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Climate projection of rainfall series for design and analysis of urban drainage systems

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Abstract

A novel method to develop continuous rainfall series for urban drainage system design and analysis is proposed, evaluated and demonstrated. The method is used to stochastically replicate historical rain series statistically as well as climate project rain series to represent specific climate scenarios and projection times. Continuous climate projected rainfall series are a crucial necessity for designing complex drainage systems and climate adaption solutions robustly for future loading as well as evaluating impacts of climate changes on the urban hydrological cycle.

Motivation and objectives

The series can be used as an alternative to urban drainage design and planning design using IDF-curves or design storms. Using continuous rain series as inputs to urban drainage models, it is possible to simulate the system response and relate the response to return periods of exceeding critical levels rather than return periods of the rain.

The main objectives of the project (KLIMAKS) is to develop and demonstrate application of continuous historical and climate projected rain series, which can be applied to:

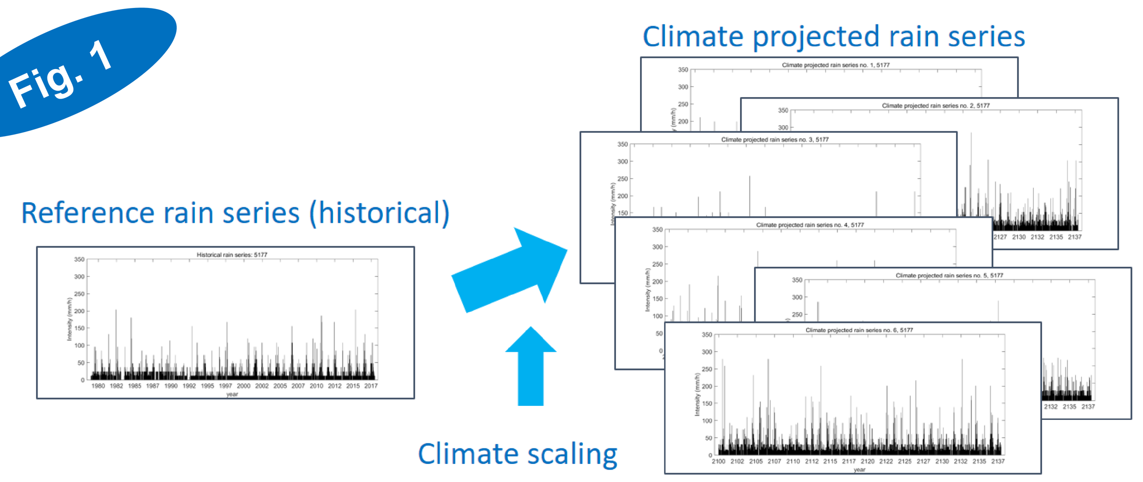
1. model the complete urban hydrological cycle (e.g. including the interaction between drainage system and watercourses, infiltration excess overland flow processes, ground water infiltration to drainage system, etc.)
2. model multiple function levels such as:
   - every-day rainfall (relevant for storm water pond filling, combined sewer overflow estimation, real-time operation and control of waste water systems and treatment plants, etc.),
   - design situations that corresponds to full capacity utilization (e.g. surcharging to critical levels with specific return periods),
   - extreme situations where system capacity is exceeded and the aim is either to investigate potential flood damage or to design adaption solutions to minimize flood damages.

In this poster, we focus on stochastic generation and evaluation of rain series and stormwater detention pond design using the developed series. More details on the evaluation of rain series in urban drainage models can be found in [2].

Tab. 1

Target climate variable	Notation	RCP 4.5		RCP 8.5	
		Mean	SD	Mean	SD
Annual precipitation	ap (mm)	1.07	0.10	1.14	0.09
Seasonal precipitation, winter	spwi (mm)	1.12	0.11	1.24	0.13
Seasonal precipitation, spring	spsp (mm)	1.12	0.11	1.20	0.13
Seasonal precipitation, summer	spsu (mm)	1.05	0.20	0.98	0.23
Seasonal precipitation, autumn	spau (mm)	1.04	0.09	1.10	0.13
Annual number of events above 10 mm per day	n10mm (#)	1.15	0.18	1.29	0.13
Annual number of events above 20 mm per day	n20mm (#)	1.31	0.33	1.61	0.31
Annual Maximum daily precipitation	mdp (mm)	1.13	0.11	1.23	0.16
Annual Maximum 5-day precipitation	m5dp (mm)	1.09	0.10	1.18	0.11
Rain intensity for 10 min, T=2 years	d10T2 (mm/h)	1.18	0.16	1.31	0.20
Rain intensity for 10 min, T=10 years	d10T10 (mm/h)	1.23	0.20	1.38	0.29
Rain intensity for 60 min, T=2 years	d60T2 (mm/h)	1.18	0.16	1.31	0.20
Rain intensity for 60 min, T=10 years	d60T10 (mm/h)	1.23	0.20	1.38	0.29
Rain intensity for 360 min, T=2 years	d360T2 (mm/h)	1.18	0.16	1.31	0.20
Rain intensity for 360 min, T=10 years	d360T10 (mm/h)	1.23	0.20	1.38	0.29

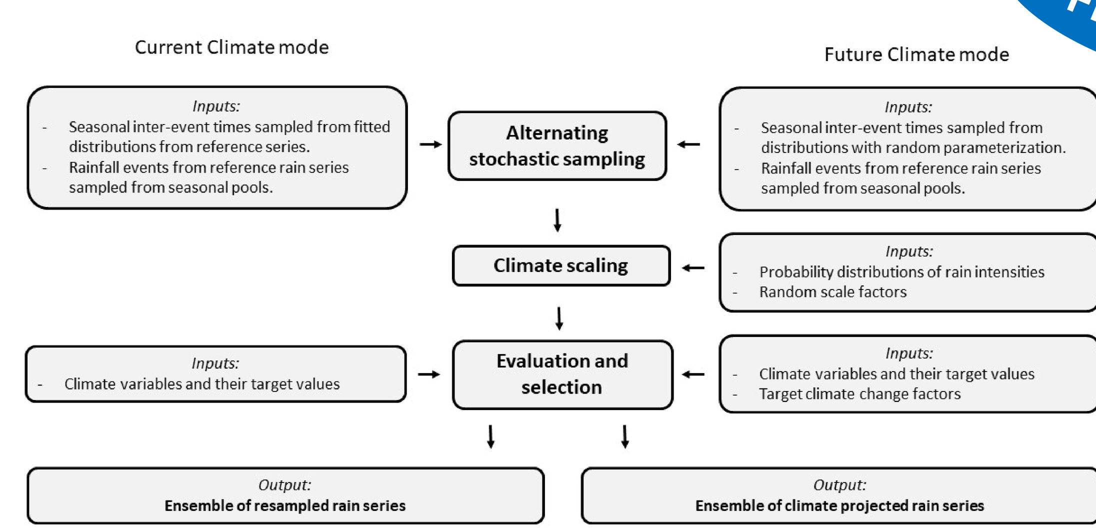
Fig. 1



Stochastic sampling and climate projection

Rain series are stochastically generated to represent the current climate (1980-2010) and climate scenarios RCP 4.5 and 8.5 in 2070-2100. Individual rain events are sampled from a reference time series season by season and scaled to represent changes in rainfall intensity. The time between events is sampled from a two-component exponential distribution to represent a change in the time between events in the future climate. The overall concept is to generate a large ensemble of rain series and evaluate them against a number of different climate variables (Tab. 1). The procedure is described in Fig. 2 and more details can be found in [1] and [3].

Fig. 2



For each climate scenario, the top 100 rain series with the lowest weighted errors between climate parameter target and realization are selected for further analysis. The results are show in fig. 4 as boxplots for annual precipitation, seasonal precipitation, extremes and the three climate scenarios. The boxplots illustrate aggregated results of all realizations and the boxplot variability therefore represent both the year-to-year variability as well as the uncertainty related to climate projection.

Fig. 3 shows IDF curves for each climate scenario.

Fig. 3

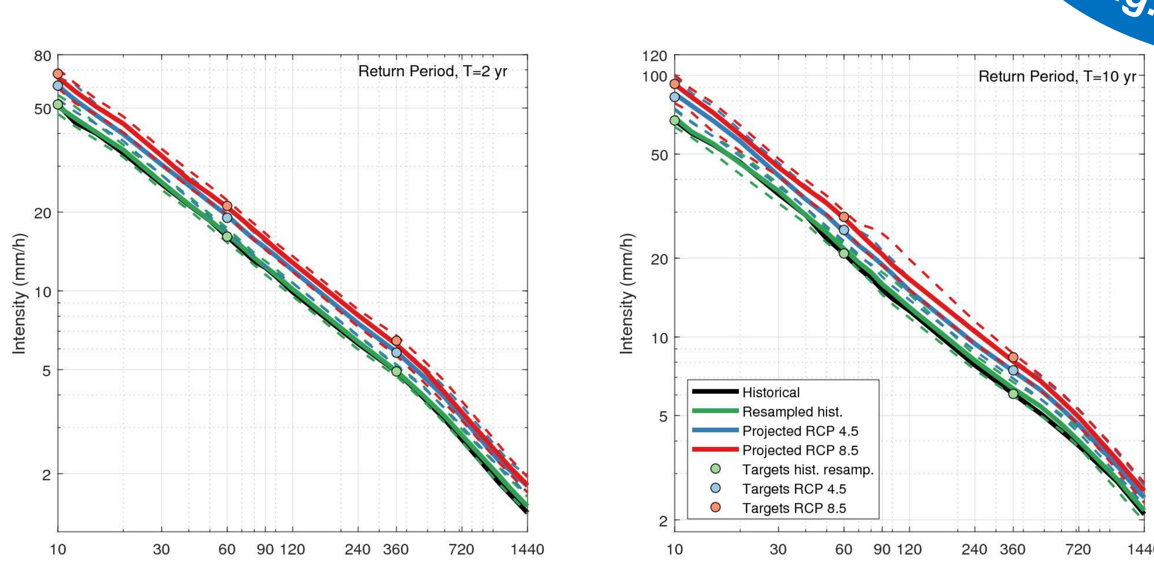
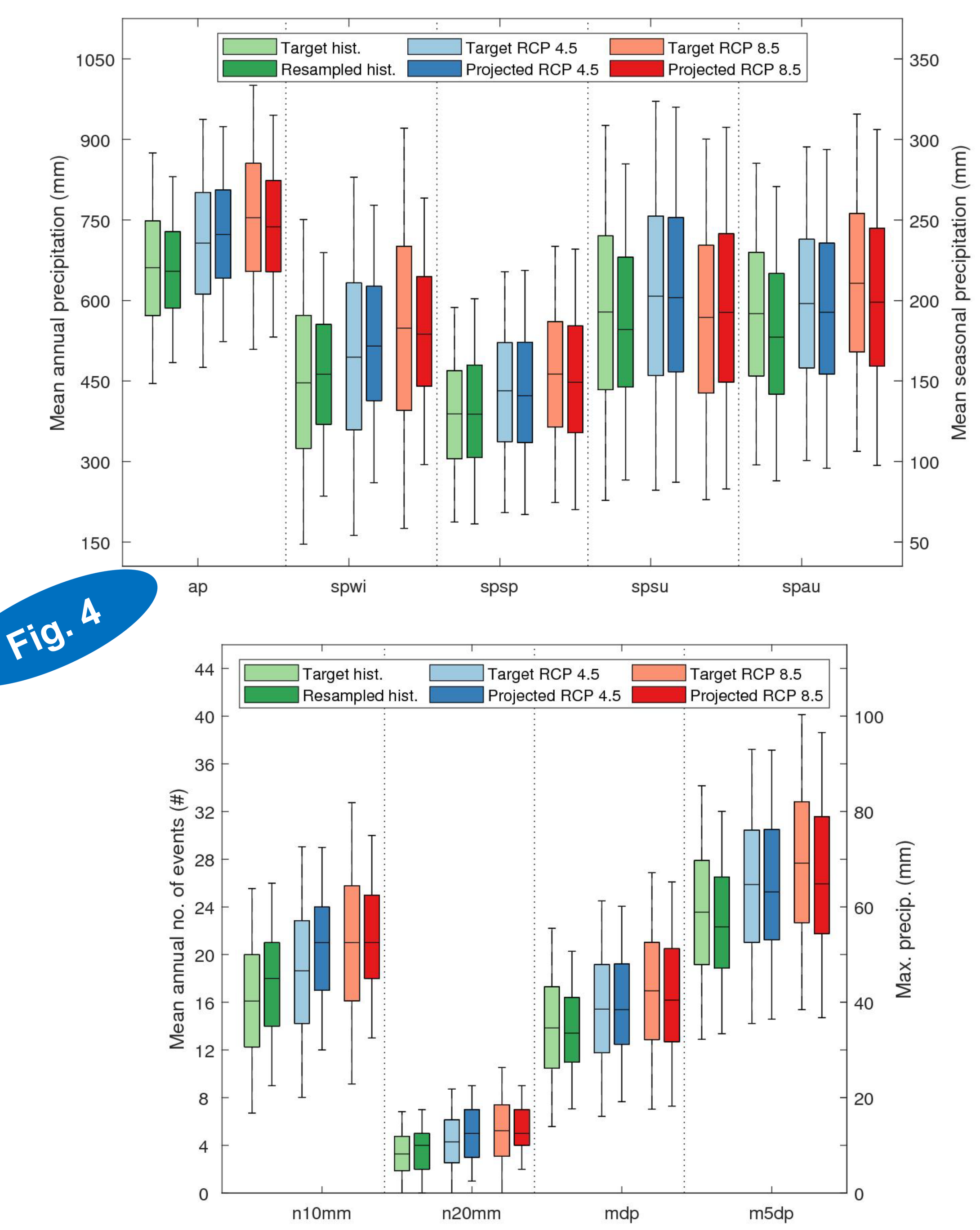


Fig. 4

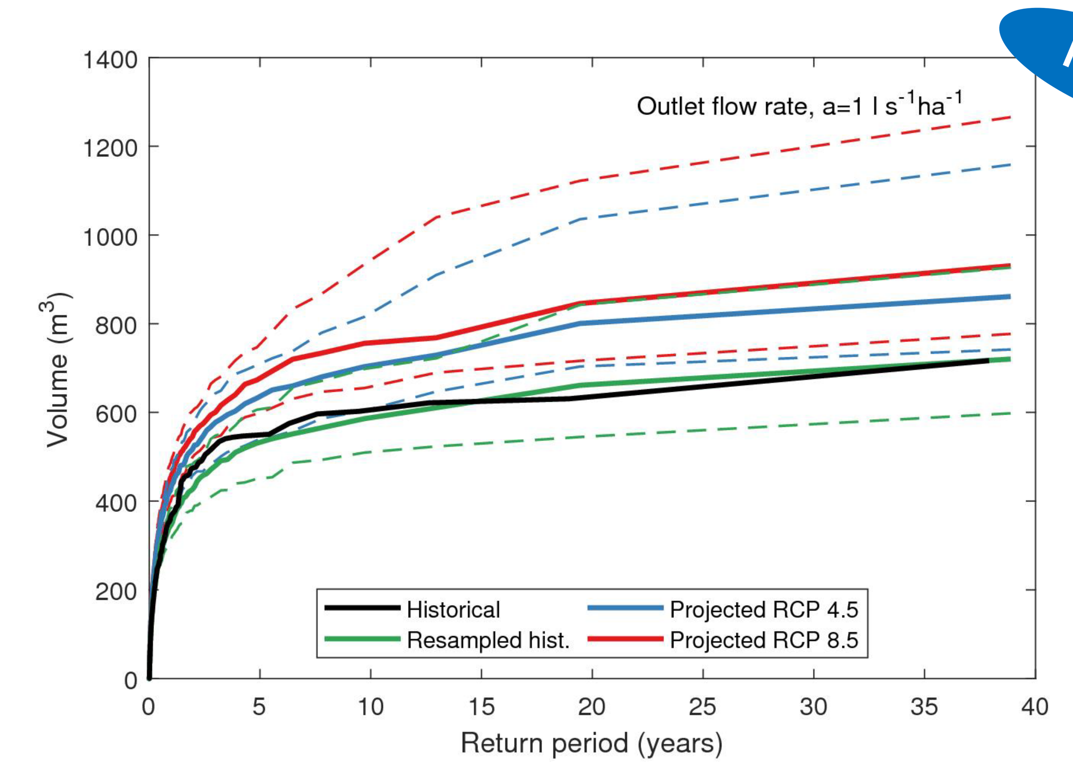


Design of stormwater ponds

The generated rain series are applied for simple design of storm water detention ponds with different outlet flow rates for a connected catchment area of 1 ha. The procedure serves the purpose to investigate the variability between the accepted realizations in each climate scenario ensemble and to explore differences in design volumes depending on the design parameters and choice of the climate scenario.

Fig. 5 shows design volumes as function of return period for a fixed outlet flow rate of 1 l/s/ha. Fig. 6 shows volumes with outlet flow rates of 0.5, 1.0 and 5.0 l/s/ha for a 5-year return period.

Fig. 5



The difference in required storage volumes between current climate and future climate scenarios are shown in fig. 7 as function of outlet flow rate. The fact that RCP 8.5 has larger intensities but longer drought periods between rain events works in favor of smaller outlet flow rates.

Fig. 6

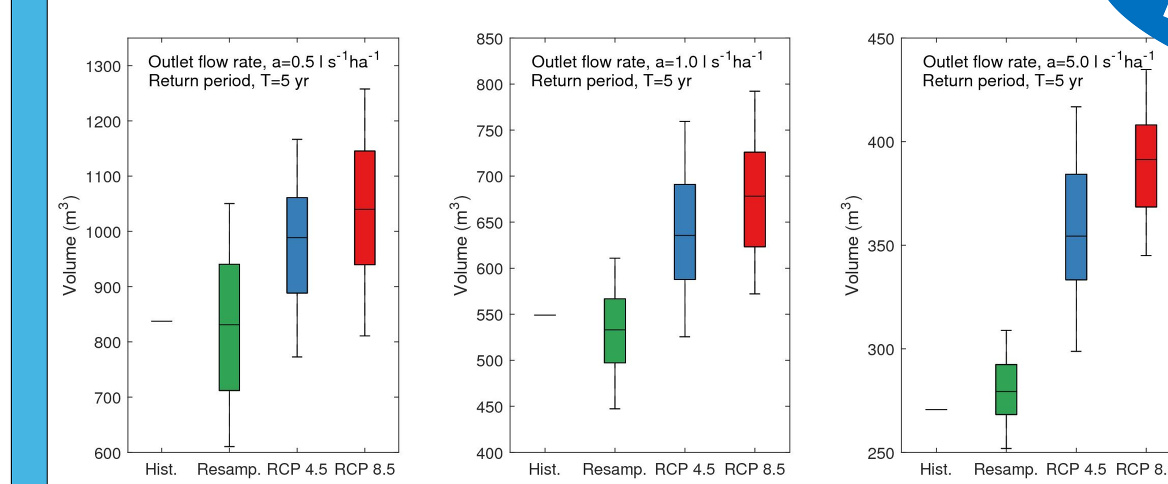
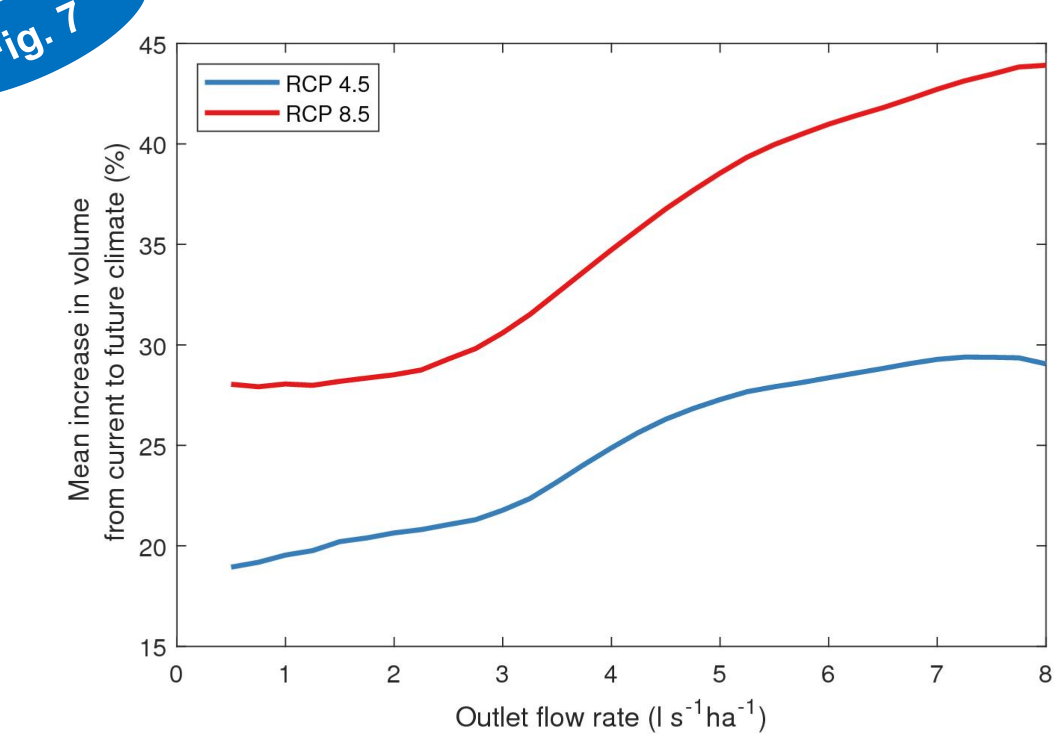


Fig. 7



Conclusion

- We can generate series that represent RCP 4.5 and 8.5 in the year 2100.
- We show how rain series can be applied to the design of stormwater detention ponds.
- There are large uncertainties in climate projections, which gives large variability between generated series. An ensemble of rain series is therefore recommended for application.
- The stormwater pond design showcases the importance of applying continuous rain series which include changes in multiple climate parameters and not only the extreme rainfall.

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