Assessing future extreme rainfall trends through multifractal scaling arguments

A CONUS-wide analysis based on NA-CORDEX model outputs

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Introduction

Problem statement

- Assess the **impacts** of the **evolution of extreme rainfall** events under **rapidly changing climatic conditions**
- Quantify **future flood risk**

→ **Multi-year** information at adequately **fine spatiotemporal scales**

- Spatial and temporal **evolution** of regional extreme rainfall patterns → **Challenging** to describe due to:
  - i. natural **climate variability**
  - ii. local **topography**

- Evaluation of the **frequency of extreme events** from conventional **climate model outputs** → **Demanding** due to introduction of **epistemic uncertainties**

Overarching Goal

Robust assessment of future trends related to **extreme rainfall** over the entire **CONUS**, while considering the **non-stationary nature of the rainfall process**

→ Using **high-resolution rainfall data** and an **elaborate multifractal framework** for IDF estimation

Methods

Framework in-brief

Data

Stage IV
4-km, hourly
2002 – 2019

CORDEX-NA
22-km, hourly
1950 – 2099
Solely WRF and RCP8.5
- **GFDL-ESM2M**
- **HadGem2-ES**
- **MPI-ESM-LR**

Downscaling and bias-correction

Parametric Q-Q mapping
Emmanouil *et al*. (2021)

Calibration:	2011 – 2019
Validation:	2002 – 2010
Extrapolation:	1979 – 2001 2020 – 2099

Downscaled NA-CORDEX

Evolution of IDF curves

Parametric multifractal approach
Emmanouil *et al*. (2022) and Langousis *et al*. (2009)

- Applied to sequential 10-yr segments
- Robust for short records
- Parameters that vary slowly **across** (not within) realizations

IDF estimates for different time segments
- Validation using historical recordings (1979-2019)
- Various averaging durations, *d*, and return periods, *T*

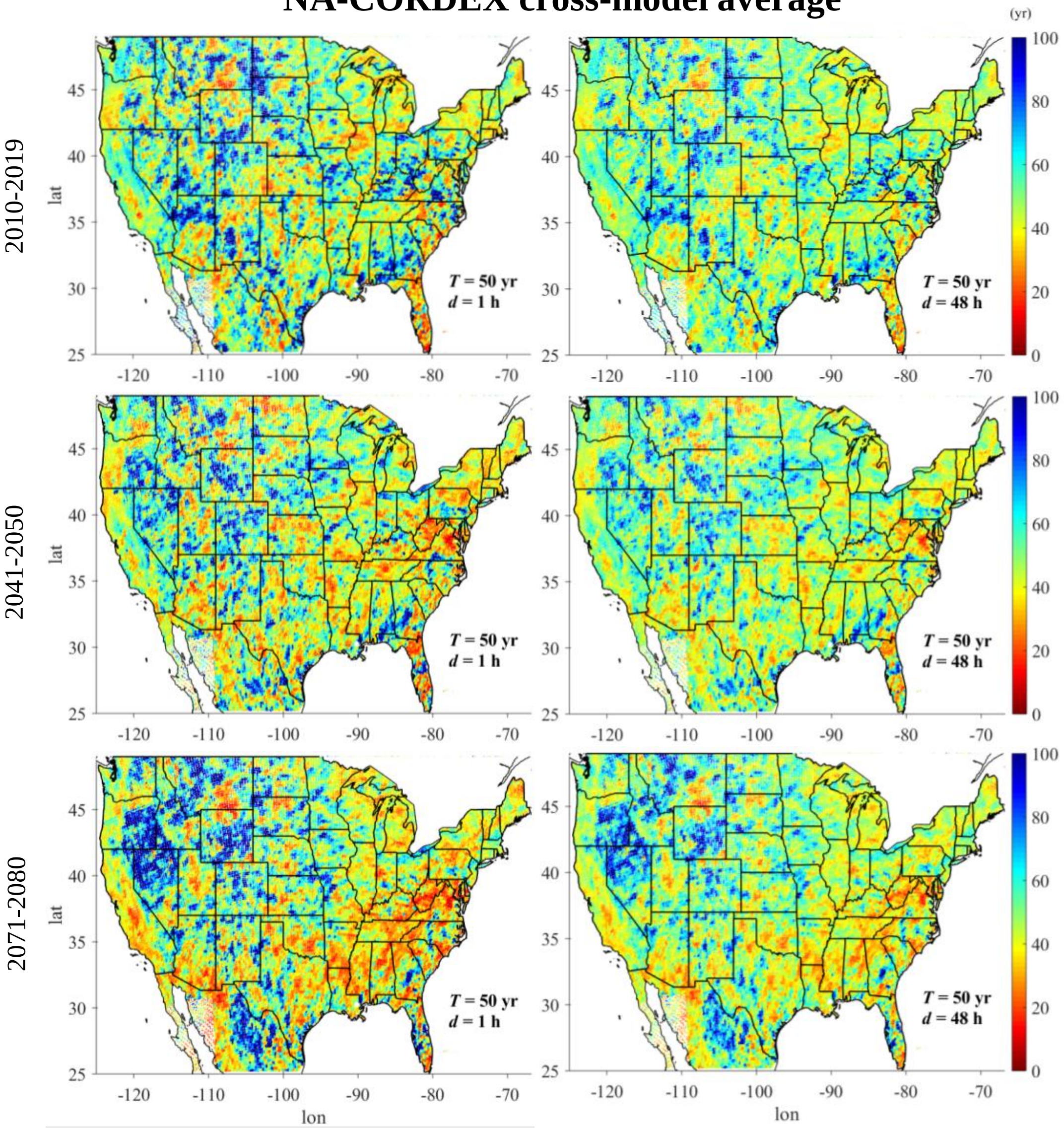
Output

Return period estimates for various times segments
- Multiple climate model outputs
- Using *T* –*yr* return levels in 1979-1988 as reference

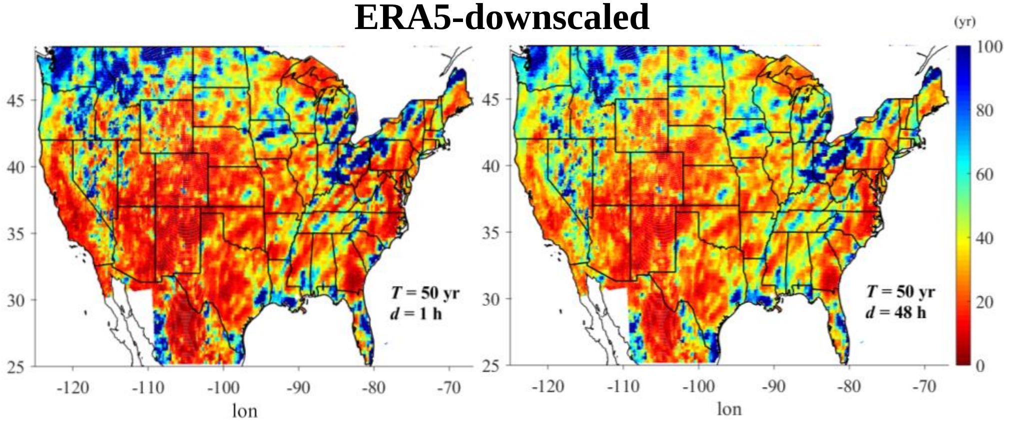
Results

Mapping the evolution of return period levels

NA-CORDEX cross-model average



ERA5-downscaled



- The **return period estimates** from the downscaled **CORDEX-NA** display **higher spatial variability** compared to those from the **downscaled ERA5** (Emmanouil *et al.*, 2021) in the **historical period** (1979–2019).
- The **erraticity** can be **potentially attributed** to the **lack of dynamic consistency** of climate model simulations.
- The **decreasing trends** of the return periods in the **future** (2020–2050 and 2051–2080) seem overall **slightly more pronounced**.

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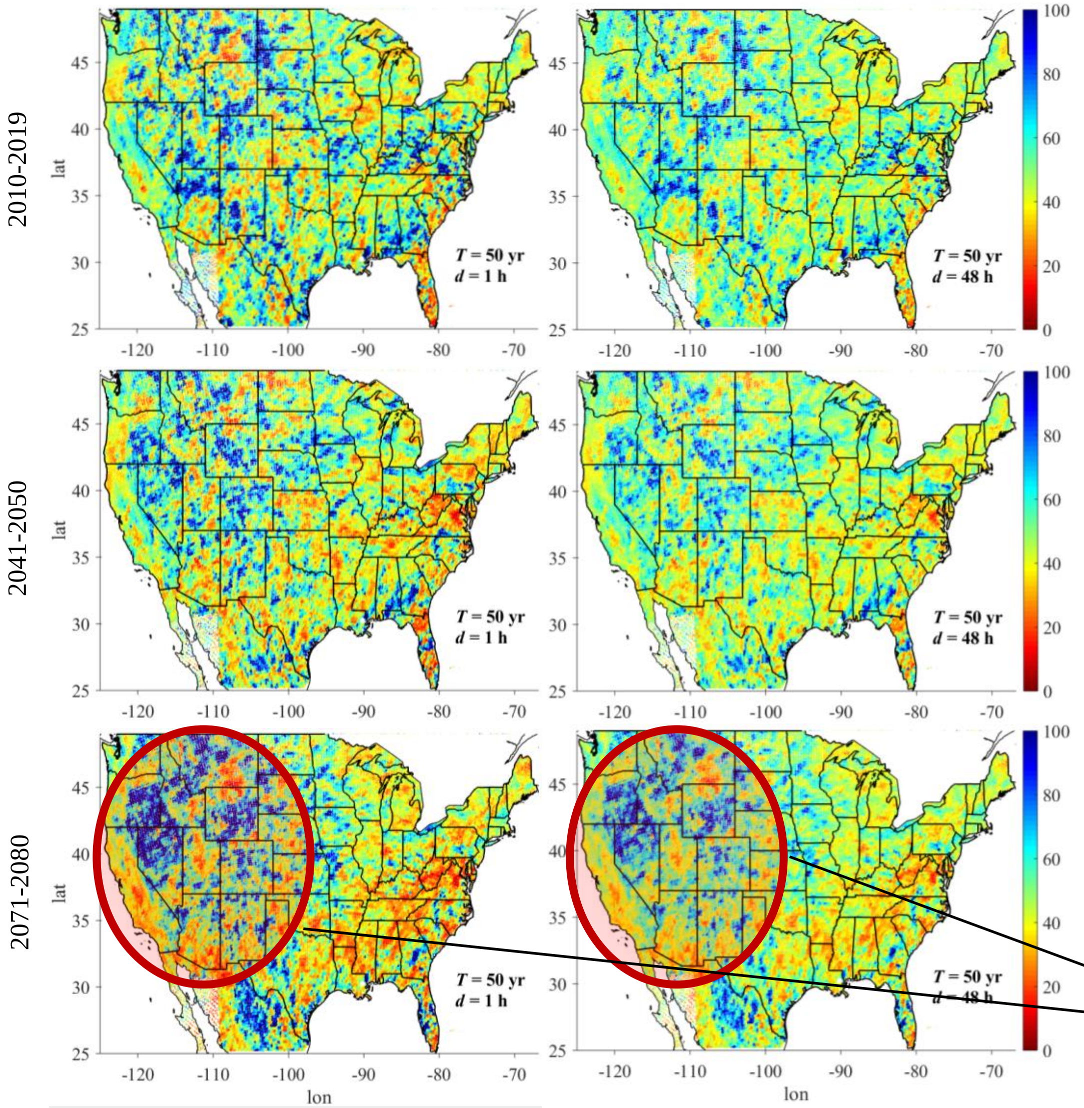

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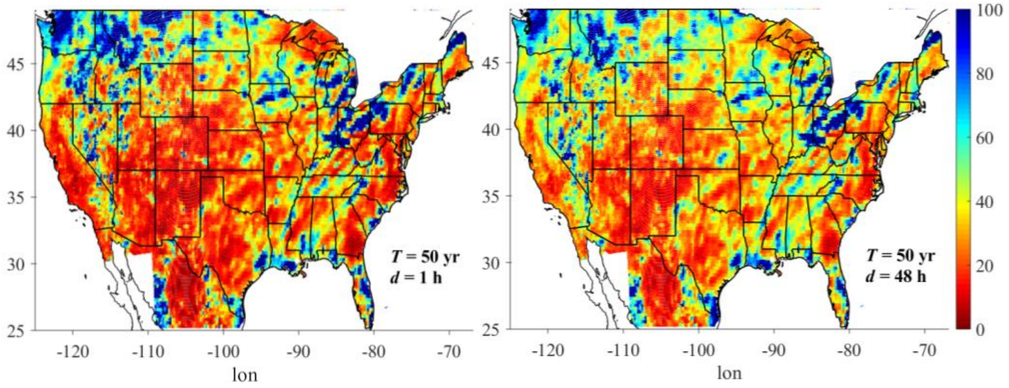

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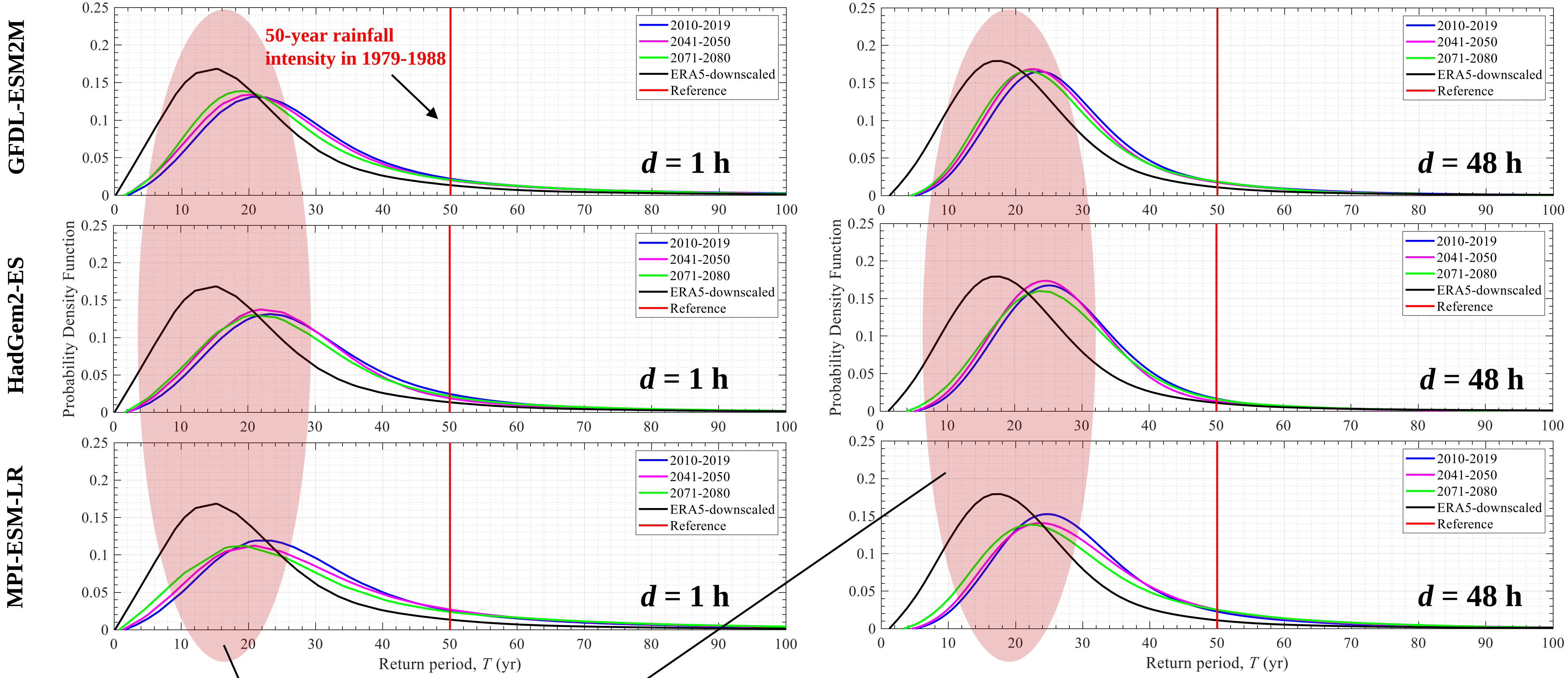
Increasing trends over the **Rockies** and certain **western regions** (e.g., Nevada and Oregon) **regardless of *d***.

Results

Overall trends in return period levels



Clear **differences** in **modal values** compared to estimates based on **downscaled ERA5 data**

- ✓ Overall, **decrease of return periods** in **all 30-year segments**.
- ✓ More **pronounced changes** seem to take place in the period from **1979 to 2019**.

Summary and Conclusions

- **Limited knowledge** on the **evolution** of **extreme precipitation patterns** ➔
  - ✓ Under the **influence of climate change**.
  - ✓ At **spatiotemporal resolutions** suitable for **hydrological modeling**.
  - ✓ Considering the **non-stationarity** of rainfall as a process.

- **Intensity-Duration-Frequency** (IDF) curves ➔
  - ✓ Reveal **future infrastructure vulnerabilities**.
  - ✓ Wide range of **characteristic temporal scales** and **exceedance probability levels**.
  - ✓ Elaborate **multifractal framework** (see Emmanouil *et al*., 2022)
  - ✓ Derived using **CORDEX-based**, **gridded** (4-km), **hourly precipitation estimates**, covering the **entire CONUS** for a period of **120 years**.

Main findings and concluding remarks

- ✓ **Return period estimates** obtained from **CORDEX-NA** data display **high spatial variability**
  ➔ **Potentially attributed** to the **lack of dynamic consistency** of climate model simulations.
- ✓ On average, **reduced return periods** in **all 30-year segments studied**.
- ✓ More **pronounced changes** seem to take place in the period from **1979 to 2019**.
- ✓ **Rate of changes** in future IDF estimates ➔ **strategically planned future infrastructure** could **encapsulate** all possible outcomes for the **remainder of the century**

Selected Bibliography

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Thank you!

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