How do hydrological processes change in their spatio-temporal relevance under changing climatic conditions?

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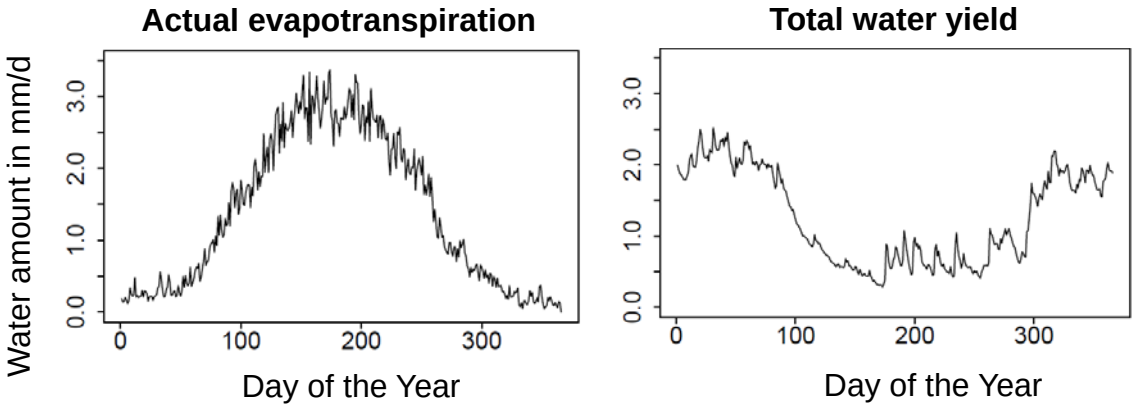
DFG

Spatio-temporal process variability in models

- The relevance of hydrological processes varies

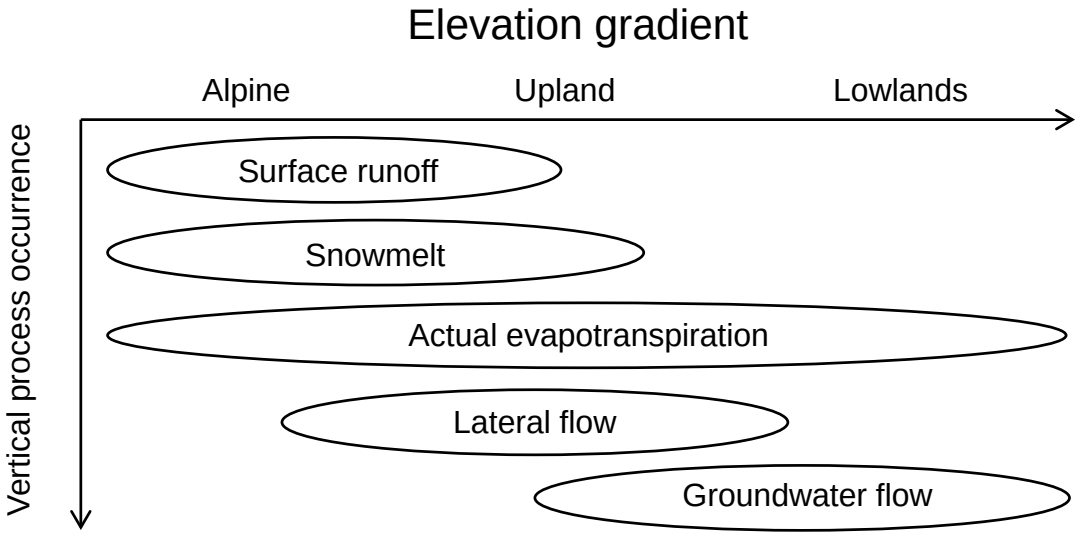
... temporally between different seasons

Average values of SWAT model results (2000-2010) in the Treene catchment / Northern Germany



... spatially between catchments

Concept of changes of dominant processes along an elevation gradient

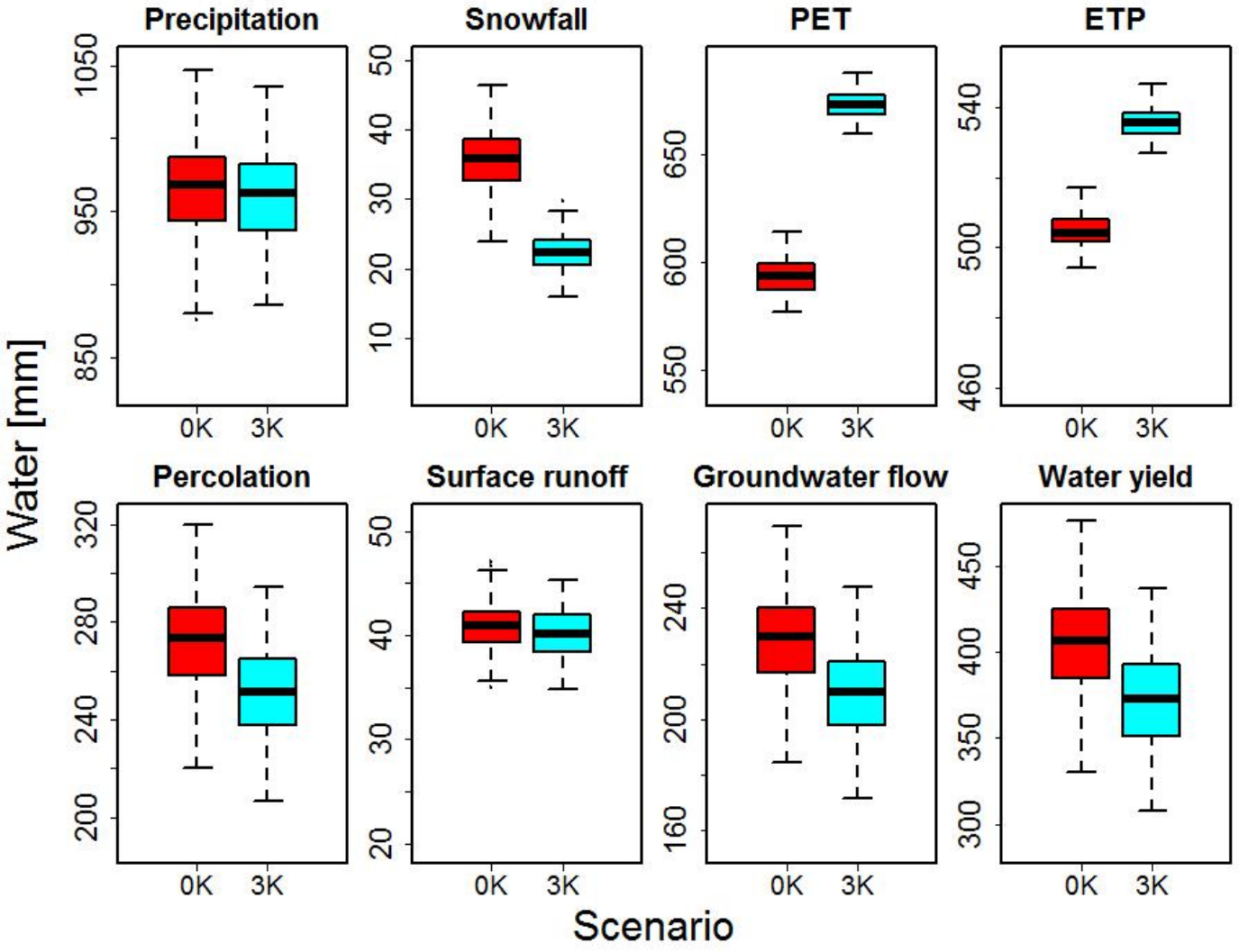


Modified from Guse et al. (2016, WRR)

Impact of climate change on water balance components

Treene catchment (2021-2060):

Comparison of modelled water balance components with SWAT between 0K- and 3K-scenarios



Requirement on model-based analyses of nonstationarity

Reproduction of spatio-temporal process dynamics for the current period

- Optimal parameter values vary if using a different calibration period even for recent conditions *(Vaze et al., 2010, Merz et al. 2011)*

Analysis of hydrological situation under changing conditions

- Simulation of model scenarios to estimate future development
- Assumption of a realistic process representation now and in future
- But: Process relevance may change

Investigation how the relevance of model parameters changed when using modified input data

Methodical approach

- Determination of monthly averaged sensitivity patterns for model parameters in contrasting catchments

- Modification of input data and repetition of sensitivity analysis with identical parameter sets

  Temperature scenario: Increase of 2K

  Precipitation scenario: Increase of 10%

- Change in results directly shows the impact of modified input data

Temporal dynamics in parameter sensitivity (TEDPAS)

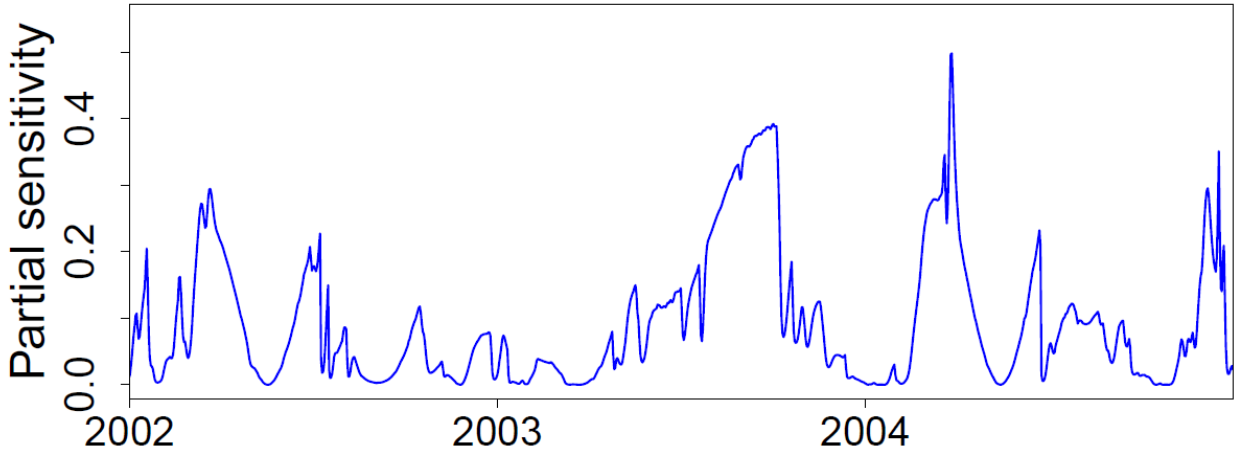
- provides daily sensitivities for each model parameter
- Identifying temporal patterns of dominant model parameters
- Global Sensitivity Analysis using a Fourier Amplitude Sensitivity Test (FAST)
- Response variable: Modelled hydrological component and not deviation to observed data (performance measure)

$$S = \frac{V_i}{V_t}$$

S = First-order sensitivity

V_i = First-order variance

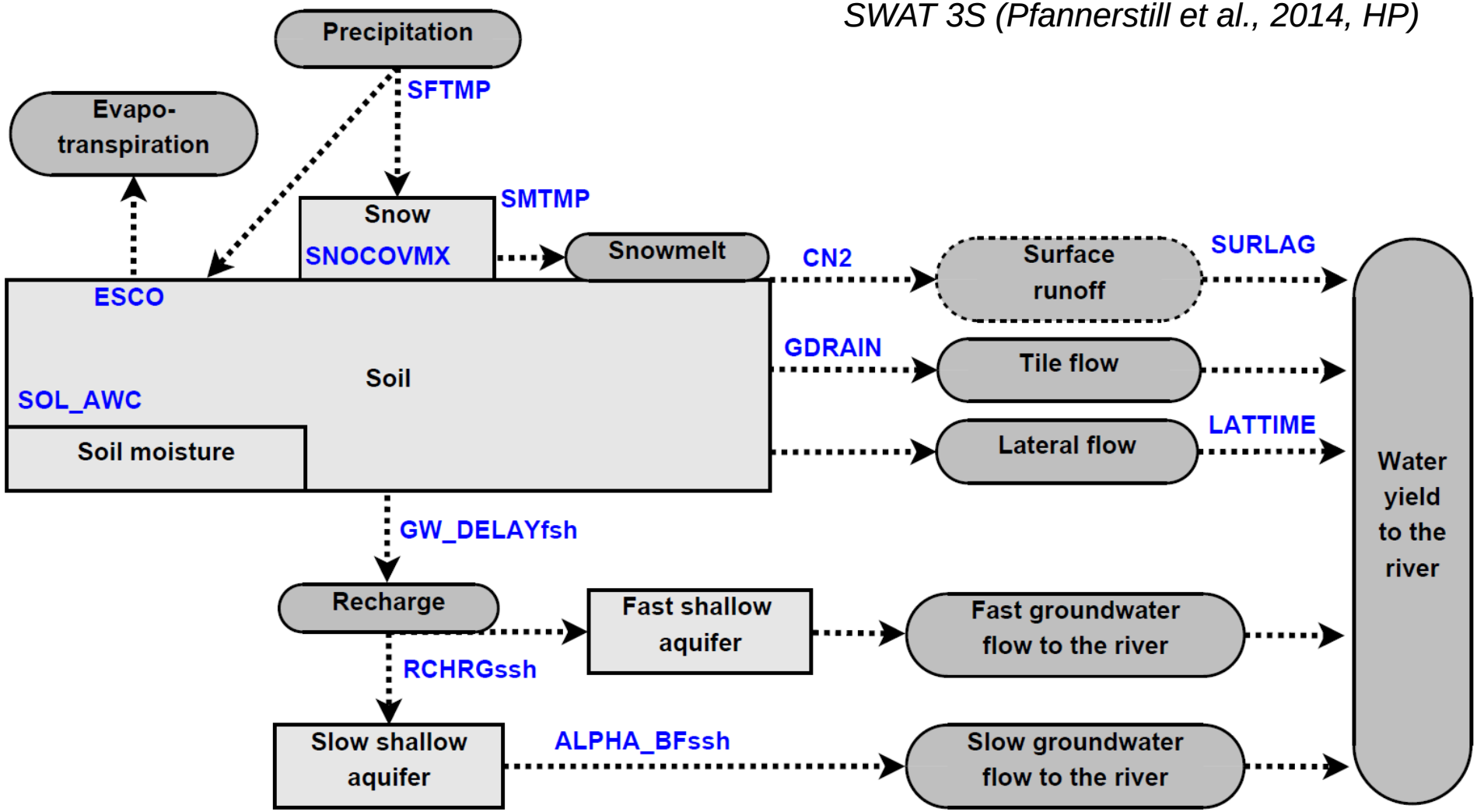
V_t = Total variance



Reusser et al. (2011, WRR), Guse et al. (2014, HP)

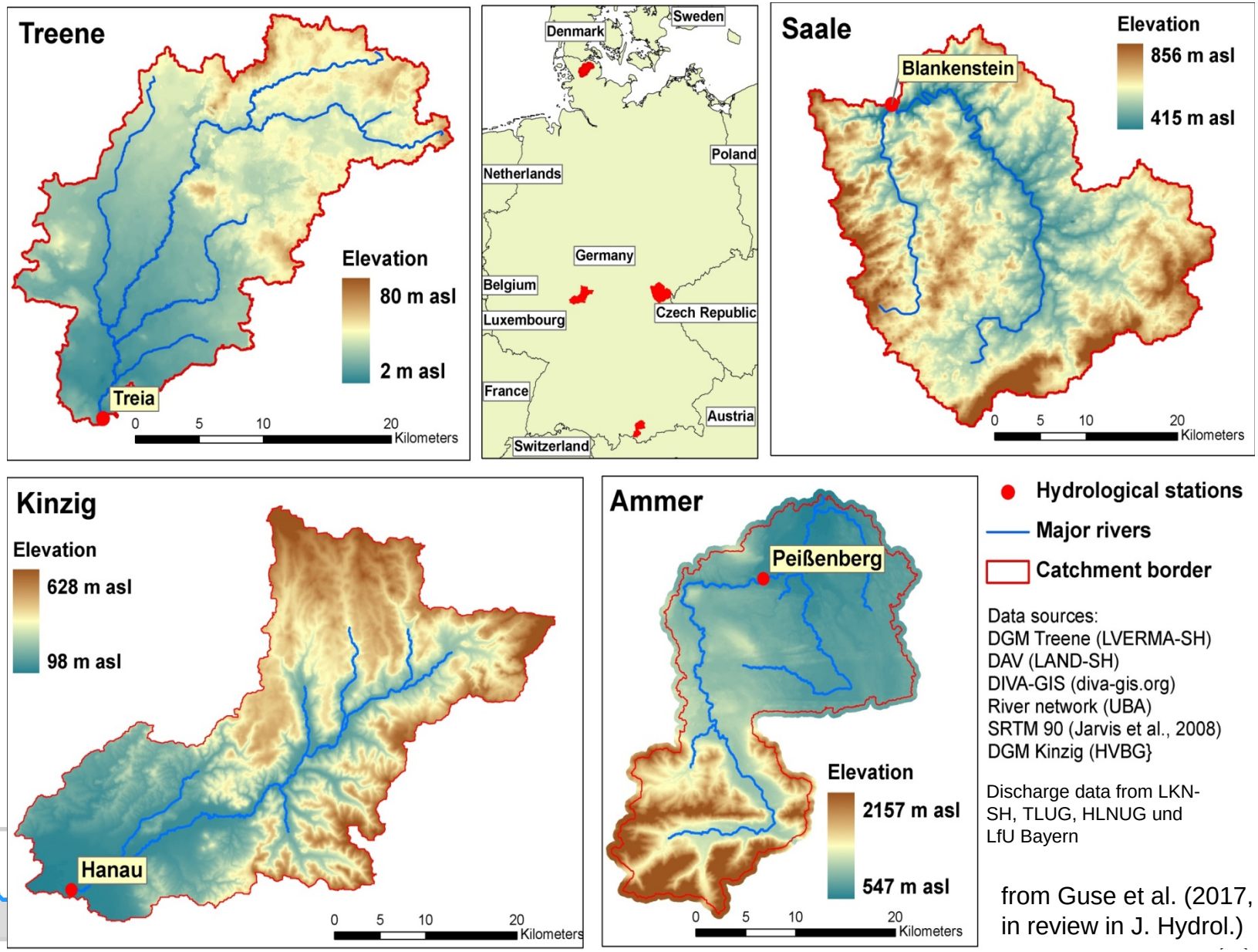
SWAT3S model version

SWAT 3S (Pfannerstill et al., 2014, HP)



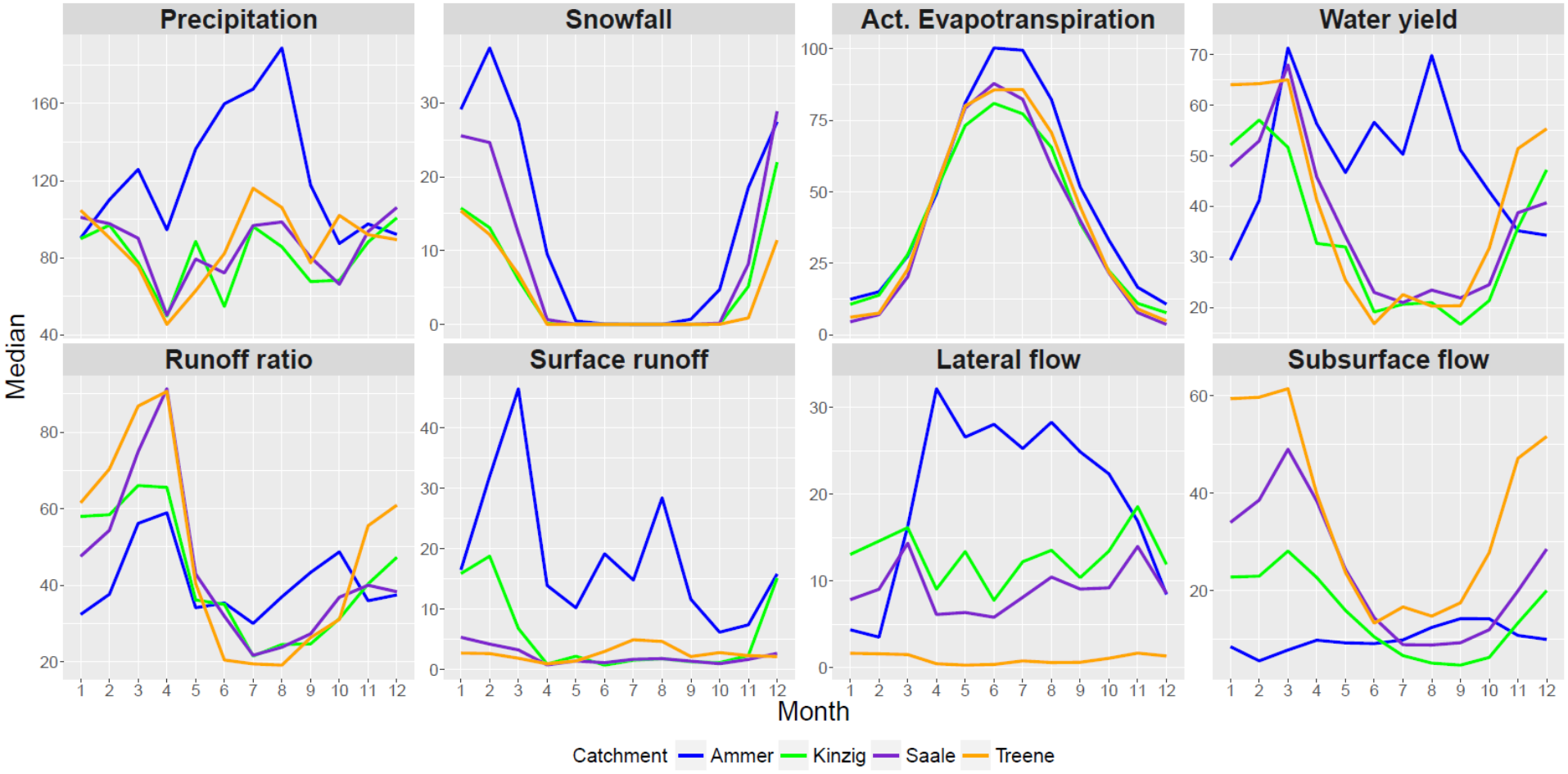
Modified from Guse et al. (2014, HP; 2016, WRR)

Four catchments



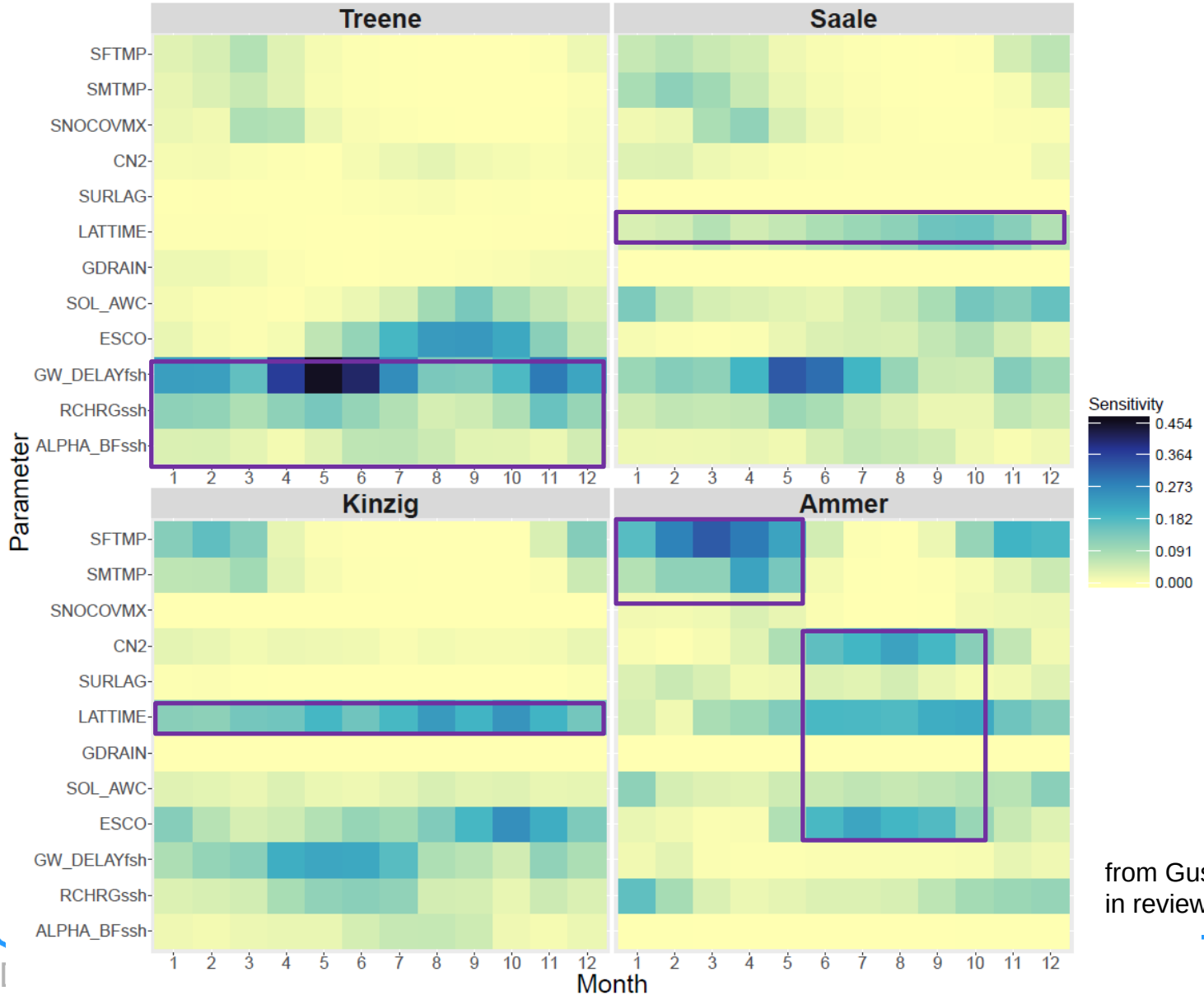
from Guse et al. (2017, in review in J. Hydrol.)

Monthly variability in hydrological components



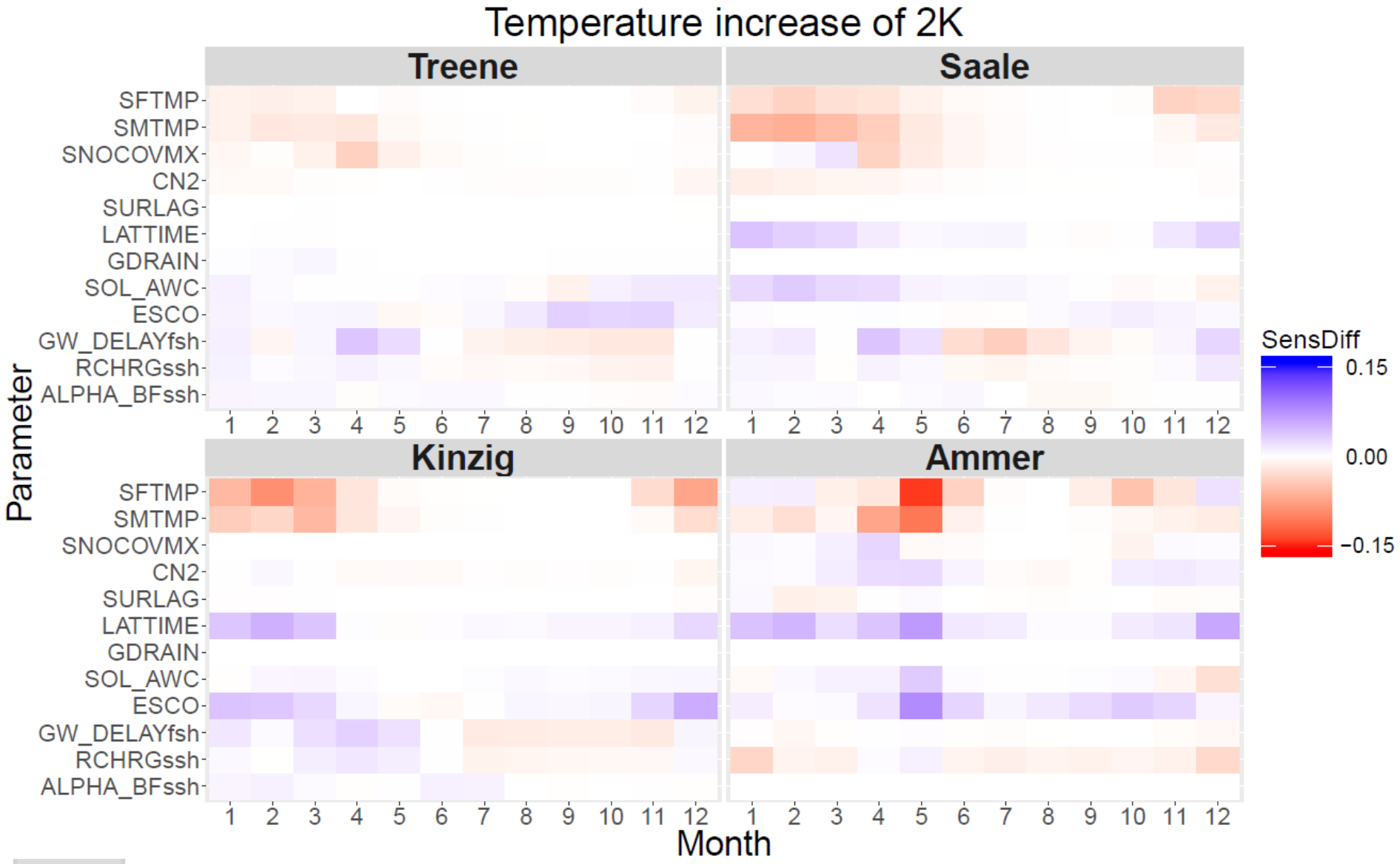
from Guse et al. (2017, in review in J. Hydrol.)

Monthly averaged parameter sensitivities

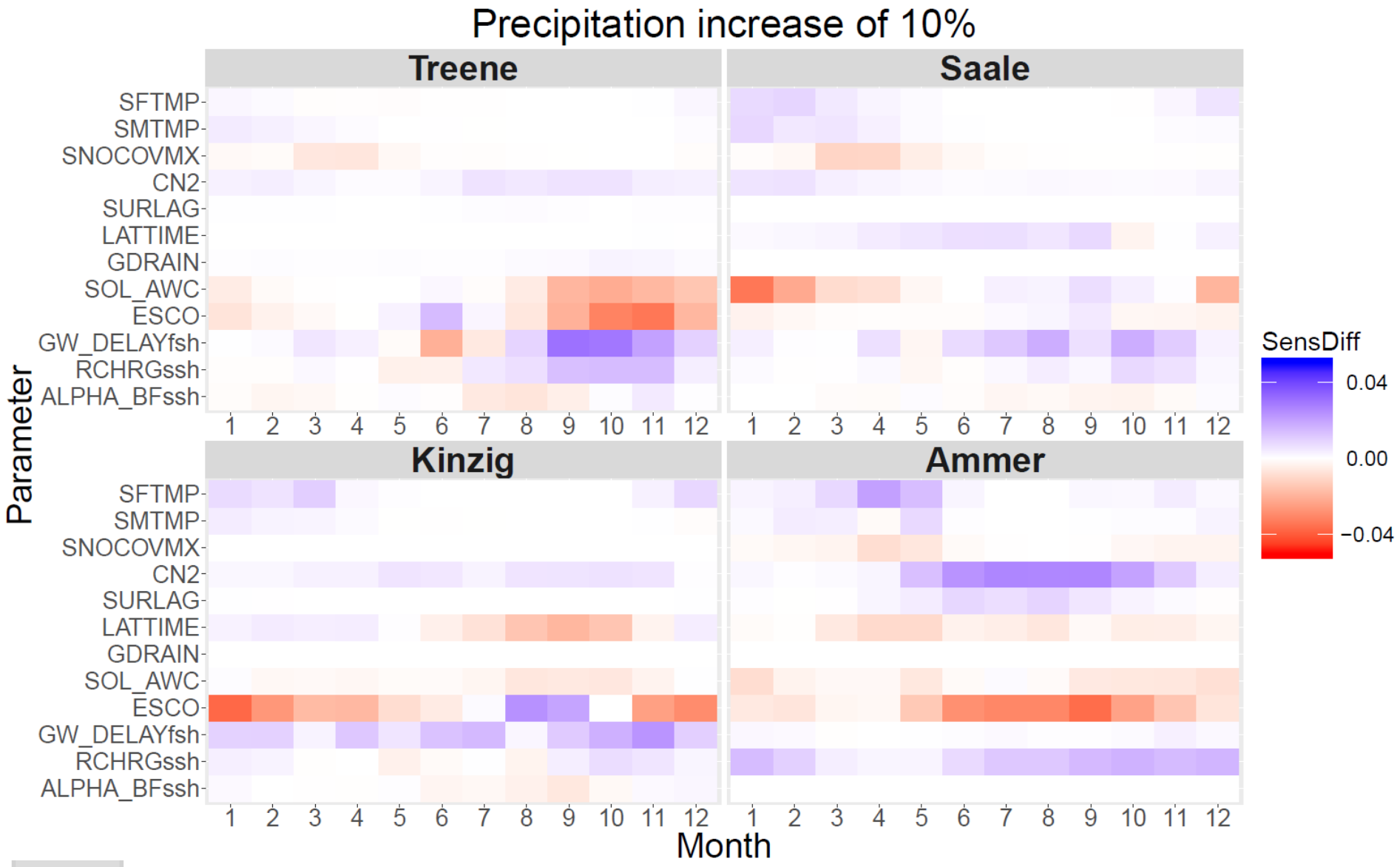


from Guse et al. (2017, in review in J. Hydrol.)

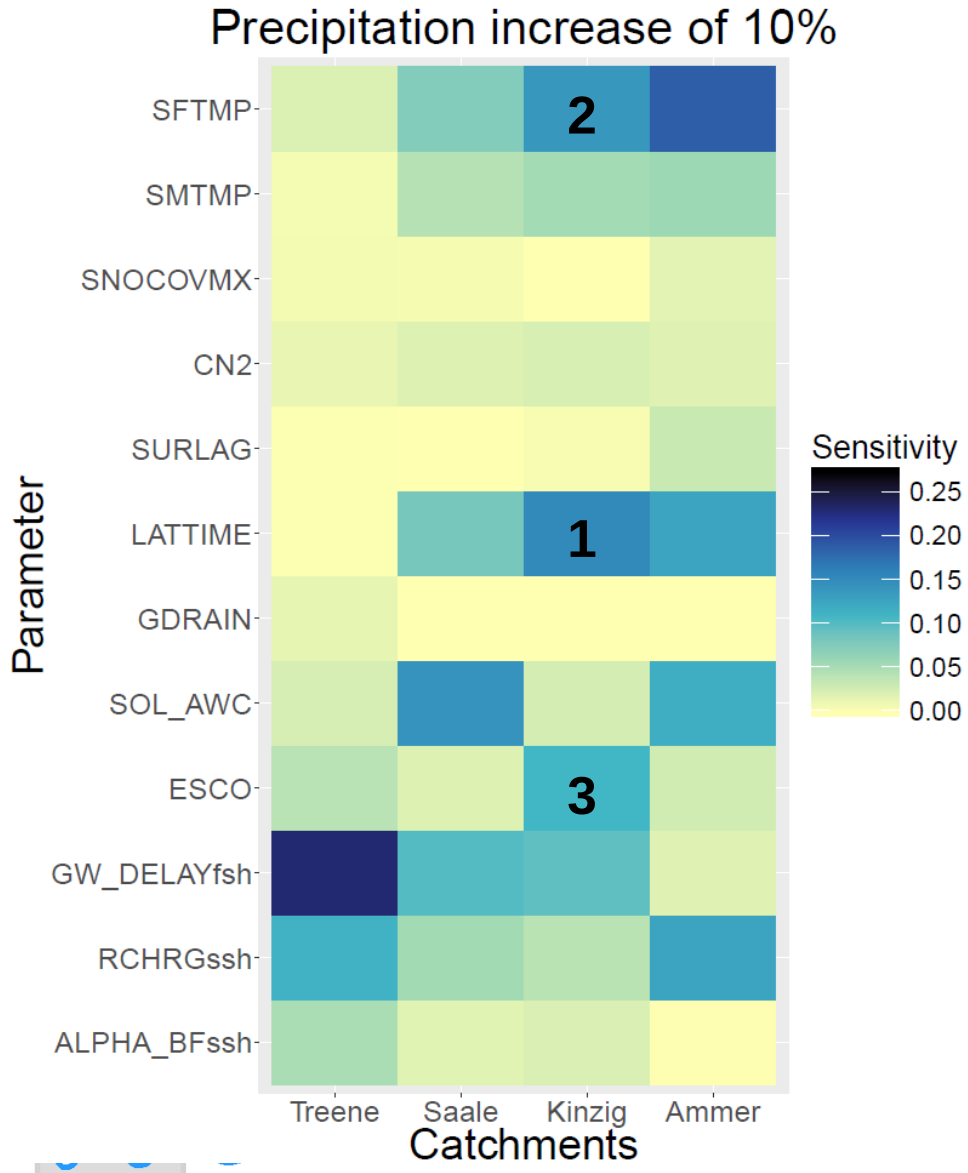
Impact of temperature change on monthly parameter sensitivities

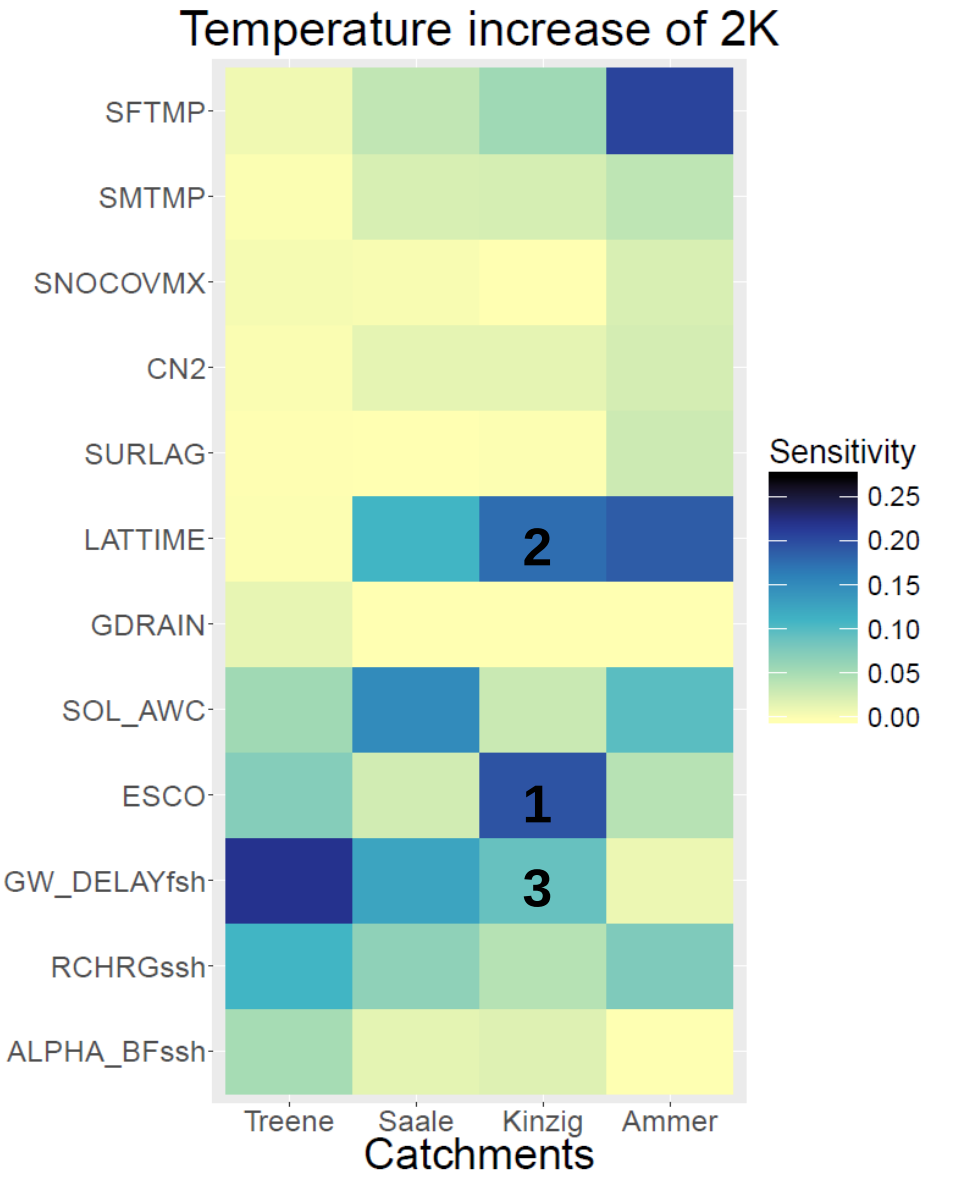


Impact of precipitation change on monthly parameter sensitivities



Comparison of mean sensitivities between both scenarios





Summary

- Parameter relevance is impacted by changing climate conditions
- Impact of increase in precipitation or temperature on parameter sensitivity varies between catchments and in different seasons
- Depending on the degree of changes in sensitivities, model calibration and selection of best parameter sets can be influenced.

Thank you for your attention

Further information:

Guse, B.; Reusser, D. E.; Fohrer, N. (2014): How to improve the representation of hydrological processes in SWAT for a lowland catchment - Temporal analysis of parameter sensitivity and model performance, Hydrol. Process., 28: 2651–2670

Guse, B.; Pfannerstill, M.; Strauch, M.; Reusser, D.; Lüdtke, S.; Volk, M.; Gupta, H.; Fohrer, N. (2016): On characterizing the temporal dominance patterns of model parameters and processes, Hydrol. Process., 30(13), 2255-2270, doi: 10.1002/hyp.10764.

Pfannerstill, M.; Guse, B. and Fohrer, N. (2014). A multi-storage groundwater concept for the SWAT model to emphasize nonlinear groundwater dynamics in lowland catchments. Hydrol. Process., 28(22):5599-5612, doi:10.1002/hyp.10062.