Systemic change in Hydrology

Spatio-temporal parameter variability of the PCR-GLOBWB hydrological model in the Rhine-Meuse basin.

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EGU General Assembly 2020

Vienna | Austria | 3–8 May 2020

What is systemic change?

- Fundamental changes in system behaviour that cannot be represented by a constant model structure or parameterization[1]
- Model parameters change, if calibrated for different periods

- Caused by e.g. land use change, climate change or new reservoirs, if not or only simplified incorporated in the model

Research goals

- Detect systemic change in the Rhine-Meuse basin
  - Between 1901 and 2010
  - PCR-GLOBWB hydrological model
  - By calibrating the model for different periods
- Describe potential causes of systemic change
  - Climate change
  - Land use change
  - River structures

- Contribute to a better understanding of hydrological modelling under changing conditions

Study area

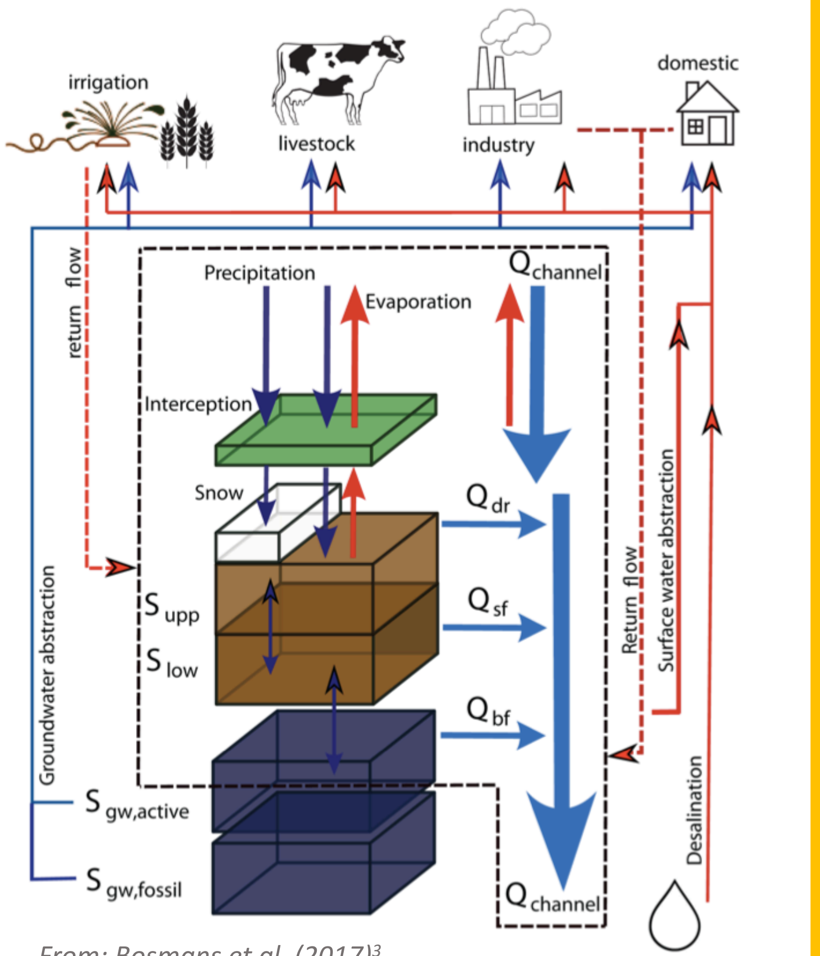
- Rhine-Meuse basin
- 200,000 km^2
- Combined rainfall-snowmelt regime
- Long period of discharge measurements available

- 5 calibration locations:
  - Basel, Maxau, Lobith (Rhine)
  - Cochem (Moselle)
  - Borgharen (Meuse)

Model: PCR-GLOBWB 2.0

- Grid-based global hydrology and water resources model[2]
- Developed by the Department of Physical Geography, Utrecht University, the Netherlands

- 30 arcminutes resolution grid
- Calculates discharge at daily time steps

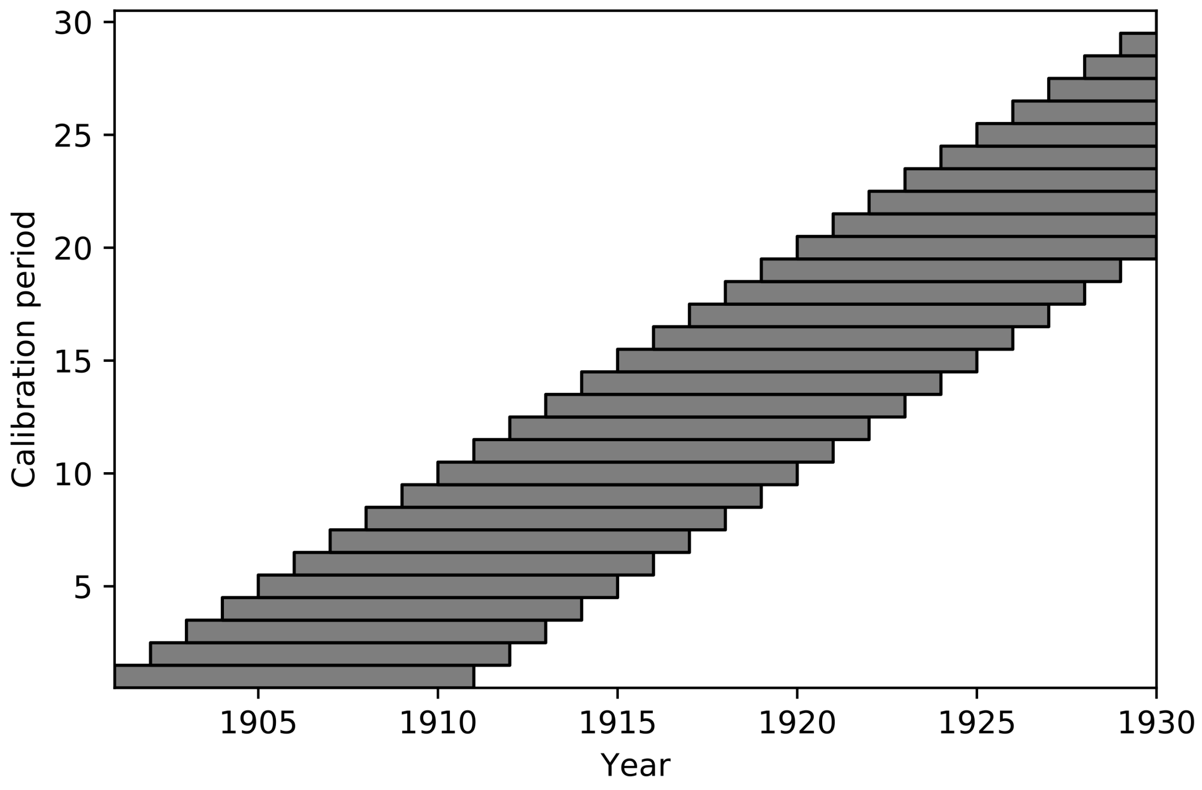


From: Bosmans et al. (2017)[3]

Methods: Detecting systemic change

- Calibrate PCR-GLOBWB for 1901-2010 using 10-year rolling calibration periods
- Determine optimal parameter set for each of these periods

- Calibration parameters
  - Minimum soil depth fraction
  - Saturated hydraulic conductivity
  - Groundwater recession coefficient
  - Degree day factor
  - Manning's n
- Spatial patterns remain constant by using multiplication factors



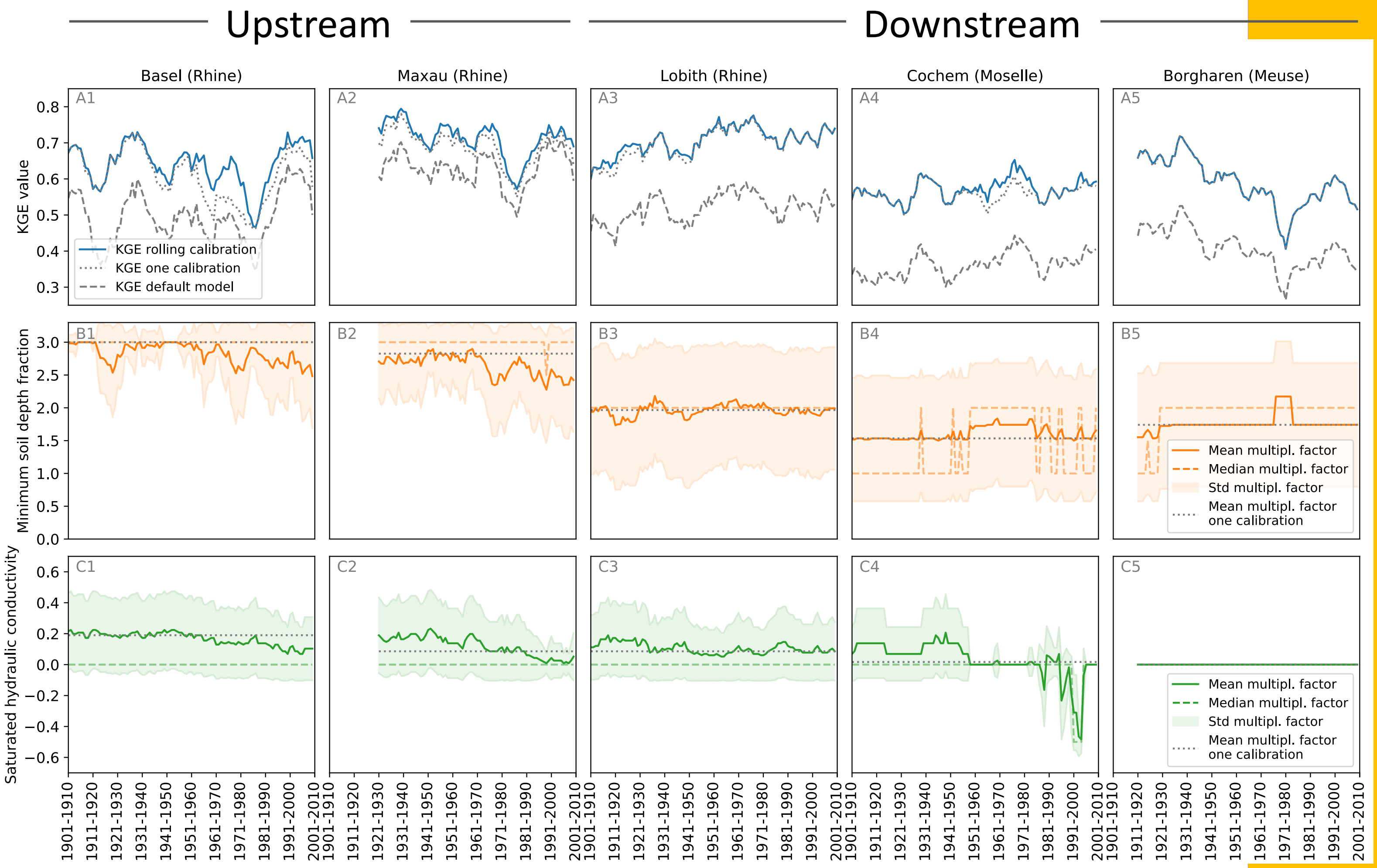
Methods: Potential causes of systemic change

- Compare trends in optimal parameter values with
  - Trends in climatic forcing data: CRU TS 3.2 data[4], downscaled with ERA40[5] and ERA-Interim[6]
  - Land use changes: HYDE 3.2 database[7]
  - River structures: from literature

- For each of the 5 calibration locations, the upstream average values are calculated for different time steps, to include changes in the entire catchment.

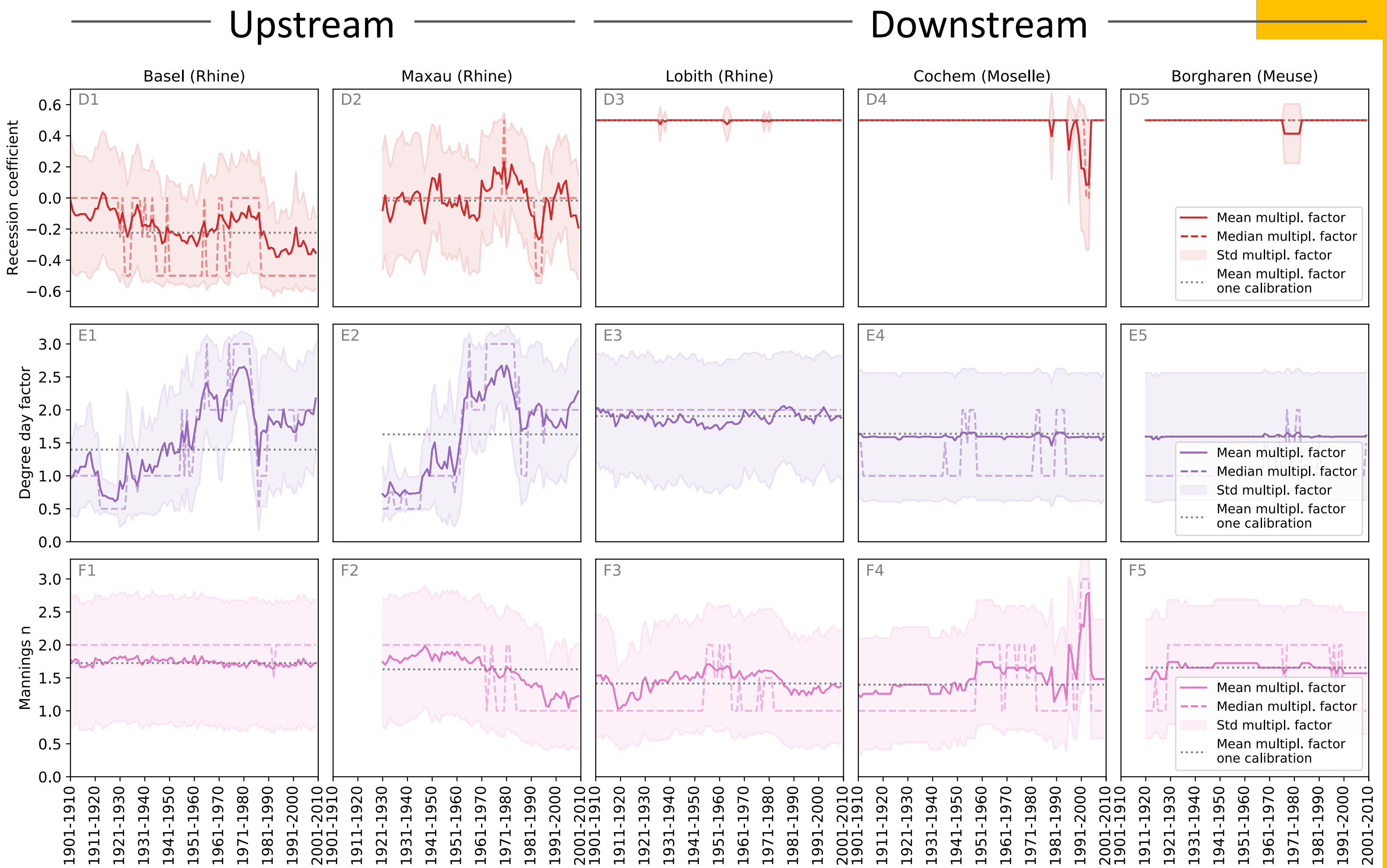
Results of rolling calibration

- Kling-Gupta efficiency (KGE):
  - Higher with a rolling calibration than with one single calibration
- Minimum soil depth fraction:
  - Upstream: decrease
  - Downstream: stable
- Saturated hydraulic conductivity:
  - Upstream: slight decrease
  - Downstream: stable



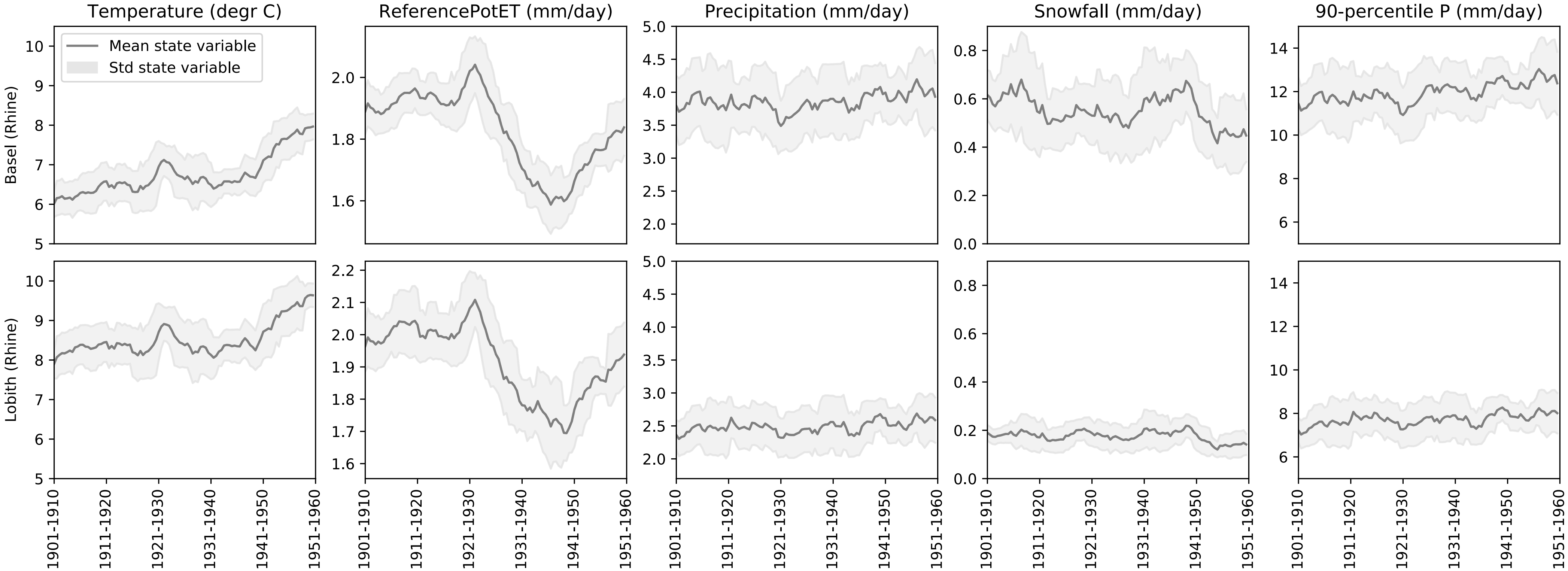
Results of rolling calibration

- Groundwater recession coefficient:
  - Upstream: decrease
  - Downstream: very stable
- Degree day factor:
  - Upstream: increase followed by decrease
  - Downstream: stable
- Manning's n:
  - Upstream: constant at Basel, decrease at Maxau
  - Downstream: some variations

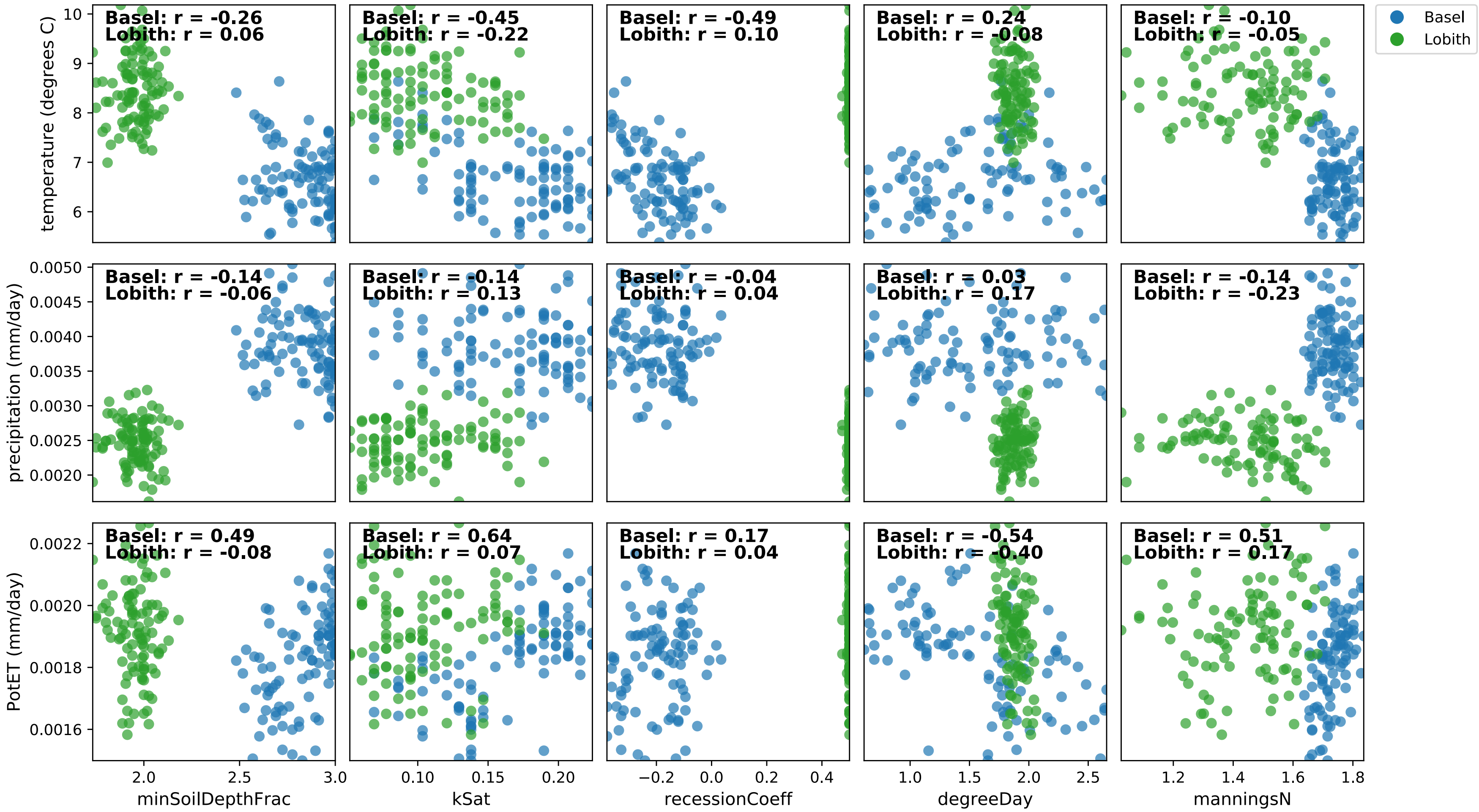


Relations with Climate change

- Changes in climatic input data: upstream averages at Basel and Lobith

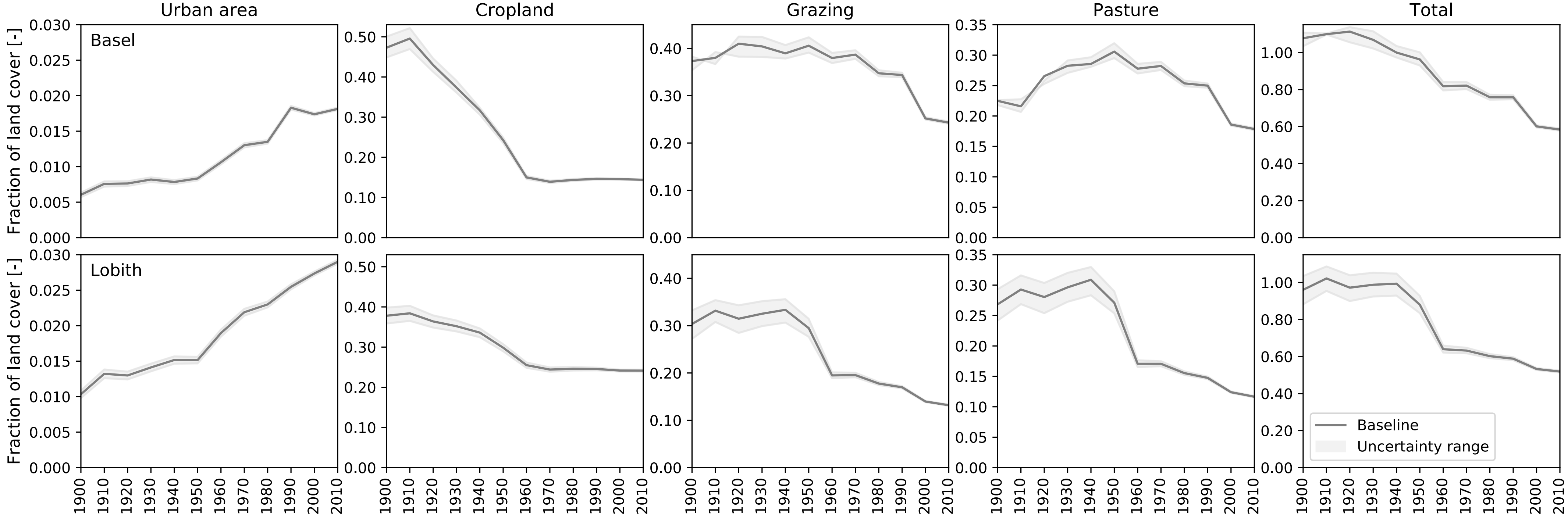


Relations with Climate change

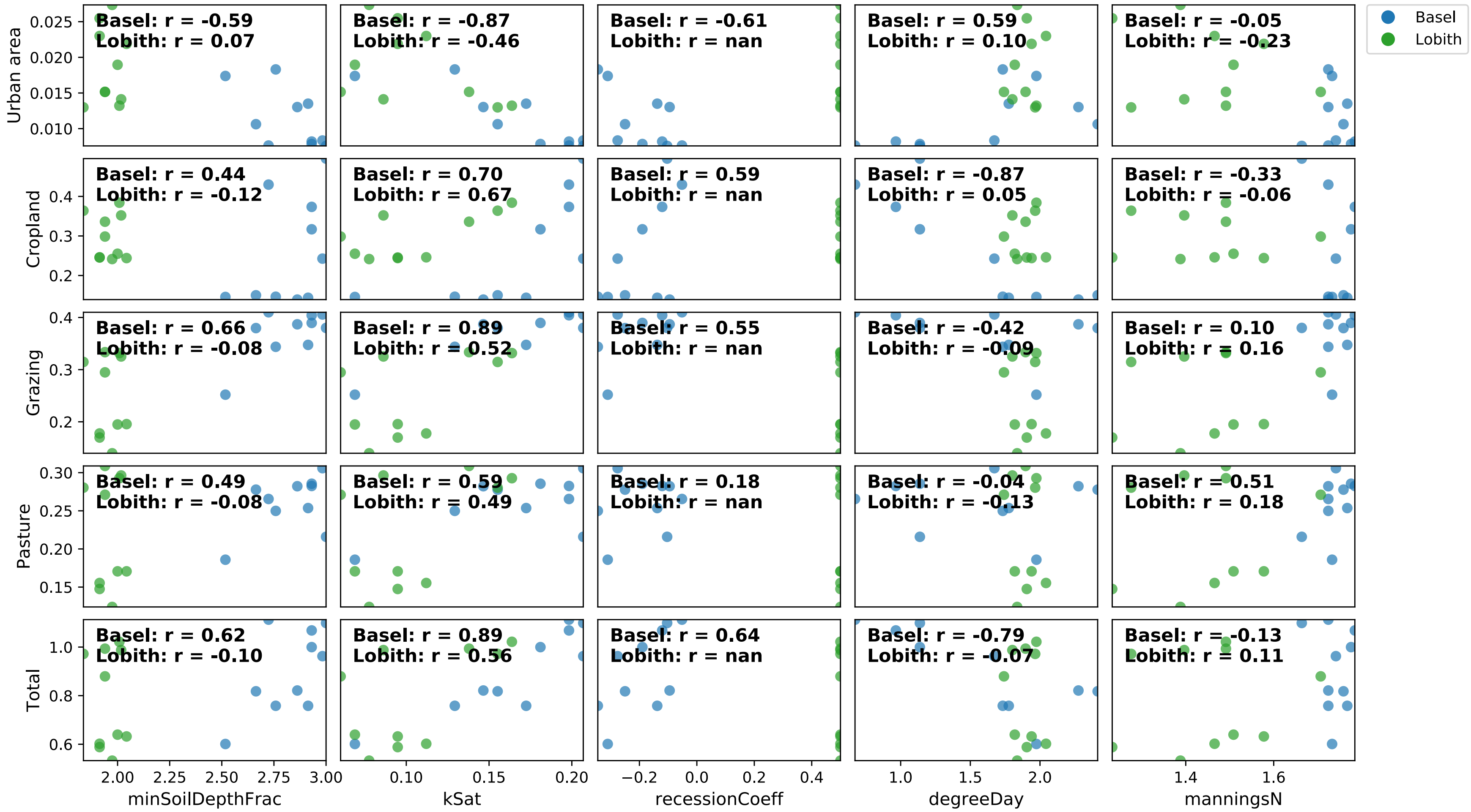


Relations with Land use change

- Land use changes: upstream averages at Basel and Lobith



Relations with Land use change



Conclusions

- Systemic change has occurred in the Rhine-Meuse basin
  - Optimal parameter values change when calibrated for different periods, especially after 1950
  - The change in parameter values is larger at the upstream locations
  - The degree day factor shows the largest changes, between 0.5 and 2.5 times the default value
- The parameters correlate with climate variables and land use
  - Correlation coefficients up to 0.64 for climate variables
  - Correlation coefficients up to 0.89 for land use

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