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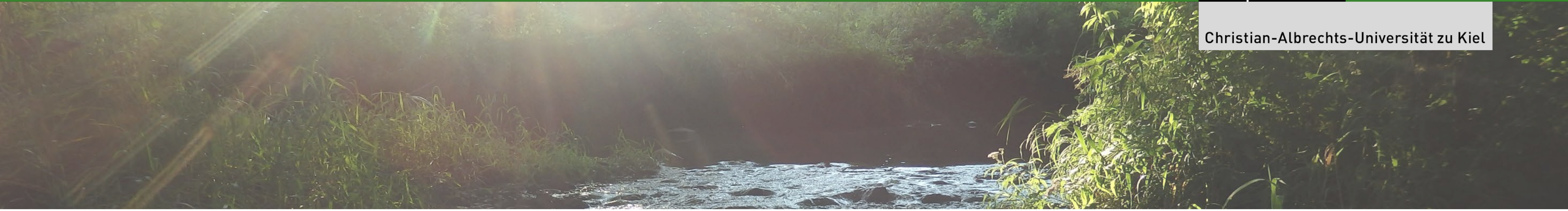
Christian-Albrechts-Universität zu Kiel



The integration of hydrological and heat exchange processes improves stream temperature simulations for SWAT+

Kristin Peters, Jens Kiesel, Isabel Oswald, Björn Guse, Efrain Noa-Yarasca, Jeffrey G. Arnold, Javier M. Osorio Leyton, Katrin Bieger & Nicola Fohrer

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Species such as trout are threatened by rising stream temperatures

Quelle: Ennio Leanza/KEYSTONE/dpa/Archivbild
https://www.welt.de/regionales/thueringen/article250309762/
in-Thueringen-gibt-es-Bedrohungen-fuer-die-Forelle.html

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Stream Temperature in SWAT+

SWAT+ estimates the stream temperature from a linear relationship developed by Stefan and Preud'homme (1993)

$$T_{water} = 5.0 + 0.75 * T_{air}$$

T_{water} = average daily water temperature [°C]
T_{air} = average daily air temperature [°C]

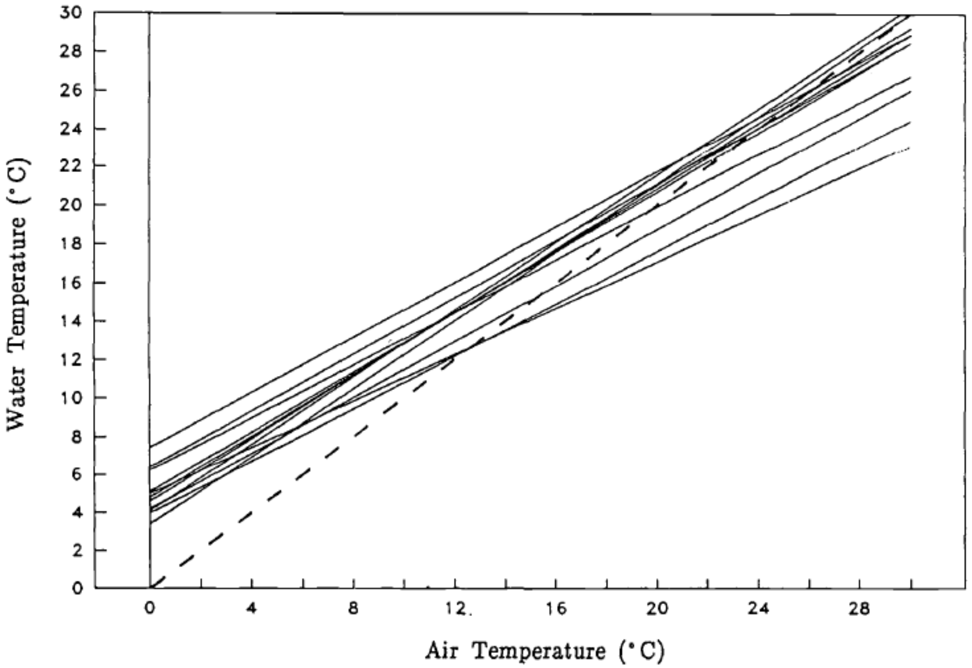

Figure 9. Relationship Obtained from the Regression Analyses Between the Daily Water and Air Temperatures for the 11 Rivers Studied.

Incorporation of temperature processes

1. **mixing of flow components**: snowmelt, groundwater, surface runoff (Ficklin et al. 2012)
2. **equilibrium temperature**: heat transfer processes at the air-water interface (Du et al. 2018)
3. **shade factor**: include riparian vegetation (Noa-Yarasca et al. 2023)

- exist for SWAT 2012 only
- are based on each other

→ integrate and improve SWAT+ (60.5.4) routines and test for study area

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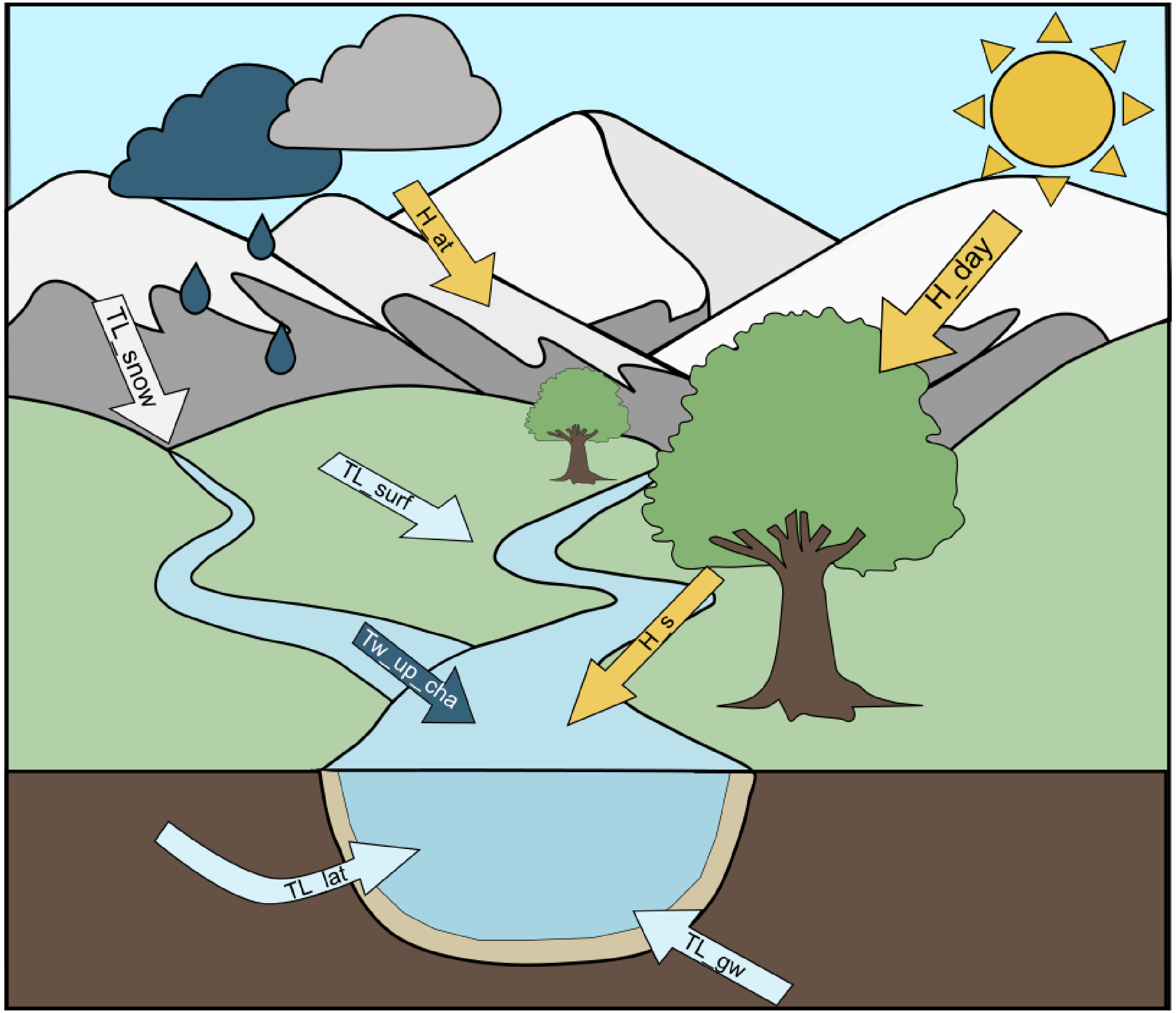
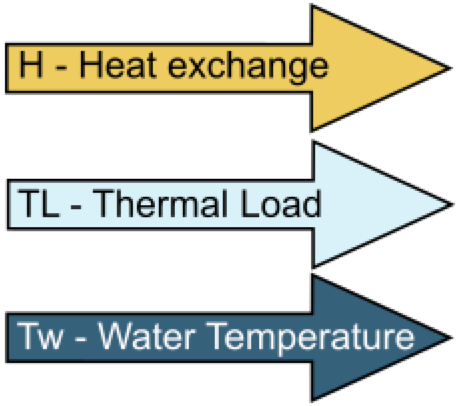
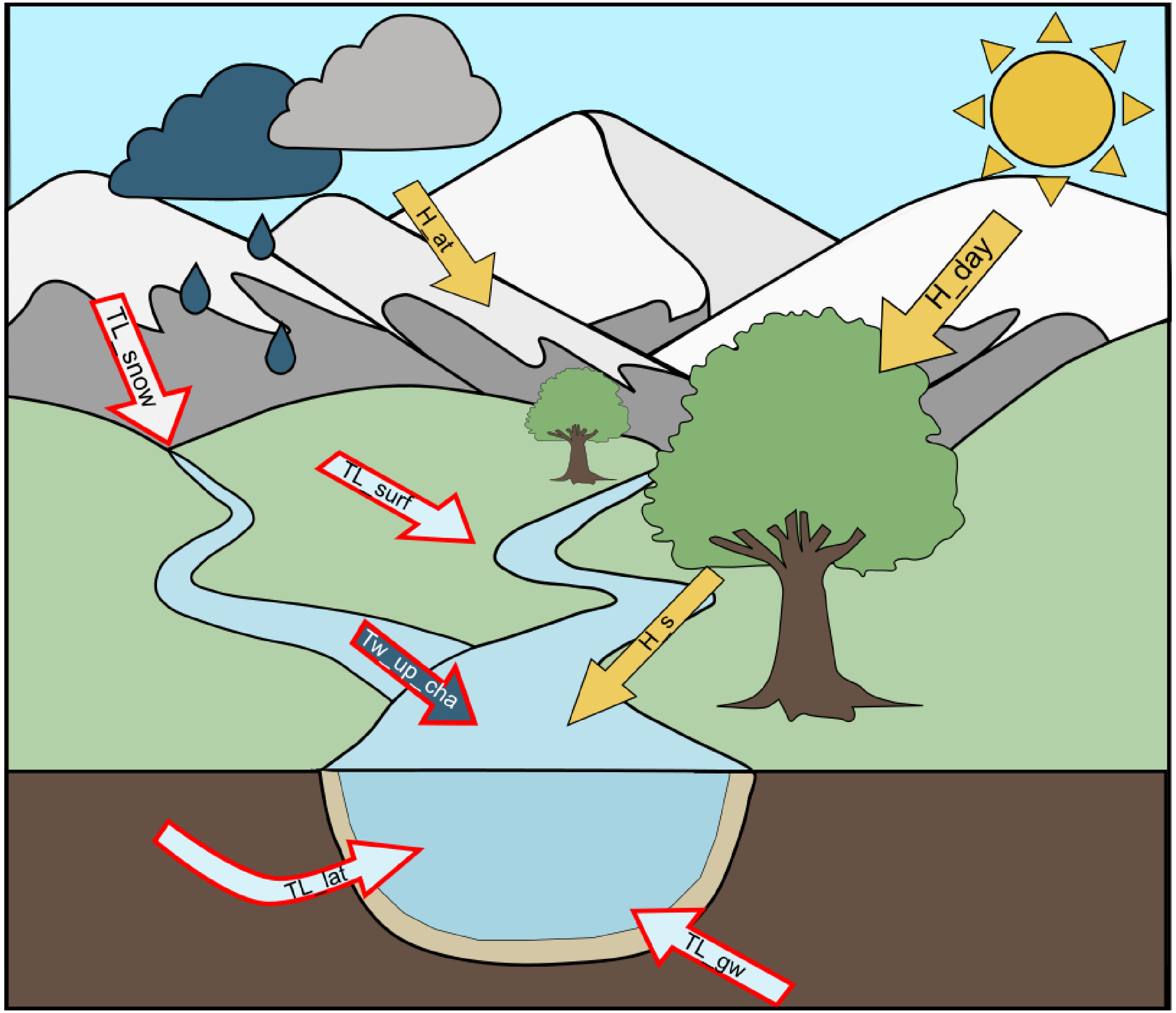
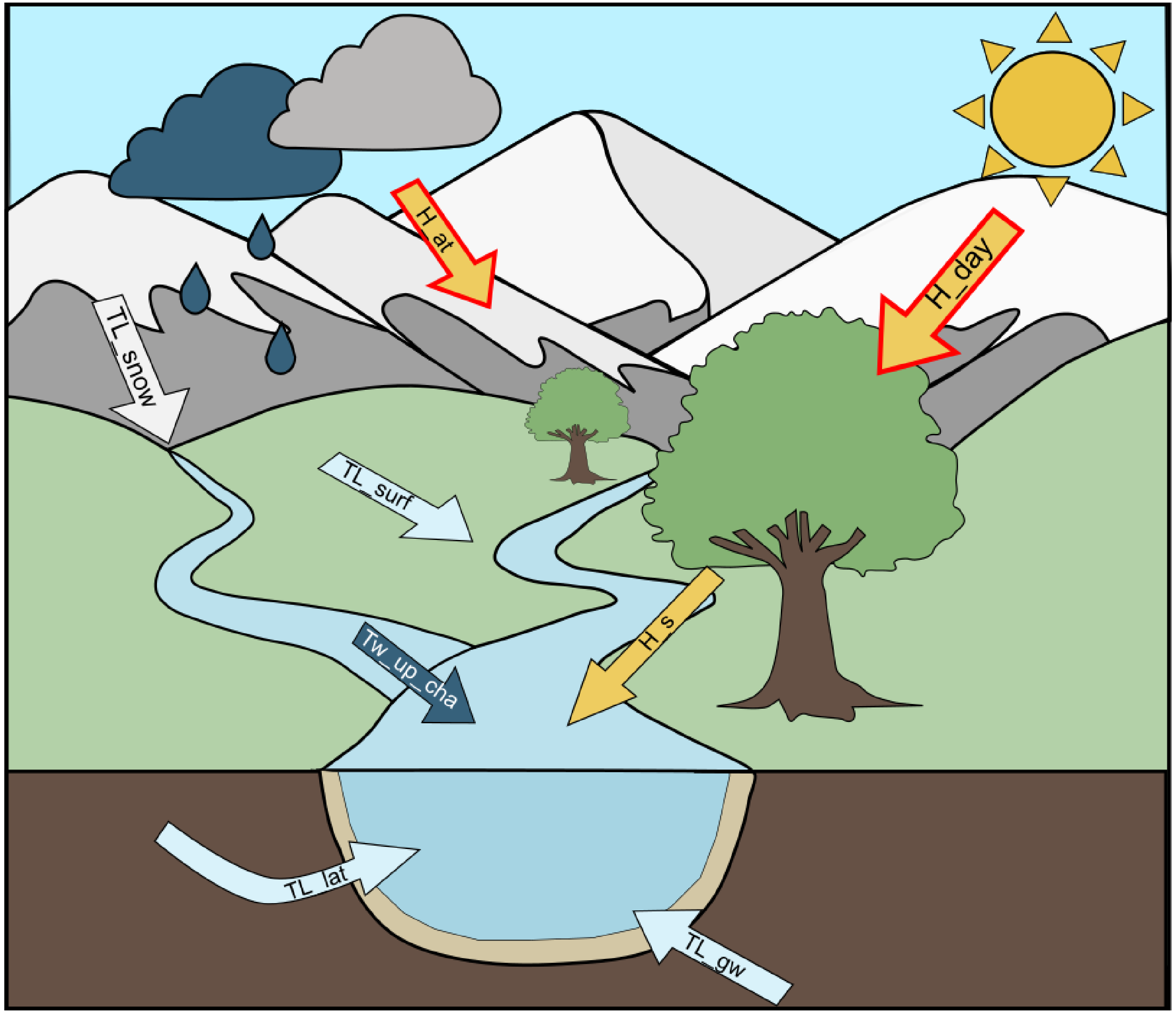


Temperature processes that require integration into SWAT+

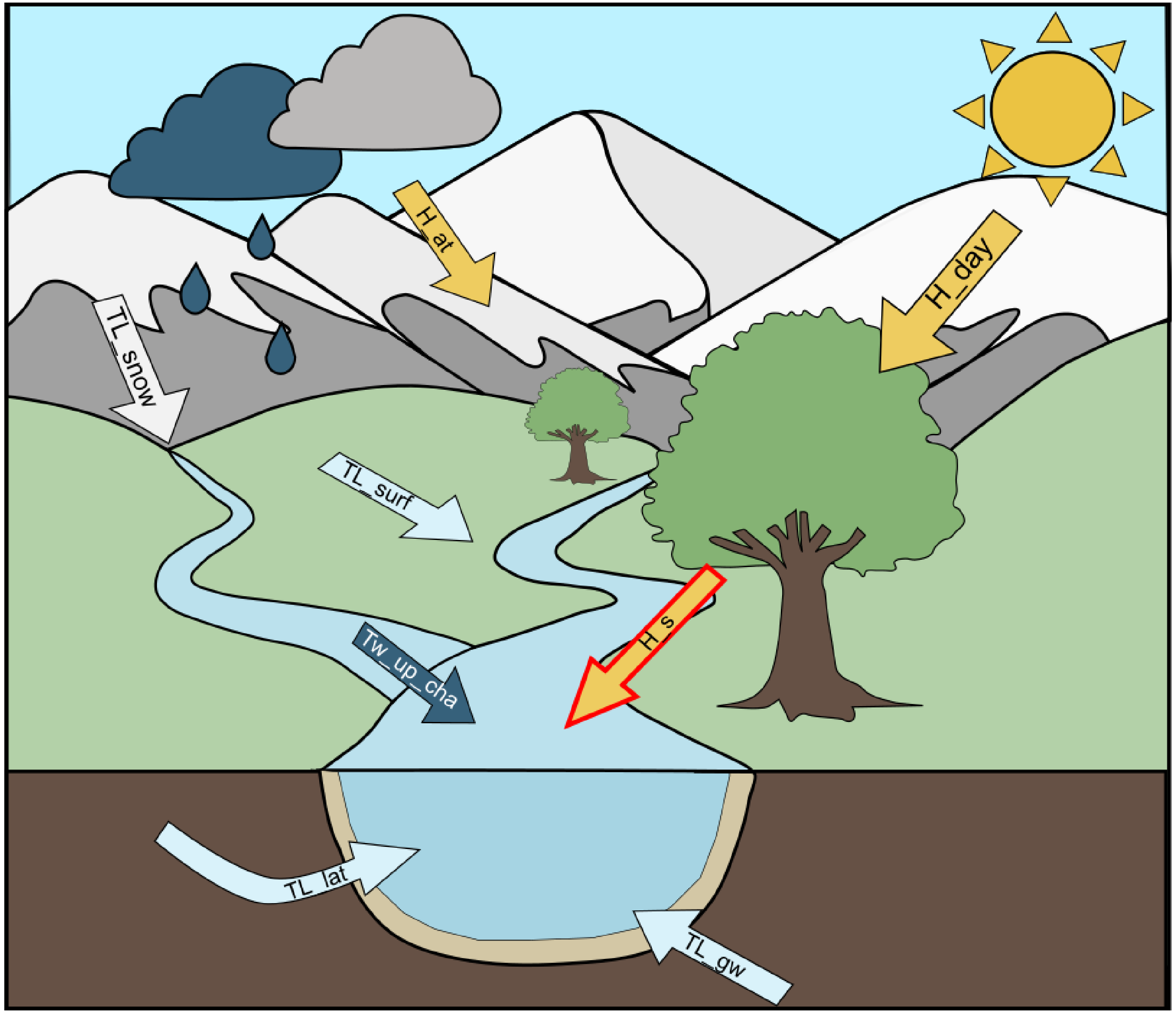




- mixing of runoff components
- improved by calibration parameters that affect the thermal load of each runoff component

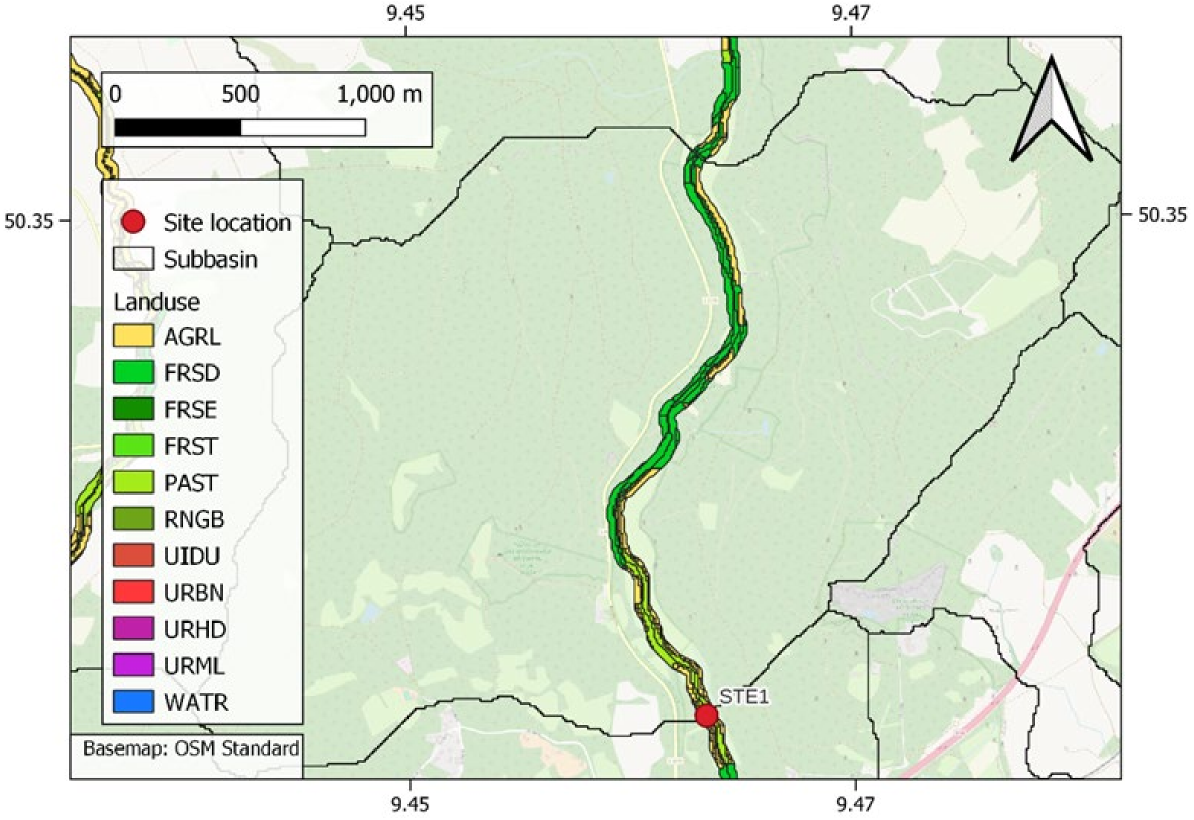


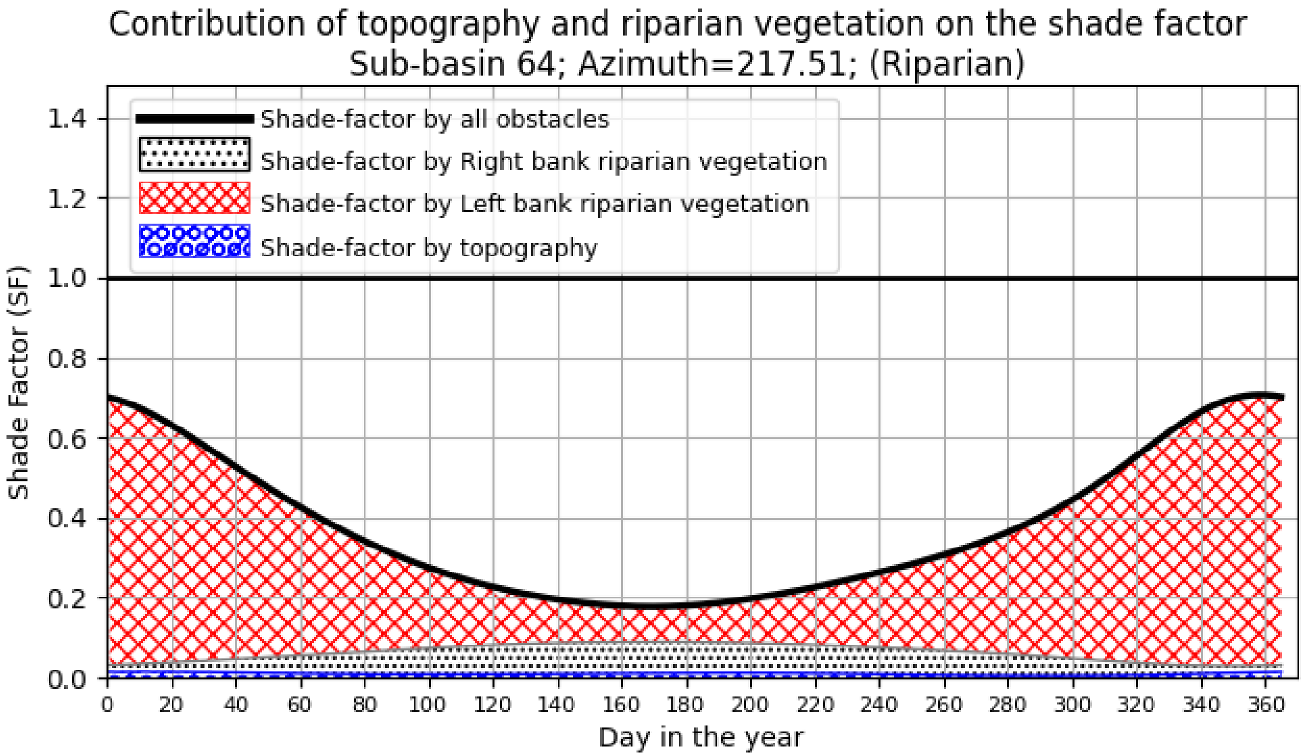
- equilibrium temperature includes heat exchange processes at the air-water interface
- improved by geometry factor



- shade factor reduces shortwave radiation
- improved with dew point temperature calibration

Shade Factor





based on Python script by Noa-Yarasca et al., (2023)

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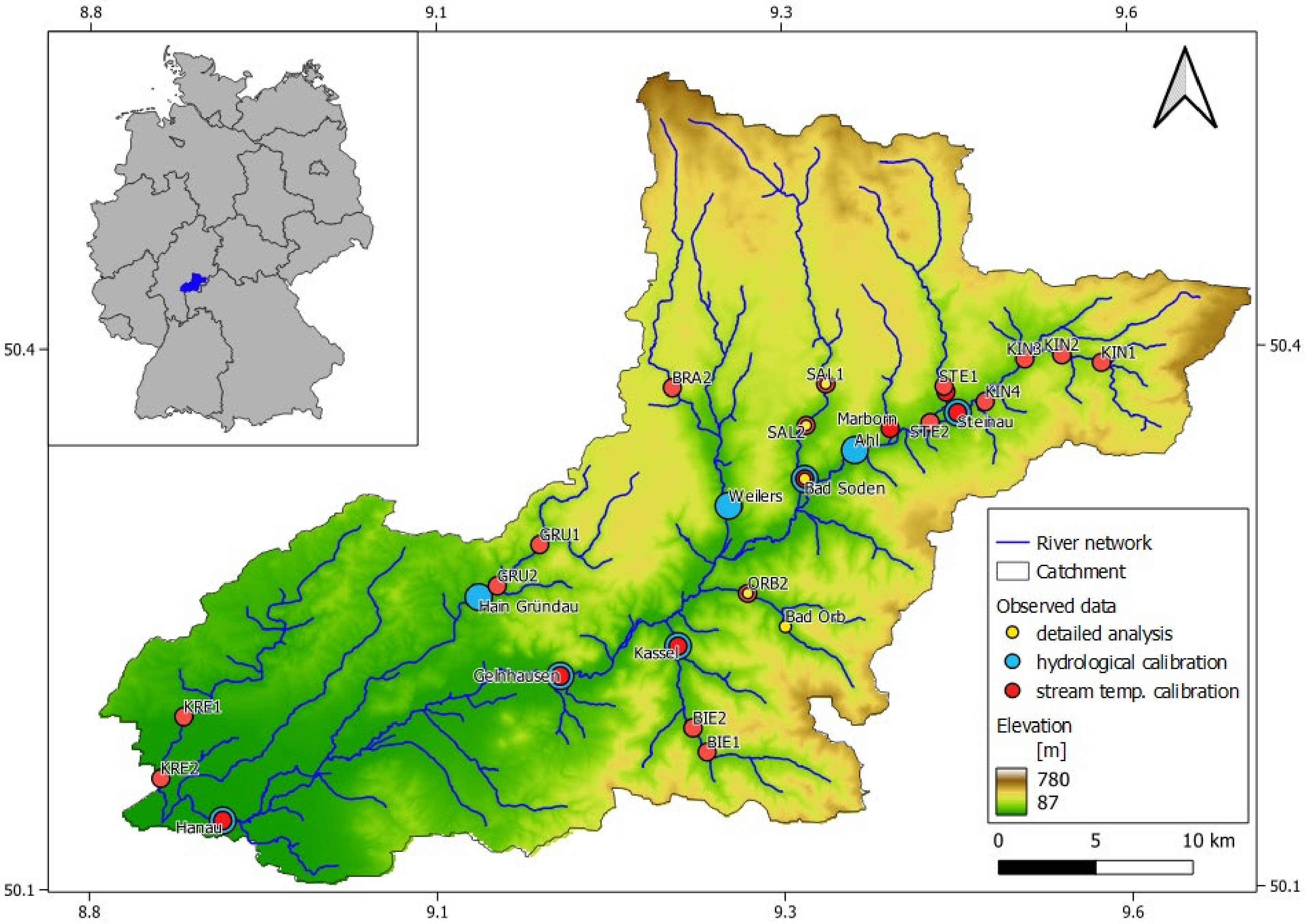
Kinzig study catchment and observed data



	RESIST locations	State agency stations
Number	16	7
Time period	2 years	12 years
Resolution	daily	daily
Years	2021 – 2023	2012 – 2023
Used for	calibration	calibration and validation

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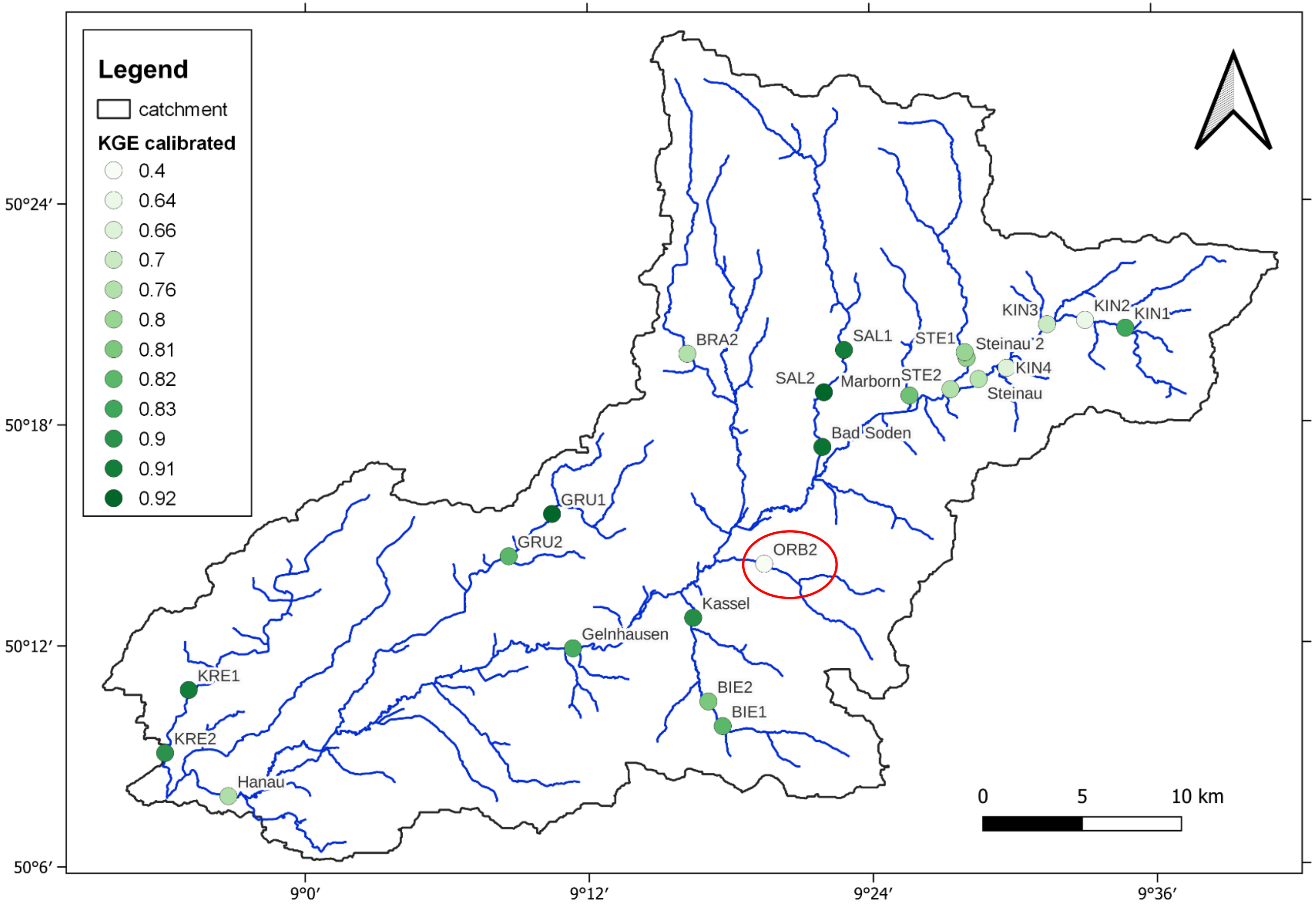
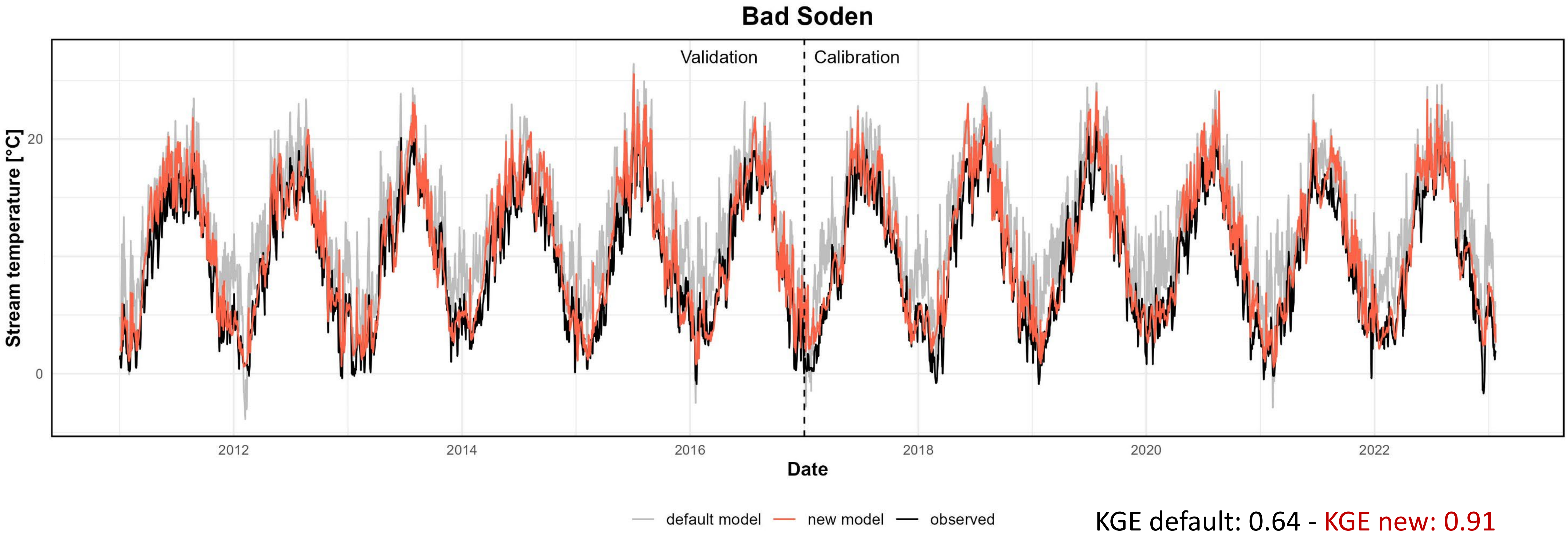
KGE at multiple calibration sites



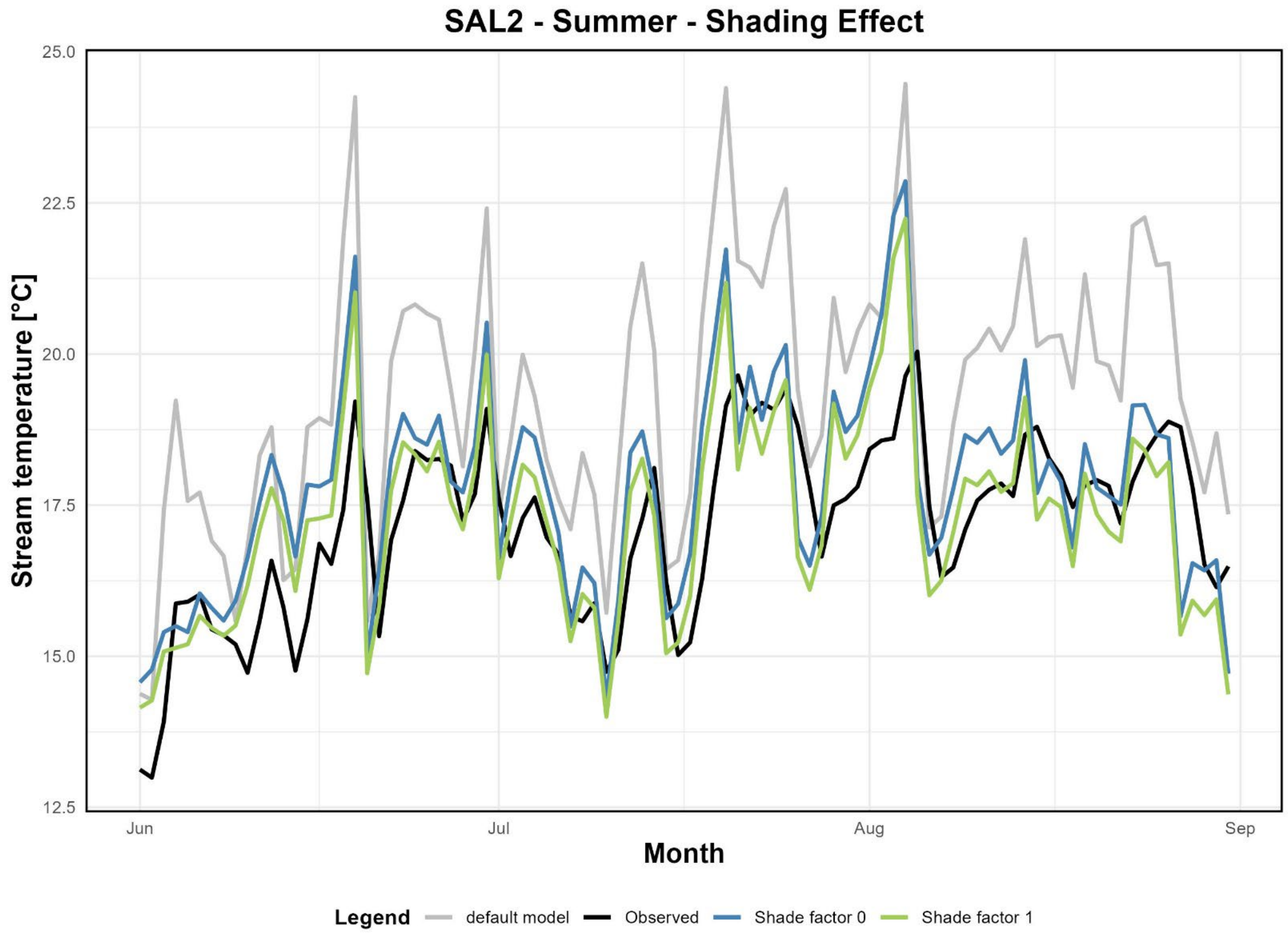
- KGE across multiple calibration sites: 0.8
- range from 0.4 to 0.92
- One outlier with lower performance than others: ORB2

Model performance time series



KGE default: 0.64 - KGE new: 0.91

Shading effect



- Full shade reduces stream temperature in summer
- Modelled difference between no shade and full shade: **0.51°C**
- Observed difference between shaded site (SAL1) and unshaded site (SAL2): **0.76°C**

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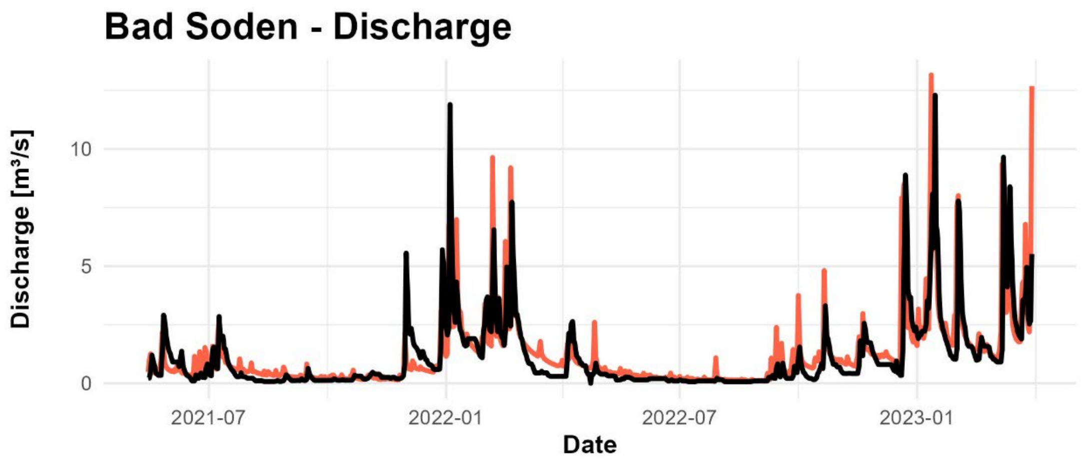
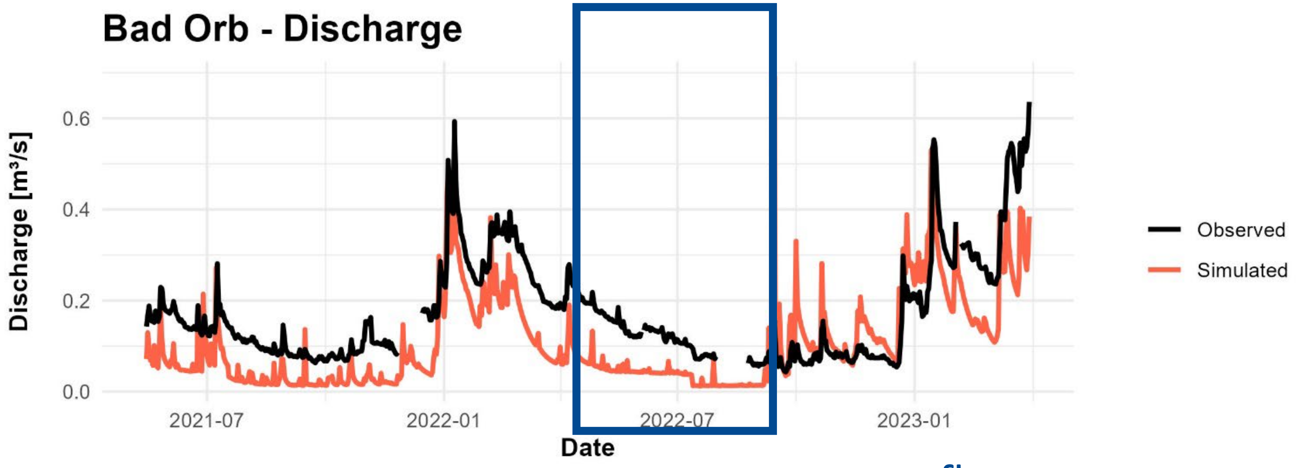
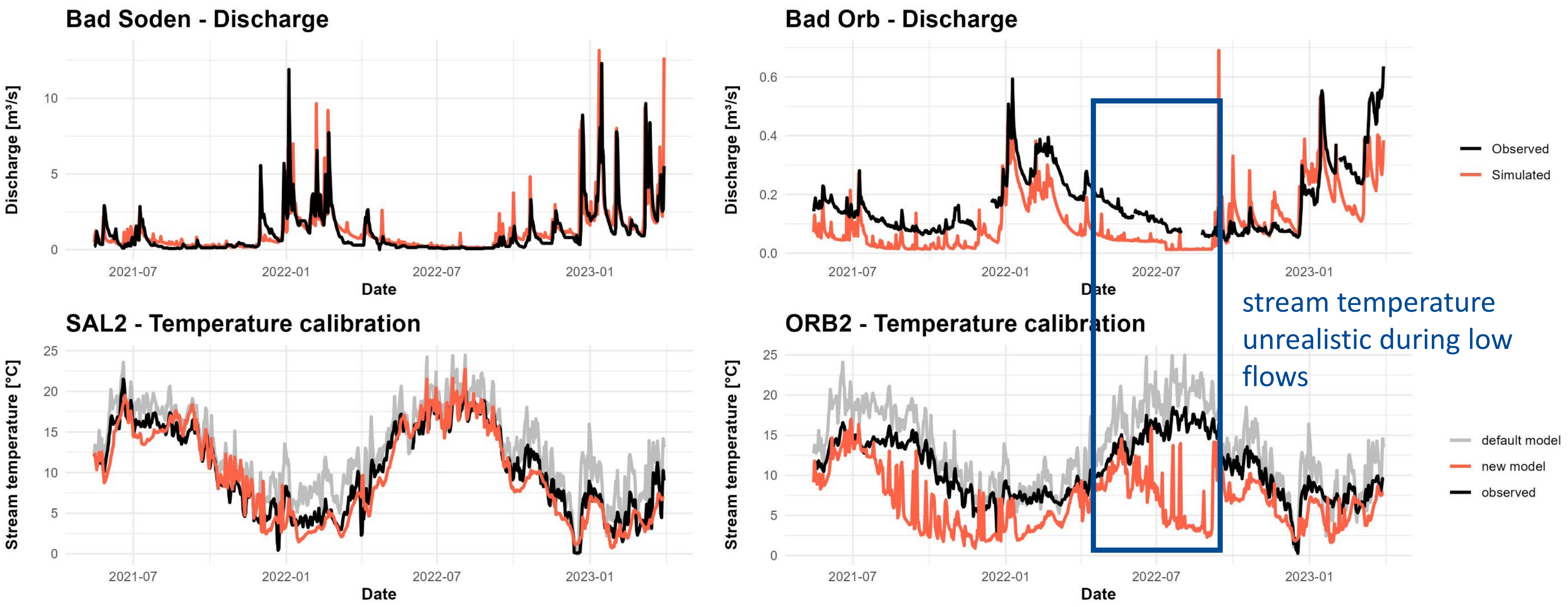
Importance of groundwater process representation





streamflow uncalibrated in Orb tributary: baseflow problems

Importance of groundwater process representation



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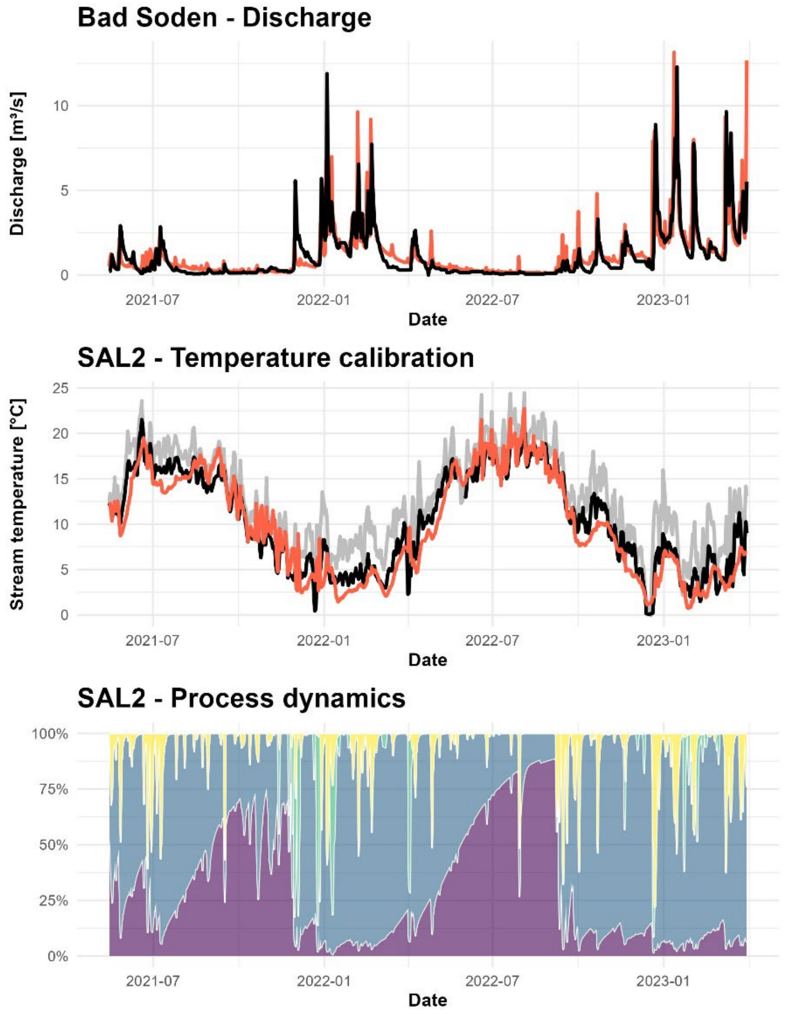
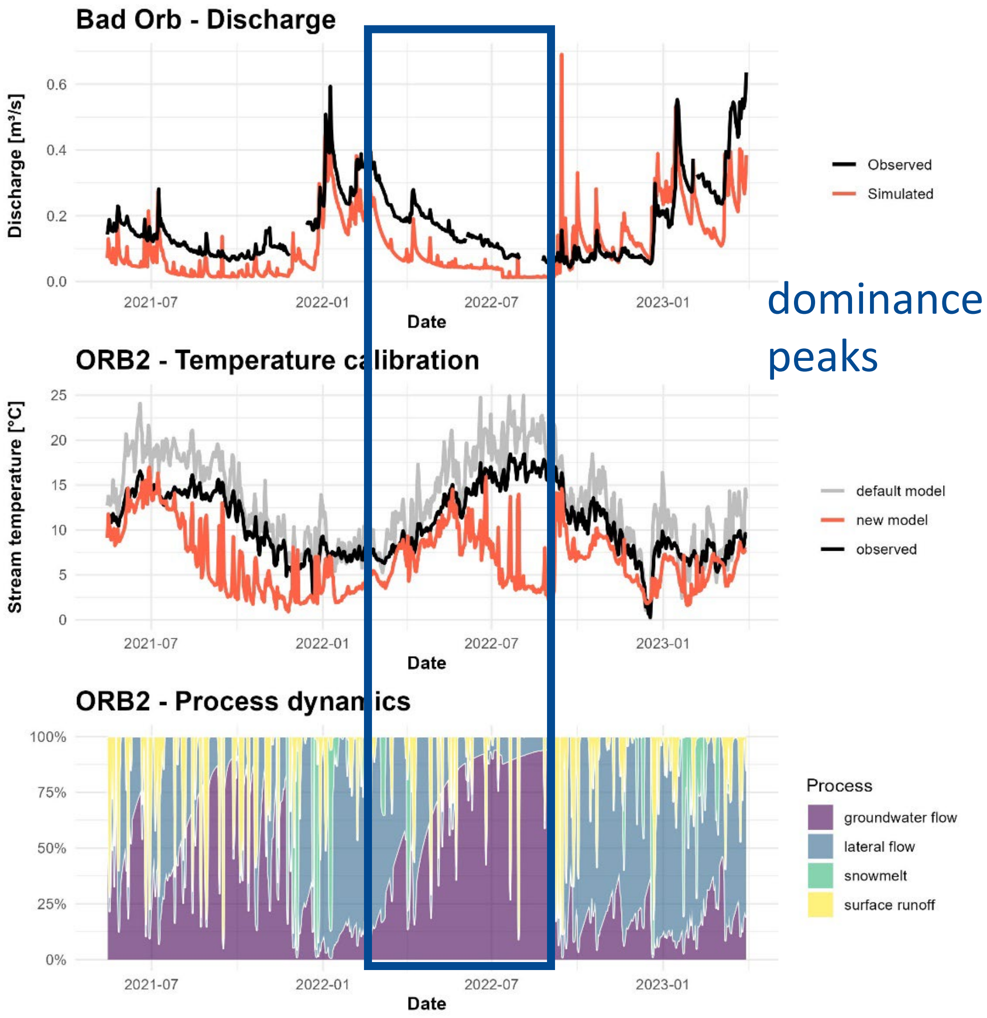
Importance of groundwater process representation





dominance of surface runoff peaks

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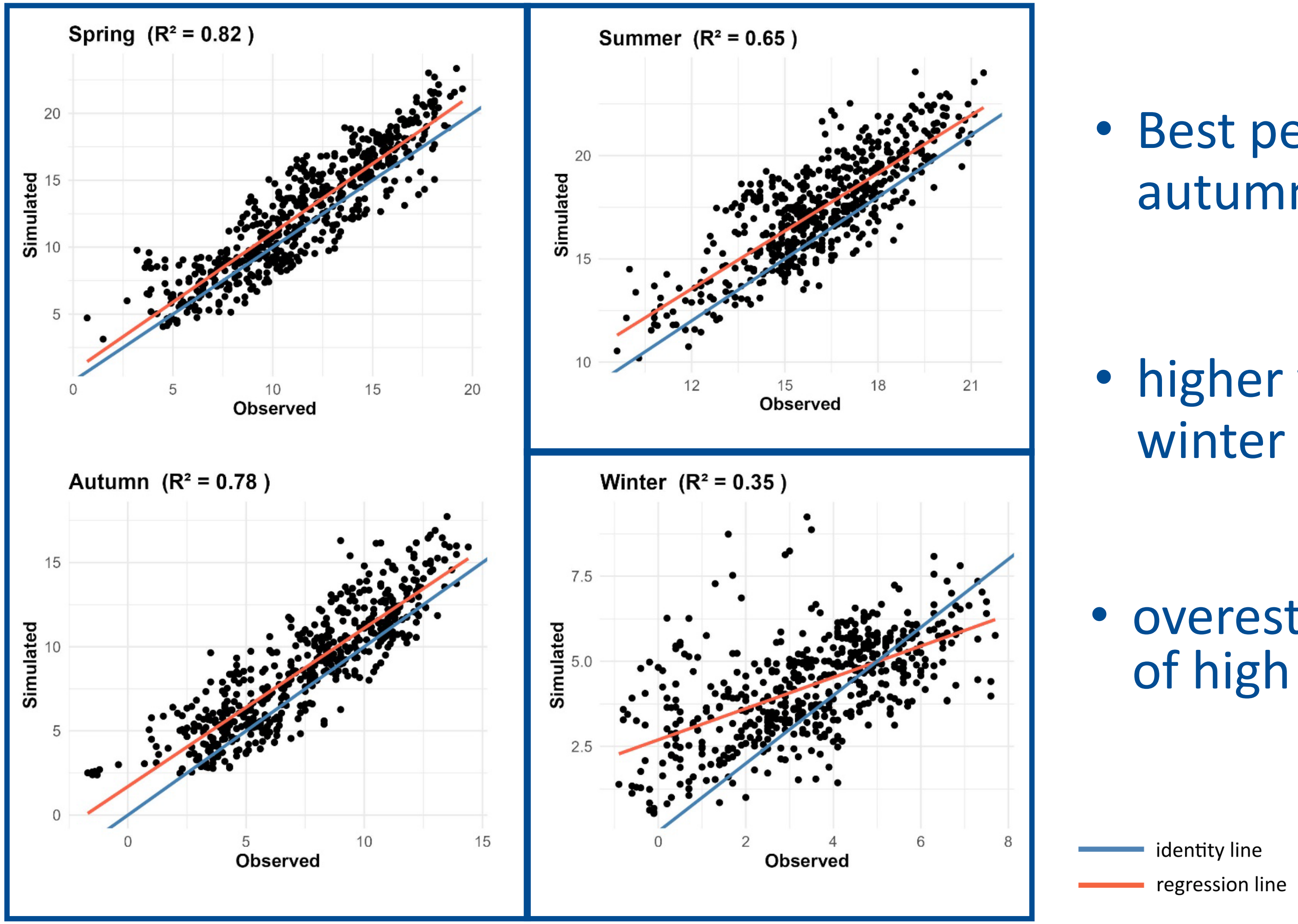
Seasonality of model performance



- Best performance in spring and autumn
- higher variability in summer and winter
- overestimation of low and underestimation of high winter temperatures

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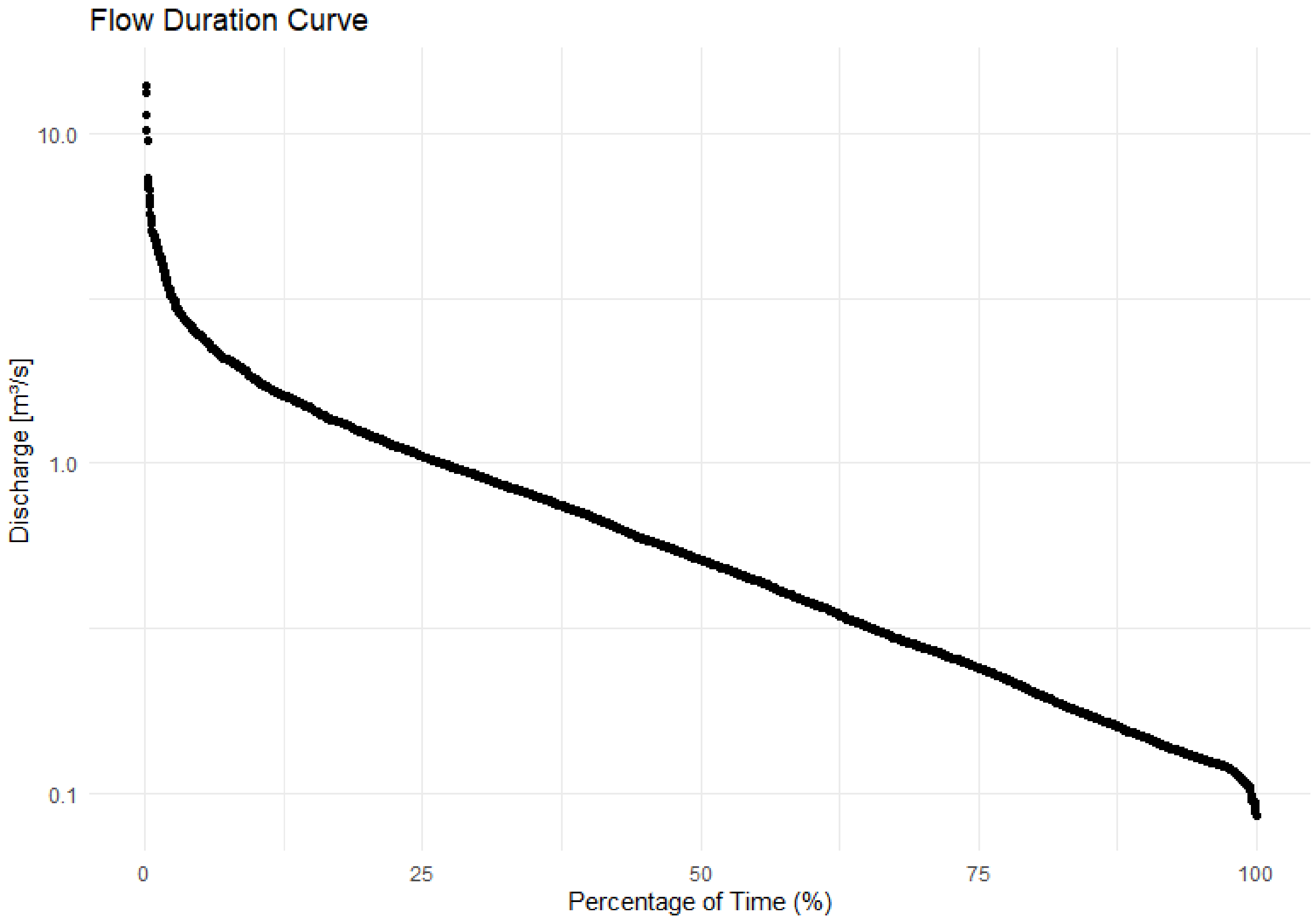
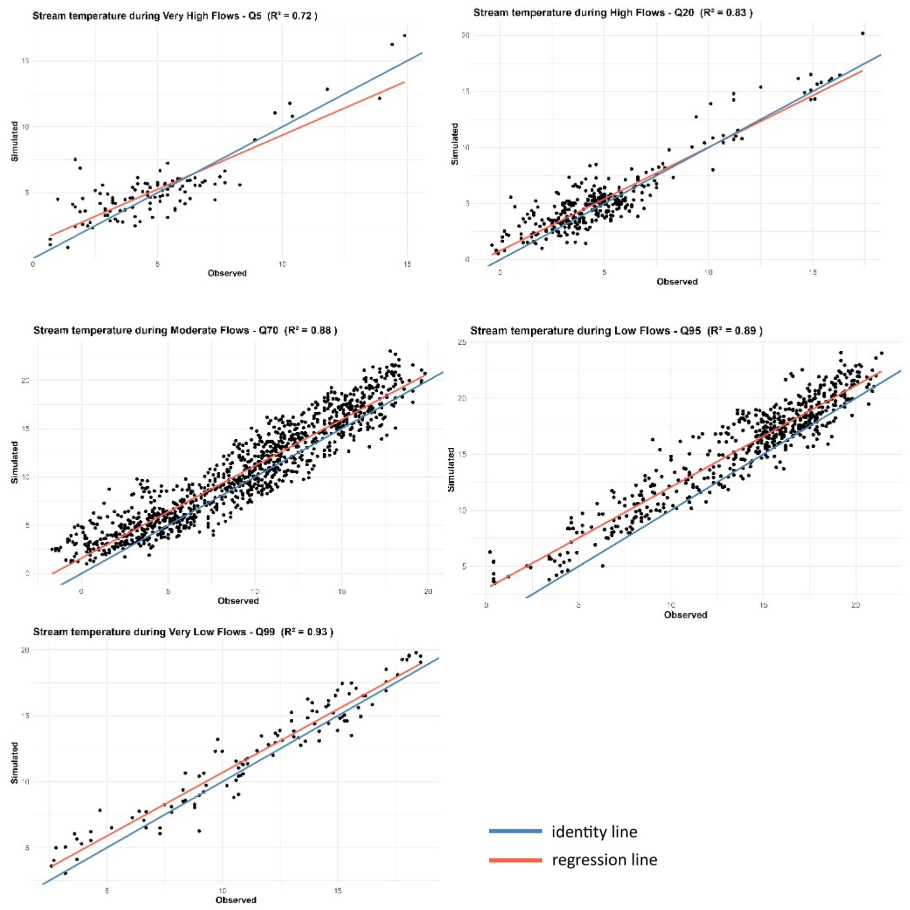
Flow-dependent model performance





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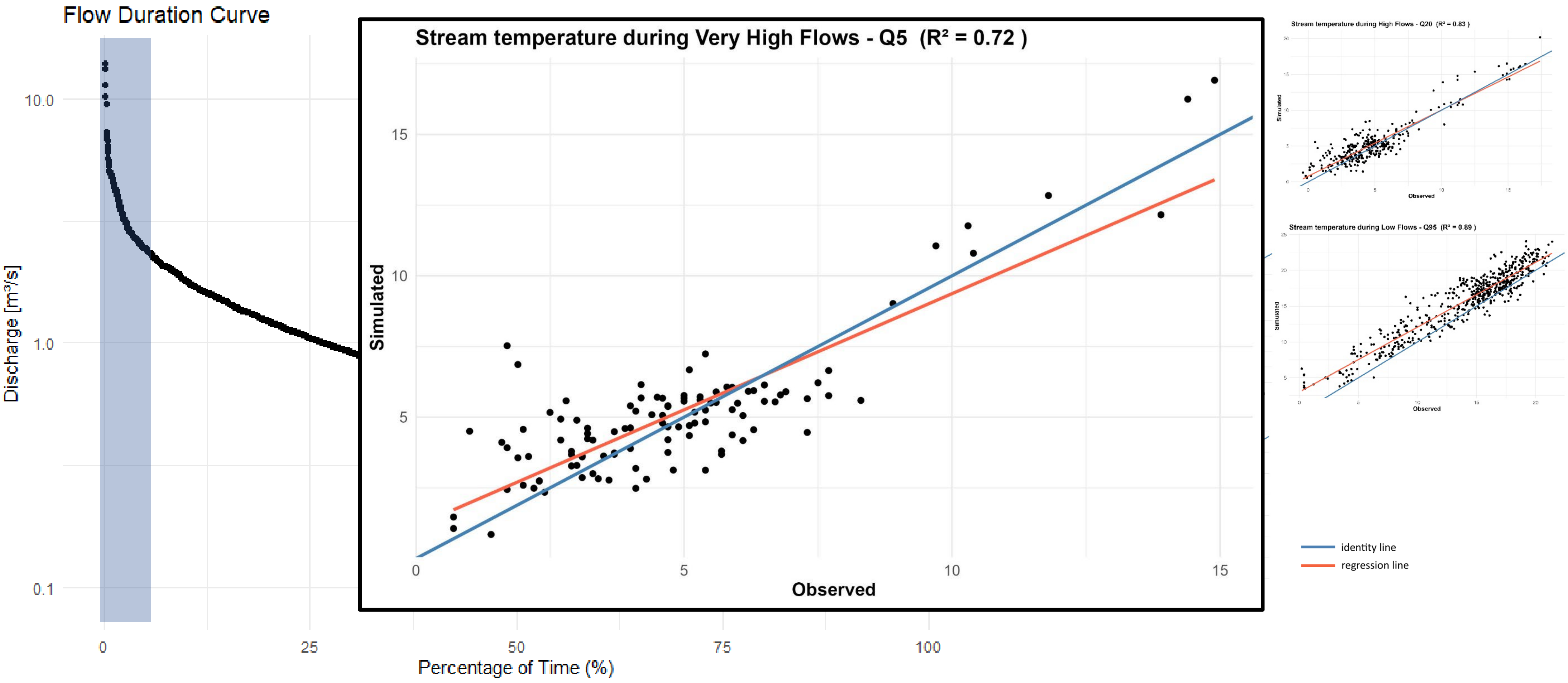
Flow-dependent model performance



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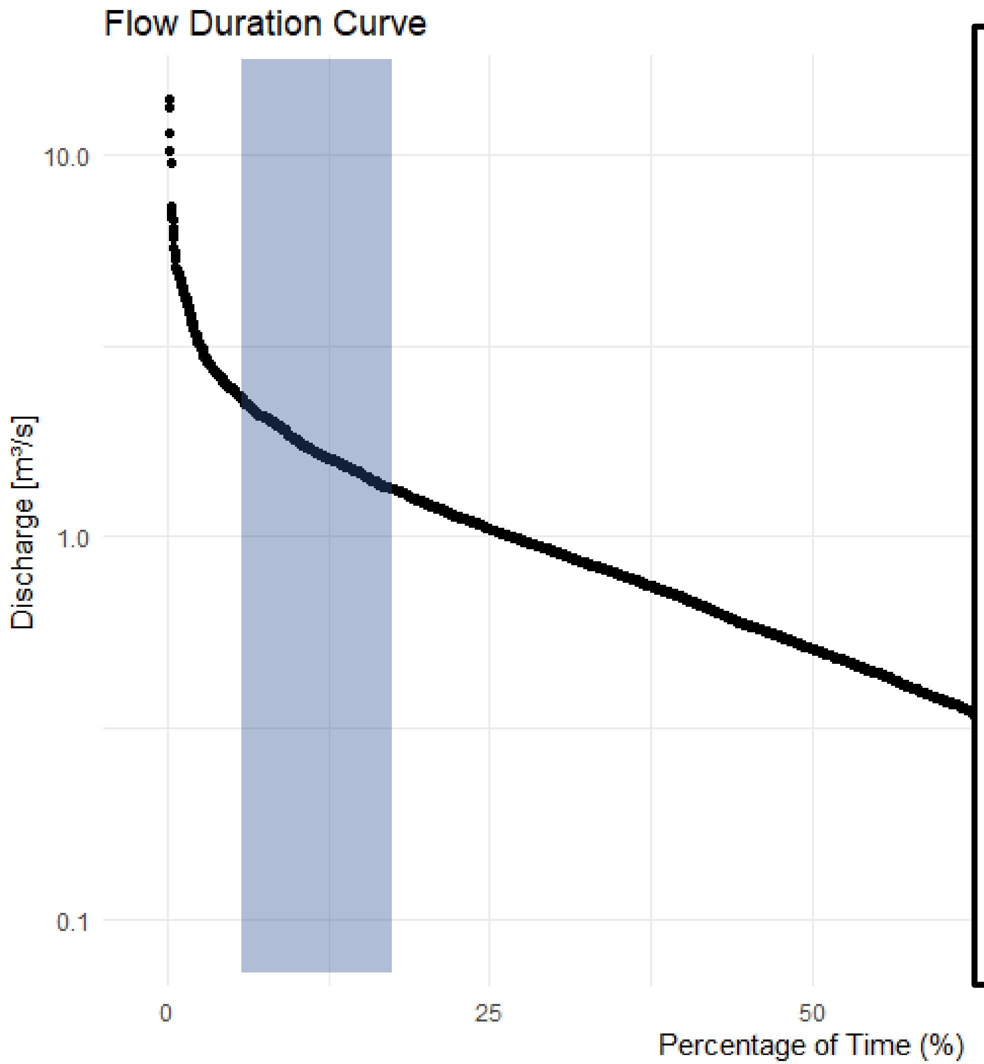
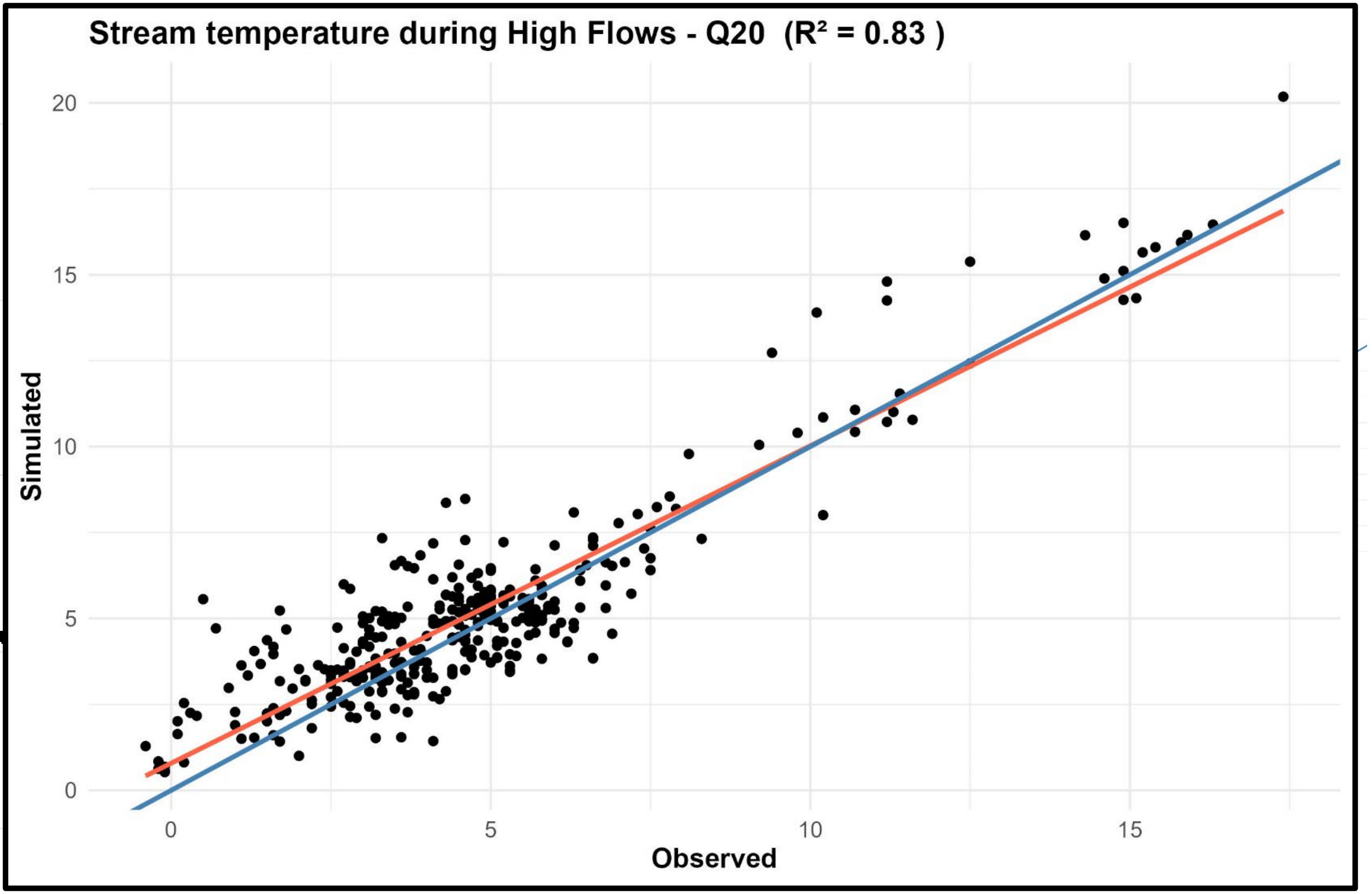
Flow-dependent model performance





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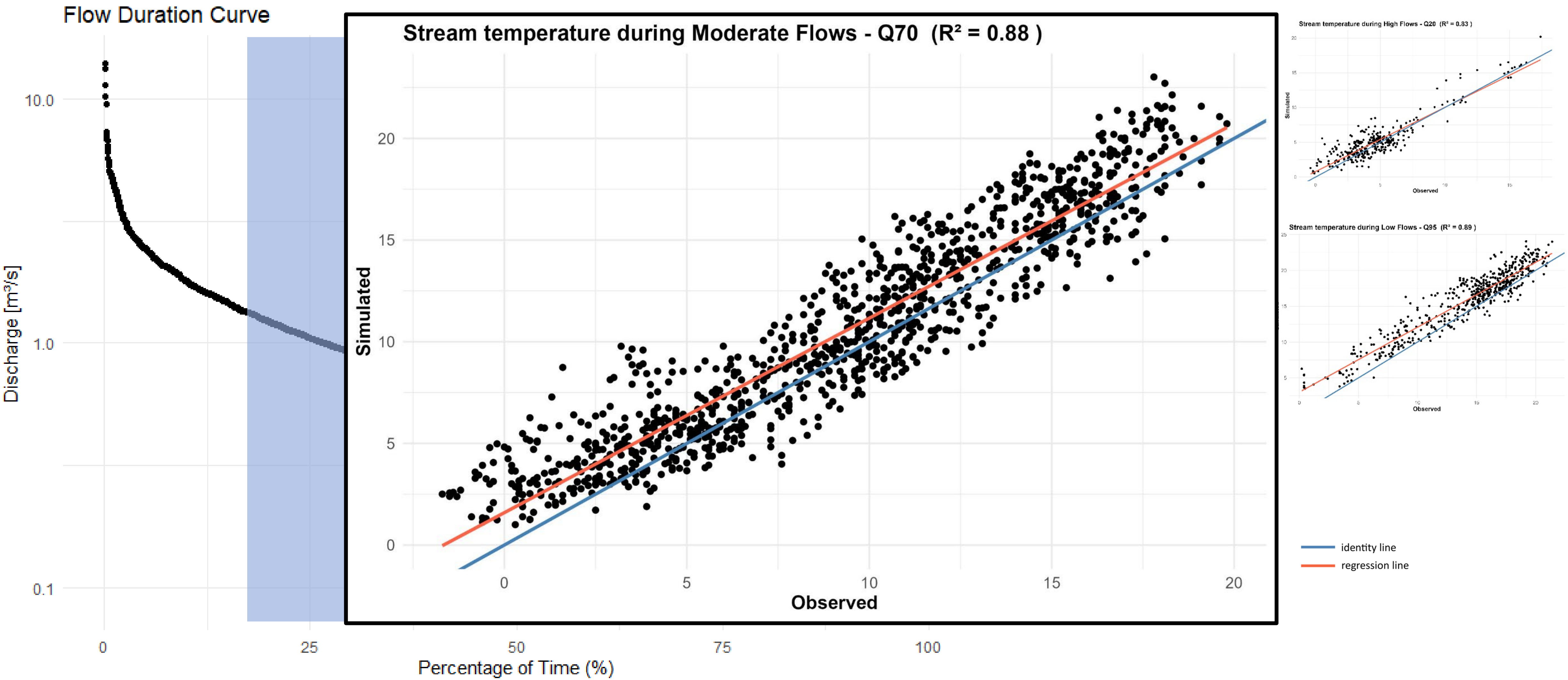
Flow-dependent model performance



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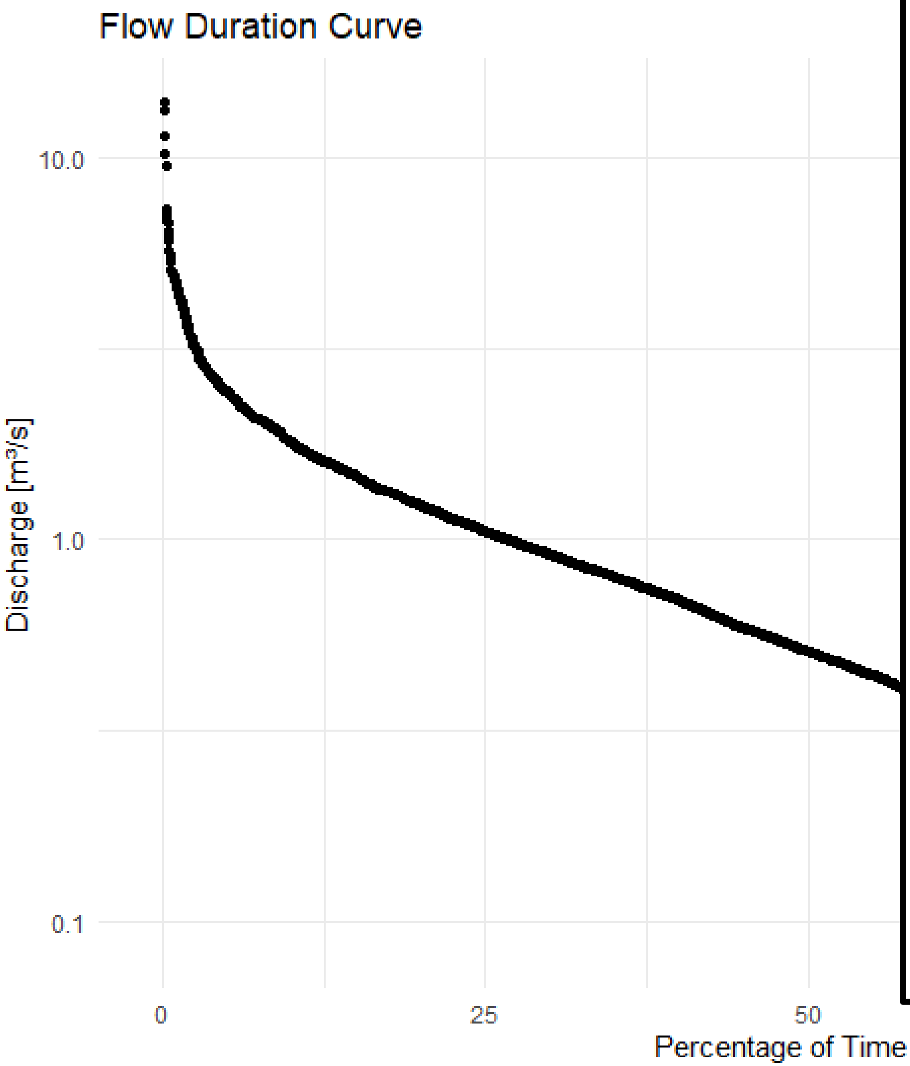
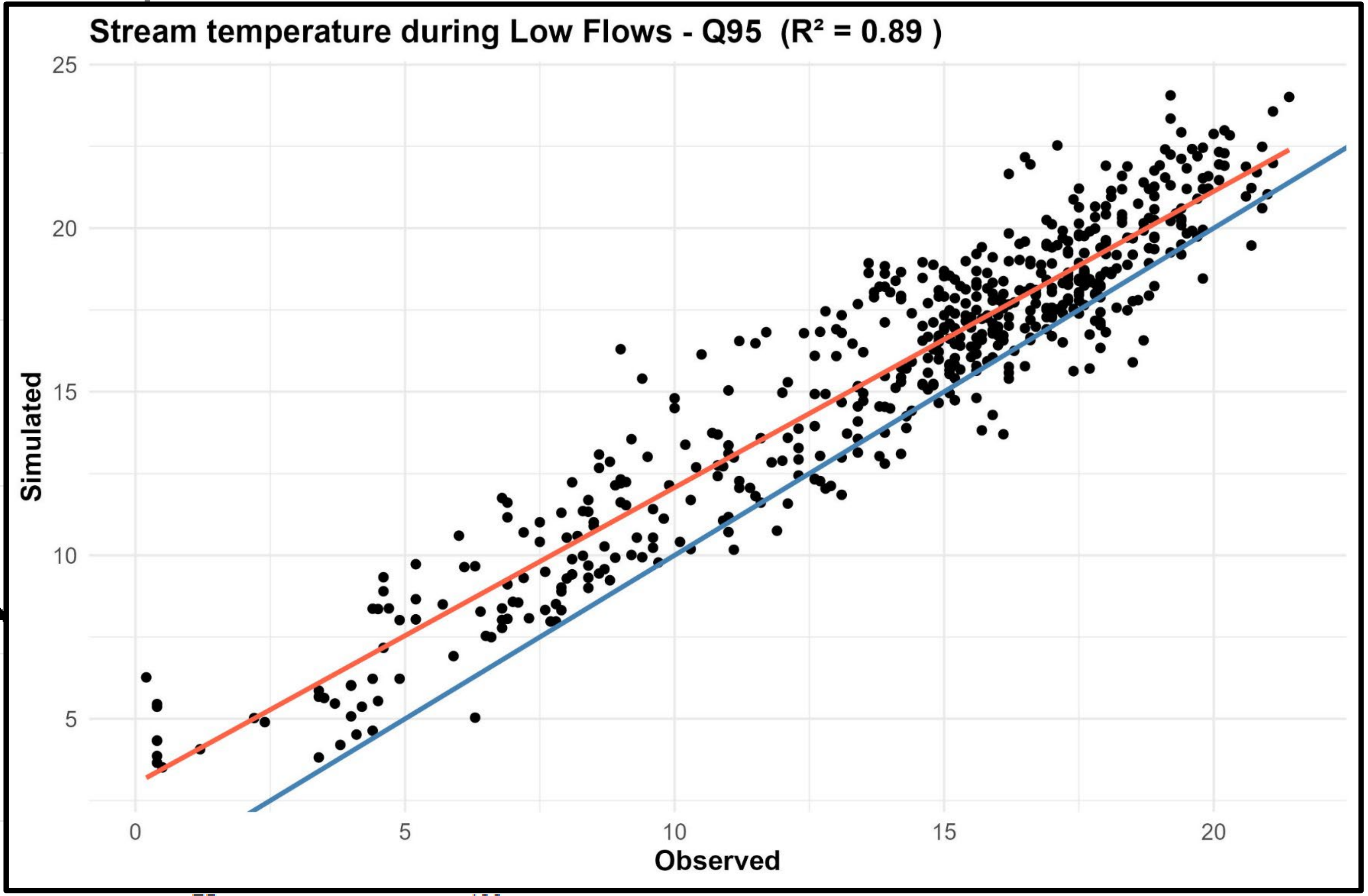
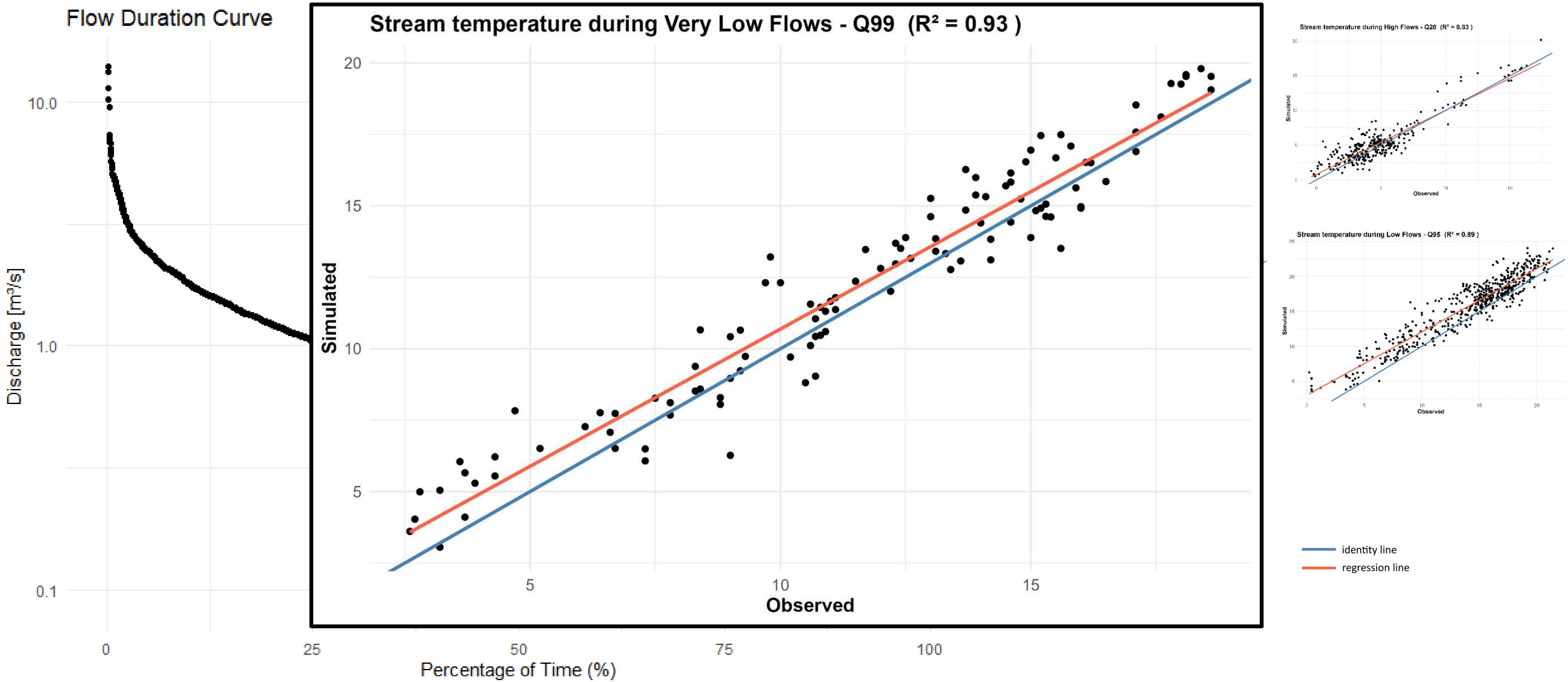
Flow-dependent model performance





Flow-dependent model performance



Summary

- Process-based improvement of the stream temperature model
- Substantial improvement of stream temperature model performance
- Model performance depends on hydrological process representation, particularly groundwater flow
- Added process representation allows complex scenario analyses (change in flow components, shading, climate change)

Thank you!

Contact: kpeters@hydrology.uni-kiel.de

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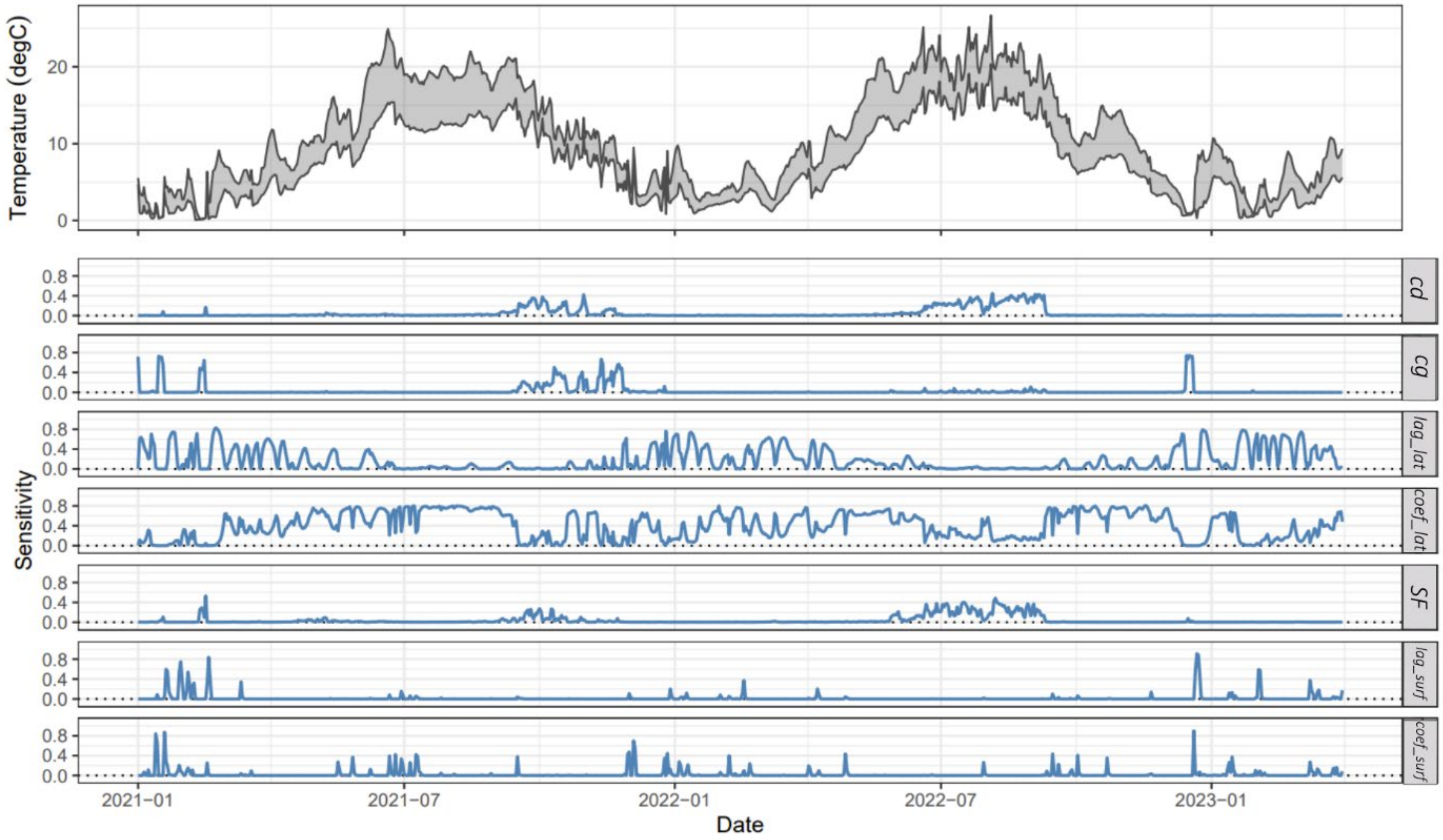
Temporal sensitivity



- Different parameter sensitivity confirms different impact and required separation of runoff components

Sensitivity Correlation