Rainfall synthesis conditioned on circulation patterns

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1. Motivation and Objectives

- **Large scale circulation patterns** have long been associated with **local weather** conditions (i.e. rain!)
- Obs. rainfall time series often too short/incomplete ➔ need for stochastic simulation!
- A **conditioning** of a **stochastic precipitation model** should hopefully improve it's ability to better reproduce observed rainfall, especially extremes
- Can other atm. variables improve CP classification?
- Conditioning allows synthesis of **future climates**

2. Study Area and Data

Observed Rainfall (German Weather Service DWD):

- 1 minute temporal resolution, aggregated to 1hr
- Rainfall gauges in/near German federal state of Lower Saxony (Figure 1)
- Continuous observations between 1996-2016

Atmospheric data (NCEP-DOE Reanalysis 2):

- 1979 onwards, 2.5 degree grid coverage, daily
- Geopotential heights: 500hPa, 850hPa, 1000hPa
  - Spatial scale: 35°N to 65°N, 30°W to 45°E
  - Anomalised: $A(i,t) = (P_i - P_{min,t}) / (P_{max,t} - P_{min,t})$
  - PCA transformed to 14 principal components, explaining >95% variance
- Regional climate variables (extent: Lower Saxony)
  - 2m daily temp. / seasonal temp. anomaly
  - 10m V-wind, U-wind
  - Daily max convective available potential energy
  - 2m specific humidity
  - Relative humidity at selected pressure level
  - Precipitable water
- All fields PCA transformed, scaled and centered

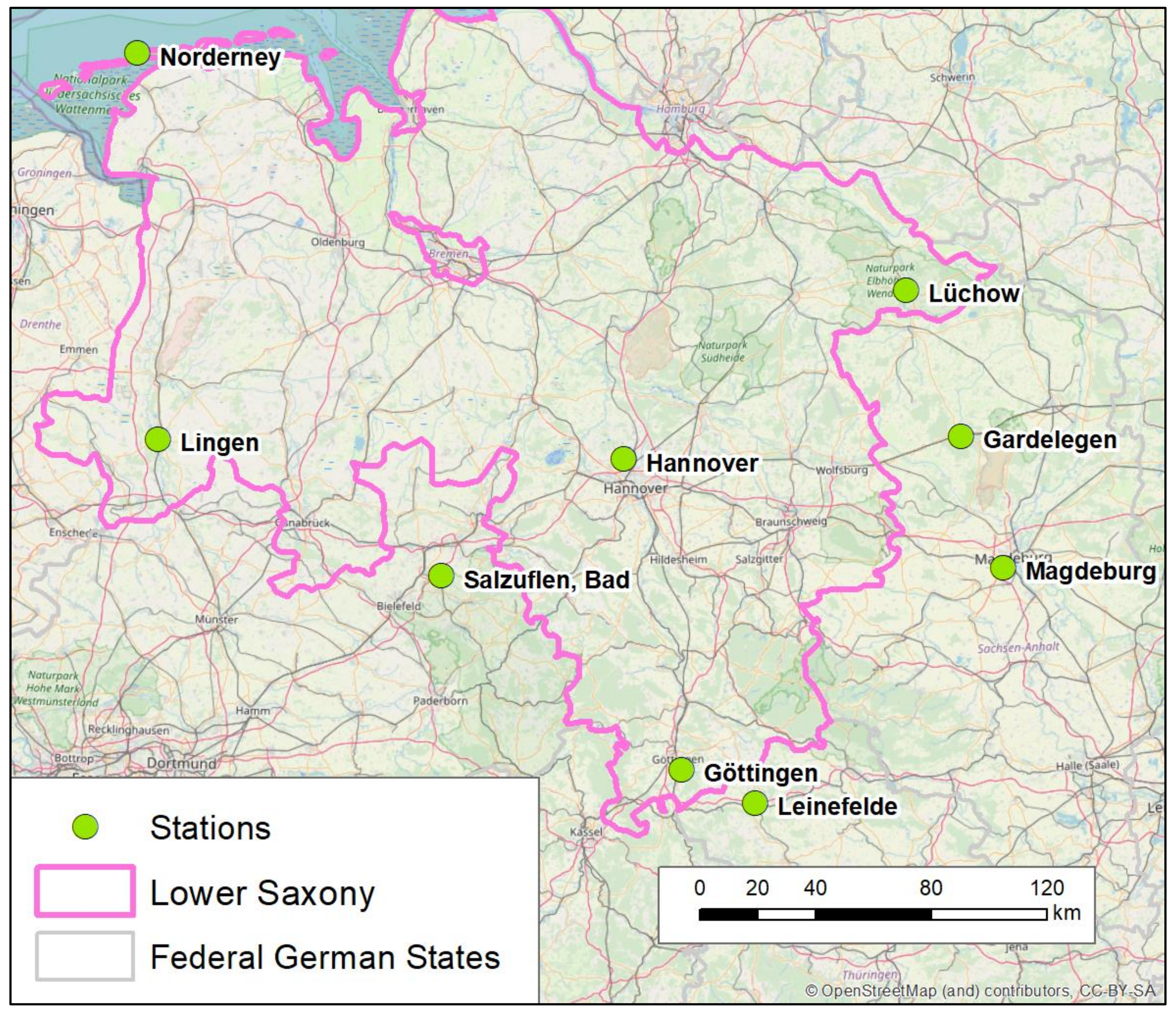

Figure 1: Study area outlining rain gauge locations (N=9)

3. Methodology

A: Stochastic Precipitation Model (hourly timestep)

- **Alternating Renewal Model** (Callau, Haberlandt 2017)
- Model describes rainfall as series of independent wet and dry spells.
- External structure: wet spell amount/duration, dry spell duration
- Internal structure: distribution of rainfall within wet spell

B: CP Classification (daily timestep)

- **Automated objective fuzzy based** classification (Bardossy et al. 2002)
- Simulated annealing (SA) optimisation to assign 'best' fuzzy rules
- A **fuzzy rule** is a set of **membership functions**, which describes the state of each input variable: very low, low, high, very high, not relevant
- The SA objective function favours **divergent CPs** (wetter/drier)
- The fuzzy rule with the highest **degree of fulfilment** is chosen as the CP
- **Calib. period**: 12/1996 – 11/2006; **Valid. period**: 12/2006 – 11/2016
- **Trialed CP counts**: 4, 6, 8, 10
- CP synthesis for use by precipitation model via first order Markov chain

4. Results and Discussion

- Lower CP counts generally better: shown here N=4, 1000hPa geopotential height
- **Wetness indexes** (Fig. 3) between calib. & valid. periods stable ➔ robust classification
- **Performance of extremes** assessed using an IDF test statistic comparing 50×20 years simulated time series against obs. (20 years) for CP and simpler classifications (Fig. 4)
- **Overall performance** is poorer for most rainfall event variables (Table 1)

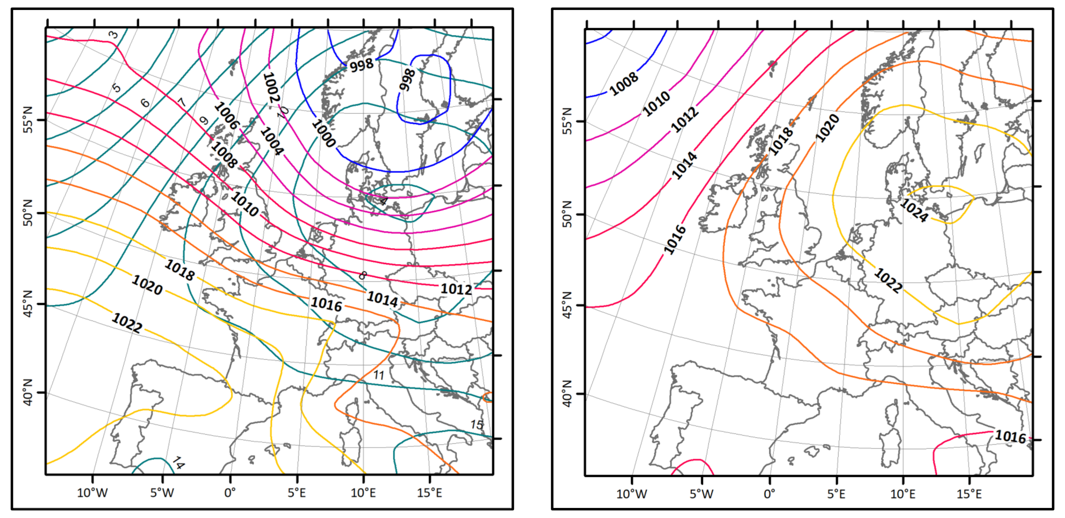

Figure 2: Mean sea level pressure of wettest/driest CP

	Wet Spell Volume	Dry Spell Duration	Wet Spell Duration	Wet Spell Intensity
4 Seasons	0.40	0.40	3.72	0.45
2 Seasons	0.44	0.41	3.66	0.39
Bissolli/Dittmann	0.99	2.31	4.51	2.37
Fuzzy Method	1.28	1.25	3.73	0.91

Table 1: Median Cramer von Mises test statistic for 9 stations 50×20yrs simulated against observed (≈20yrs). Lower is better.

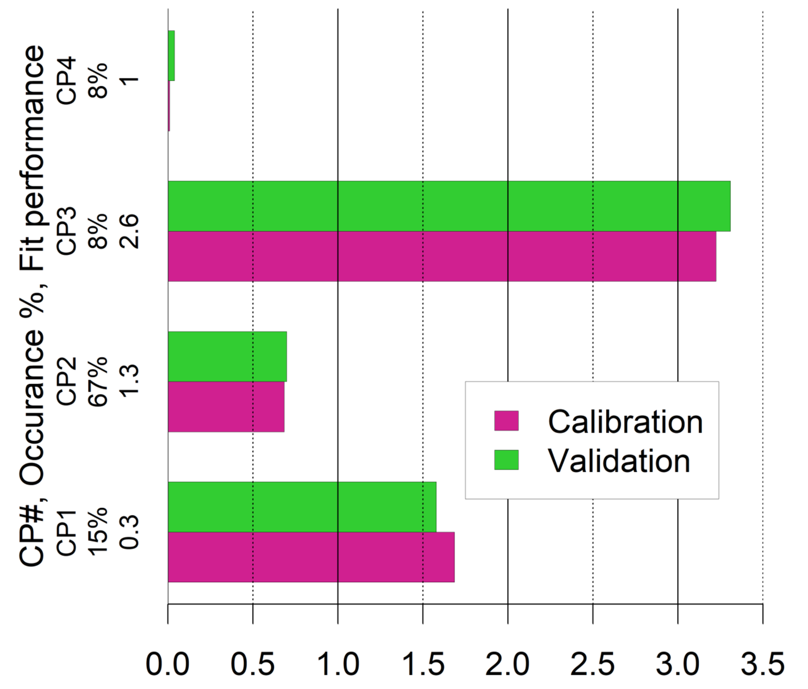

Figure 3: Wetness index of each CP. $Wetness\ index = \bar{P}_{CP}/\bar{P}_{all}$

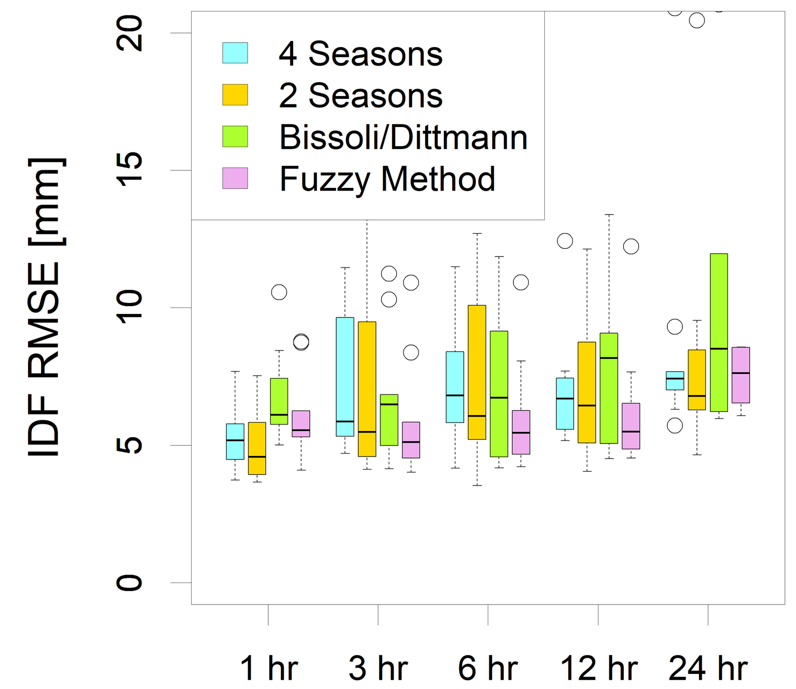

Figure 4: RMSE of IDF quantiles between obs and sim for ARI 2, 5, 10, 20, 9 Stations

5. Conclusions and Outlook

- Addition of further atmospheric variables led to more robust and varied CPs (wetter and drier) 👍
- Generally better representation of extreme events 👍
- Overall precipitation model performance declined 👎
- Issues due to a mismatch in the temporal resolution between CPs (daily) and precipitation events (hourly, arbitary lengths)

References:
Bárdossy, A.; Stehlík, J.; Caspary, H. J. (2002): Automated objective classification of daily circulation patterns for precipitation and temperature downscaling based on optimized fuzzy rules. In Clim. Res. 23, pp. 11–22.
Callau Poduje, A. C.; Haberlandt, U. (2017): Short time step continuous rainfall modeling and simulation of extreme events. In Journal of Hydrology 552, pp. 182–197.

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