Indiana University Bloomington

Analyzing Extreme Precipitation Events in Bloomington Using Generalized Extreme Value Regression

Current and Future Trends in Extreme Weather (Fall 2024)
Graduate Major Assignment

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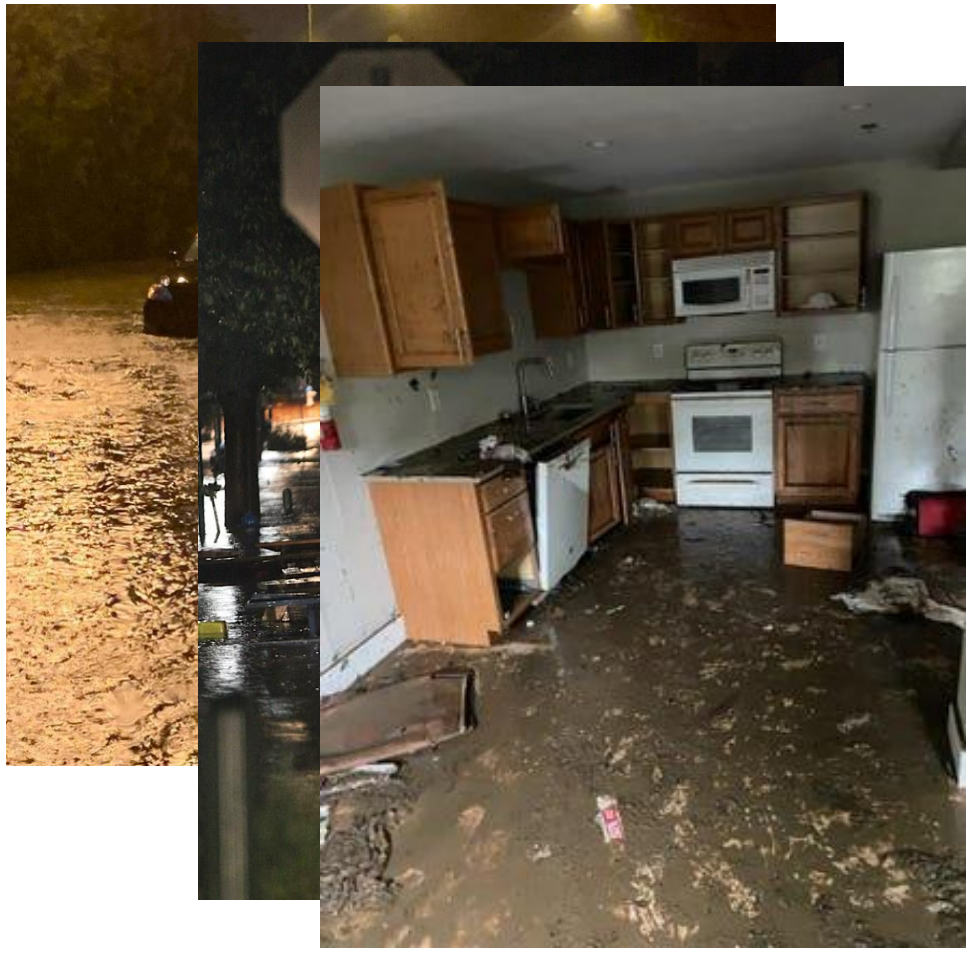
News on extreme precipitation and flooding in Bloomington 2021



Precipitation intensity

- Two-day rainfall reached 6.1 inches
- Strongest precipitation event in a century

Impact of the event

- Caused severe flooding
- Power outages
- Streets and apartments inundated
- Bridges submerged by gravel
- Cars swept away by floodwaters
- Economic losses
- Casualties

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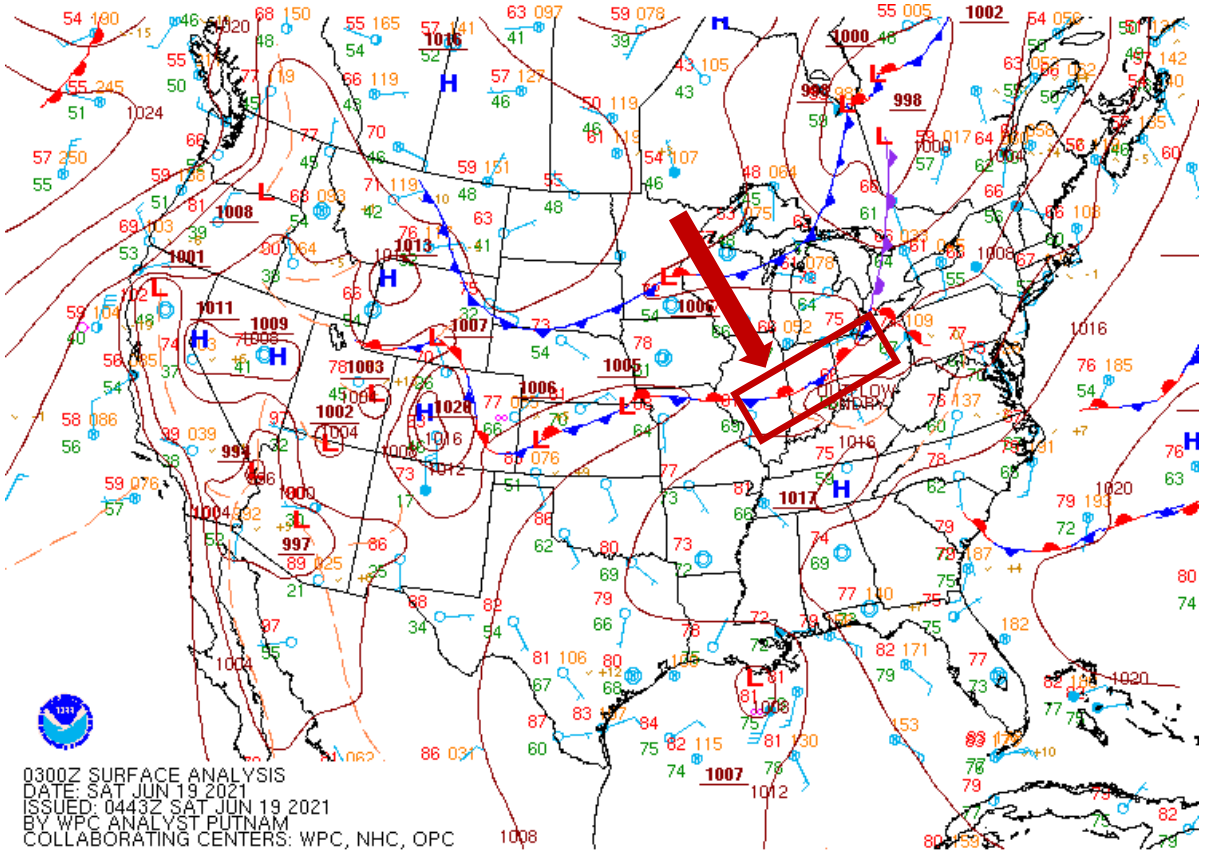
The causes of this event



Mesoscale Convective System

- Quasi-stationary front
- High instability in the atmosphere
- Temperatures above normal
- Strong south winds
- Stronger moisture transport from the ocean

Thunderstorms

- Multiple rounds
- Intense rainfall rates
- ”Training" pattern

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Historical trend in extreme precipitation and methods

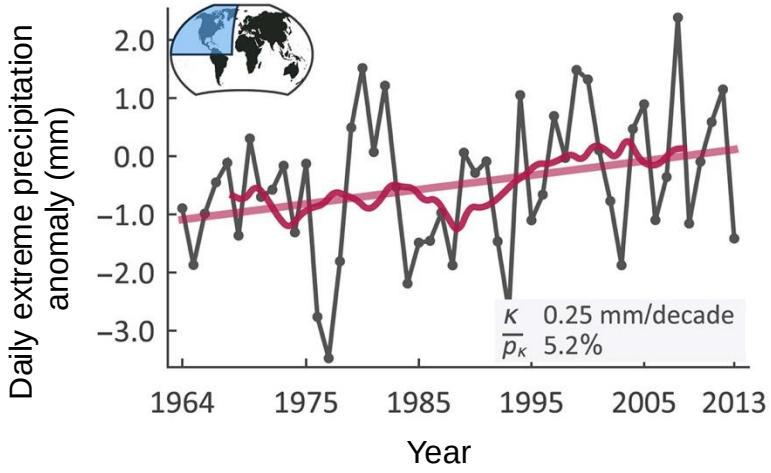
Historical trend

- Increased trends in extreme precipitation are observed across various datasets and methods

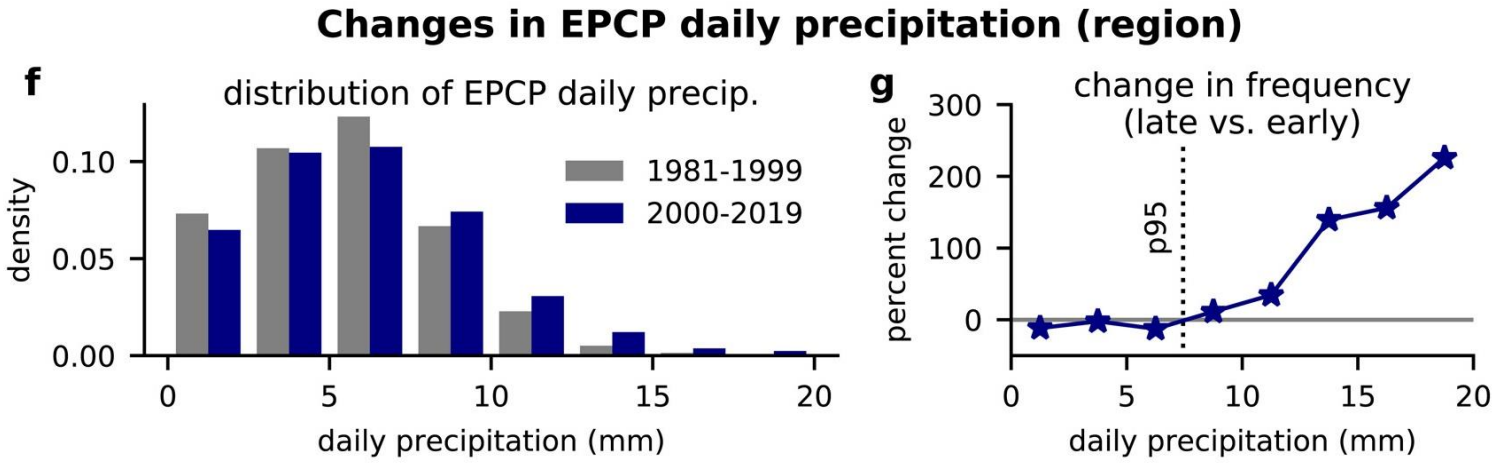
Methods

- Linear Regression
- Machine Learning
- GEV Regression

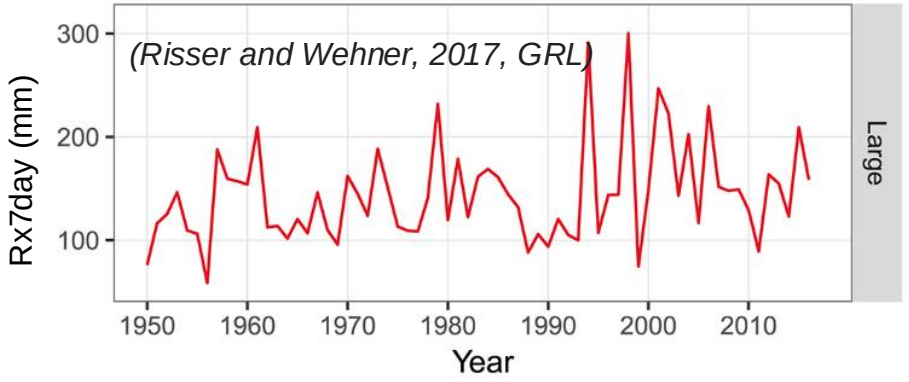
(Papalexiou et al., 2019, WRR)



(Davenport et al., 2021, GRL)



(Risser and Wehner, 2017, GRL)



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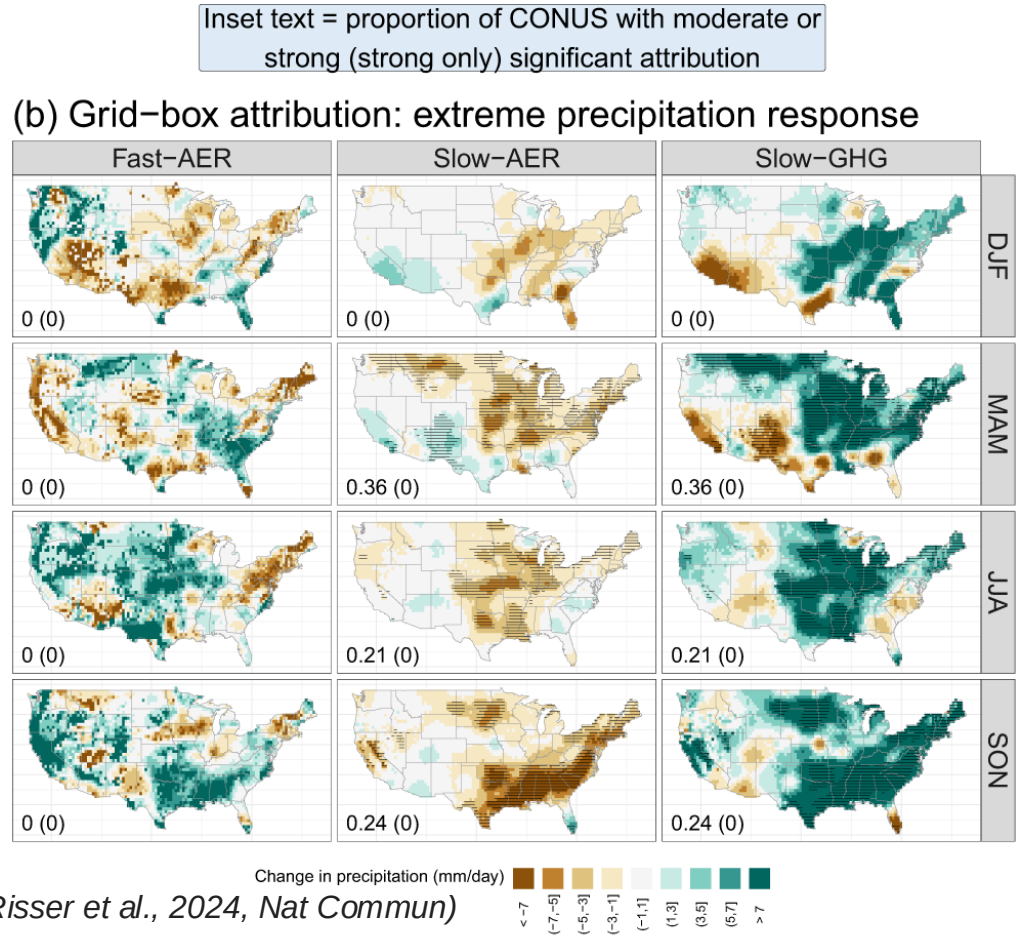
The impact of human activities on extreme precipitation



(Risser et al., 2024, Nat Commun)

Fig. Grid-box attribution for the fast aerosol (Fast-AER), slow aerosol (Slow-AER), and greenhouse gas (Slow-GHG) precipitation responses.

Anthropogenic attribution of extreme precipitation

- The anthropogenic signal is strongest for the GHG influence of extreme daily precipitation
- The response of slow-aerosols to extreme precipitation is negative almost everywhere.
- The response of fast-aerosols to precipitation exhibits a seasonal pattern
- Human activities have shortened the return periods of extreme precipitation.

(Kirchmeier-Young et al., 2020, PNAS)

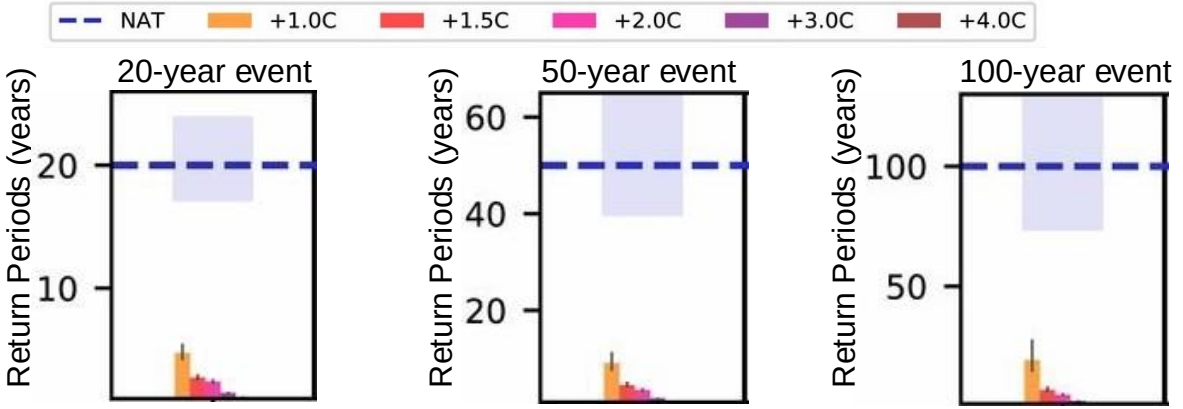


Fig. Return periods for Rx1day 20-y (A), 50-y (B), and 100-y (C) events in North America

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The impact of human activities on extreme precipitation

Extreme events have become more probable and more intense. Many of these changes can be attributed to human influence on the climate.

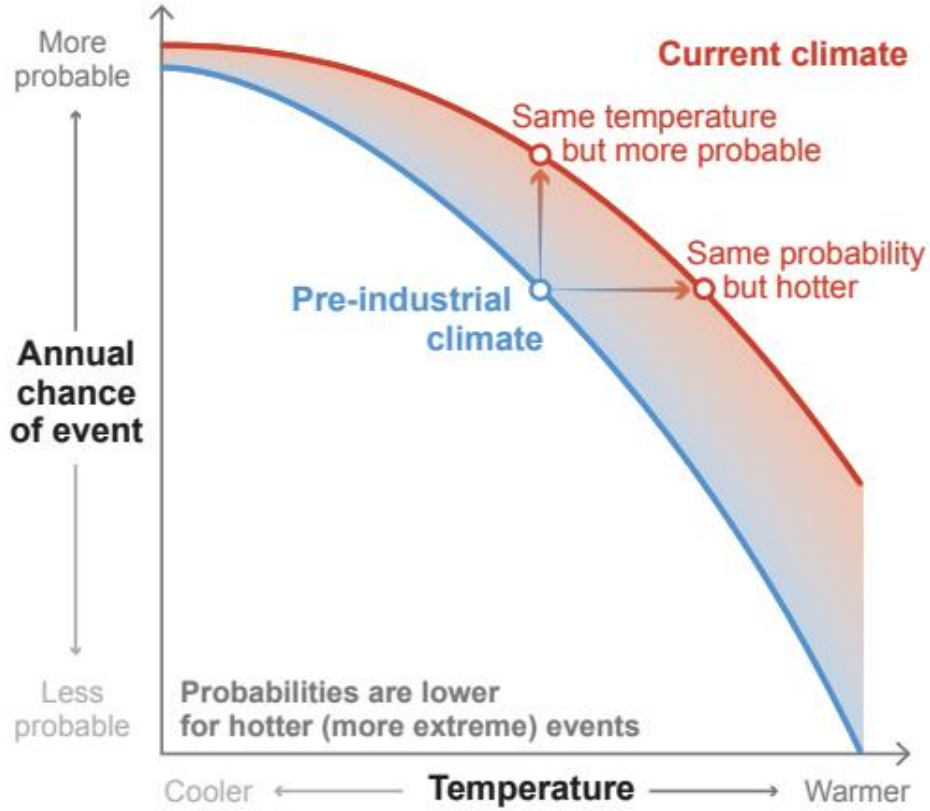

Fig. Changes in climate result in changes in the magnitude and probability of extremes.

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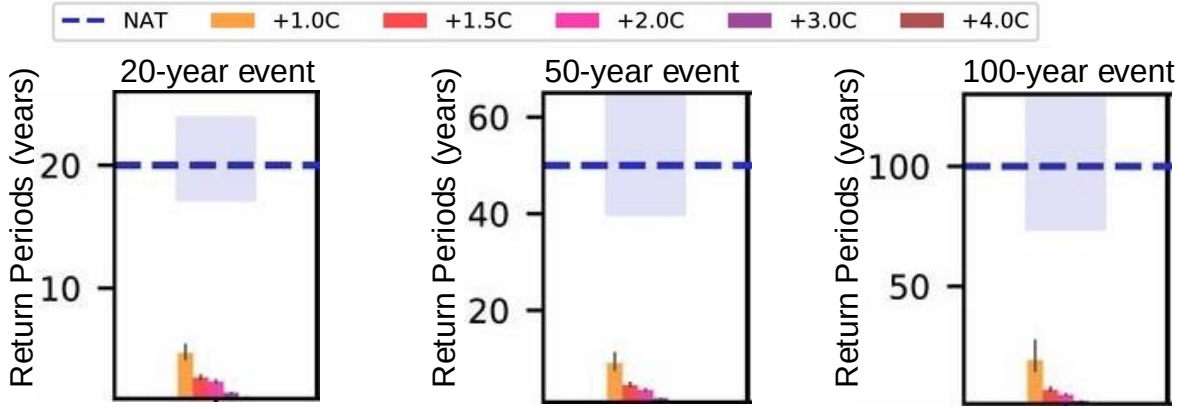

Fig. Return periods for Rx1day 20-y (A), 50-y (B), and 100-y (C) events in North America

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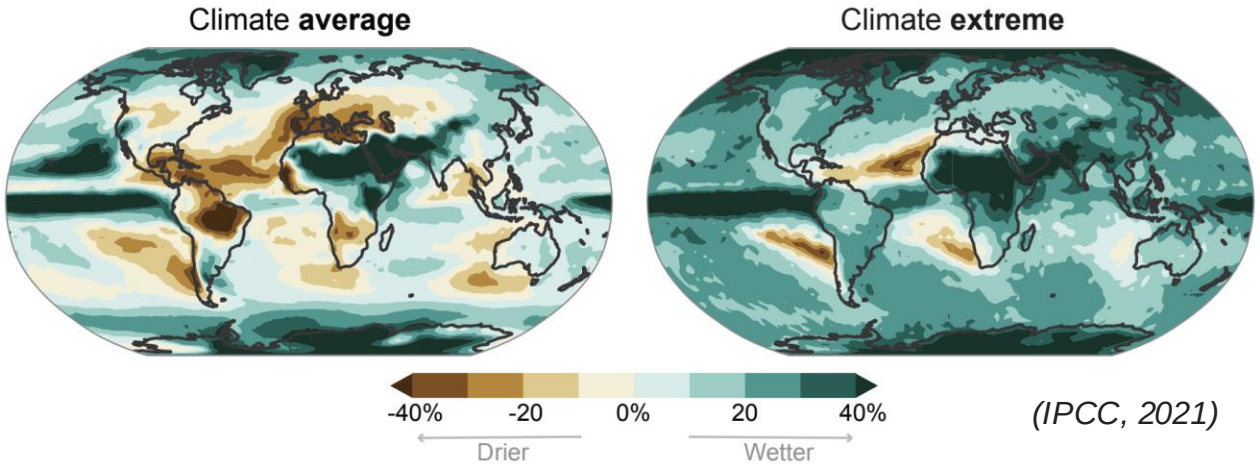
Future changes in extreme precipitation



(IPCC, 2021)

Fig. Future changes in averages and extremes precipitation (Rx1day)

(Kirchmeier-Young et al., 2020, PNAS)

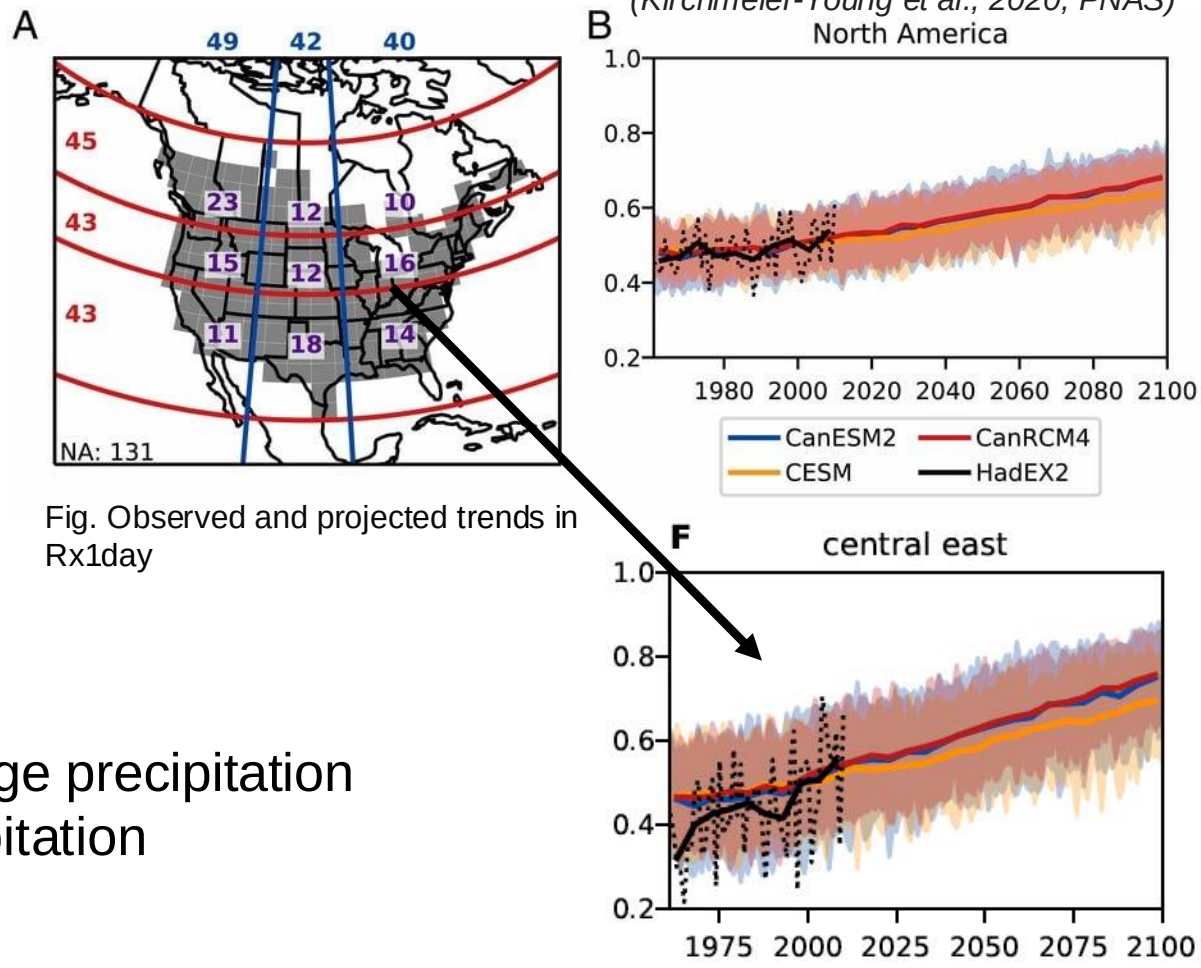


Fig. Observed and projected trends in Rx1day

Observed and projected changes

- Extreme precipitation increases more than average precipitation
- Future trends show an increase in Rx1day precipitation

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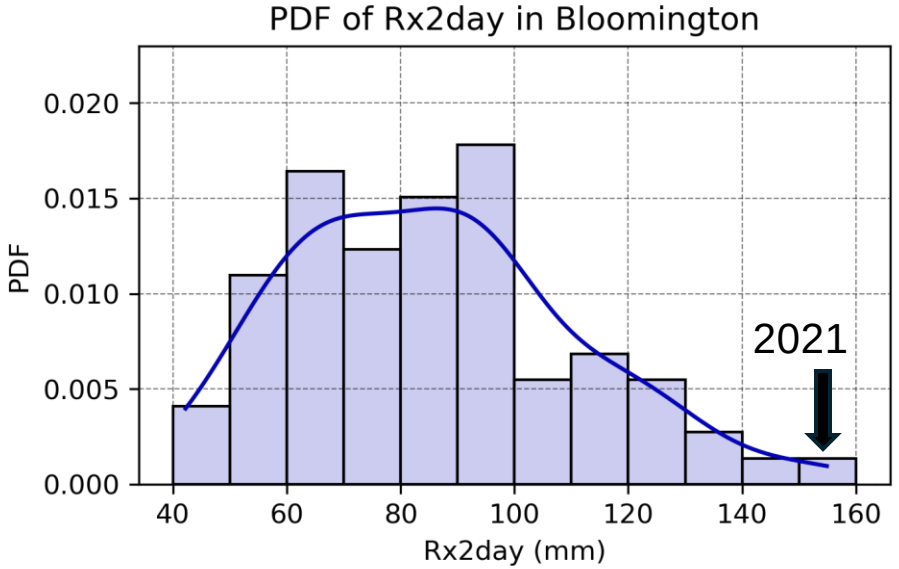
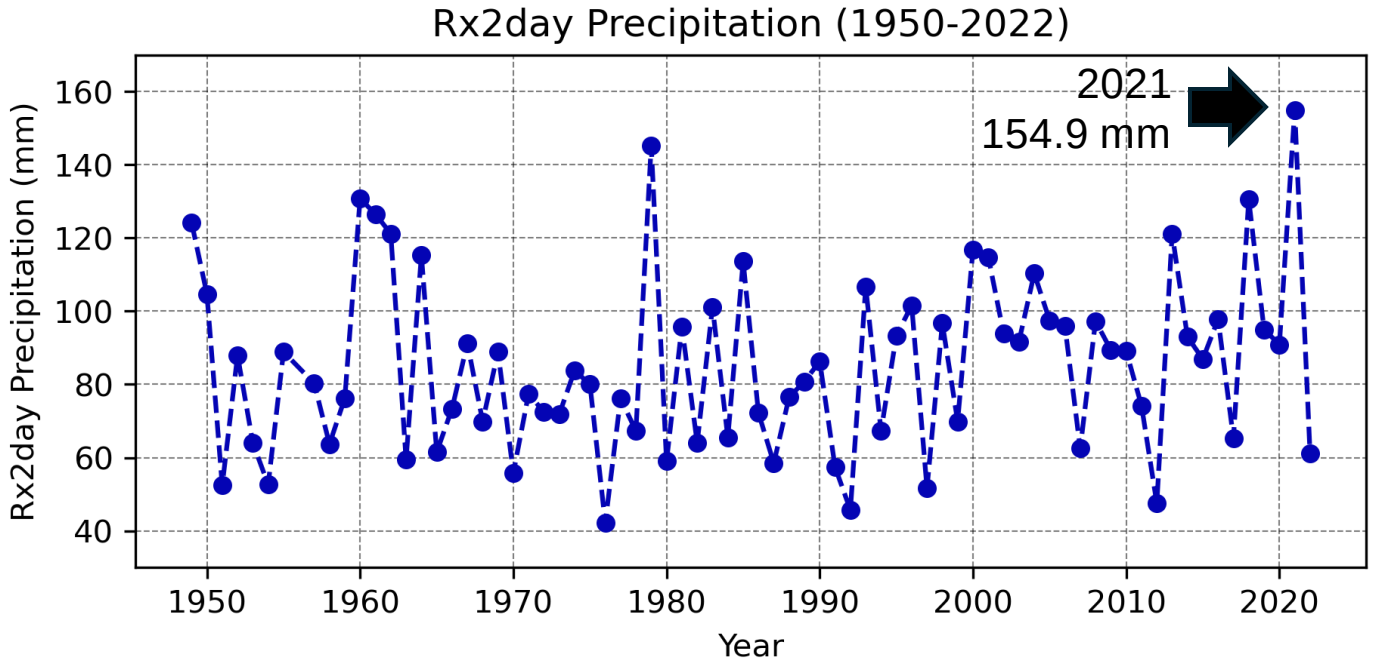
Historical records of extreme precipitation and flooding in Bloomington 2021

Data source

- IU station (1895-2022)
- focusing primarily on 1950-2022
- with comparisons to 1895-2022





Precipitation characteristics

- Two-day rainfall reached 154.9 mm
- Strongest precipitation event in a century
- Trend analysis is inconclusive

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Generalized Extreme Value (GEV) Regression

The central to D&A methodologies

- Evaluating changes in the probability of extreme events (change of μ, σ, ξ).
- Attributing causes of changes in extreme events
- Projecting future risks of extreme events

The valid statistical conditions for the GEV method

- Independent and Identically Distributed
- Sufficiently Long Time Series
- Block Maxima Method
- Parameter Stability Assumption

Comparison with the Central Limit Theorem

Characteristic	Generalized Extreme Value	Central Limit Theorem
Focus	Extremes (max/min values)	Mean or sum of data
Core Theory	Extremes converge to GEV distribution	Sample means approach normal distribution
Scope	Extreme phenomena (e.g., rainfall, temperature)	Central tendency of populations
Distribution	Converges to GEV (Weibull, Gumbel, Fréchet)	Converges to normal distribution
Use	Analyzing frequency, intensity of extremes	Describing mean, confidence intervals

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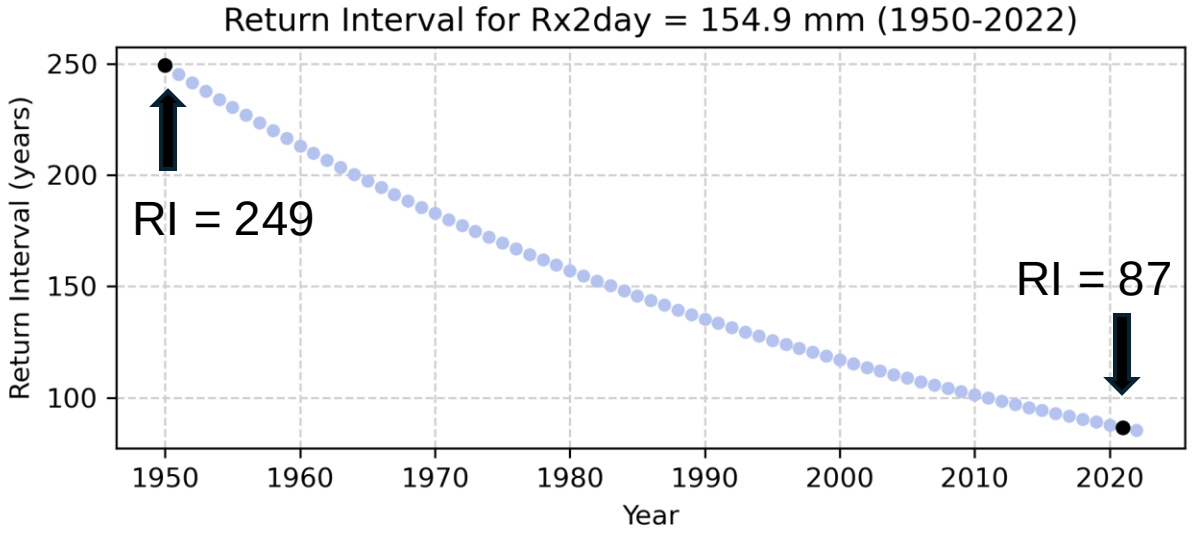
Return interval and risk ratio of the event

$$Survival\ Function = 1 - \ CDF$$

$$Return\ Interval = \frac{1}{n\ \text{sample} * \ Survival\ Function}$$

Rx2day return interval

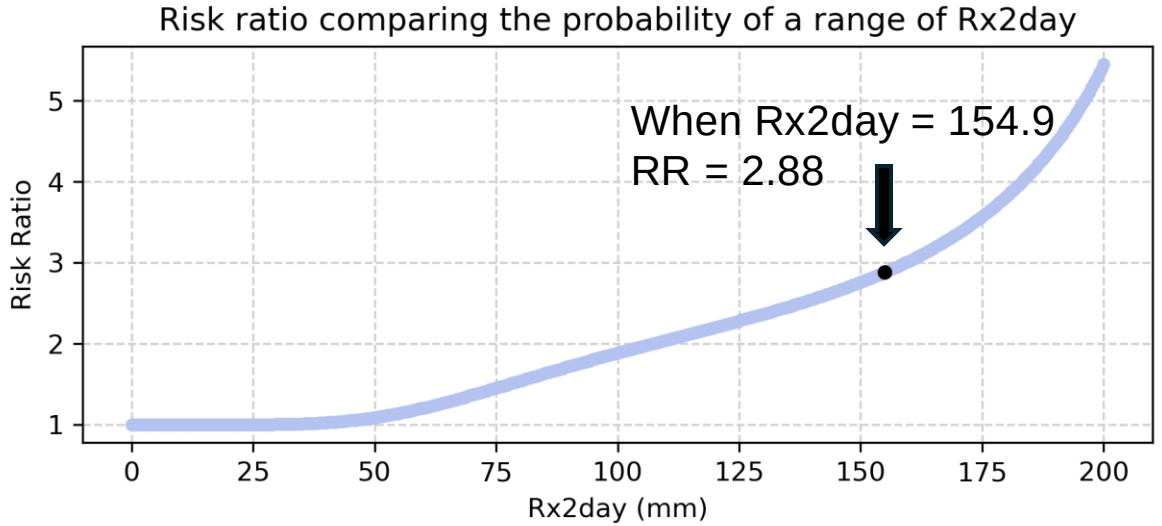
- Return Interval for Rx2day 2021: 86.57 years
- Return Interval for Rx2day 1950: 249.36 years



$$Risk\ Ratio = \frac{Survival\ Function\_2021}{Survival\ Function\_1950}$$

Rx2day risk ratio

- The risk ratio is 2.88
- Stronger precipitation, faster risk ratio increase



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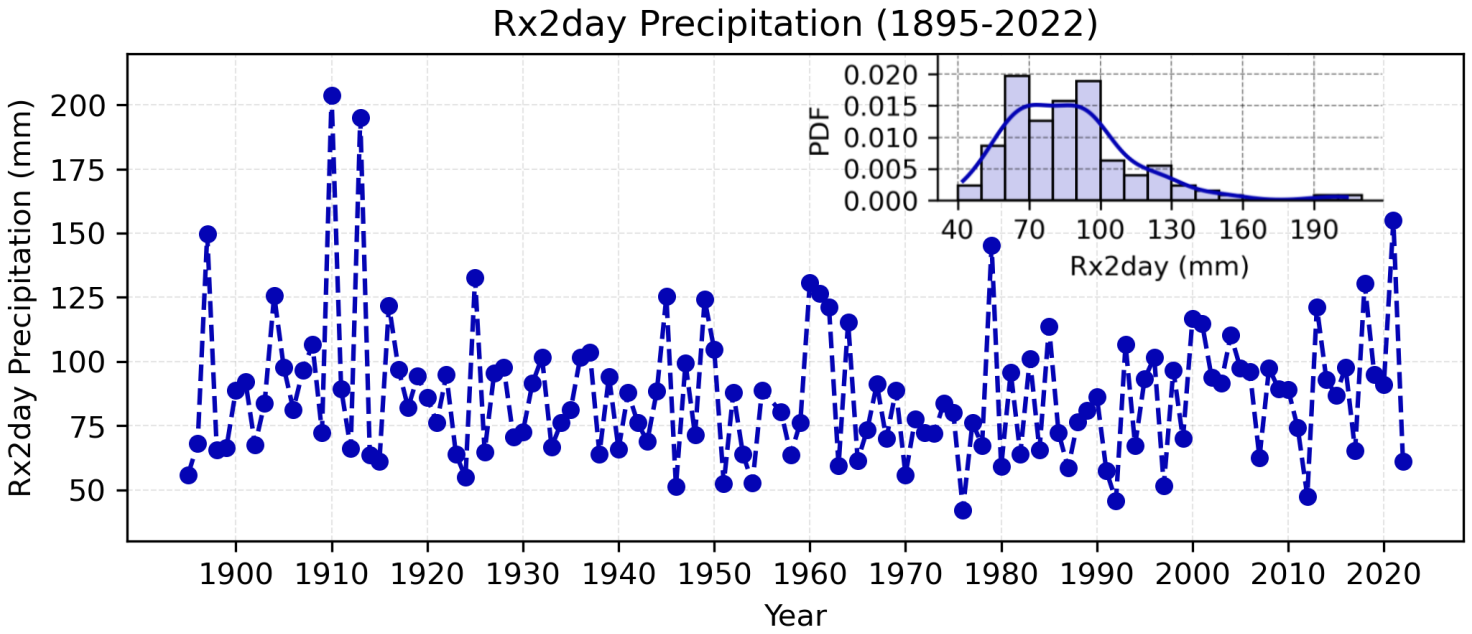
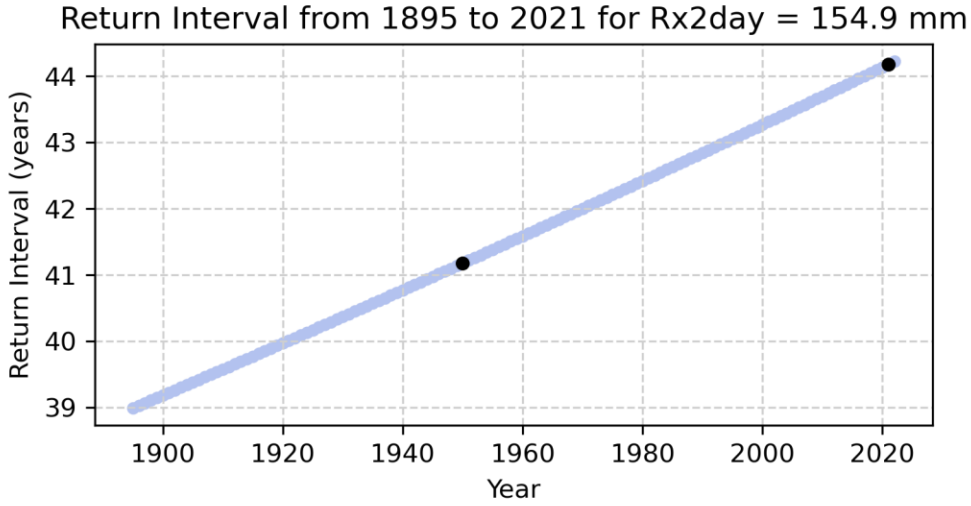
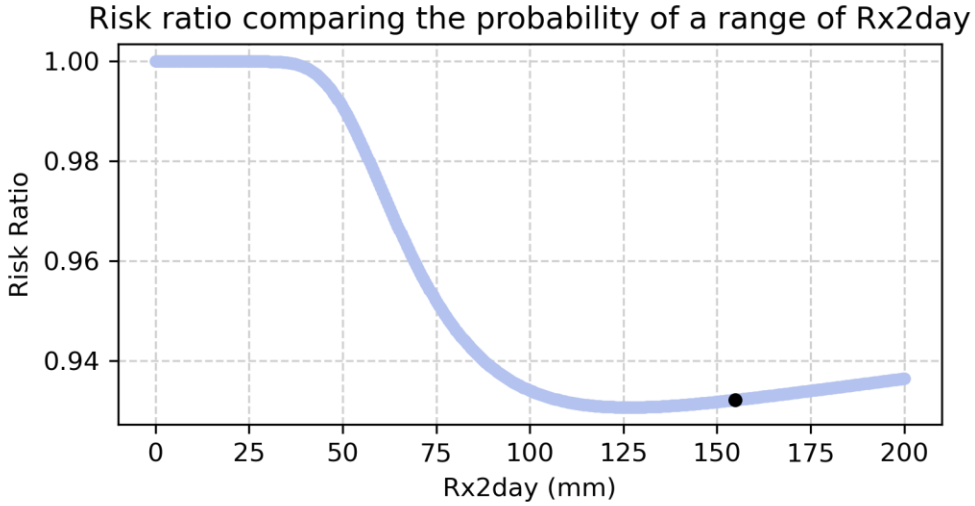
Discussion and Compared to the period 1895-2022







Rx2day return interval

- Return Interval for Rx2day 2021: 46.65 years
- Return Interval for Rx2day 1950: 43.49 years

Rx2day risk ratio

- The risk ratio is 0.93
- The risk is now lower than it was in the past

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Summary

- **Extreme Precipitation Trend**

Confirmed rise across various datasets.

- **Human Impact**

Clear evidence of altered precipitation patterns due to increased GHGs and aerosols.

- **Increased Frequency and Intensity**

Predictions show ongoing rises in extreme precipitation.

- **GEV Regression Effectiveness**

Proven robust in providing precise estimates for extreme events.

- **Recent Analysis**

70-year data shows a 2.8 time increase in risk ratio.

- **Data Comparison Needs**

Future studies should justify the selected time series.