Assessing climatological trends in daily precipitation extremes in Berlin-Brandenburg, Germany, using 44 years of station-based and reanalysis-based data

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Heavy precipitation days in summer with a two-year return period have become ~32% more intense over the last 44 years (in Berlin-Brandenburg)

Introduction

Motivation:

- Changing precipitation conditions in the Berlin-Brandenburg region (Kundzewicz et al., 2006)
- Station networks might not be able to capture spatial extent of extreme precipitation events accurately (Lengfeld et al., 2019)
- High resolution measurement data often only available for short time series or interpolated
  - ➢ **Possible added value of dynamical downscaling based on global reanalysis data**

Research questions:

- **R1:** What changes in seasonal return levels/ periods can be identified on the basis of daily station measurements over the last 44 years ?
- **R2:** Is a reanalysis-based dataset able to reconstruct the spatiotemporal variations of return level/ period changes ?
- **R3:** How pronounced is the spatial variability of the changes in areas between the stations (based on the reanalysis-based data) ?

Full abstract

Methodology

Data:

Rain gauge measurements:

- Precipitation data of 227 daily stations in the area of Berlin-Brandenburg from the German Meteorological Service (DWD)
- Filtering based on the data availability between 1980 and 2023

Reanalysis-based data:

- CER v2 data set (Bart et al., 2025)
- WRF based dynamical downscaling of ERA5 (ECMWF Reanalysis v5) data
- 2 km grid spacing for Berlin-Brandenburg (Fig. 2)
- Selection of values at grid cells via nearest neighbor

CER v2 data set

Study area:

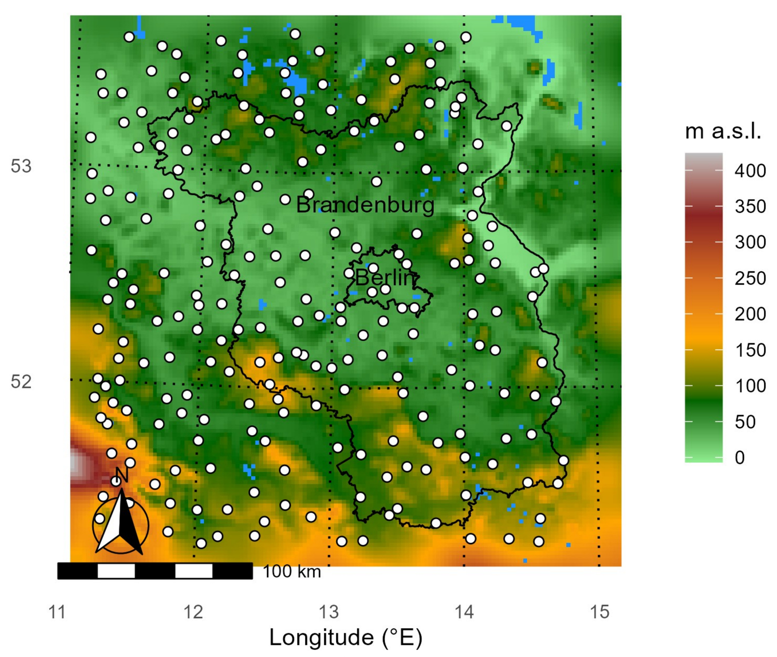

Fig. 2: Terrain Height for the CER v2 domain. White dots represent the selected DWD rain gauges (Projection: Lambert conformal conic; DATUM: WGS84).

Return Level (RL) estimation:

- Based on a Generalized Pareto Distribution (GPD)
- Parameter Maximum Likelihood Estimation (MLE)
- Threshold selection for the 90th percentile
- Estimation of Changes in RL using a time dependent scale parameter (Fig. 4)
- Goodness of Fit (GOF) evaluation (Tab. 1)

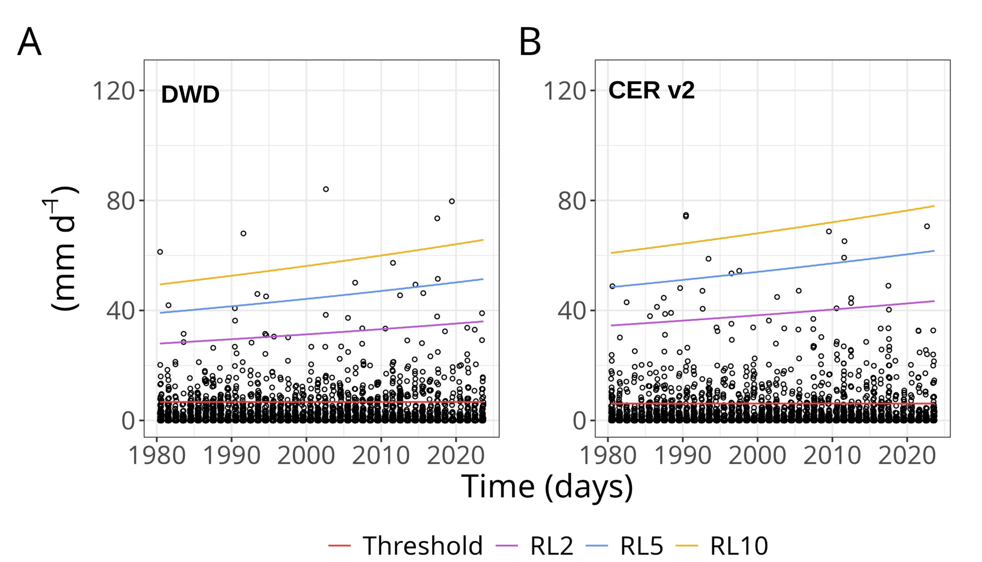

Fig. 4: Example of the daily precipitation data at the DWD station Berlin Potsdam/ the nearest CER v2 grid cell during summer with the estimated 2-, 5- and 10-year return level (MOD2) and threshold.

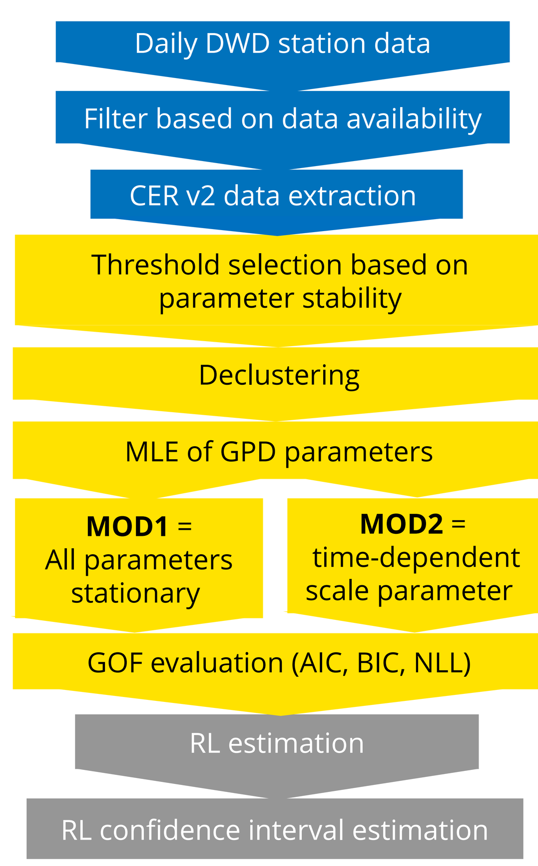

Fig. 3: Schematic overview of the data analysis procedure.

Tab. 1: GOF-Metrics and statistical tests used for the comparison between stationary and time-dependent models.

Metric	Purpose	Comment
Negative Log Likelihood (NLL)	Measures model fit	Does not penalize number of paramters/ sample size
Akaike Information Criterion (AIC)	Model selection (fit vs. complexity)	Penalizes number of parameters
Bayesian Information Criterion (BIC)	Model selection (fit vs. complexity, favors simplicity)	Penalizes number of parameters and sample size
One-sample Kolmogorov-Smirnov (K-S) test	Compare sample(s) to a reference distribution	Uniform across the whole distribution

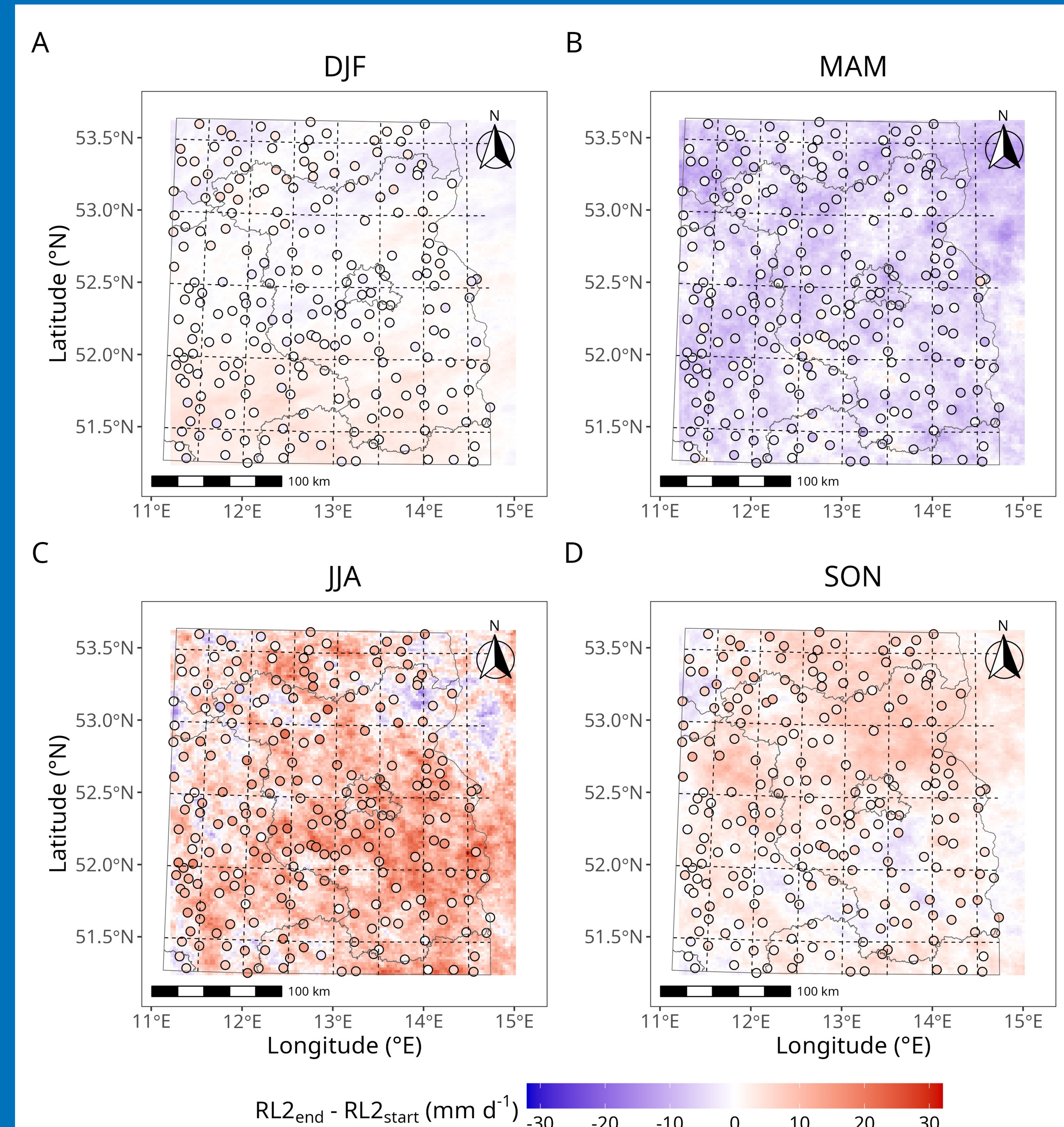

Fig. 1: Estimated seasonal 2-year return level change between 1980 and 2023 based on daily CER v2 total precipitation products. Comparable results based on daily rain gauge measurements by the German Meteorological Service (DWD) have been included as dots.

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Results

Tab. 2: GOF comparison between a stationary (MOD1) and the non-stationary GPD fit (MOD2). Values for GOF-metrics (NLL, AIC, BIC) indicate the number of stations where MOD2 achieved a better model fit. Additionally, the mean difference (MD) MOD1 - MOD2 is provided.

	No. of stations								
	MOD1 ≥ MOD2							K-S test p > 0.05*	
Season	NLL	MD (NLL)	AIC	MD (AIC)	BIC	MD (BIC)		MOD1	MOD2
DJF	227	0.47	50	-1.04	4	-4.72		192	185
JJA	227	1.61	151	-1.10	45	-2.59		135	120
MAM	227	0.83	79	-0.48	9	-4.13		135	129
SON	227	1.32	125	0.64	34	-3.00		178	147

*p-value adjusted based on parametric bootstrapping with 1000 samples

- For the NLL, MOD2 was generally performing better (Tab. 2)
- Both AIC and BIC show a reduced GOF especially during winter and spring
- KS-Testing indicates slightly lower number of stations with significant GPD for MOD2
- Uncertainties were in gereral highest during the summer months (Fig. 5)
- Especially large uncertainties present at higher RL
- Focus on 2-year RL estimates in the data comparison

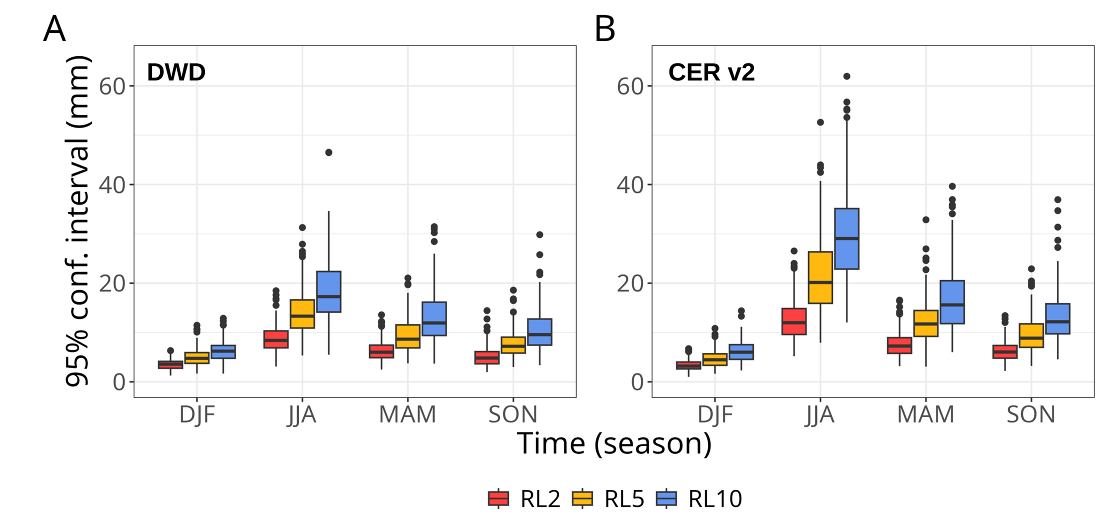

Fig. 5: Average 95% bootstrapping confidence interval of return level estimates at each DWD station and for each season.

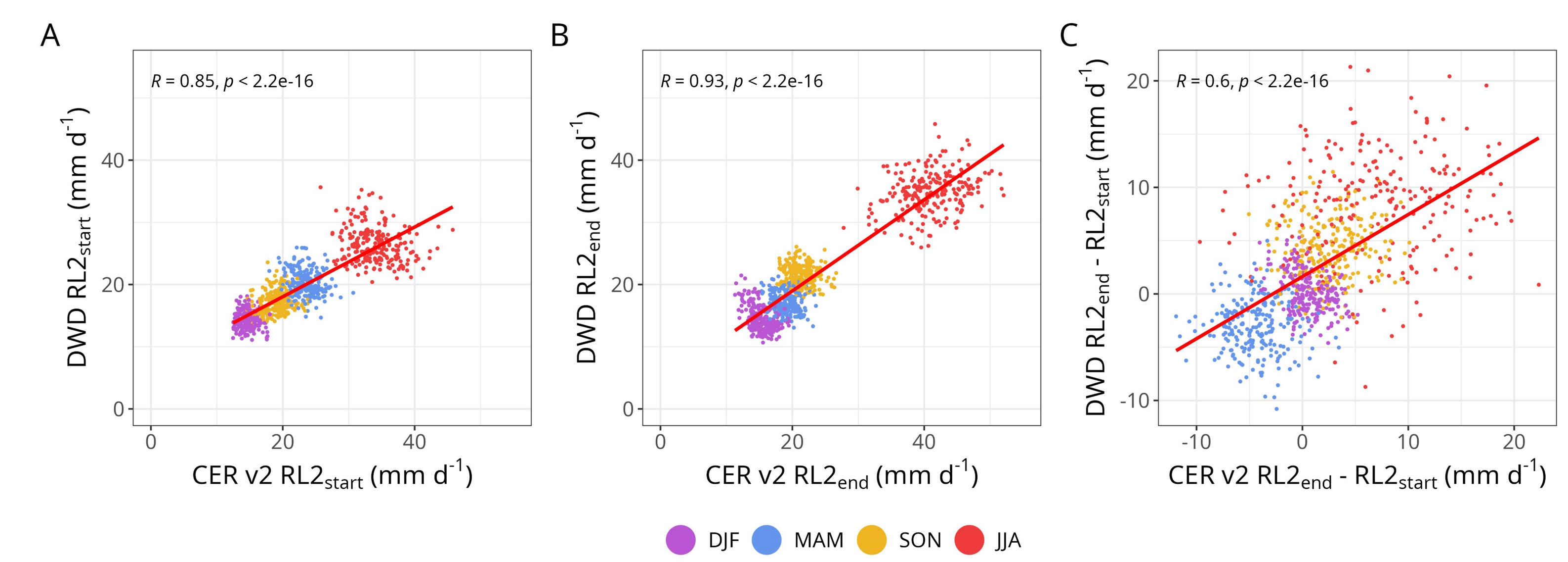

Fig. 6: Comparison for RL2 between DWD station and CER v2 data. Results are given for MOD2 at the initial (RL_{start} = 1980, A) and final (RL_{end} = 2023, B) timestep as well as the difference $RL2_{end}$ - $RL2_{start}$ (C).

- Average DWD RL2 increase during the summer months by 9 mm and decrease in spring by 3 mm (Fig. 6)
- Deviations from DWD measurement data were highest during the summer with an mean absolute deviation of 6 mm

Conclusions

R1:

- Highest positive change in all RL was observed during the summer months (Fig.1, +32% on average at DWD stations)
- Decline in return levels is observable at most DWD stations during Spring (-15% on average)

R2:

- Return level estimates show the highest agreement with station data at initial timestep
- Direction of change in RL2 agreed with DWD estimates at about 72% of stations (lowest during winter)

R3:

- Spatial variability of CER v2 RL changes was highest during summer and autumn (10 mm standard deviation)

Summary:

- ➢ Potential added value of information for extreme value statistics using reanalysis-based data
- ➢ Precise evaluation of the goodness of fit as a prerequisite
- ➢ Applicability in regions with low availability of measurement data

References

Bart, F., Schmidt, B., Wang, X., Holtmann, A., Meier, F., Otto, M., Scherer, D., 2025. The Central Europe Refined analysis version 2 (CER v2): evaluating three decades of high-resolution precipitation data for the Berlin-Brandenburg metropolitan region. metz. https://doi.org/10.1127/metz/2024/1233

Kundzewicz, Z., Radziejewski, M., Pinskwar, I., 2006. Precipitation extremes in the changing climate of Europe. Clim. Res. 31, 51–58. https://doi.org/10.3354/cr031051

Lengfeld, K., Winterrath, T., Junghänel, T., Hafer, M., Becker, A., 2019. Characteristic spatial extent of hourly and daily precipitation events in Germany derived from 16 years of radar data. Meteorologische Zeitschrift 28, 363–378. https://doi.org/10.1127/metz/2019/0964