Extracting Signals from Satellite retrieved Land Surface Temperature for the Calibration of a Hydrological Model

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1. Motivation

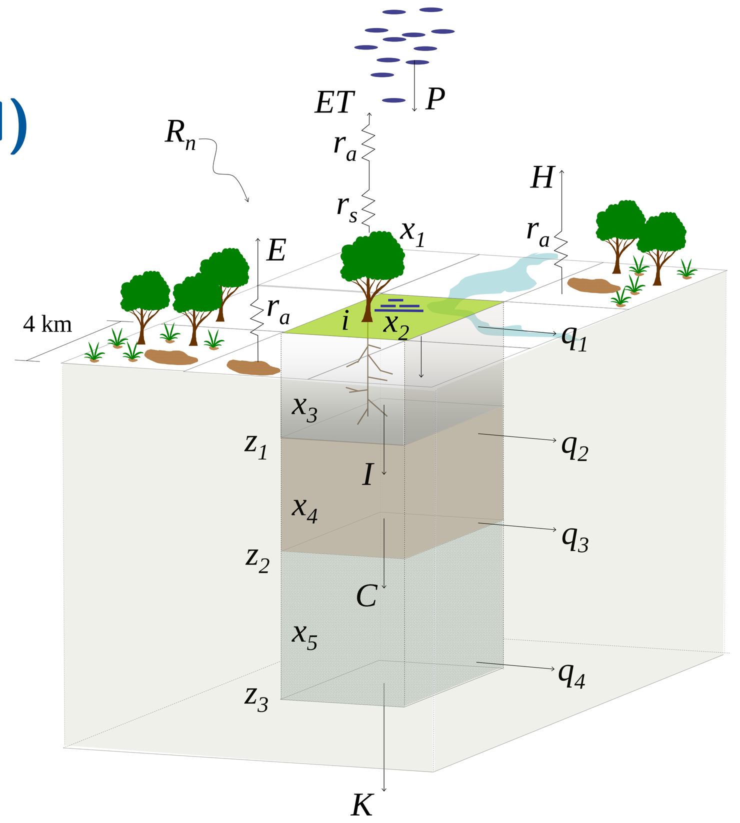
Hydrological models are usually calibrated against discharge measurements, and thus are only trained on information of a few points within a catchment. This procedure does not take into account any spatio-temporal variability of fluxes or state variables. Satellite data may help to account for this spatial variability. The objective of this study is to calibrate a hydrological model with satellite derived land surface temperature T_s. These data have the advantage to be broadly available even in regions where discharge measurements are barely on hand.

2. Methodology

Mesoscale Hydrologic Model (mHM)

To incorporate satellite data into the hydrological model mHM [1] an additional module has been developed to estimate $\widehat{T}_s$ using the energy balance. By closing the water balance with mHM the evapotranspiration is estimated by

$$\mathbf{ET} = P - Q - \Delta S \,.$$



Land Surface Temperature Model

$\widehat{T}_s$ was derived using mHM's **ET** estimation for solving the energy balance and the sensible heat equation. Assuming that the soil heat flux is negligible at the daily time scale, we get:

$$H = R_n - \lambda \cdot \mathbf{ET}$$

$$H = \rho \cdot c_p \cdot \frac{\widehat{T}_s - T_a}{r_a}$$

$$\widehat{T}_s = r_a \cdot \frac{R_n - \lambda \cdot \mathbf{ET}}{\rho \cdot c_p} + T_a$$

ET	...	evapotranspiration	$[mm\ d^{-1}]$
H	...	sensible heat flux	$[W\ m^{-2}]$
P	...	precipitation	$[mm\ d^{-1}]$
Q	...	observed discharge	$[mm\ d^{-1}]$
$\widehat{Q}$	...	simulated discharge	$[mm\ d^{-1}]$
r_a	...	aerodynamic resistance	$[s\ m^{-1}]$
R_n	...	net radiation	$[W\ m^{-2}]$
T_a	...	air temperature	$[K]$
T_s	...	satellite land surface temperature	$[K]$
$\widehat{T}_s$	...	simulated T_s	$[K]$
ΔS	...	change in soil moisture	$[mm\ d^{-1}]$
λ	...	latent heat of vaporization	$[kJ\ kg^{-1}]$

Optimization Objectives

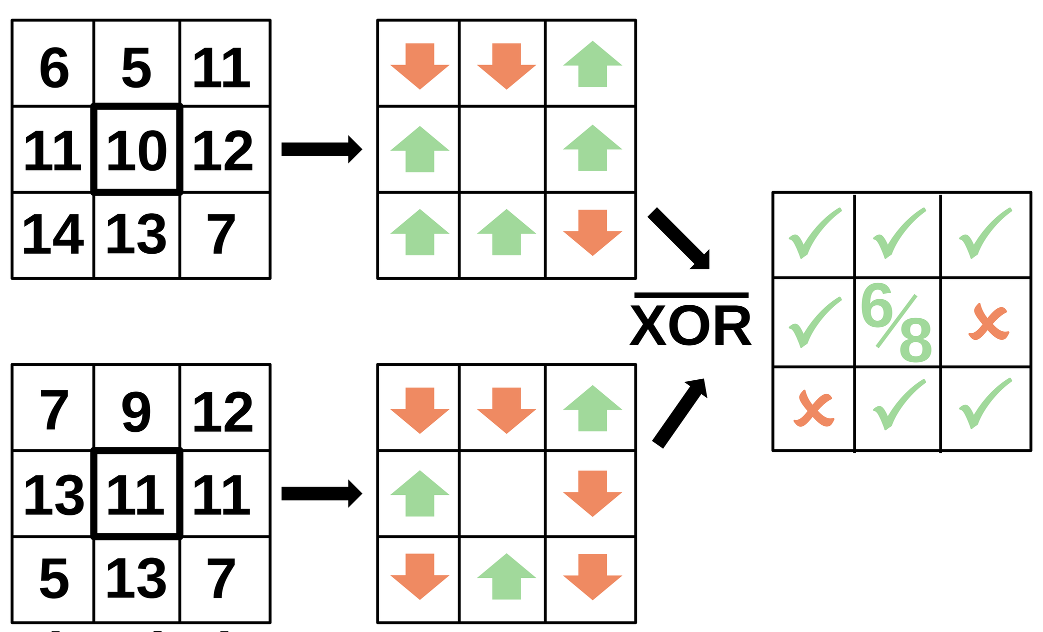
Q : $\|E_1 + E_2\|$

T$_s$: $\|E_3 + E_4\|$

Q & T$_s$: $\frac{2}{3}$ **Q** + $\frac{1}{3}$ **T**$_s$

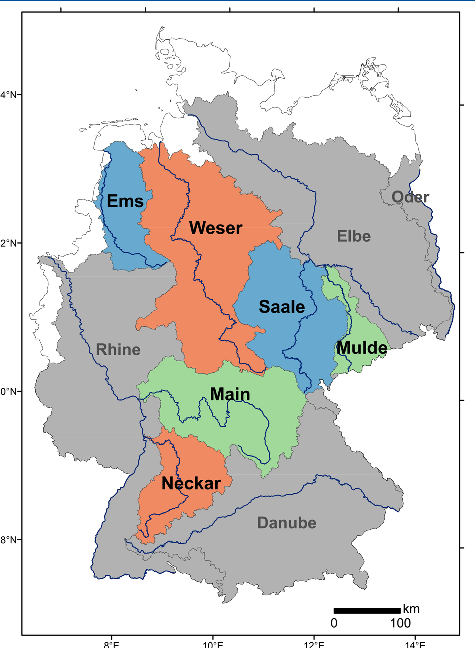
$E_1 = \mathrm{NSE}(Q, \widehat{Q})$
$E_2 = \mathrm{NSE}(\ln Q, \ln \widehat{Q})$
$E_3 = \mathrm{PS}(T_s, \widehat{T}_s)$
$E_4 = \rho(T_s, \widehat{T}_s)$

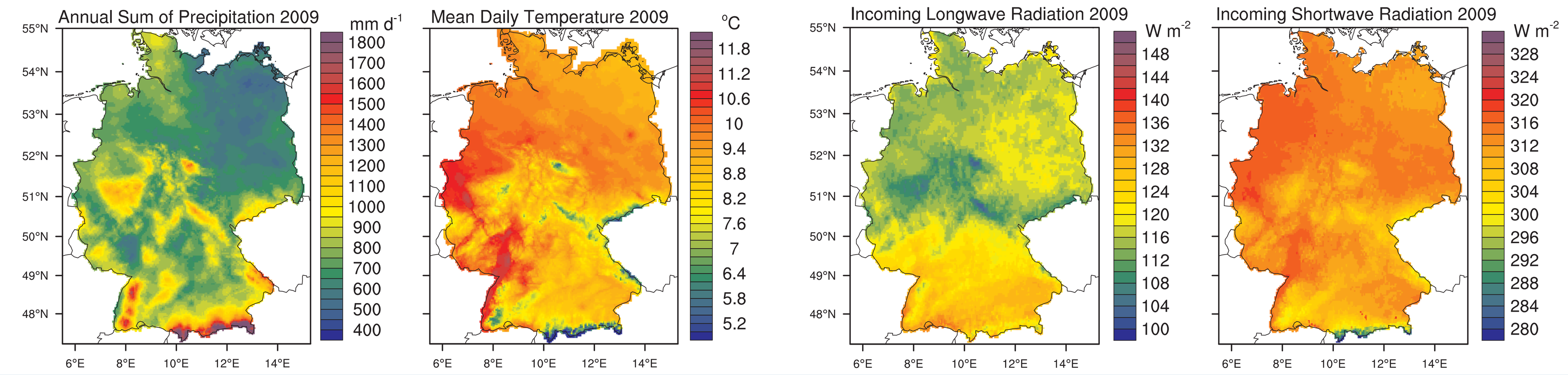
Pattern Similarity (PS)



3. Input Data & Study Domain

- LSA SAF [2]: T_s, long- and shortwave radiation, albedo, emissivity
- German Weather Service [3]: air temperature, precipitation
- NCEP-CFSR [4]: wind data
- German authorities [5][6]: DEM, pedological and geological data

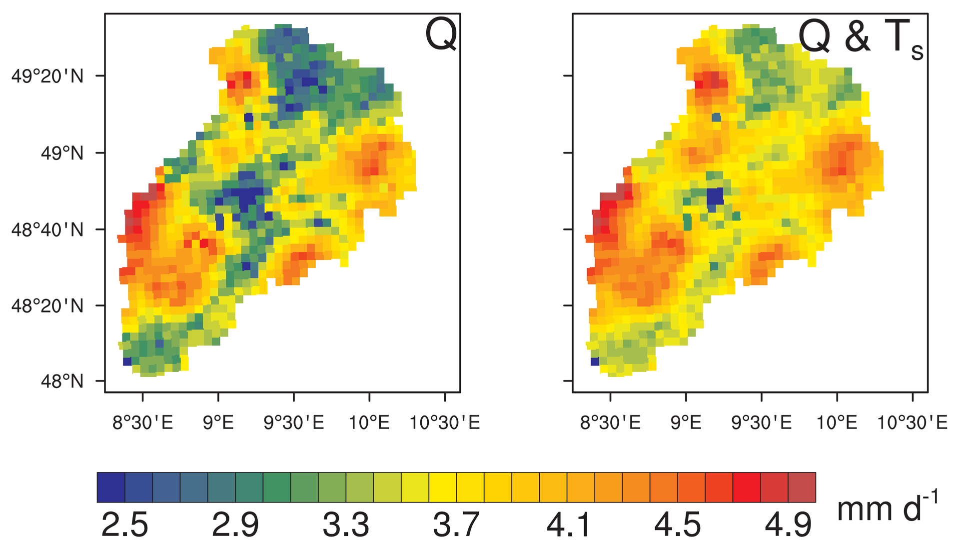




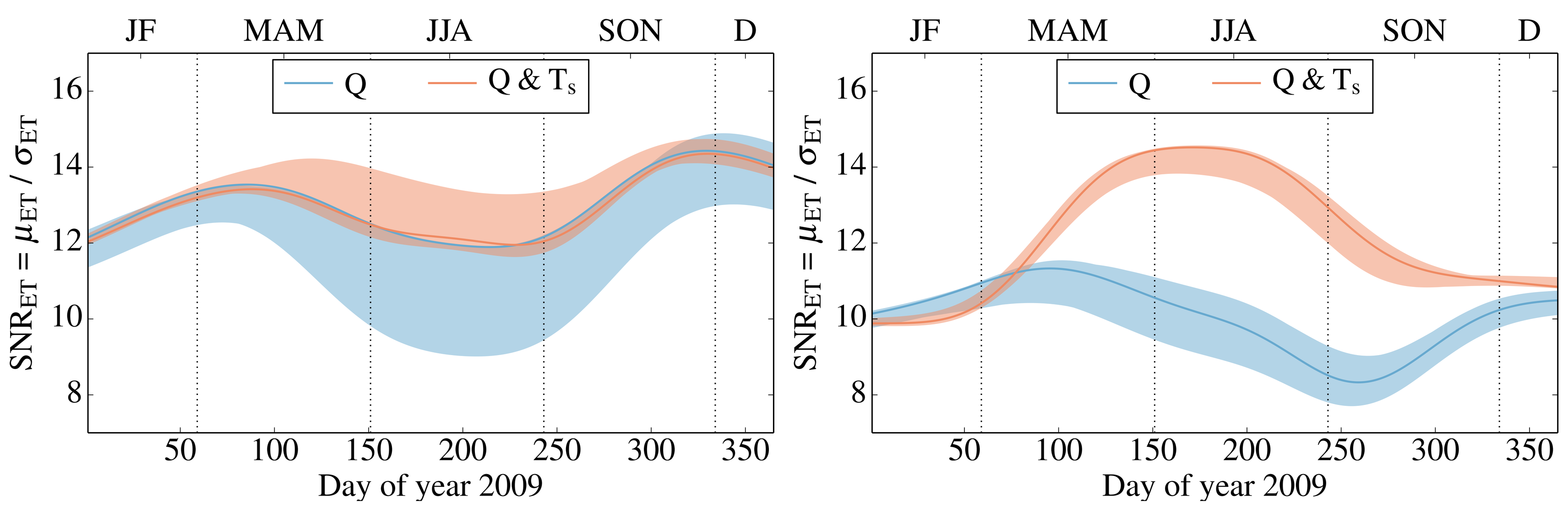
4. Optimization Regarding Q & T_s

Evaluation regarding Evapotranspiration ET

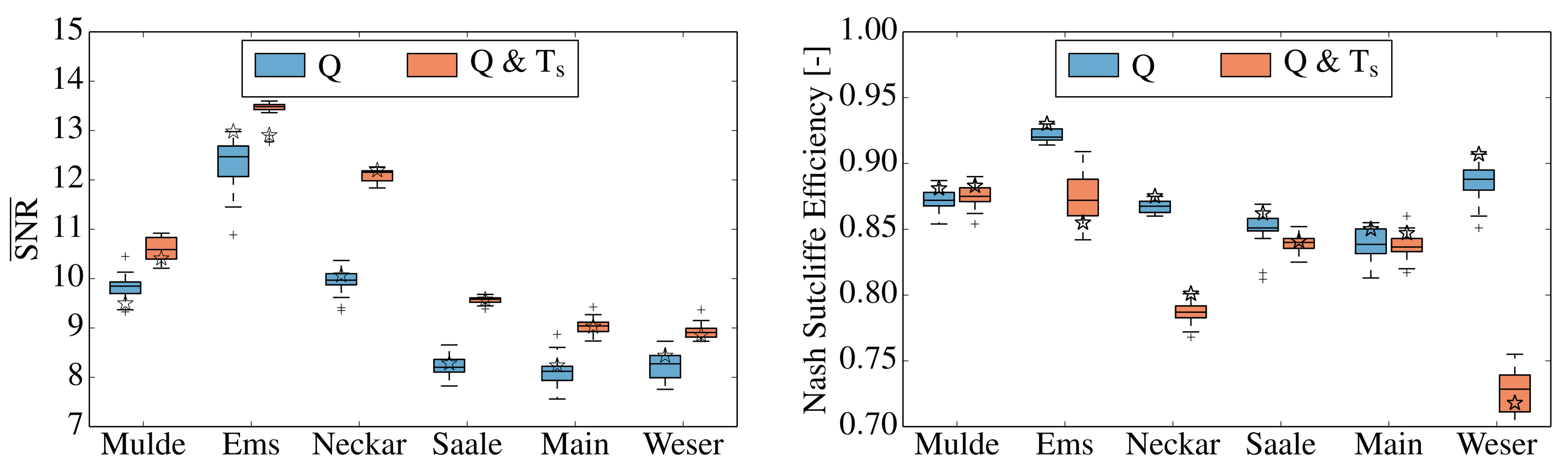
The evapotranspiration estimation which has been derived by the calibration against discharge and land surface temperature (**Q & T**$_s$) has lower spatial variabilities compared to calibrations against only discharge (**Q**). This behavior is observed especially during summer.



ET estimation for 2009-07-01 in the Neckar



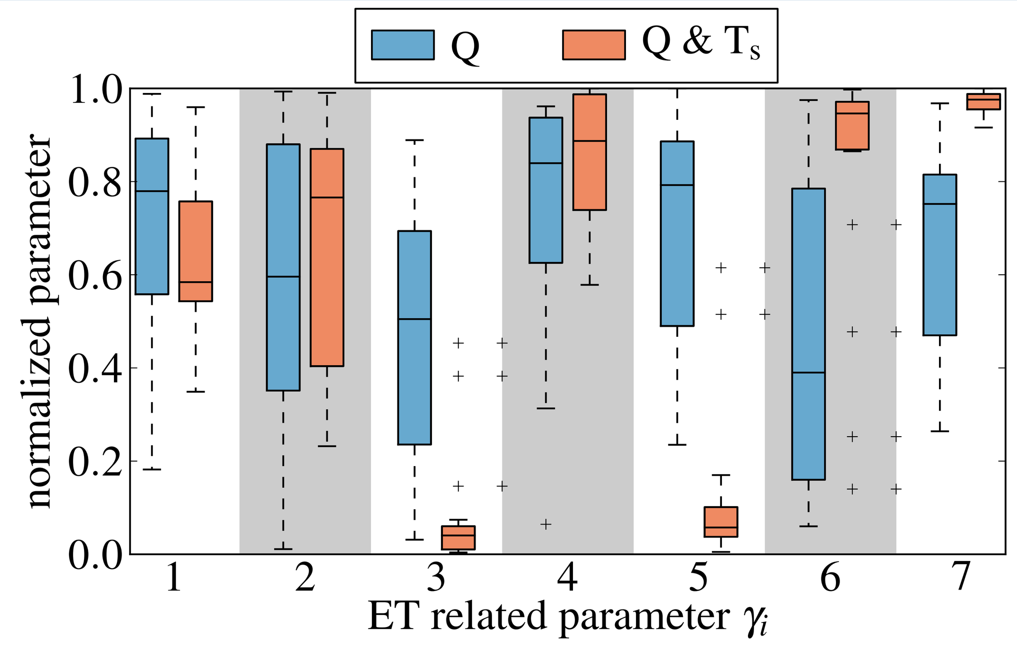
Signal to Noise ratio of the catchments Ems (left) and Neckar (right)



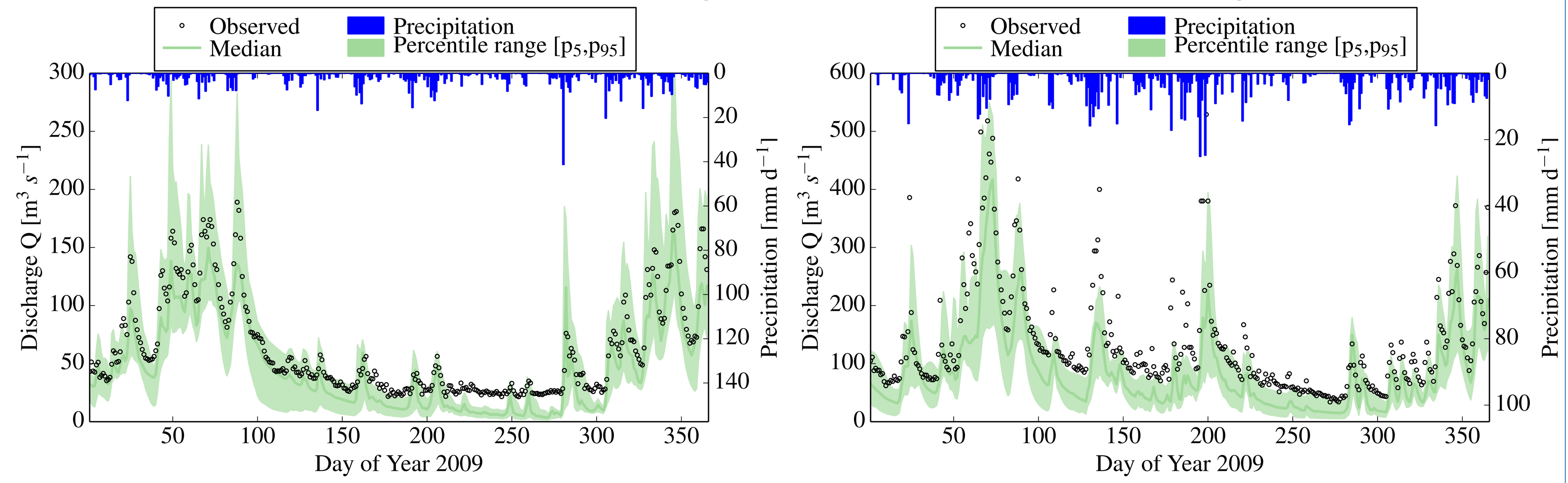
Temporal average of SNR (left), and model performance regarding discharge (right)

Parametric Uncertainty

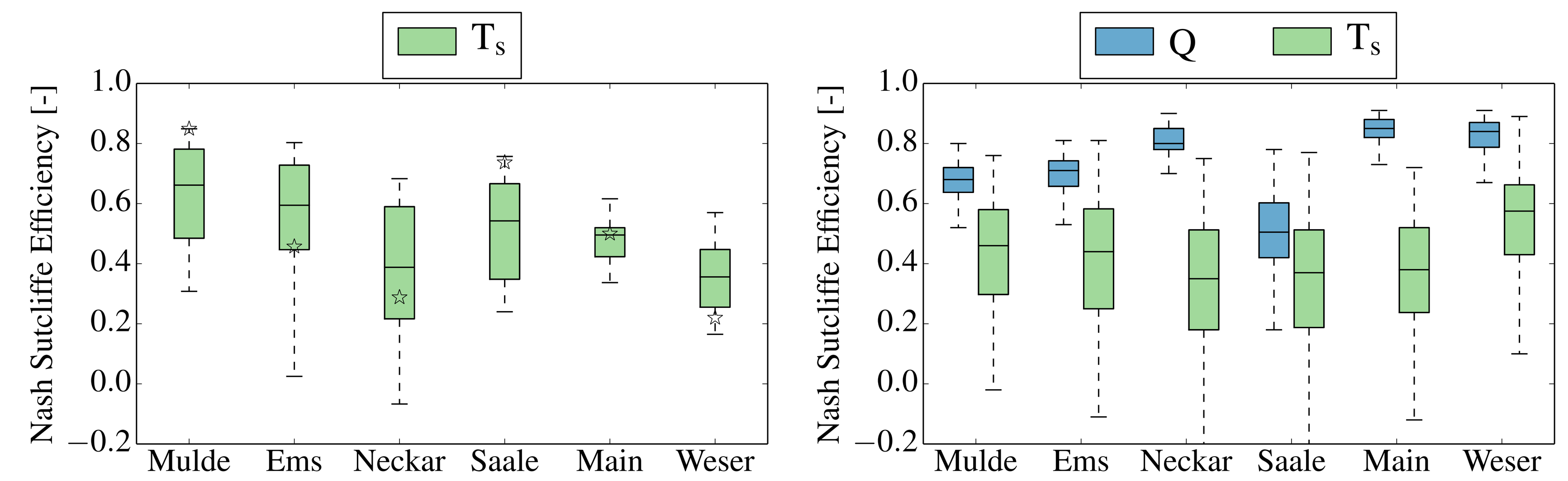
γ_1	...	infiltration shape parameter
γ_2	...	max. capacity of surface water reservoir
γ_3	...	permanent wilting point
γ_4	...	field capacity
γ_5	...	fraction of roots (forest)
γ_6	...	fraction of roots (pervious)
γ_7	...	fraction of roots (impervious)



5. Predictive Skill of T_s (T_s only Calibration)



Estimation of discharge for Ems (left) and Neckar (right).



Model performance regarding Q for site specific (left) and transferred parameters (right).

6. Conclusions

- The spatial variability of ET is reduced by incorporating T_s in the calibration.
- The modification of the spatial fields of ET are evoked by a reduced uncertainty in the estimation of ET related parameters.
- The dynamics and high flows in Q are well captured by a T_s only calibration.

References

[1] L. Samaniego, R. Kumar, and S. Attinger, "Multiscale parameter regionalization of a grid-based hydrologic model at the mesoscale," *Water Resources Research*, 2010.

[2] Satellite Application Facility for Land Surface Analysis (LSA SAF), EUMETSAT.

[3] Deutscher Wetterdienst (DWD), Offenbach, Germany.

[4] National Centers for Environmental Prediction (NCEP), National Weather Service (NOAA), USA.

[5] Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover und Berlin, Germany.

[6] Bundesamt für Kartographie und Geodäsie (BKG), Frankfurt am Main, Germany.

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