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Supplement of

Why does a conceptual hydrological model fail to correctly predict discharge changes in response to climate change?

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Supplement S1 Influence of including a penalty for model parameters that deviate from an a priori distribution into the objective function

The objective function applied for model calibration contains a penalty for model parameters that deviate from an a priori distribution, consistent with the study by Merz2011. In order to test the possible influence of this criterion on the difference between simulated and observed discharge trends, we also performed simulations where the model was calibrated without this criterion, i.e. w_3 in Eq. 1 was set to 0. This had only small effects on changes in model performance over time (Fig. S1). When the penalty for deviating from the prior distributions was omitted from the objective function, calibrating the model in subperiod S1 and applying it to 1978–2013 resulted in a gap between simulated and observed discharge trends of 91 ± 49 mm yr^{-1} per 35 yrs and thus only very small differences to the original model with a gap of 95 ± 50 mm yr^{-1} per 35 yrs.

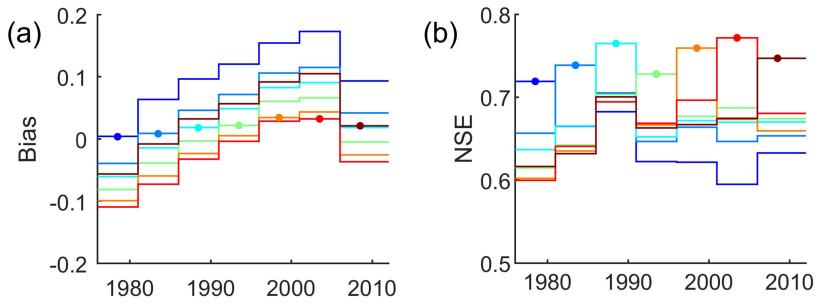

Figure S1. (a) Bias and **(b)** NSE for the different subperiods averaged over all study catchments when omitting the penalty for deviating from the prior distributions. Each line refers to models calibrated in one subperiod, showing bias and NSE during calibration (marked by the filled circles) and during evaluation in the other six subperiods.

Further supplementary tables and figures

Table S1 Model performance with respect to discharge and snow cover for the baseline model *V*0 and model variant *V*6 (where a criterion on snow cover was included in the objective function), as averages over all catchments. Values indicate the range over 7 calibration periods and 42 evaluation periods (using the other 6 subperiods for each calibration period). NSE: Nash-Sutcliffe efficiency for discharge, bias: volume bias for discharge, Z_s: ratio of days with poor snow cover performance (see main text) to the total number of days in the simulation period.

	NSE		Bias		Z_s	
	Calibration	Evaluation	Calibration	Evaluation	Calibration	Evaluation
*V*0 baseline model	0.70–0.75	0.56–0.71	0.005–0.03	-0.13–0.18	0.08–0.12	0.07–0.13
*V*6 include snow data in calibration	0.70–0.75	0.58–0.71	0.004–0.04	-0.11–0.18	0.05–0.08	0.05–0.09

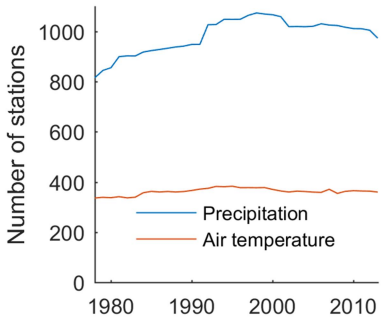

Figure S2. Number of precipitation and air temperature stations included for the interpolation of precipitation and air temperature in the data sets *P*0 and *T*0.

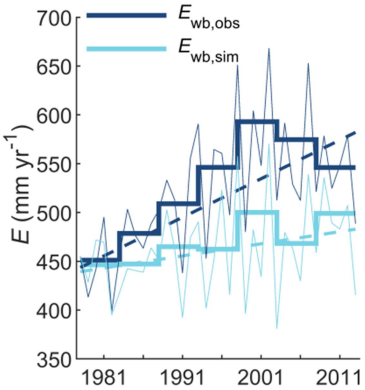

Figure S3. Temporal variations in simulated and observed water balance derived evaporation plus storage changes (calculated as precipitation minus simulated respectively observed discharge), as averages over all study catchments. The thick lines show subperiod annual means, the thin lines annual sums, and the broken lines linear trends.

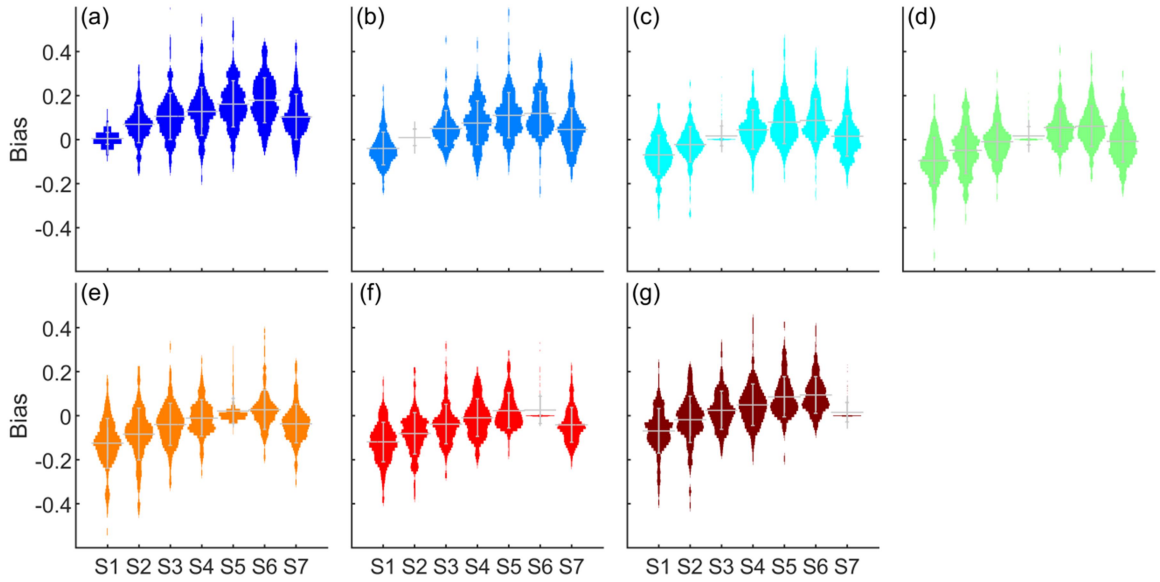

Figure S4. Violin plots showing the distribution of the bias across the 156 study catchments of the models calibrated in subperiod *S*1 **(a)**, *S*2 **(b)**, *S*3 **(c)**, *S*4 **(d)**, *S*5 **(e)**, *S*6 **(f)**, and *S*7 **(g)**, evaluated for subperiod *S*1– *S*7 (*x*-axis in each subplot). Grey crosses represent the mean and standard deviation. The means are the same as shown in Fig. 4 (a).

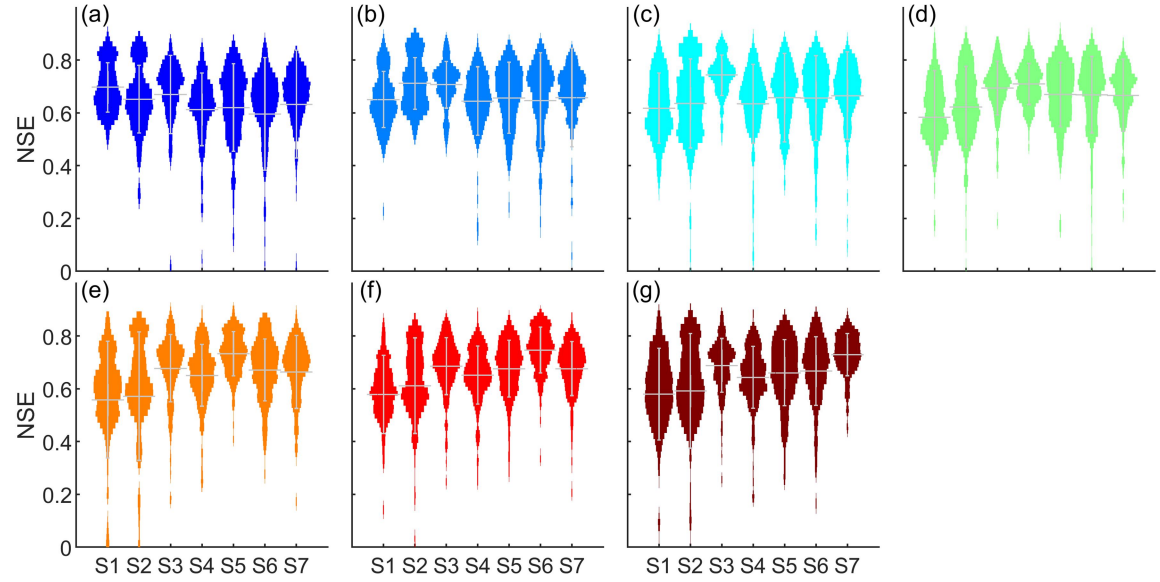

Figure S5. Violin plots showing the distribution of NSE across the 156 study catchments of the models calibrated in subperiod *S*1 **(a)**, *S*2 **(b)**, *S*3 **(c)**, *S*4 **(d)**, *S*5 **(e)**, *S*6 **(f)**, and *S*7 **(g)**, evaluated for subperiod *S*1– *S*7 (*x*-axis in each subplot). Grey crosses represent the mean and standard deviation. The means are the same as shown in Fig. 4 (b).

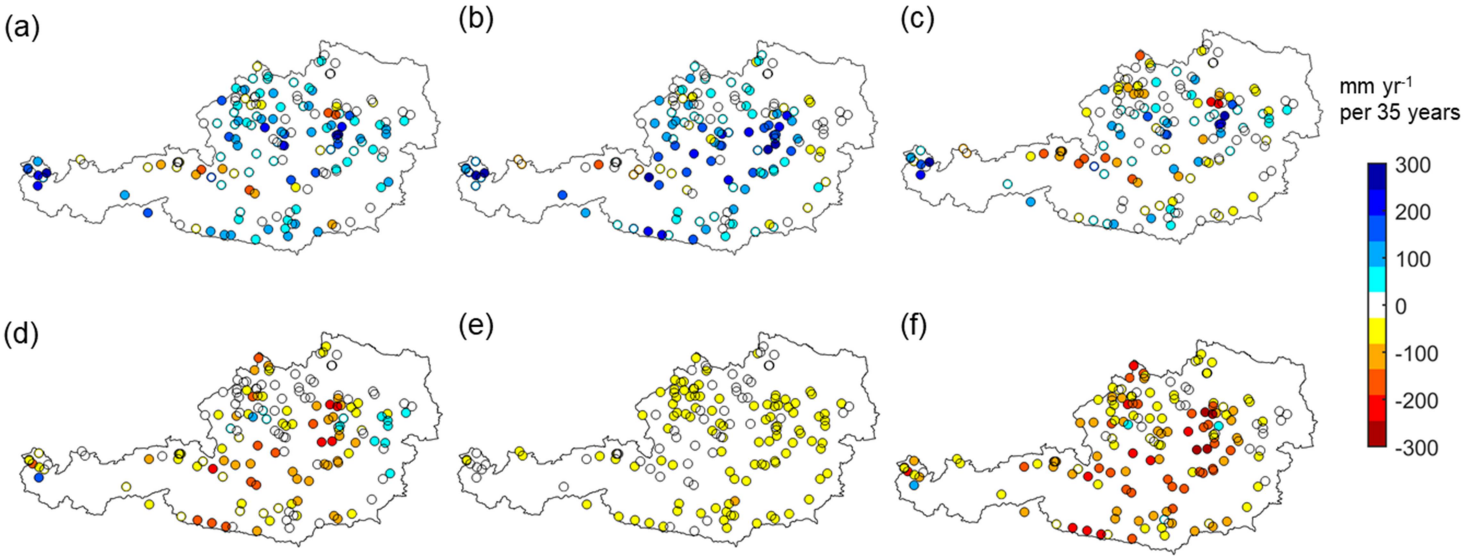

Figure S6. Spatial patterns of trends of the differences between simulated discharge for selected model variants and **(a–c)** observed discharge, or **(d–f)** simulated discharge of the baseline model *V*0. **(a,d)** refer to model variant *V*2, **(b,e)** to *V*8, and **(c,f)** to *V*9. Filled circles indicate significant trends at $p \leq 0.05$.