Regionalisation of climate change factors of peak flow quantiles in Lower Saxony

S. Plötner, U. Haberlandt, U. Petry

1 Motivation and objectives

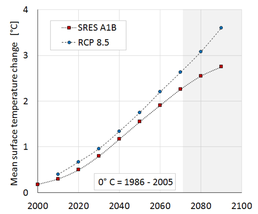
- Consideration of climate change impact on peak flows by climate change factors (ΔHQ)
- ΔHQ are estimated by hydrological modelling for historical and future conditions deriving flood-frequency each

$$\Delta HQ\ (T) = \frac{HQ\ (T)_{future} - HQ\ (T)_{historic}}{HQ\ (T)_{historic}}$$

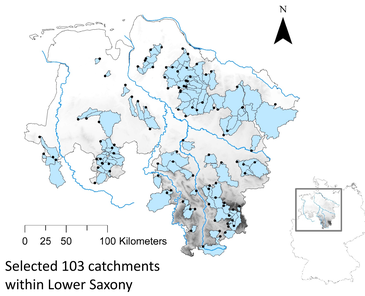
- Prediction in ungauged basins is done by regionalisation
- Objectives: 1) Estimation of median ΔHQ scenario signals
  2) Performance of ΔHQ regionalisation methods

2 Study area and data

- 103 meso-scale catchments (areas: 20-1400 km², Ø = 185 km²)
- Daily observed runoff and climate data (1950-2013)
- 6 SRES A1B and 8 RCP 8.5 climate scenarios (1970-2100)
- Supplementary: physiographic catchment descriptors (CDs) including topography, land use, climate and soil
- Target variable: **ΔHQ100**



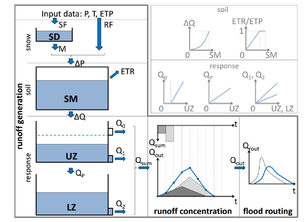
IPCC climate scenarios [1]



Selected 103 catchments within Lower Saxony

3 Methods

- Hyd. modelling using HBV-IWW [2]:
  Conceptual, daily, lumped model
  Optimisation using AMALGAM [3]
  Calibration using observed data
  Clustering of pareto-front to derive optimal parameter sets



HBV-IWW structure [2]

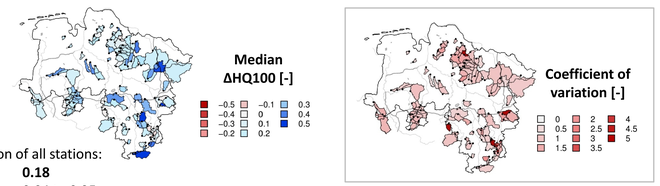
- Flood-Frequency-Analysis:
  Historic: **1971-2000**, future: **2071-2100**
  Gumbel probability distribution function by L-moments
- ΔHQ-Regionalisation:
  Multiple Linear Regression **(MLR)**
  Ordinary Kriging **(OK)** and Kriging with External Drift **(EDK)**
- Criteria of fit:

$$NSE = 1 - \frac{\sum(Z-\hat{Z})^2}{\sum(Z-\bar{Z})^2} \quad MRE = \frac{1}{n}\sum RE \quad RE = \left|\frac{Z-\hat{Z}}{Z}\right| \quad RRMSE = \sqrt{\frac{1}{n}\sum\left(\frac{Z-\hat{Z}}{Z}\right)^2}$$

4.1 Results: ΔHQ estimation

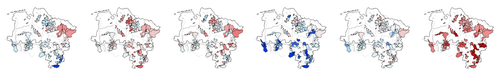
- T = 100, median signal from optimal parameter sets

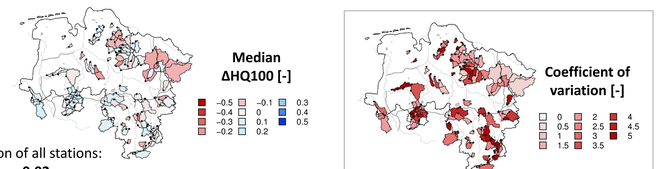
RCP 8.5



Aggregation of all stations:
Median: 0.18
Q10-Q90: 0.04 to 0.35

SRES A1B





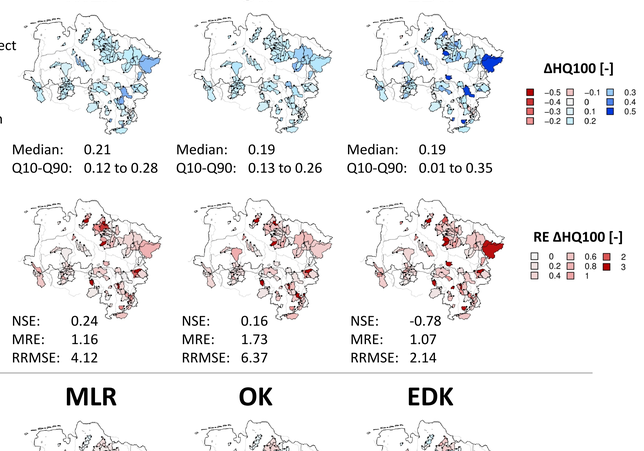
Aggregation of all stations:
Median: 0.02
Q10-Q90: -0.14 to 0.12

Q10 equals 10% quantile
* mean of 3 realisations
° bias-adjusted precipitation and temperature using linear-scaling

4.2 Results: ΔHQ regionalisation

- T = 100, cross-validation

	MLR	OK	EDK
CDs for MLR and EDK:	- standard deviation of aspect - catchment stretch ratio - distance to groundwater - effective field capacity - Δ daily mean precipitation		
	Median: 0.21 Q10-Q90: 0.12 to 0.28	Median: 0.19 Q10-Q90: 0.13 to 0.26	Median: 0.19 Q10-Q90: 0.01 to 0.35
using ΔHQ median of all stations as regionalisation:	NSE: -0.01 MRE: 2.19 RRMSE: 7.57	NSE: 0.24 MRE: 1.16 RRMSE: 4.12	NSE: 0.16 MRE: 1.73 RRMSE: 6.37	NSE: -0.78 MRE: 1.07 RRMSE: 2.14
CDs for MLR and EDK:	- catchment stretch ratio - effective rooting depth - min. temperature - 7 day max. precipitation - Δ daily mean precipitation		
	Median: 0.01 Q10-Q90: -0.06 to 0.09	Median: 0.01 Q10-Q90: -0.06 to 0.08	Median: 0.01 Q10-Q90: -0.09 to 0.10
using ΔHQ median of all stations as regionalisation:	NSE: -0.02 MRE: 1.17 RRMSE: 1.74	NSE: 0.23 MRE: 1.39 RRMSE: 2.83	NSE: 0.13 MRE: 1.37 RRMSE: 2.59	NSE: 0.14 MRE: 1.88 RRMSE: 4.90



5 Conclusions

- 80% of stations show good hyd. model fit with NSE in validation period for best parameter set in hydrograph 0.61-0.83, mean seasonal cycle 0.78-0.97 and annual peal flows 0.37-0.79
- median ΔHQ100 of RCP 8.5 signals indicates positive change of 18% overall and 4-35% for 80% of all stations, SRES A1B with overall median of 2% and varying direction of change from -4 to 12%
- 80% of stations show coefficient of variation of ΔHQ100 between 0.6-2.0 for RCP 8.5 and 1.0-13.0 for SRES A1B, indicating RCP 8.5 scenario ensemble to be more homogeneous
- Best method according to RRMSE is EDK followed by MLR and OK for RCP 8.5, for SRES A1B OK is superior to MLR and EDK, but worse than overall median
- Smoothing effect of ΔHQ regionalisation might be beneficial
- Climate change factors are recommended, for practical purposes overall median values might be more robust than ΔHQ-regionalisation
- Outlook: enlargement of climate scenario ensemble, robustness, uncertainty analysis

References:

[1] *modified*: Burkett, V.R., Suarez, A.G., Bindi, M., Conde, C., Mukerji, R., Prather, M.J., St. Clair, A.L., Yohe, G.W., 2014. Point of departure. In: Climate Change, 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

[2] *modified*: Wallner, M., Haberlandt, U., Dietrich, J., 2013. A one-step similarity approach for the regionalization of hydrological model parameters based on Self-Organizing Maps. Journal of Hydrology 494, 59–71. doi:10.1016/j.jhydrol.2013.04.022

[3] Vrugt, J.A., Robinson, B.A., 2007. Improved evolutionary optimization from genetically adaptive multimethod search. Proc Natl Acad Sci U S A 104, 708–711. doi:10.1073/pnas.0610471104

Institute of Hydrology and Water Resources Management, University of Hannover,
ploetner@iww.uni-hannover.de

EGU General Assembly, 2017, Vienna