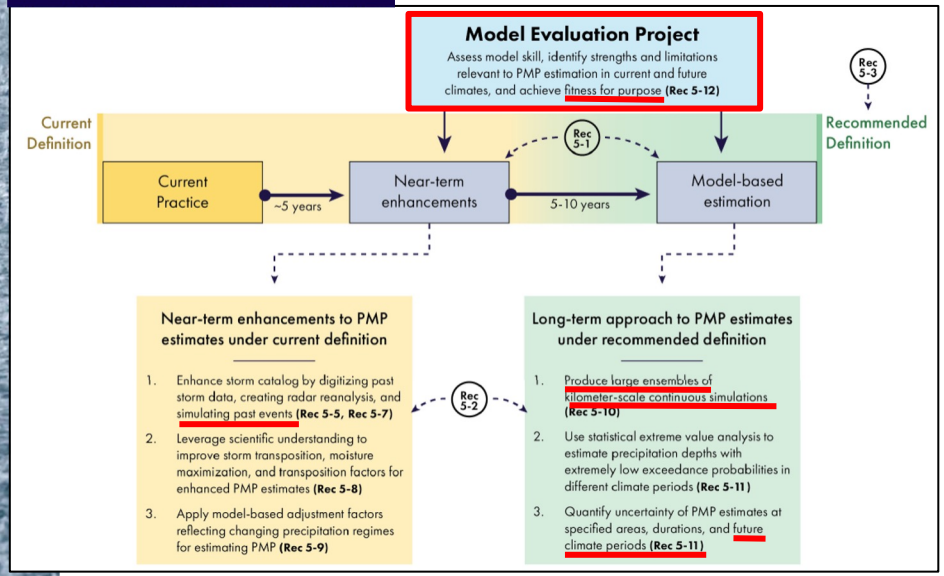
Motivation

NATIONAL ACADEMIES Sciences Engineering Medicine

Modernizing Probable Maximum Precipitation Estimation



To determine if data is "**Fit for Purpose**," we must look from multiple angles

Process Fidelity:
Does the model/data capture the actual physics ?

- Case studies
- "Forecast-style" validation (CSI, Bias, etc.)

Statistical Robustness:
Does the data behave correctly at the "tails" of the distribution?

- *Reality checks*
- *Seasonal, diurnal cycles*
- *Precipitation distribution*
- *Upper quantiles captured*

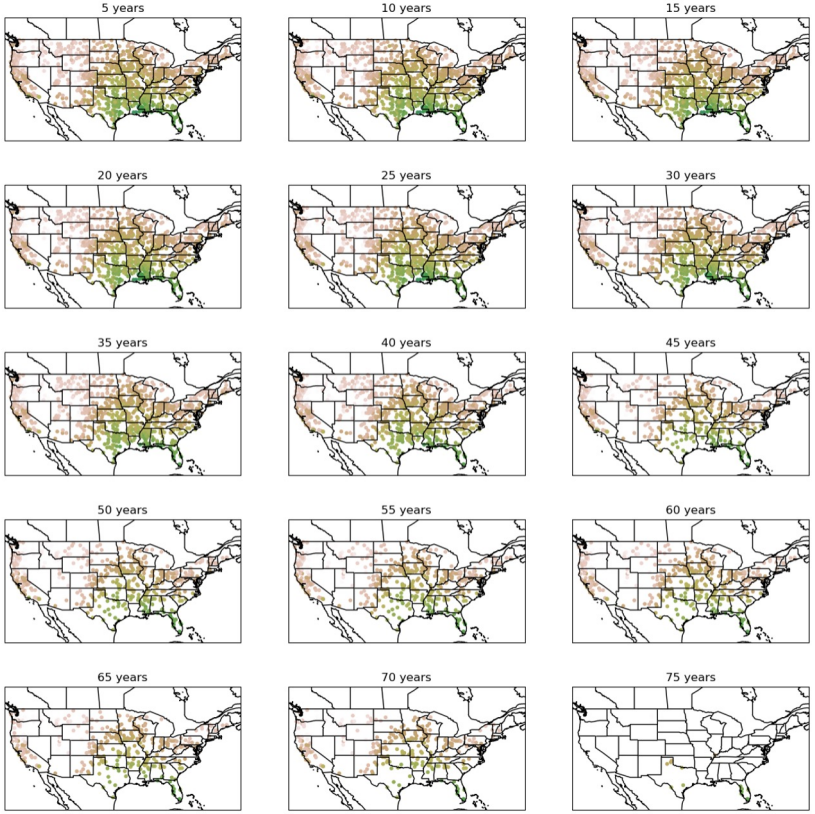
Require high-resolution, long period-of-record reference dataset(s)

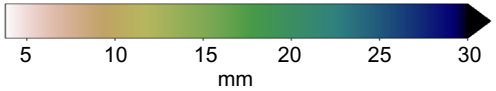
Data/Methods

- Data
  - Hourly rain gauge data from GHCN
  - Gridded hourly precipitation
    - AORC (1km, 1980-2024)
    - CONUS404 (4km, 1980-2021)
    - Stage IV (~4km, 2002-2025)
- Methods
  - Use bootstrapping with replacement to calculate 1000 estimates of the upper quantiles and GPD parameters of the precipitation distribution for each dataset
  - Repeat bootstrapping using 5, 10,...n-year subsets of the data (n = period of record)
  - Calculate relative 95% confidence interval of the estimates
    - Find 97.5th and 2.5th percentile of the 1000 estimates
    - Divide the difference between these values by the mean of the 1000 estimates

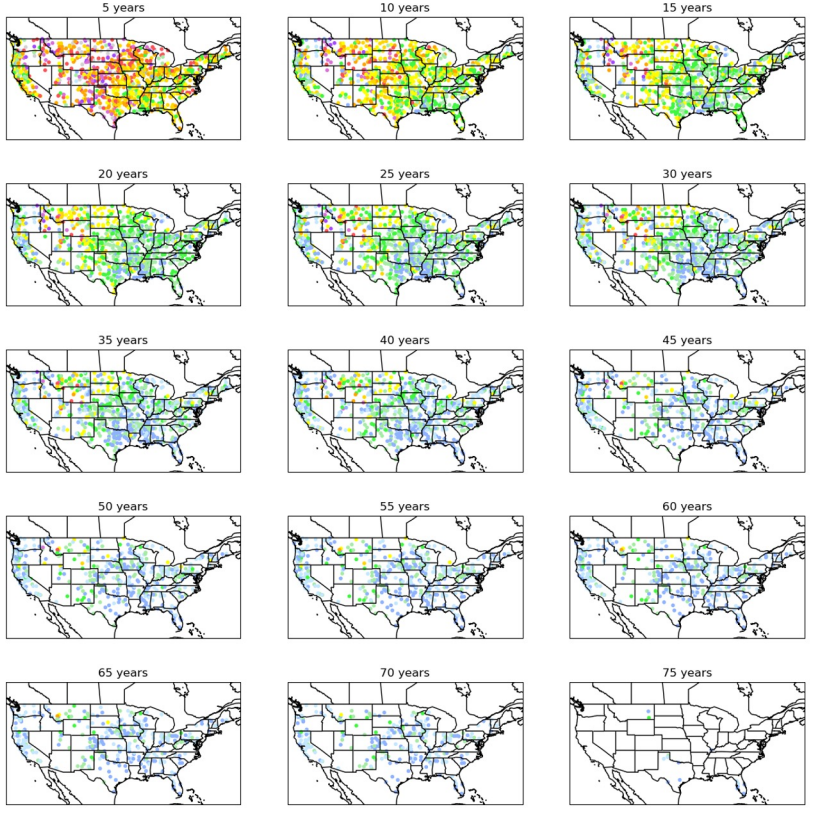
- Gauge QC
  - Based on that developed by international INTElligent use of climate models for adaptatioN to non-Stationary hydrological Extremes (INTENSE) Global Sub-Daily Rainfall Dataset (GSDR) effort (Lewis et al. 2019, 2021)
  - Applied to GHCN hourly over the CONUS
    - Removal of gauges with < 5 years data
    - Removal of world record hourly precipitation (381 mm) exceedances
    - Removal of suspicious extremes likely representing longer accumulation periods.
    - Removal of streaks
    - Removal of years with 0 recorded rainfall
    - Removal of gauges with >25% missing data
    - Removal of gauges with daily accumulated rainfall that compares poorly to GHCN daily data

Gauge Q95 Hourly Rainfall



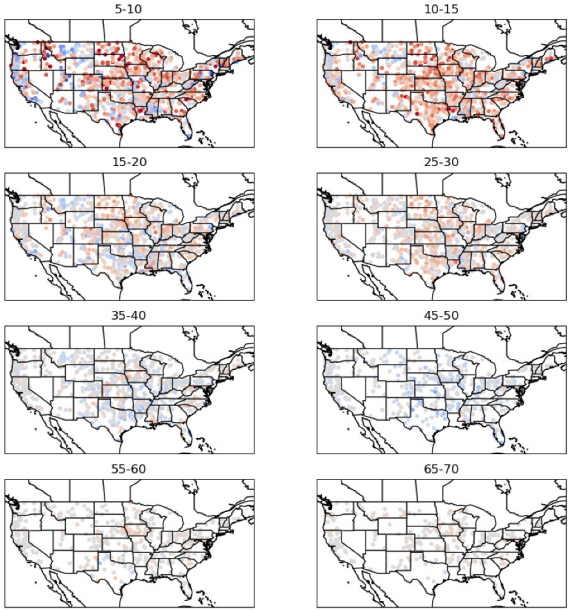


Gauge Q95 Relative CI

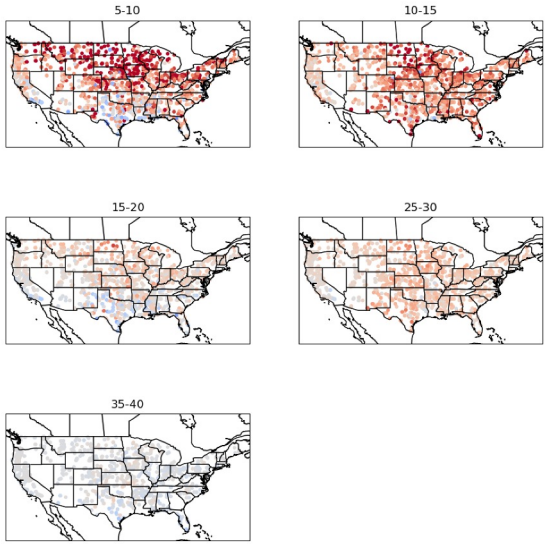


Impact of additional data on Q95 value

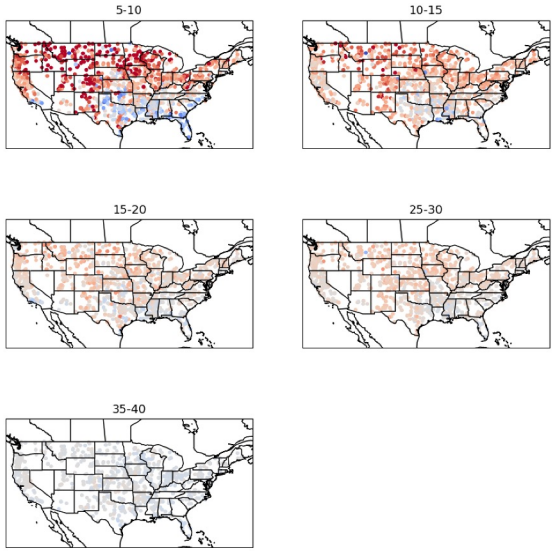
Gauge



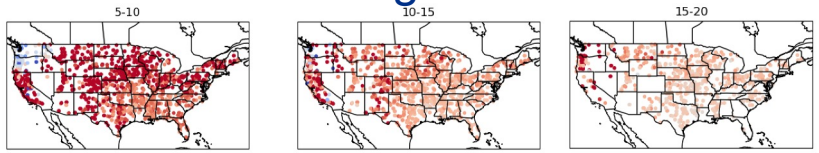
CONUS404

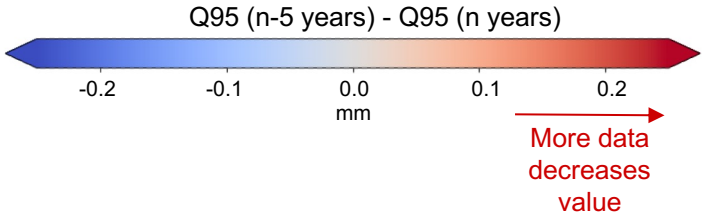


AORC



Stage IV





Impact of additional data on Q95 value

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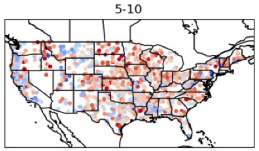
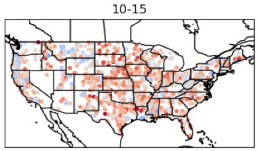
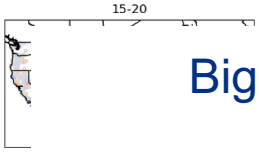
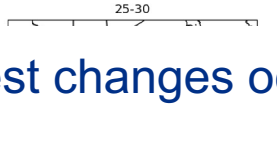
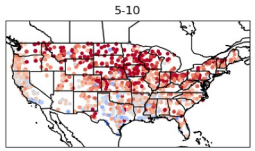


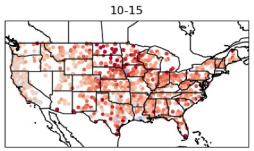


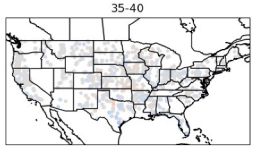




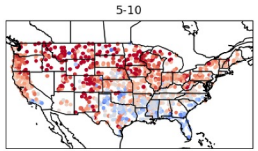
CONUS404

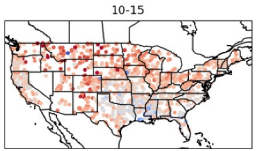


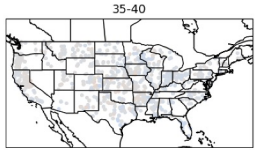




AORC

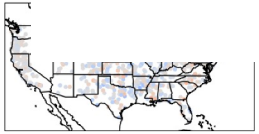


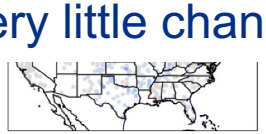


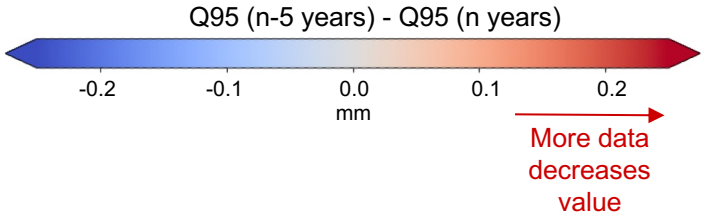


Biggest changes occur when increasing from 5 to 15 years of data.

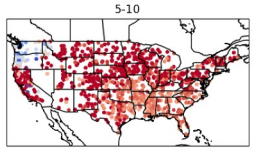
Very little change when increasing from 35-40 years of data.

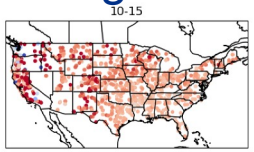


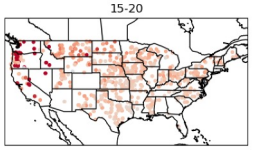




Stage IV

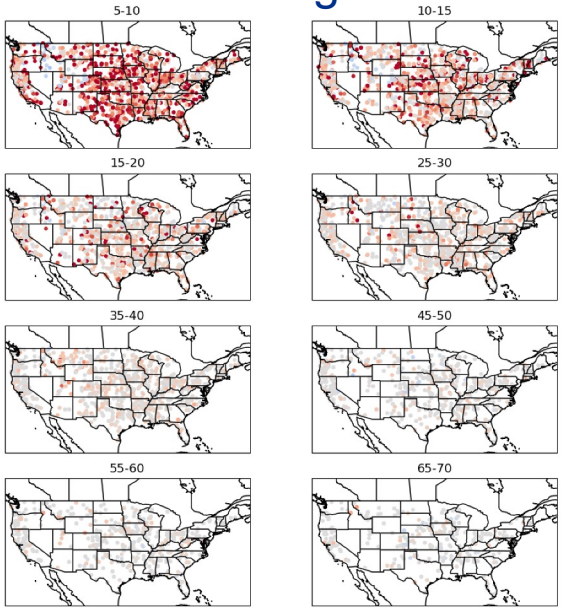




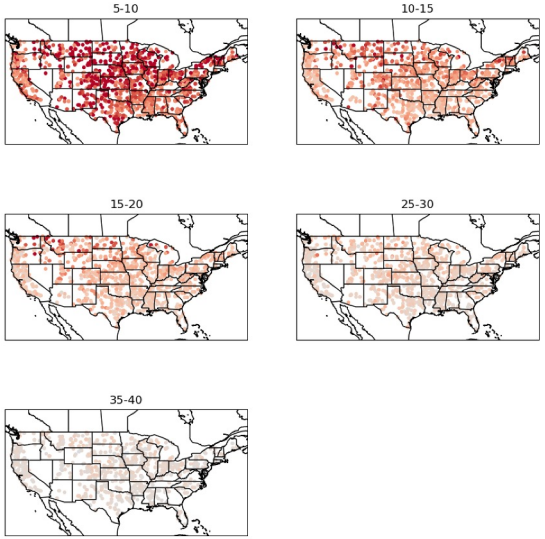


Impact of additional data on Q95 Relative CI

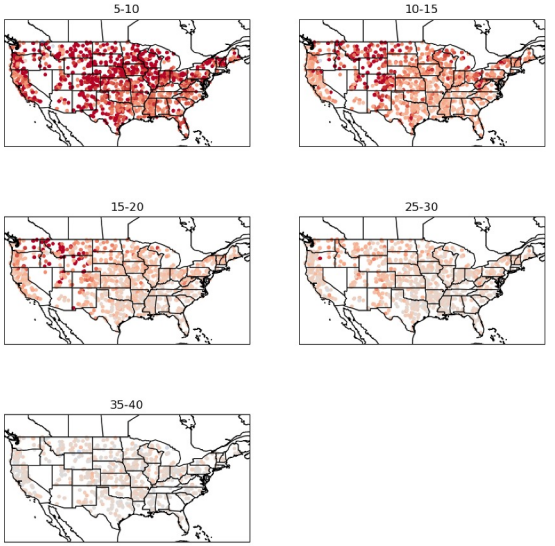
Gauge



CONUS404



AORC



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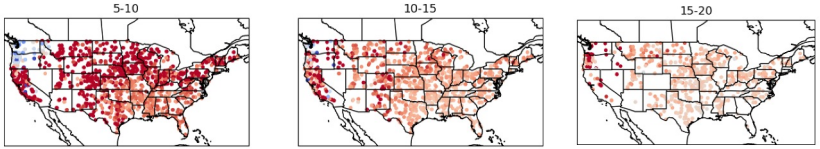
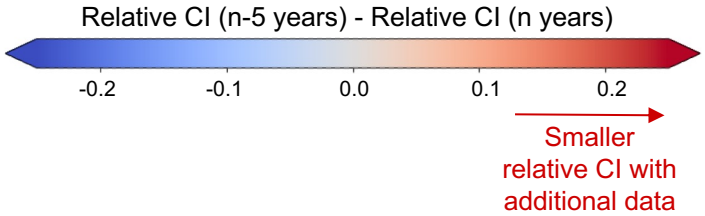
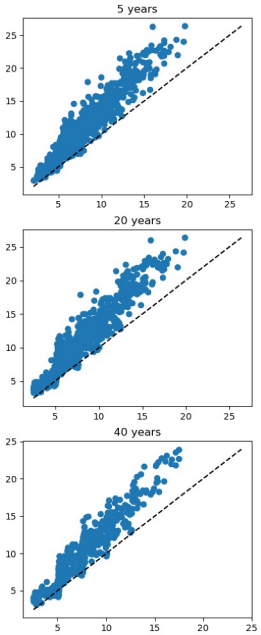




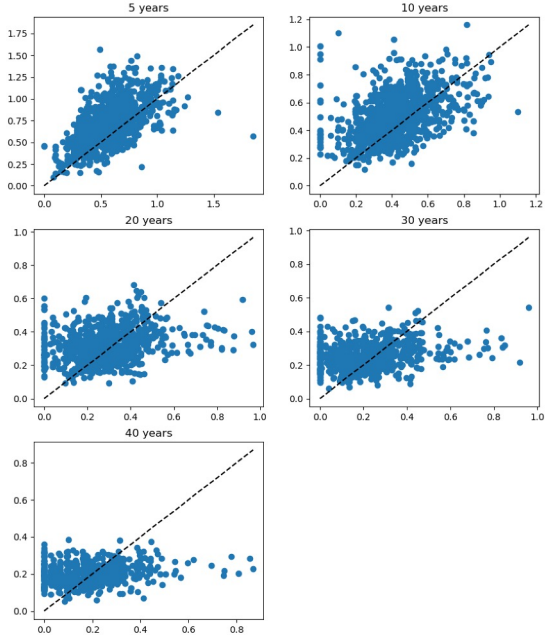
95th Percentile: Gridded datasets vs. gauge

CONUS404

Q95 Rainfall

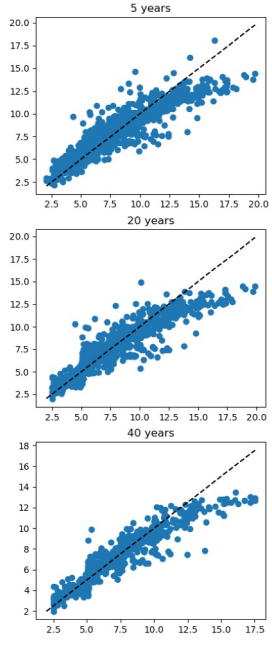


Relative Confidence Interval

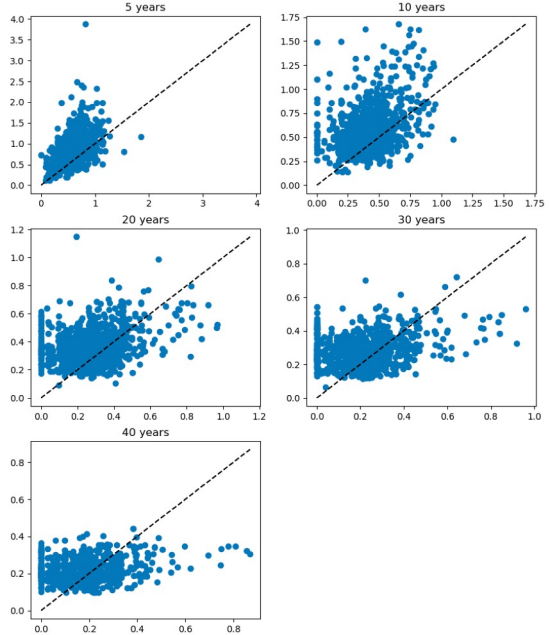


AORC

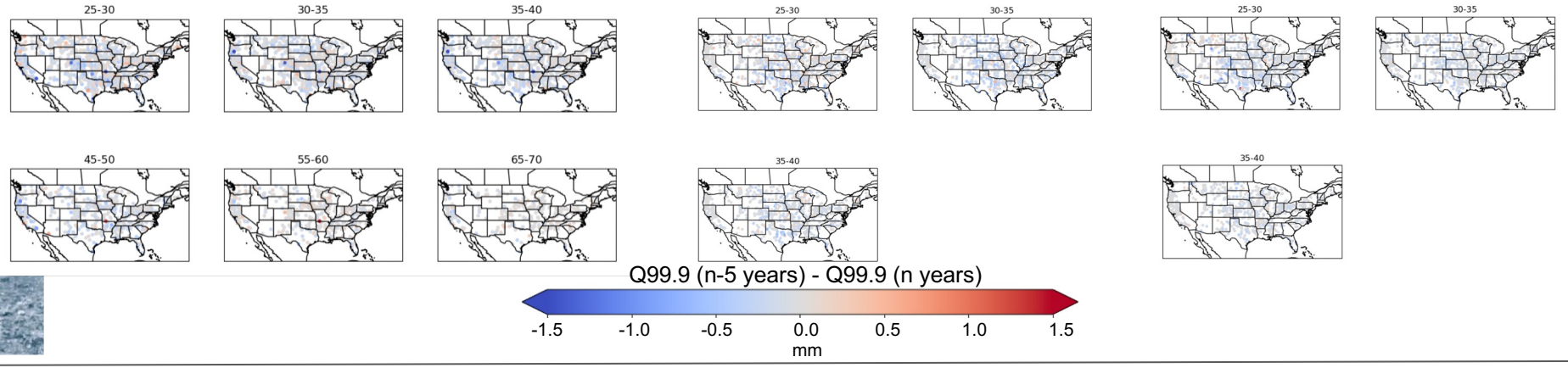
Q95 Rainfall

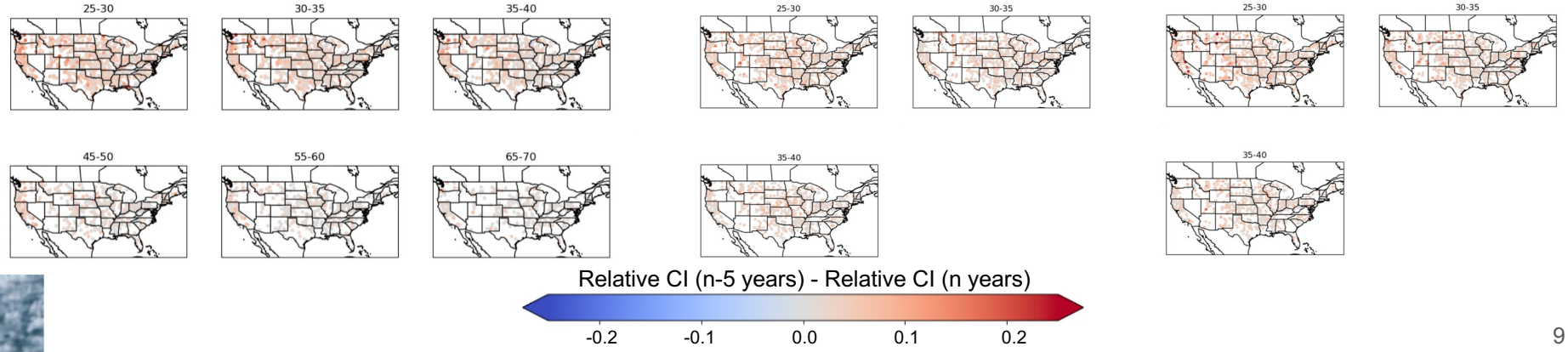


Relative Confidence Interval



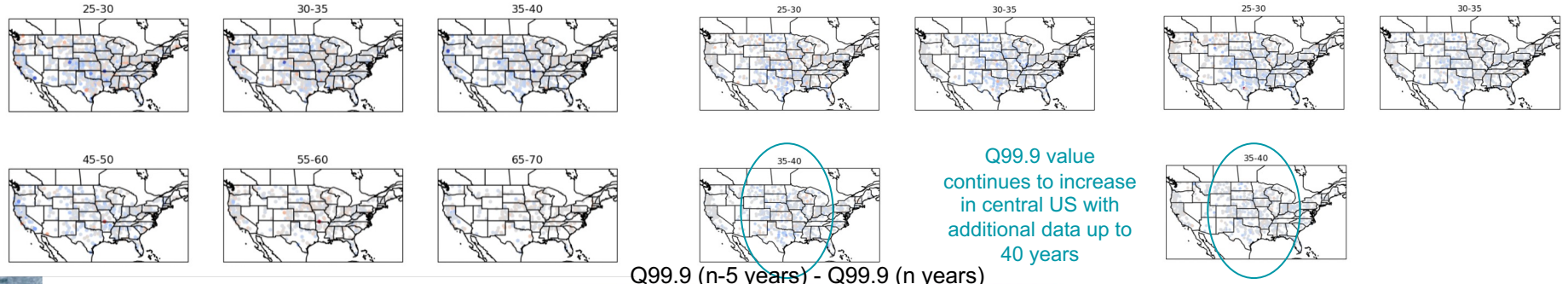
Impact of additional data on Q99.9 value and relative CI





Impact of additional data on Q99.9 value and relative CI

Gauge | CONUS404 | AORC

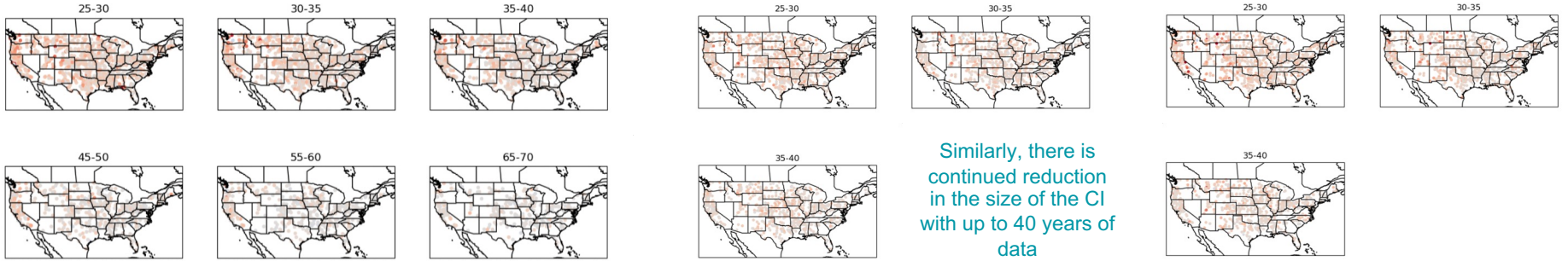


Q99.9 value continues to increase in central US with additional data up to 40 years

Q99.9 (n-5 years) - Q99.9 (n years)

-1.5 -1.0 -0.5 0.0 0.5 1.0 1.5

mm



Similarly, there is continued reduction in the size of the CI with up to 40 years of data

Relative CI (n-5 years) - Relative CI (n years)

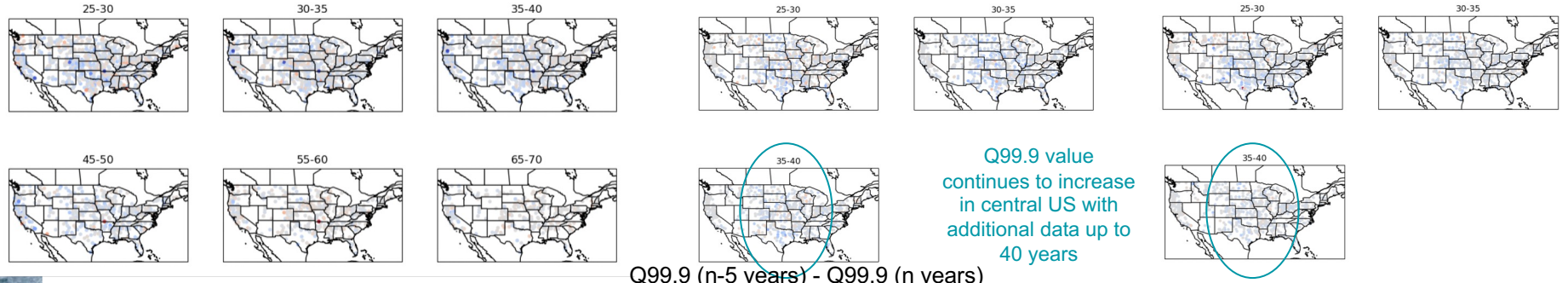
-0.2 -0.1 0.0 0.1 0.2

Impact of additional data on Q99.9 value and relative CI

Gauge

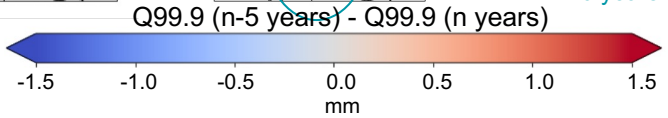
CONUS404

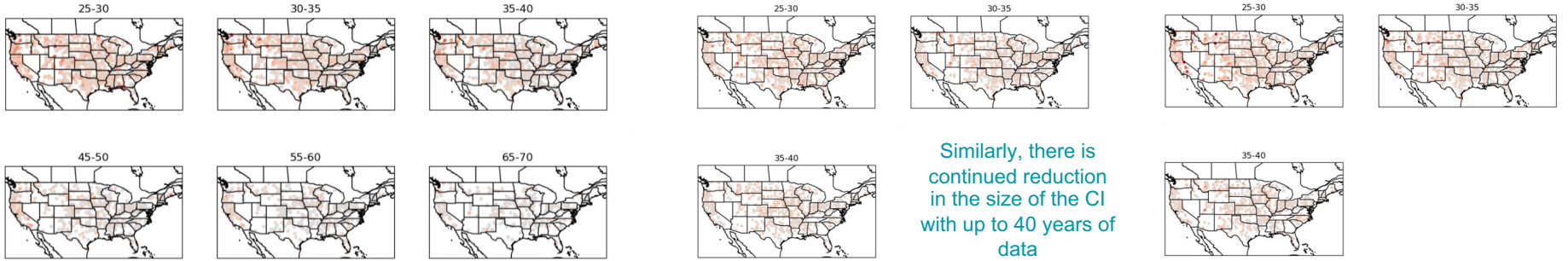
AORC



Q99.9 value continues to increase in central US with additional data up to 40 years

Not until there are ~60 years of data does change in mean estimated Q99.9 value and reduction in relative CI with additional data become negligible





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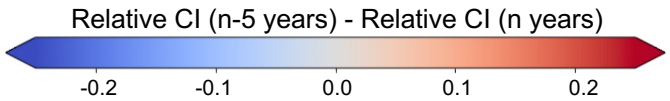
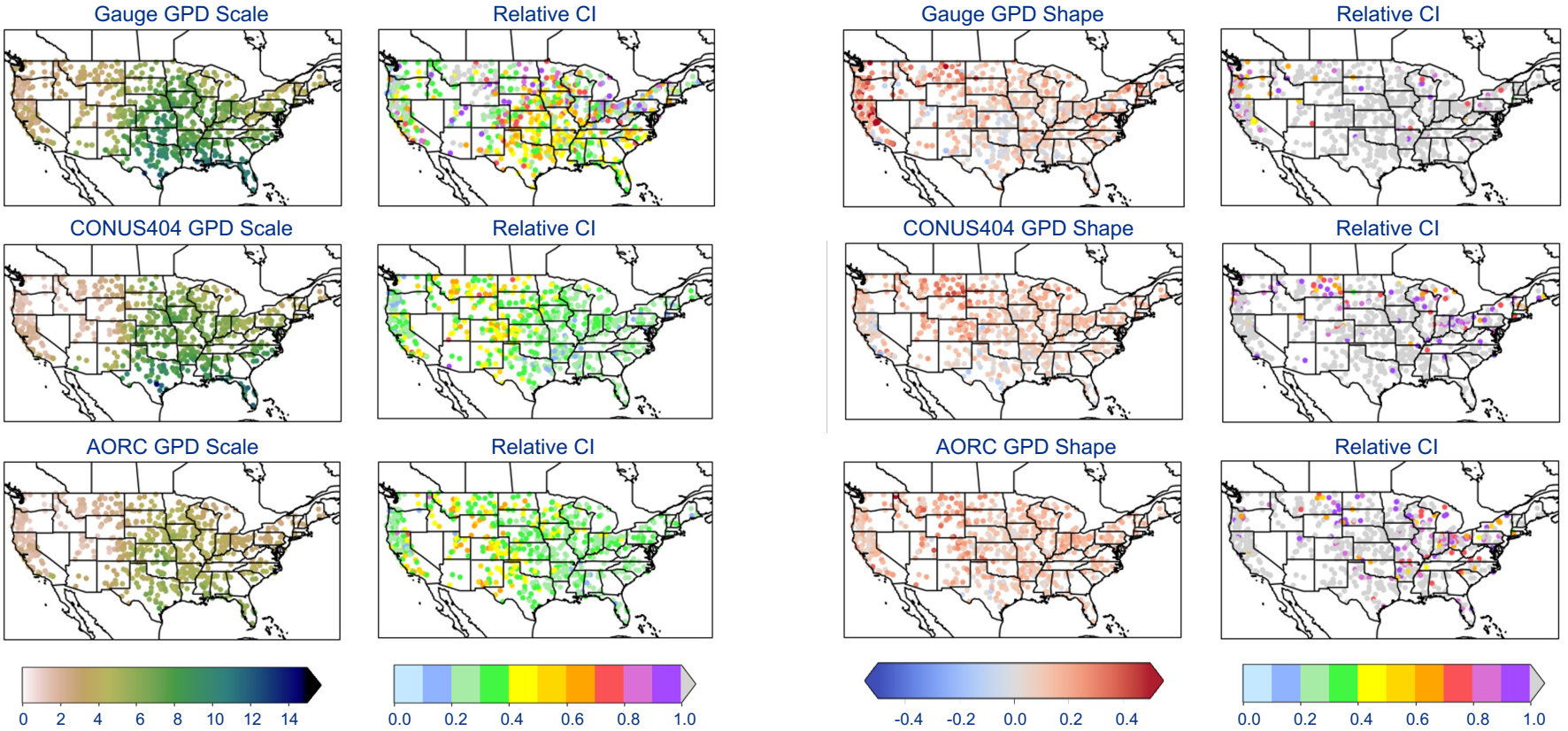
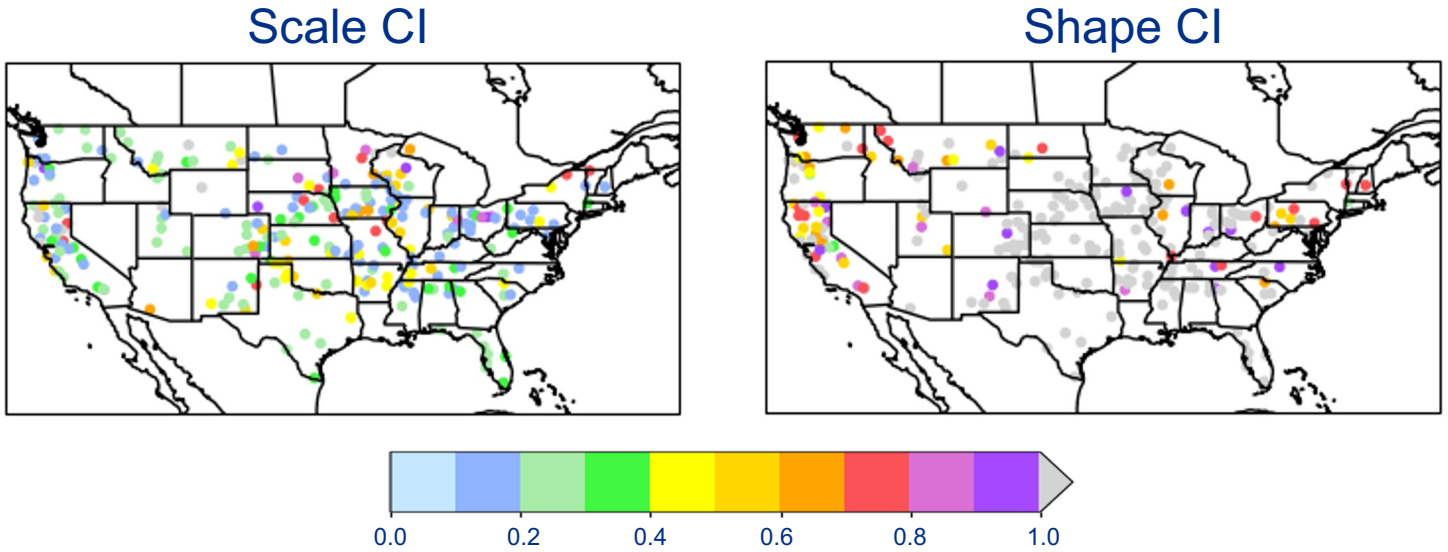


GPD Scale, Shape, and Relative CI with 40 years



GPD Scale and Shape CI with 70 years

Gauge only



Conclusions

- Gridded datasets exhibit biases in the upper quantiles of hourly precipitation compared to gauges.
  - AORC biased low for highest values, CONUS404 consistently biased high, moreso at high values.
  - Bytheway et al. 2026, submitted to Journal of Hydrometeorology
- Gridded datasets show more reduction in 95% confidence interval with more data.
  - Continuous hourly values versus potential missing data and inaccurate extremes/bad observations (e.g. frozen) from gauges?
- Additional data has the most impact on the most extreme precipitation.
  - Less change in value and CI of Q95 than of Q99.9.
- 40 years of data is not enough to capture GPD parameters.
  - 70 gets you reduced uncertainty in scale parameter, but not shape parameter.
- What does this mean for PMP and the Model Evaluation Project?
  - We should be able to evaluate how models capture moderate extremes (<= Q95), particularly in the eastern US.
  - Higher quantiles and the the representation of the most extreme precipitation remains uncertain.

Thank you

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