UNIKASSEL VERSITÄT | CIVIL AND ENVIRONMENTAL ENGINEERING

Modelling runoff generation of a small catchment in the context of climate change by using an ensemble of different climate model outputs and bias correction methods

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Introduction

Due to climate change, meteorological extremes affected the environment and our society in the past decades. The change in meteorological conditions also affects the water balance and thus runoff generation processes. The aim of this work was to estimate this future change for a small low-mountain catchment in central Germany using climate projections and hydrological modelling. The considered catchment area covers 54 km^2 and is largely covered by forest (60 %) and agriculture (25 %). The following research questions are part of the displayed project :

- How does the total discharge and the runoff components change in the future?
- How well does the bias correction methods perform?
- How much do the climate and hydrological projections scatter?

Discharge Modelling

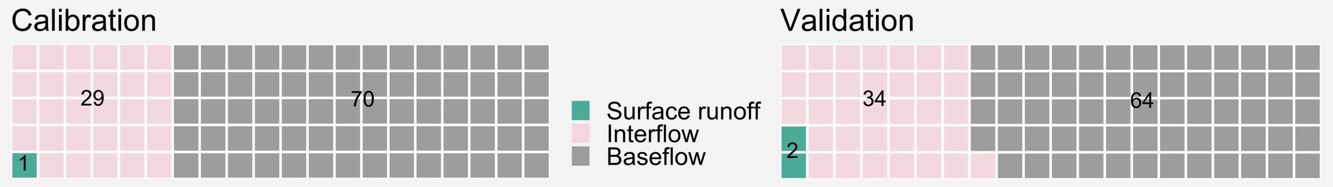
Methods

- Discharge simulation using HBV Light
- Calibration using GAP-Optimization (5000 Model runs)
- Split-Sample-Validation (Calibration: 2010 - 2016, Validation 2017 - 2018)

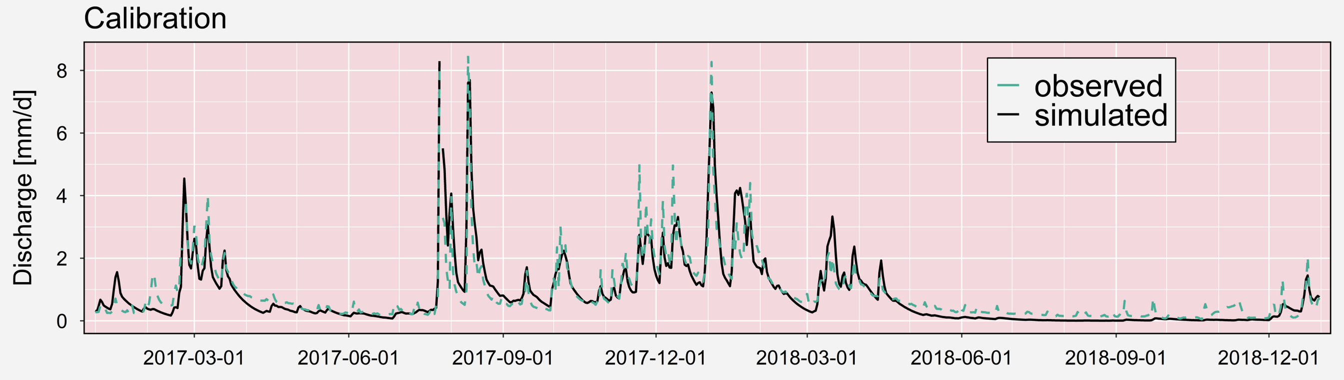
Results & Conclusions

- ▶ Calibration Nash-Sutcliffe efficiency 0.86
- ▶ Validation Nash-Sutcliffe efficiency 0.83

Discharge proportions



Hydrograph of the validation period



- ▶ Most of the discharge is generated by the baseflow
- ▶ Baseflow is underestimated by the model due to calibration by Nash-Sutcliffe efficiency
- ▶ Surface runoff can only be represented to a limited extent by the conceptual model HBV Light

Climate Data

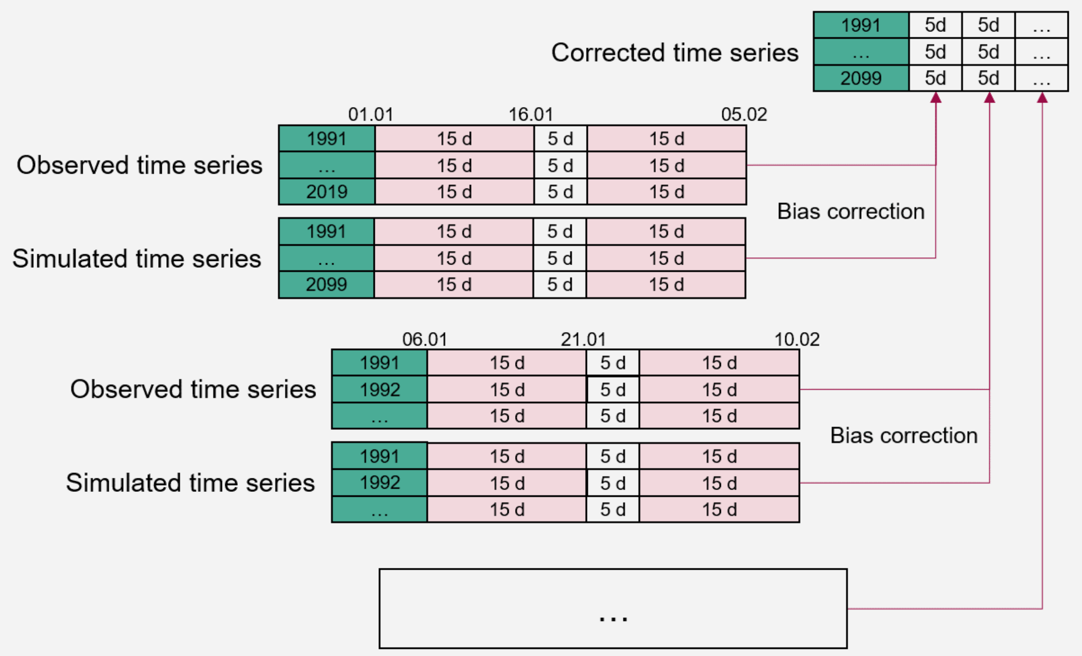
Method

- RCP8.5 scenario also known as worst case scenario
- EURO CORDEX Data:
  (timescale: daily, spatial scale: 0.11° ~ 12.5 km)
- Ensemble of 7 climate model outputs
- Calculation of the potential evapotranspiration using the formula according to Turc and the uncorrected CORDEX variables rsds, tas, hurs, huss and ps
- Validation and Calibration of the bias correction on the same time window (1991 - 2018)
- Validation of the bias correction by means of two different time series (7-day moving average method and empirical cumulated distribution functions) and three quality measures (NSE, pBias, MAE)
- Scoring of bias correction methods followed by ranking in twelve sub-categories resulting from the combination of quality measures, time series and seasonal/annual review
- Comparison of three different periods with the reference period 2009 - 2018
  - T1 2020 - 2040
  - T2 2050 - 2070
  - T3 2080 - 2099

Bias correction methods used

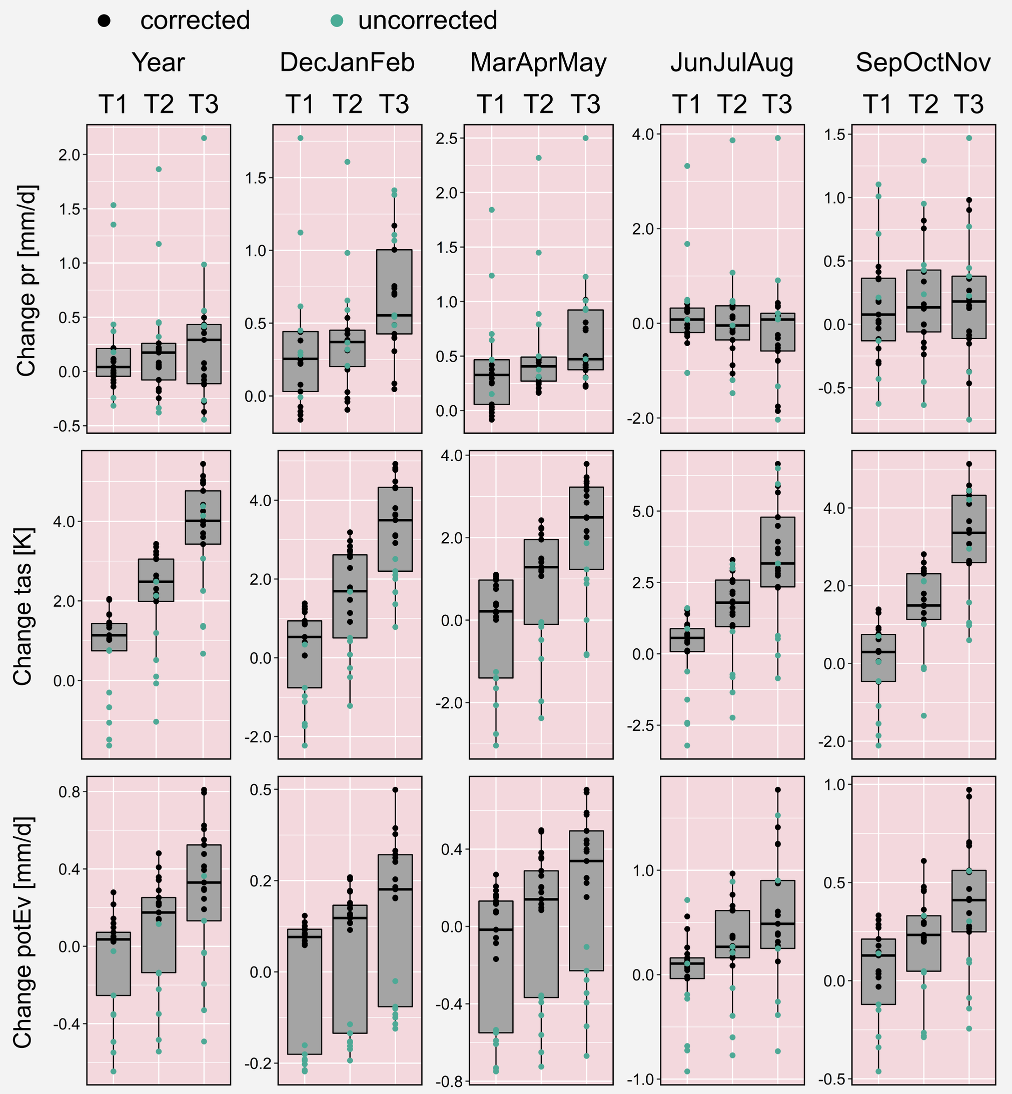
Precipitation pr	Temperature tas	Potential Evapotranspiration potEv
Linear Scaling Multi. Quantile Mapping Distribution Mapping Power Transformation	Linear Scaling Add. Quantile Mapping Distribution Mapping Variance Scaling	Linear Scaling Add. Linear Scaling Multi. Quantile Mapping

Bias correction using moving window



Results & Conclusions

- ▶ Two best performing bias correction methods:
  - pr: Power Transformation, Quantile Mapping
  - tas: Quantile Mapping, Linear Scaling Add.
  - potEv: Linear Scaling Add., Quantile Mapping
- ▶ The uncorrected data deviates strongly from corrected data and produces a large part of the scattering
- ▶ The change in temperature and potential evapotranspiration is underestimated by the raw data
- ▶ The scattering of the prognosis of potential evapotranspiration is, except for the summer months (in these months the calculation is dominated by temperature), greater than the scattering of temperature due to the inclusion of different climatic variables in the calculation
- ▶ climate ensemble trends:
  - increase in precipitation on an annual basis until the end of the century, produced by an increase in winter and spring
  - increase in temperature and potential evapotranspiration in all seasons and so on an annual basis too



Hydrological Projection

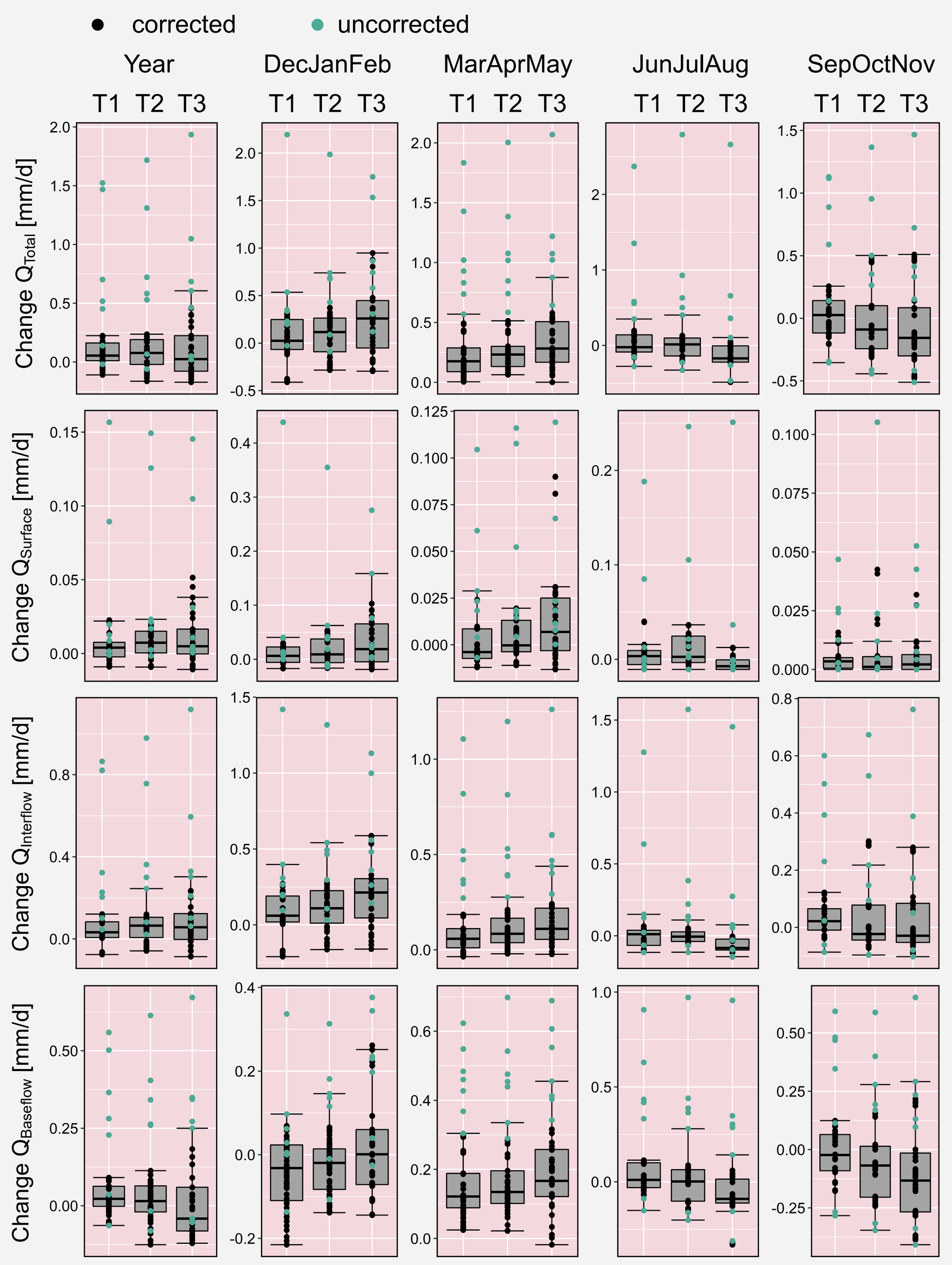
Method

- Parameter setup as previously calibrated (see Discharge Modelling)
- Number of hydrological model runs 63
  - 1 climate change scenario
  - 7 climate model outputs
  - 2 best performing bias correction methods
  - raw data
  - 3 input timeseries for HBV Light

$$N_{Sim} = N_{Sce} \cdot N_{GCM/RCM} \cdot \left(N_{Bias}{}^{N_{Input}} + N_{Raw}{}^{N_{Input}}\right) = 1 \cdot 7 \cdot (2^3 + 1^3) = 63$$

Results & Conclusions

- ▶ No clear trend in annual data can be discerned for the total discharge and for the runoff components
- ▶ Clearer trends can be identified by decomposing the runoff according to seasons and discharge components
- ▶ Winter: Increase in total runoff by the end of the century due to an increase in precipitation and a related increase in interflow, baseflow is projected to decrease by the period T3, but this decrease is shrinking
- ▶ Spring: Increase in total runoff by the end of the century due to increasing precipitation in winter and spring. The increase is due in roughly equal parts to the increase in baseflow and interflow.
- ▶ Summer: The total outflow decreases due to lower baseflow. The decrease can be explained by constant precipitation amount and a strong increase in evapotranspiration.
- ▶ Autumn: Strong decrease in baseflow due to higher temperatures in summer and autumn with only very small increases in precipitation in autumn and constant precipitation in summer. These heat effects are also noticeable in the total outflow, as the interflow also decreases slightly.
- ▶ No trend can be estimated on the basis of surface runoff. There is a tendency for runoff to increase in part, most strongly in winter, but a decrease in surface runoff is hardly possible, since surface runoff is very low in the calibration and validation
- ▶ The major uncertainties generated by the raw climate data are amplified in hydrological modelling (increase of over 300 % in some cases in the next 20 years)



Synthesis

- ▶ The total annual outflow increases till 2070 because of an increase of the outflow in winter and spring.
- ▶ Due to a constant amount of precipitation in summer and autumn with rising evapotranspiration, runoff decreases during this period.
- ▶ Quantile Mapping as a bias correction method performs very well for precipitation, temperature and potential evapotranspiration.
- ▶ The uncorrected data are very scattered and show a different trend before and after the bias correction.