



Supplement of

Impact of seasonal snow on the recharge of a mountain karst aquifer under climate change: the Dévoluy case study (Southern Alps, France)

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Hydrological year	Rainfall (mm/year)	Snowfall (mm/year)	Precipitation (rain + snow) (mm/year)	Psol vs Ptotal (%)	Snow index
2015-2016	741	261	1002	26	++
2016-2017	919	288	1207	24	++
2017-2018	741	571	1312	44	++++
2018-2019	716	443	1159	38	+++

Table S1. SAFRAN (mean over the Dévoluy massif) liquid precipitation (rainfall), solid precipitation (snowfall) and total precipitation by hydrological years (2015–2019). Psol vs. Ptotal (%) corresponds to the proportion of solid precipitation relative to total precipitation. The Snow index provides a qualitative classification of snow amount, from very low (+) to very high (++++). Snow index is arbitrary defined by ranges of 150 mm.

Hydrological year	Precipitation (mm)	Observed discharge (m ³ .s ⁻¹)	Model 2	Model 2 T+2	Model 2 T+4		
			Simulated discharge (m ³ .s ⁻¹)	Simulated discharge (m ³ .s ⁻¹)	Discharge reduction (%)	Simulated discharge (m ³ .s ⁻¹)	Discharge reduction (%)
2015-2016	1002	4.01	3,65 ± 0.11	3,29 ± 0.09	-10%	2,95 ± 0.08	-19
2016-2017	1207	3.88	4,53 ± 0.13	4,35 ± 0.12	-4%	4,08 ± 0.12	-10
2017-2018	1312	5.72	5,38 ± 0.15	5,15 ± 0.14	-4%	4,92 ± 0.14	-9
2018-2019	1159	4.19	5,07 ± 0.15	4,86 ± 0.14	-4%	4,63 ± 0.14	-9
Mean 2015- 2019	1170	4.45	4,66 ± 0.13	4,41 ± 0.12	-5%	4,14 ± 0.12	-11

Table S2. Comparison of average observed and simulated discharge for the Dévoluy aquifer over 4 hydrological years (2015–2019). Results are shown for the median value of the 5.000 simulation results and median absolute deviation for reference model (Model 2) and temperature increase scenarios (T+2°C and T+4°C). Precipitation inputs, mean annual discharges, and discharge reductions relative to Model 2 are reported.

Hydrological year	Precipitation (mm)	Model 2		Model 2 T+2		Model 2 T+4	
		PET OUDIN (mm)	AET (mm)	PET OUDIN (mm)	AET (mm)	PET OUDIN (mm)	AET (mm)
2015-2016	1002	490	439 ± 10	569	494 ± 11	649	544 ± 11
2016-2017	1207	528	455 ± 18	606	488 ± 20	685	532 ± 20
2017-2018	1312	496	418 ± 14	573	462 ± 10	651	512 ± 10
2018-2019	1159	519	397 ± 21	597	429 ± 22	676	458 ± 27
Mean 2015-2019	1170	508	427 ± 16	586	468 ± 16	665	512 ± 18

Table S3. Annual precipitation and evapotranspiration estimates for the Dévoluy aquifer over 4 hydrological years (2015-2019). PET (Oudin's method) and AET are shown for the median value of the 5.000 simulation results for reference model (Model 2) and warming scenarios (+2 °C and +4 °C).

Hydro year	Criterion	Model 1		Model 2	
		Hydro year	Snowmelt period (Apr-Aug)	Hydro year	Snowmelt period (Apr-Aug)
2015-2016	NSE	-0.26	-0.11	0.59	0.63
	VE	0.34	0.42	0.63	0.66
	KGE _{np}	0.46	0.40	0.80	0.67
	MAE	2.65	3.10	1.50	1.81
	PBIAS	-8.80	-56.5	-8.10	-30.9
2016-2017	NSE	0.29	0.44	0.66	0.75
	VE	0.34	0.53	0.57	0.69
	KGE _{np}	0.53	0.66	0.76	0.87
	MAE	2.60	2.09	1.70	1.39
	PBIAS	17.2	-28.6	16.8	-5.70
2017-2018	NSE	-0.22	-0.33	0.86	0.88
	VE	0.14	0.36	0.74	0.80
	KGE _{np}	0.62	0.34	0.89	0.90
	MAE	4.90	6.50	1.50	1.98
	PBIAS	-6.2	-57.4	-5.9	-5.10
2018-2019	NSE	-0.81	-0.05	0.29	0.26
	VE	0.22	0.46	0.54	0.59
	KGE _{np}	0.54	0.55	0.74	0.80
	MAE	3.26	2.91	1.95	2.24
	PBIAS	21.6	-35.8	20.8	11.9
2015-2019	NSE	-0.18	0.01	0.70	0.77
	VE	0.25	0.42	0.63	0.71
	KGE _{np}	0.59	0.48	0.85	0.87
	MAE	3.34	3.63	1.65	1.85
	PBIAS	4.8	-47.4	4.9	-6.9

Table S4. Performance criteria for Model 1 (without snow routine) and Model 2 (with snow routine) for the full hydrological year (September–August) and the snowmelt period (April–August). NSE: Nash-Sutcliffe Efficiency; VE: Volume Error; MAE: Mean Absolute Error ($\text{m}^3\cdot\text{s}^{-1}$); PBIAS: Percent Bias (%). Values represent the median of 5,000 calibrated parameter sets. The 2015–2019 row shows overall performance calculated on the entire four-year period.

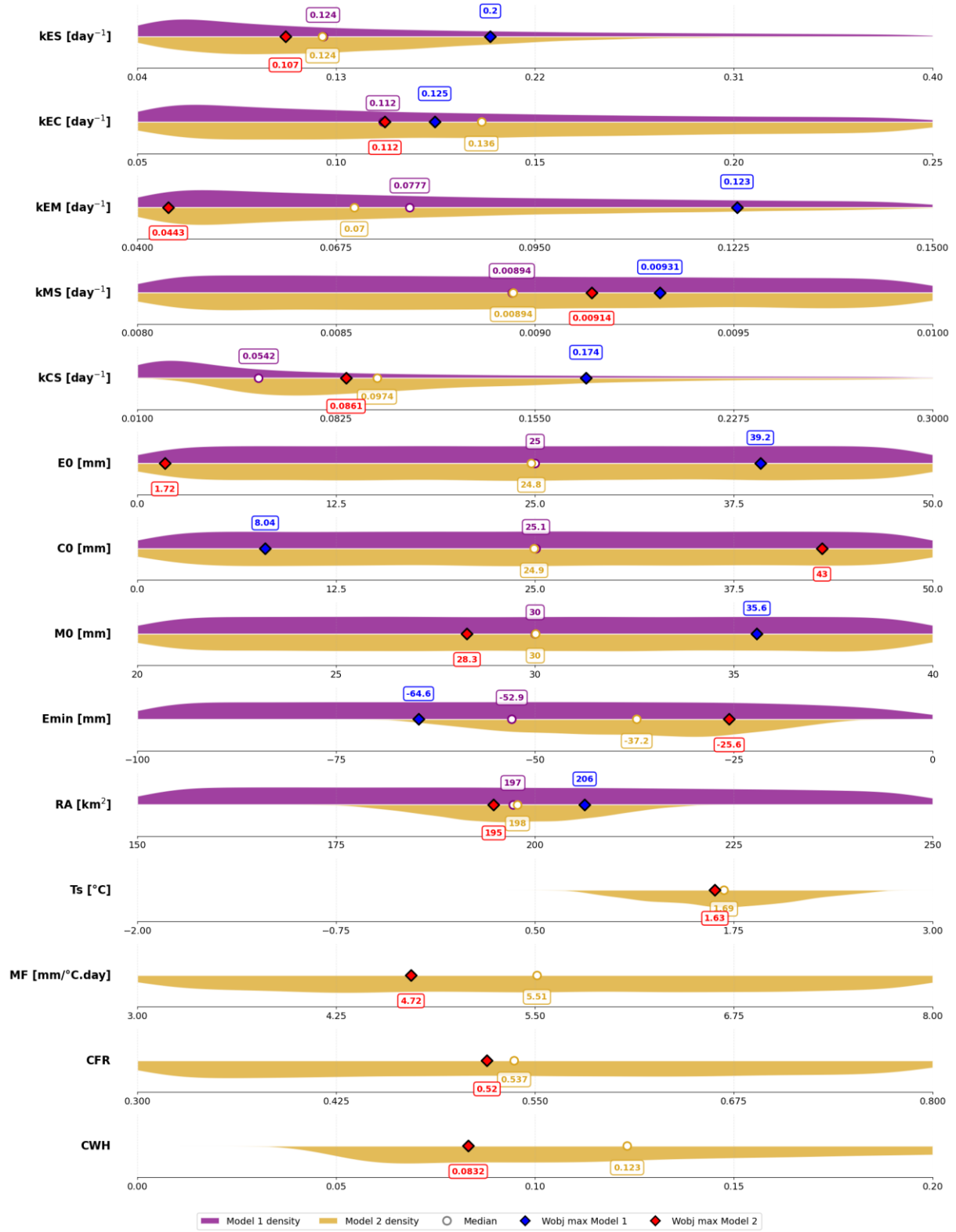


Fig. S1. Calibrated parameter distributions for Model 1 (without snow routine, purple) and Model 2 (with snow routine, gold). Violin plots show probability density distributions from the 5,000 simulations. White circles indicate median values. Blue and red diamonds mark parameter set yielding maximum objective function (W_{obj_max}) for Model 1 and Model 2, respectively. Parameters include recession coefficients (kES, kEC, kEM, kMS, kCS), warm-up initial value (E0, C0, M0), storage for evapotranspiration parameter (Emin), Recharge area (RA), and snow routine parameters (Ts, MF, CFR, CWH - Model 2 only).