Rainfall disaggregation for hydrological modeling: Is there a need for spatial consistence?

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1 Motivation & Objectives

- **High-resolution rainfall** time series are crucial for rainfall-runoff modeling
- Observed time series: **too short** for many applications, **low network density** (contrary to non-recording stations)
- Aim: **Spatio-temporal disaggregation** of daily rainfall time series **for rainfall-runoff modeling**

2 Study Area & Data

- German federal state of **Lower Saxony**
- **3 catchments** with different landuses, soil types, elevations and areas (Fig. 1)
- **1-2 recording stations** per catchment
  → time series length up to 20 y
- **3-8 non-recording stations** per catchment
  → time series length 9 – 20 y
- Discharge data:
  a) **hourly time series**
  → time series length 9 – 13 y
  b) **Monthly extreme values**
  → data sets covering 14 – 53 y

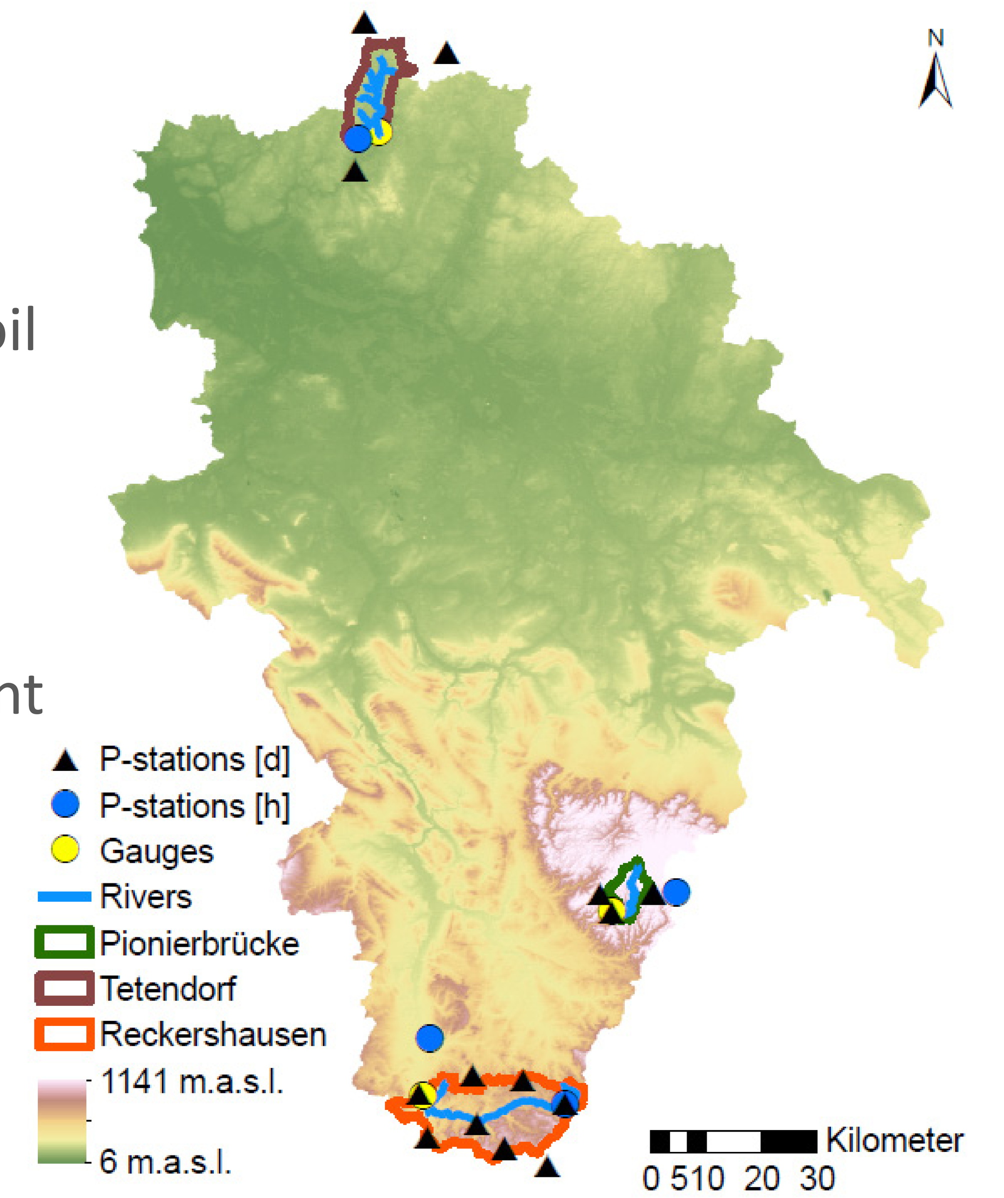

Figure 1: Aller-Leine-watershed with the investigated catchments and applied gauges

3 Rainfall disaggregation

- Disaggregation with a **multiplicative cascade model** after Müller and Haberlandt (2015) (Fig. 2)
- **Point results** for the disaggregated time series are **promising** (Table 1, Fig. 3)

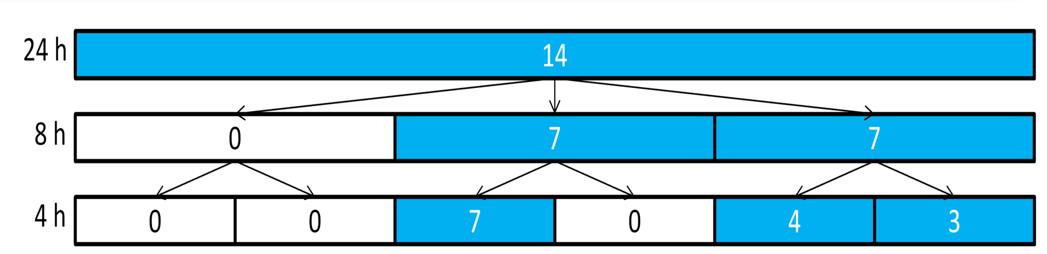

Figure 2: Scheme of the cascade model (branching with b=2 is applied for further disaggregation steps)

Table 1: Comparison of generated and observed rainfall characteristics using the relative error (Müller and Haberlandt, 2015)

Rainfall characteristic	Relative Error [%]
Wet spell duration [h]	-12
Wet spell amount [mm]	-9
Dry spell duration [h]	-6
Fraction of dry intervals [%]	-3
Average intensity [mm/h]	4

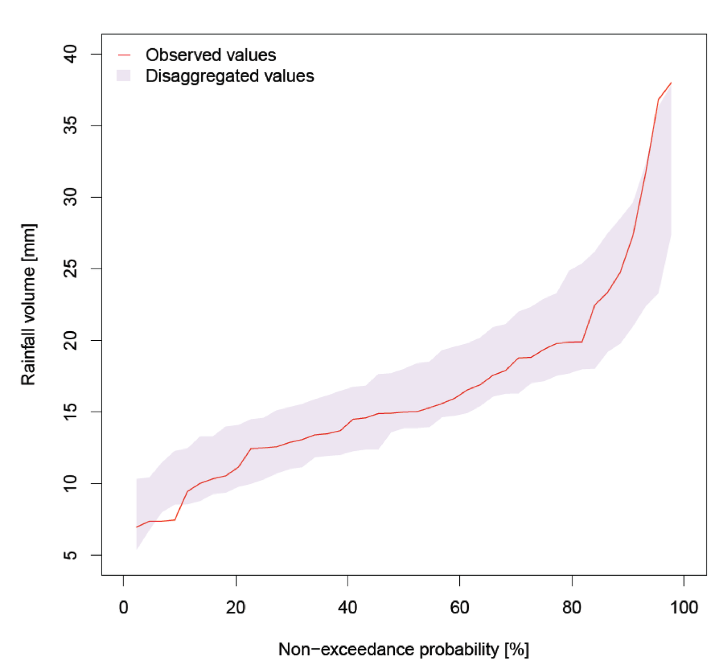

Figure 3: Non-exceedance curve of rainfall extremes with empirical probabilities for station Goettingen, shaded area represents enveloping curves of all 80 realizations

4 Spatial consistence: Implementation and effects on rainfall

- **Spatial consistence** can be represented by **bivariate characteristics** (Müller and Haberlandt, 2016)

  For pairs of station k and l:

  → Probability of occurence: $P_{k,l}(z_k > 0 \mid z_l > 0) \approx \frac{n_{11}}{n}$

  → Continuity ratio: $C_{k,l} = \frac{E(z_k \mid z_k > 0, z_l = 0)}{E(z_k \mid z_k > 0, z_l > 0)}$

  → Correlation coefficient: $\rho_{k,l} = \frac{cov(z_k, z_l)}{\sqrt{var(z_k) \times var(z_l)}}$

  (for $z_k, z_l > 0$)

- **V1: Disaggregated** time series underestimate spatial consistence
- **V2: Simulated Annealing** as a **resampling algorithm** is used for the **implementation** of spatial consistence

  Aim? Reconstruct the bivariate characteristics

  How to? Swapping of relative diurnal cycles

- **V3: Parallelization as alternative:** Diurnal cycle of the station with highest daily rainfall amount is transferred to all other stations

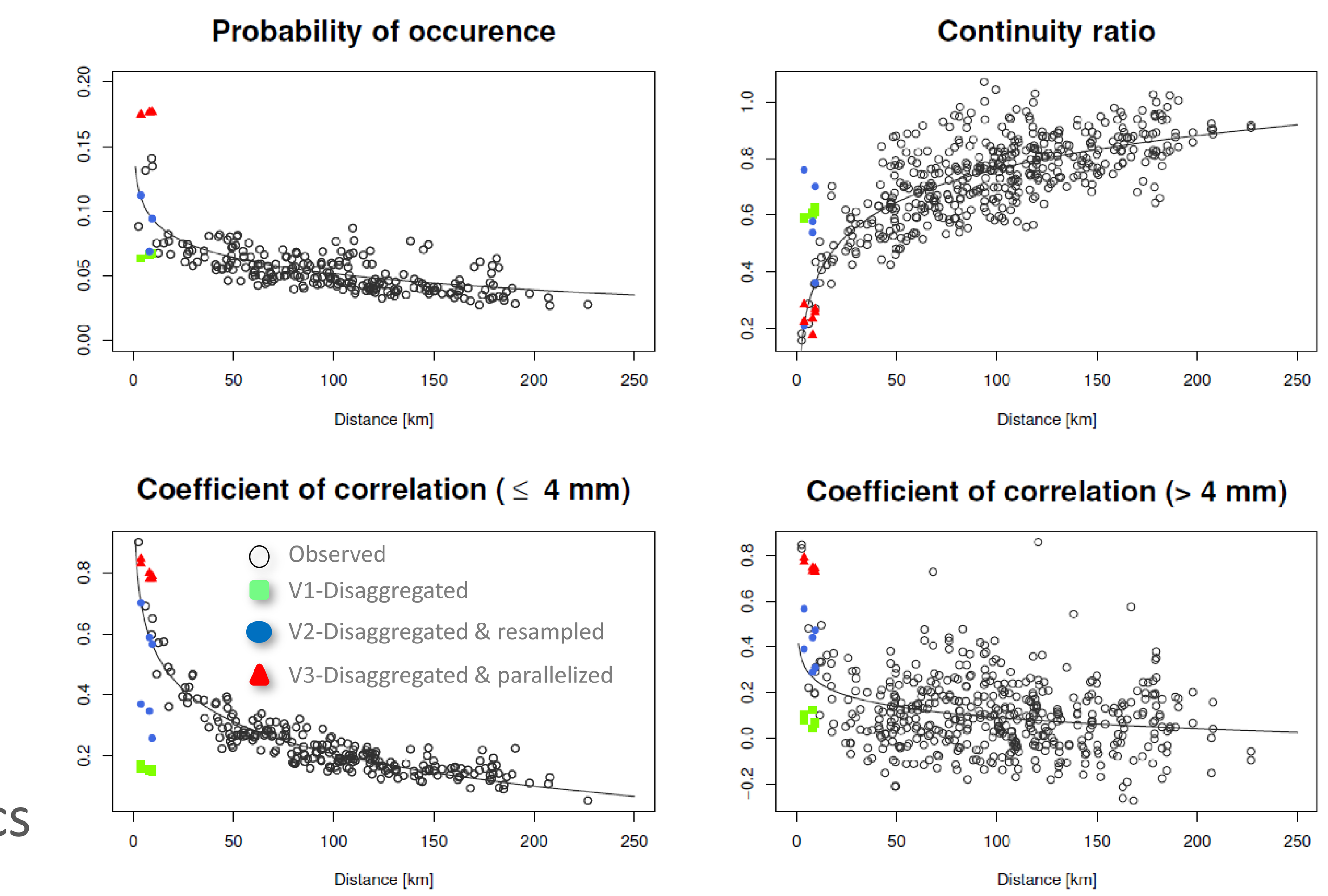

Figure 4: Comparison of distance-dependent bivariate characteristics

5 Rainfall-runoff model

- Models were set up in **HBV-IWW**, **continuous** simulations
- **Calibration** on summer and winter extremes, flow duration curve and monthly average discharge

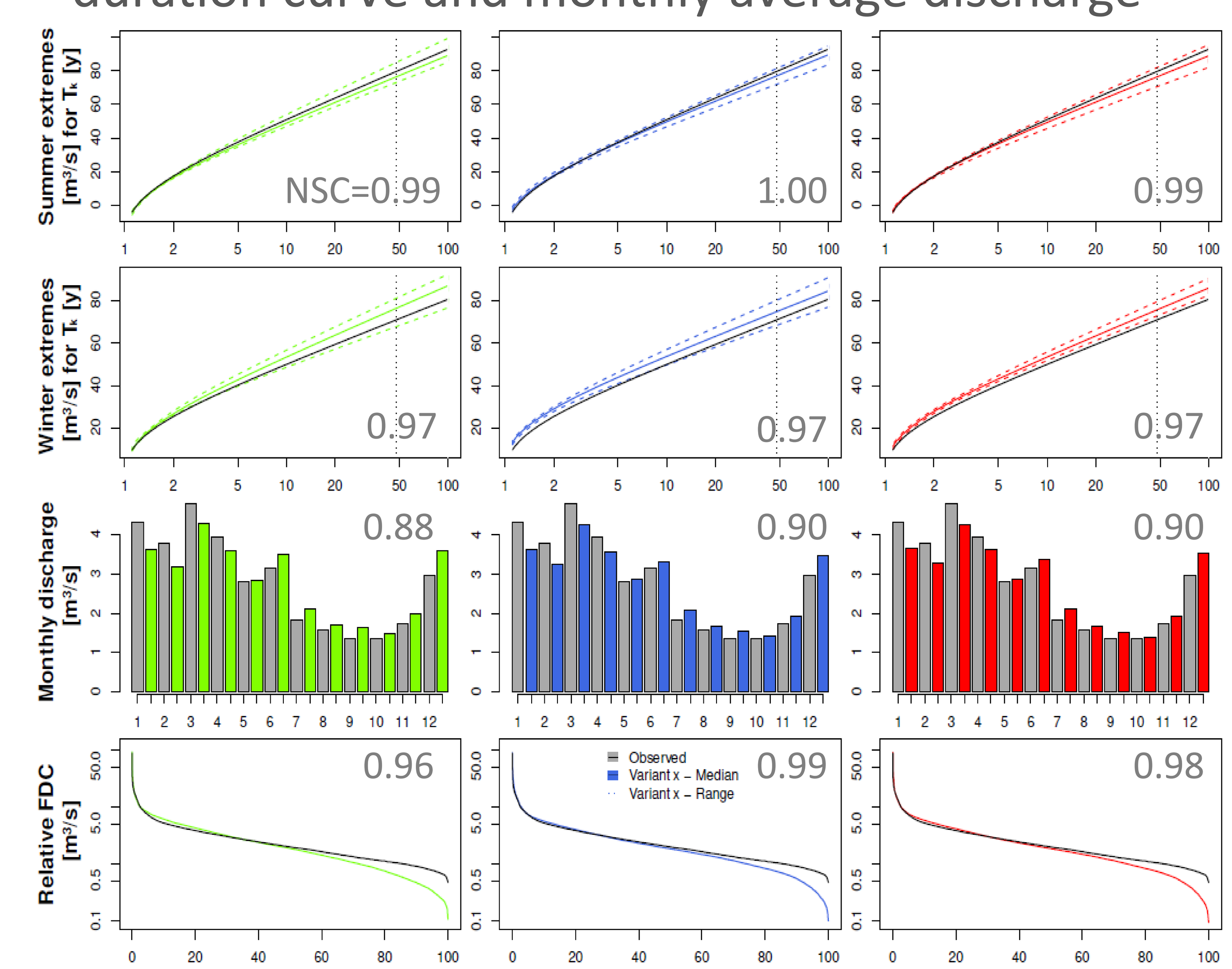

Figure 5: Simulation results of the calibration period for Reckers-hausen for all analyzed flow statistics. The value corresponds to the Nash-Sutcliff-criterion for each flow statistic

- Varying **station densities, uncalibrated** runs & an **alternative model** lead to **comparable similarities** between V1, V2 & V3

6 Conclusions & Outlook

- 3 variants of spatial consistence are tested
- Spatial rainfall consistence is:
  - underestimated, if no subsequent methods are applied after disaggregation,
  - overestimated by the parallelization,
  - best represented by the resampling.
- Simulated runoff time series show no significant differences regarding flow statistics
- Disaggregated time series lead to good representation of flow statistics

⇨ Spatial consistence can be improved

⇨ Interaction of spatial rainfall and simulated runoff has to be explored

References

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