Supplementary Material

for

Multi-decadal fluctuations in root zone storage capacity through vegetation adaptation to hydro-climatic variability has minor effects on the hydrological response in the Neckar basin, Germany.

Siyuan Wang[1], Markus Hrachowitz[1], Gerrit Schoups[1],

[1]Department of Water Management, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Stevinweg 1, 2628CN Delft, Netherlands

Correspondence to: Siyuan Wang (S.Wang-9@tudelft.nl)

Table S1. Water balance and constitutive equations of distributed hydrological model

Reservoirs	Water balance		Constitutive equations	
Interception	$\frac{ds_i}{dt} = P_{rain} - E_i - P_{re}$	(S4)	$P_{rain} = P, when\ T > T_t$	(S10)
			$E_i = \min(E_p, S_i/dt)$	(S11)
			$P_{re} = \max((S_i - S_{imax})/dt, 0)$	(S12)
Snow	$\frac{ds_{snow}}{dt} = P_{snow} - M_{snow}$	(S5)	$P_{snow,e} = P, when\ T_e \le T_t$	(S13)
			$P_{snow} = \sum P_{snow,e} \cdot W_e$	(S14)
			$M_{snow,e} = \min(C_{melt} * (T_e - T_t), S_{snow,e}/dt), when\ T_e > T_t$	(S15)
			$M_{snow} = \sum M_{snow,e} \cdot W_e$	(S16)
Unsaturated reservoir	Forest/ Grass: $\frac{ds_u}{dt} = P_e - E_a - R_u - R_{perc}$	(S6)	$P_e = P_{re} + M_{snow}$	(S17)
			$\rho = S_u/S_{umax}$	(S18)
			$E_a = (E_p - E_i) * \min(\rho/C_a, 1)$	(S19)
			$C_r = 1 - (1 - \rho)^{\gamma}$	(S20)
	Wetland: $\frac{ds_u}{dt} = P_e - E_a - R_u + R_{cap}$	(S7)	$R_u = (1 - C_r) * P_e$	(S21)
			$R_{perc} = \min(c_{pmax} * \rho, S_u/dt)$	(S22)
			$R_{cap} = \min(c_{pmax} * (1 - \rho), \frac{S_s}{dt} * P_{HRU})$	(S23)
			$R_{pref} = (1 - D) * R_u$	(S24)
Fast reservoir	$\frac{ds_f}{dt} = R_f - Q_f$	(S8)	Forest/ Grass: $R_f = D * R_u$	(S25)
			Wetland: $R_f = R_u$	(S26)
			$Q_f = K_f * S_f$	(S27)
Slow reservoir	$\frac{ds_s}{dt} = R_{perctot} + R_{preftot} - R_{captot} - Q_s$	(S9)	$R_{perctot} = \sum R_{perc} \cdot P_{HRU}$	(S28)
			$R_{preftot} = \sum R_{pref} \cdot P_{HRU}$	(S29)
			$R_{captot} = \sum R_{cap} \cdot P_{HRU}$	(S30)
			$Q_s = K_s * S_s$	(S31)

Table S2. Model parameters and their prior distributions in Borg_MOEA method.

	Parameters	Unit	Description	Parameter Constraints	Prior distributions	References
Global	T_t	°C	Threshold temperature to split snowfall and rainfall		-2.5-2.5	(Gao et al., 2014; Hrachowitz et al., 2013)
	C_{melt}	mm °C^{-1}	Melt factor		1-5	(Prenner et al., 2018)
	C_a	-	Evapotranspiration coefficient		0.1-0.7	(Gao et al., 2017)
	K_s	d^{-1}	Recession coefficient of slow response reservoir		0.002-0.2	(Prenner et al., 2018)
Forest	S_{imaxF}	mm	Interception capacity	$S_{imaxF}>S_{imaxG}$	0.1-5	(Gao et al., 2014)
	S_{umaxF}	mm	Root zone storage capacity	$S_{umaxF}>S_{umaxG}$	50-500	(Gao et al., 2014)
	γ_F	-	Shape parameter		0.1-5	(Gao et al., 2014)
	D	-	Splitter to fast and slow response reservoirs		0-1	(Gao et al., 2014)
	c_{pmaxF}	mm d^{-1}	Percolation capacity		0.1-4	(Prenner et al., 2018)
	K_{fF}	d^{-1}	Recession coefficient of fast response reservoir	$K_{fF}>K_s$	0.2-5	(Hrachowitz et al., 2013)
Grassland	S_{imaxG}	mm	Interception capacity		0.1-5	(Gao et al., 2014)
	S_{umaxG}	mm	Root zone storage capacity	$S_{umaxG}>S_{umaxW}$	50-500	(Gao et al., 2014)
	γ_G	-	Shape parameter		0.1-5	(Gao et al., 2014)
	c_{pmaxG}	mm d^{-1}	Percolation capacity		0.1-4	(Prenner et al., 2018)
	K_{fG}	d^{-1}	Recession coefficient of fast response reservoir	$K_{fG}>K_s$	0.2-5	(Hrachowitz et al., 2013)
Wetland	S_{umaxW}	mm	Root zone storage capacity	$S_{umaxW} < S_{umaxG}$	50-500	(Gao et al., 2014)
	γ_W	-	Shape parameter		0.1-5	(Gao et al., 2014)
	c_{rmax}	mm d^{-1}	Percolation capacity		0.1-4	(Gao et al., 2014)

Table S3. The performance metrics for the most balanced solution and the ranges of all performance metrics for the full set of pareto optimal solutions for the multi-objective calibration cases (Scenarios 1 – 2) are shown here.

	Scenario 1	Scenario 2			
	T (1953-2022)	t1 (1953-1972)	t2 (1973-1992)	t3 (1993-2012)	t4 (2013-2022)
NSE_Q	0.59(0.06-0.55)	0.60(-0.16-0.57)	0.57(0.02-0.54)	0.59(-0.32-0.52)	0.56(-0.61-0.50)
$NSE_{log(Q)}$	0.67(0.34-0.64)	0.69(0.23-0.62)	0.65(0.30-0.59)	0.63(-0.33-0.53)	0.72(-0.77-0.66)
$NSE_{FDClog(Q)}$	0.96(0.92-0.99)	0.96(0.94-0.99)	0.98(0.88-0.99)	0.98(0.58-0.99)	0.97(0.16-0.99)
NSE_{Cr}	0.99(0.56-0.97)	0.98(0.21-0.94)	0.87(0.47-0.96)	0.95(0.27-0.94)	0.90(0.07-0.97)
NSE_{AC}	0.90(0.86-0.91)	0.86(0.84-0.89)	0.91(0.86-0.93)	0.90(0.87-0.92)	0.89(0.63-0.92)
$RE_{Cr,summer}$	0.83(0.82-0.89)	0.90(0.81-0.90)	0.89(0.79-0.90)	0.87(0.77-0.89)	0.84(0.69-0.88)
$RE_{Cr,winter}$	0.91(0.89-0.91)	0.88(0.88-0.90)	0.92(0.92-0.93)	0.90(0.89-0.91)	0.91(0.82-0.92)

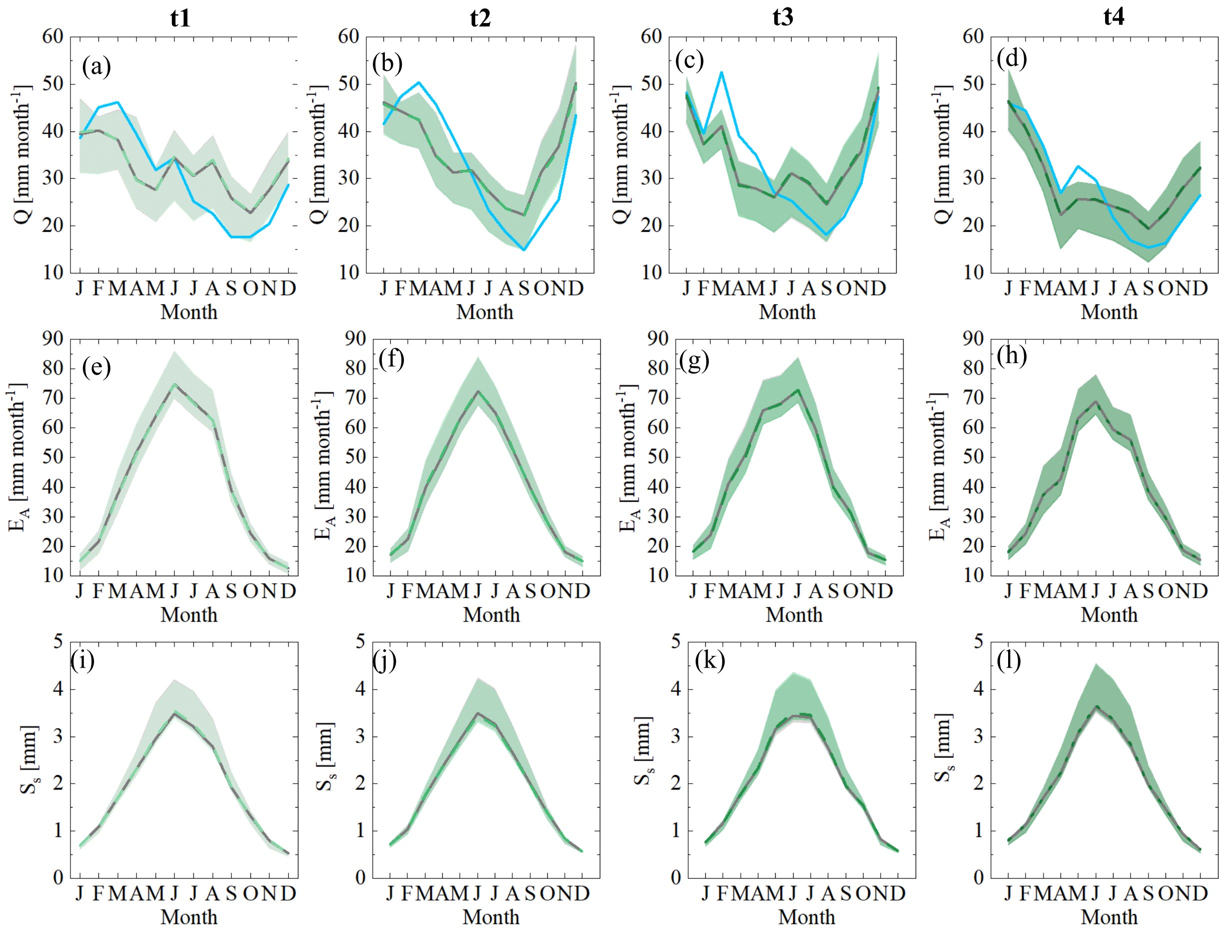

Figure S1. The mean monthly hydrological response of several flux and state variables for four sub-time periods t_1-t_4 based on two scenarios (gray shades: scenario 1, green shades: scenario 2). The mean monthly (a)-(d) streamflow Q (the blue lines indicate the observed streamflow), (e)-(h) actual evaporation E_A and (i)-(l) groundwater storage Ss are shown. The lines and shaded areas show the most balanced solution and 5th– 95th percentiles based on the pareto front solutions retained as feasible.

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