

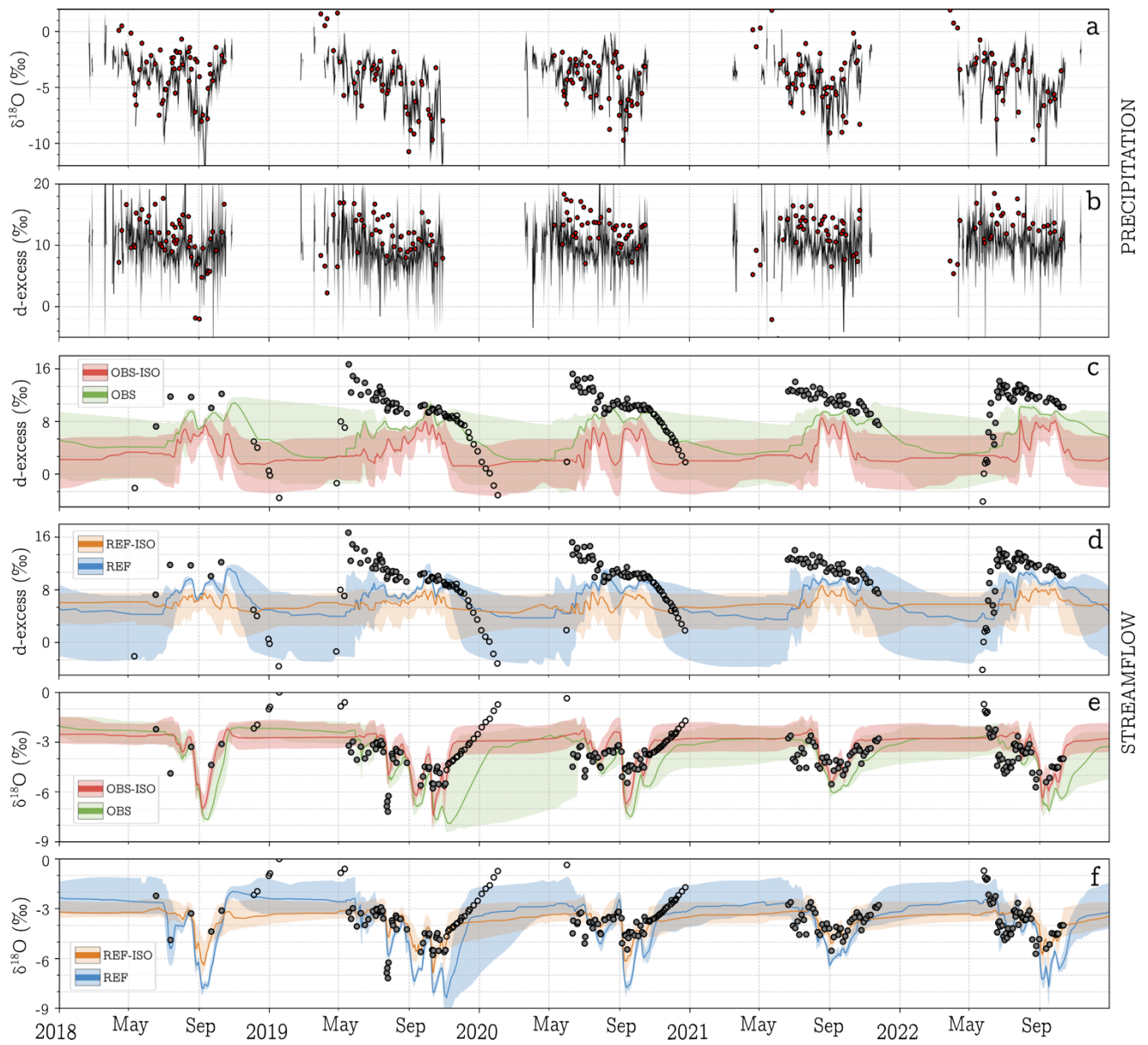


Figure S1. $\delta^{18}\text{O}$ and $d\text{-excess}$ time series (panels a-b) in precipitation —from local measurements (red dots) and IsoGSM atmospheric simulations (lines)—, and (panels c-f) at the basin outlet —measured (dots) and across calibration scenarios (colours). Shaded envelopes show the 10th–90th percentile range of simulations, with solid lines indicating the median. In panels c-f, Observations of $\delta^{18}\text{O}$ and $d\text{-excess}$ are shown for non-evaporated water as black points and for evaporated water as hollow black points; note that panel e-f is similar to Fig. 7a-b, adding evaporated measurements.

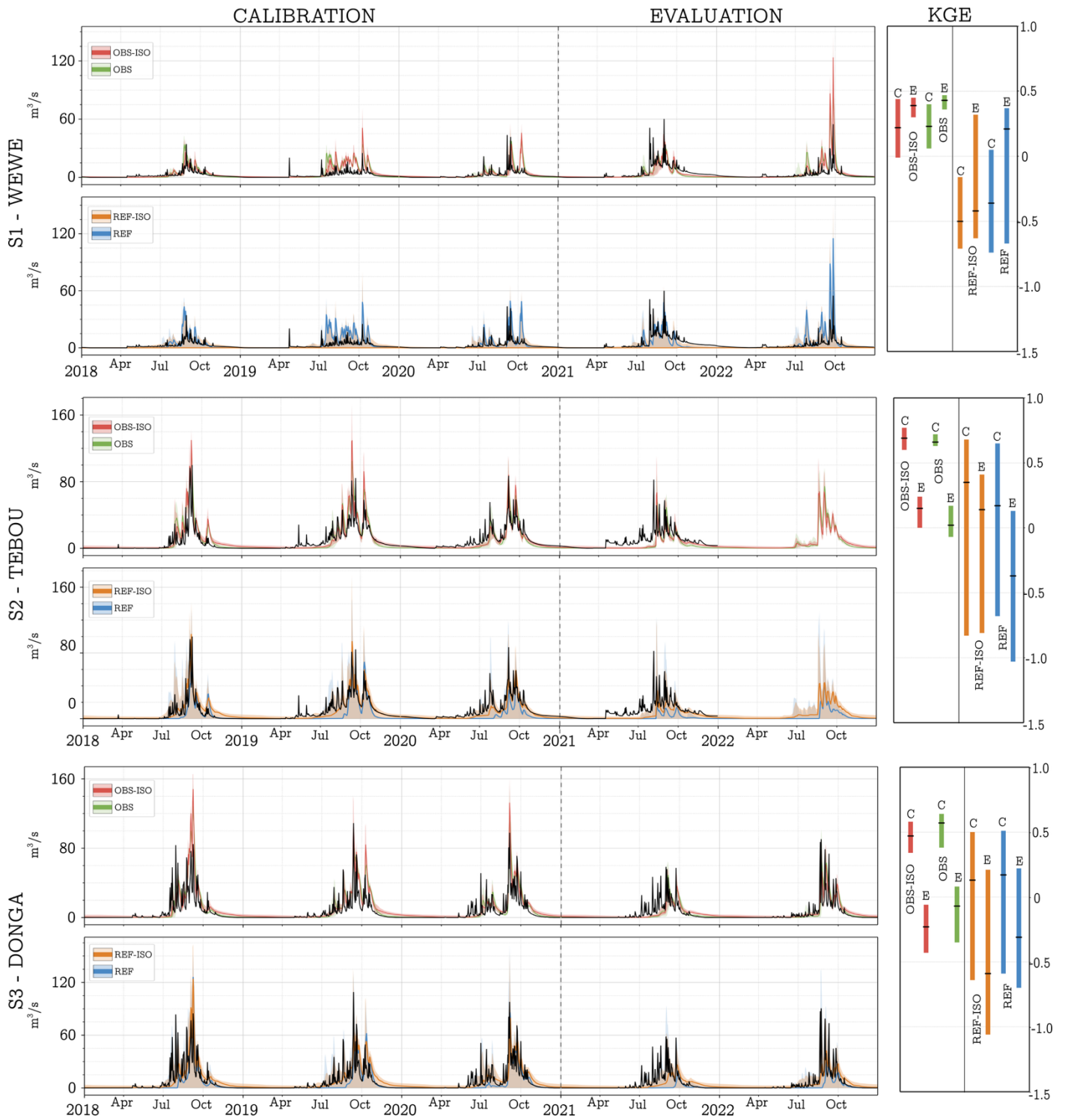


Figure S2. Left panels: simulated discharge time series at the sub-basin stations across calibration scenarios. Shaded envelopes indicate the 10th–90th percentile range of simulations, with solid lines inside representing the median. Observations are shown as black lines. Right panels: colored bars represent the 10th–90th percentile of KGE values across scenarios, for calibration (C) and evaluation (E) period, with thin black horizontal bars indicating median values.

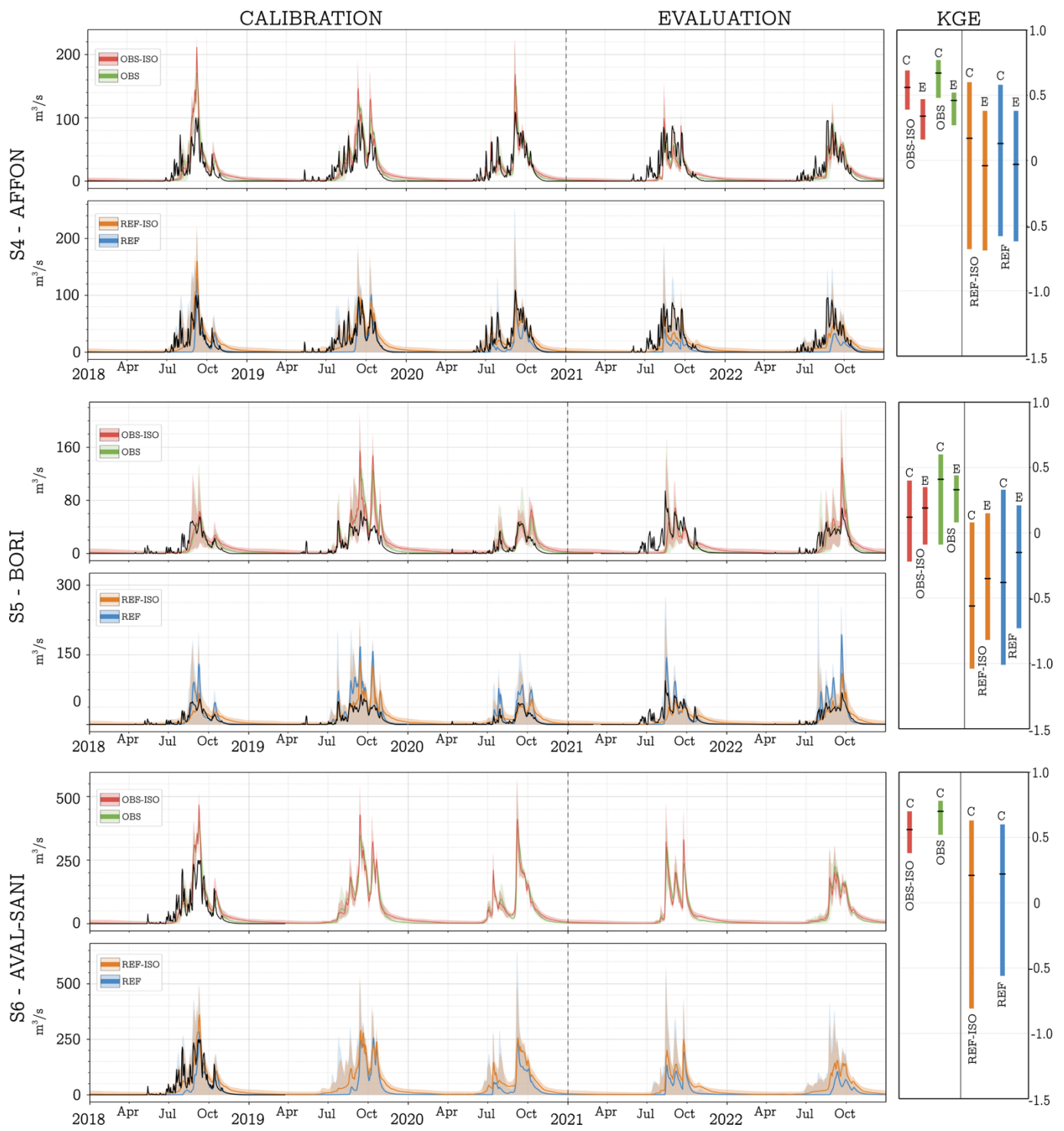


Figure S2 (continued).

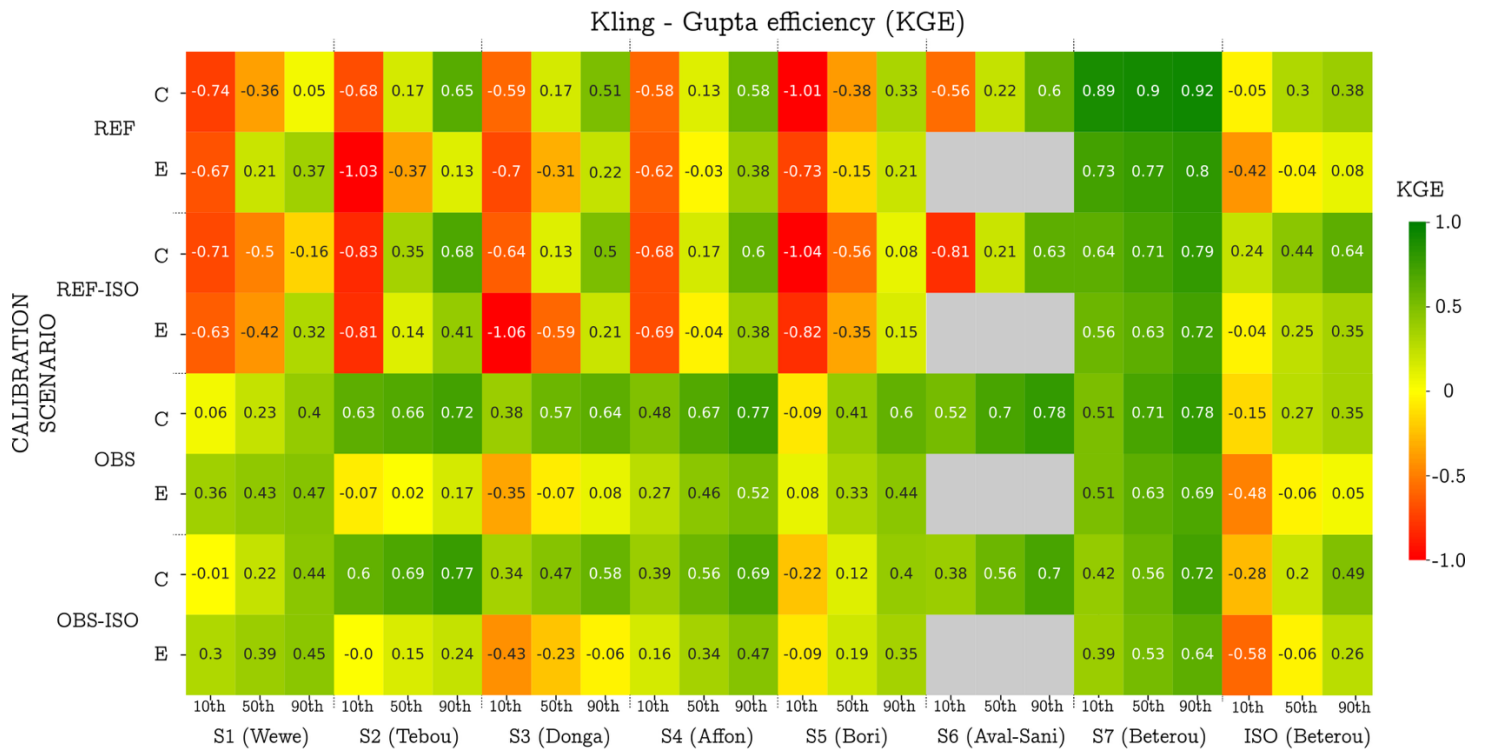


Figure S3. Median (50^{th}), 10^{th} and 90^{th} percentile KGE values for each calibration scenario during the calibration period (C, 2018-2020) and evaluation period (E, 2021-2022) across discharge (S1–S7) and the isotopic (ISO) targets. Gray cells indicate missing data for station S6 during the evaluation period.

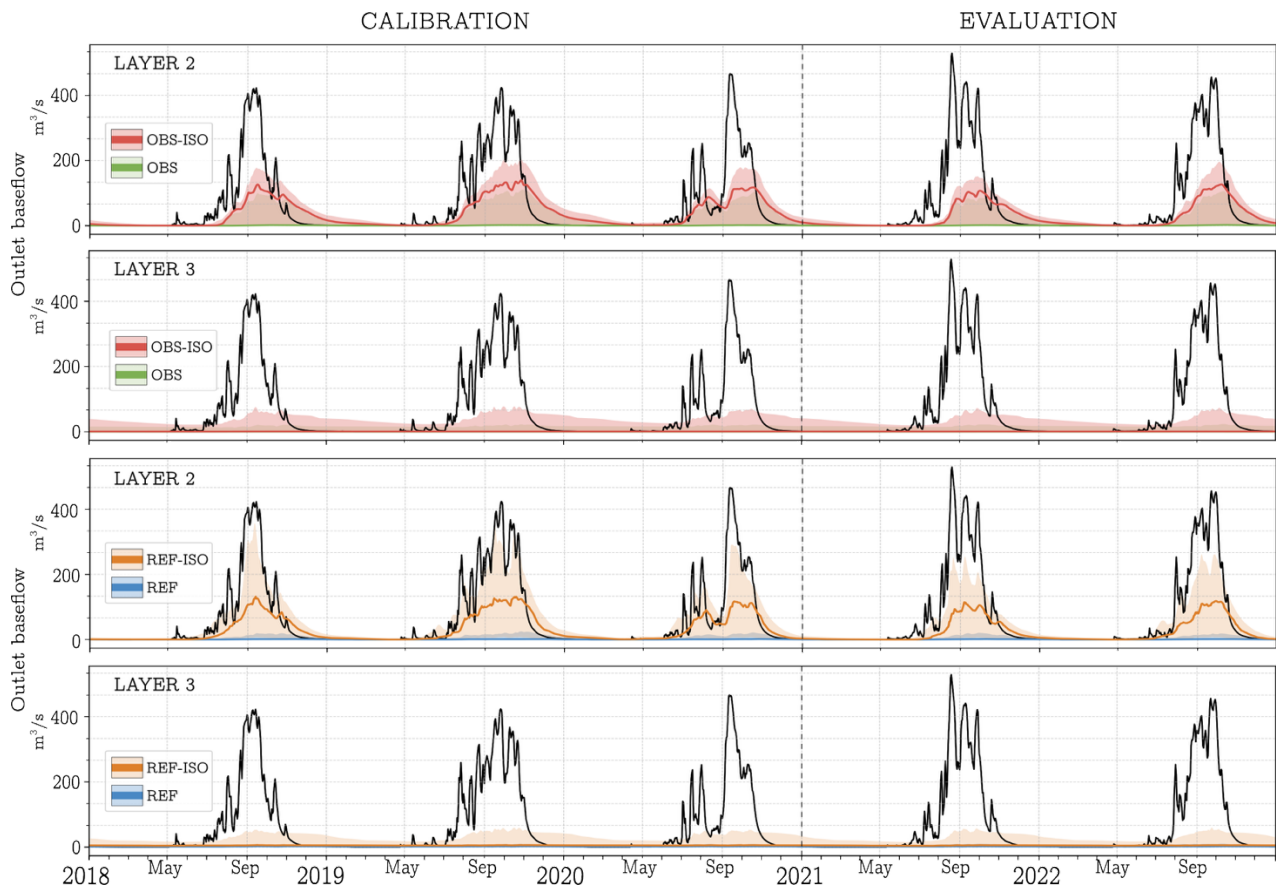


Figure S4. Simulated baseflow time series from the middle (Layer 2) and deep (Layer 3) subsurface layers at the basin outlet. The observed discharge is shown as a black line. Shaded envelopes indicate the 10th–90th percentile range of simulations, with solid lines representing the median. Baseflow from topsoil (Layer 1) is negligible and therefore omitted.

ANNUAL BASEFLOW

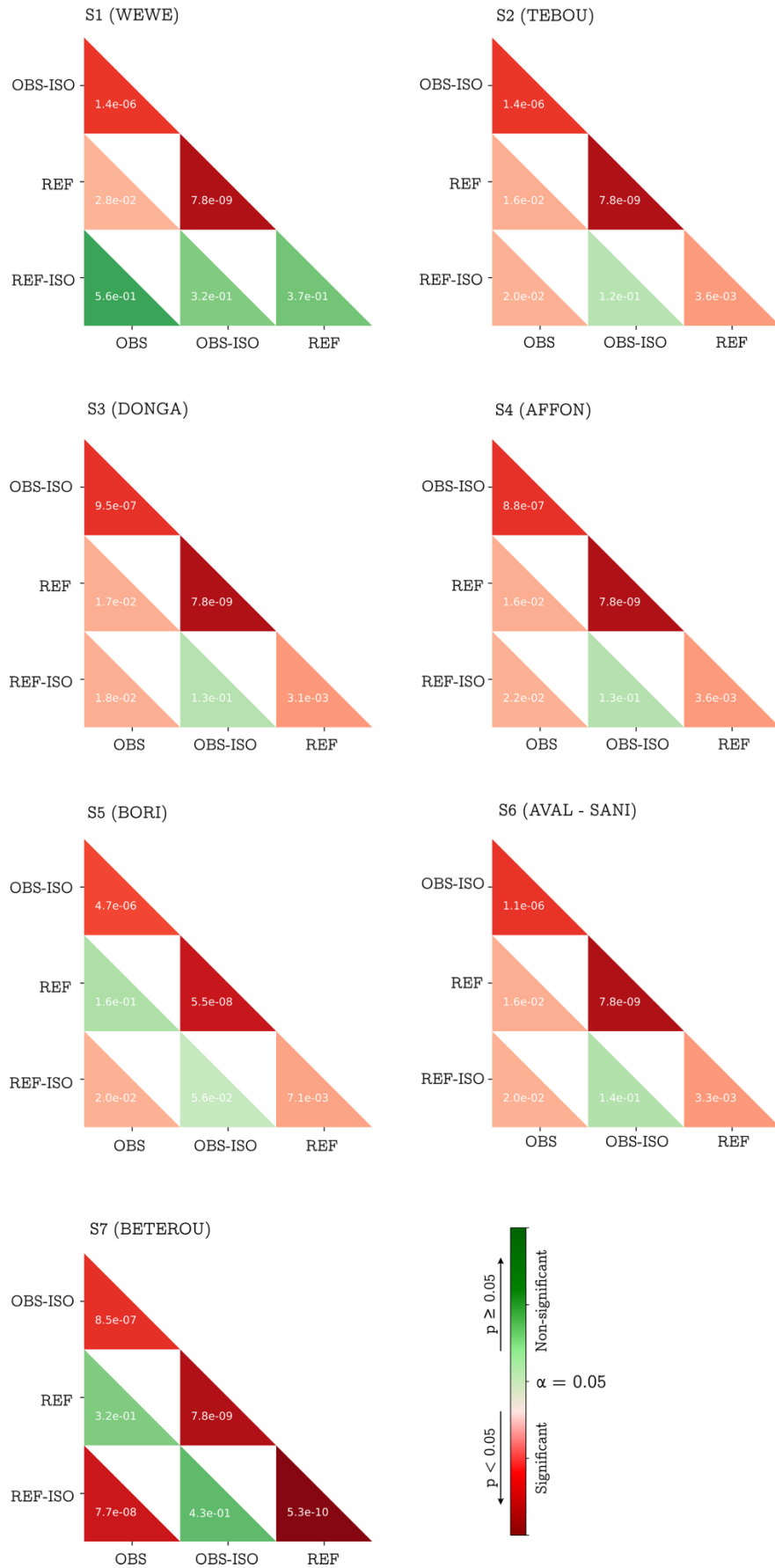


Figure S5. Statistical comparison of mean annual baseflow (2018–2022) across simulation scenarios. Triangles show Wilcoxon-Mann-Whitney (WMW) test p-values. Green tones indicate $p \geq 0.05$ (no significant difference) and red tones indicate $p < 0.05$ (significant difference).

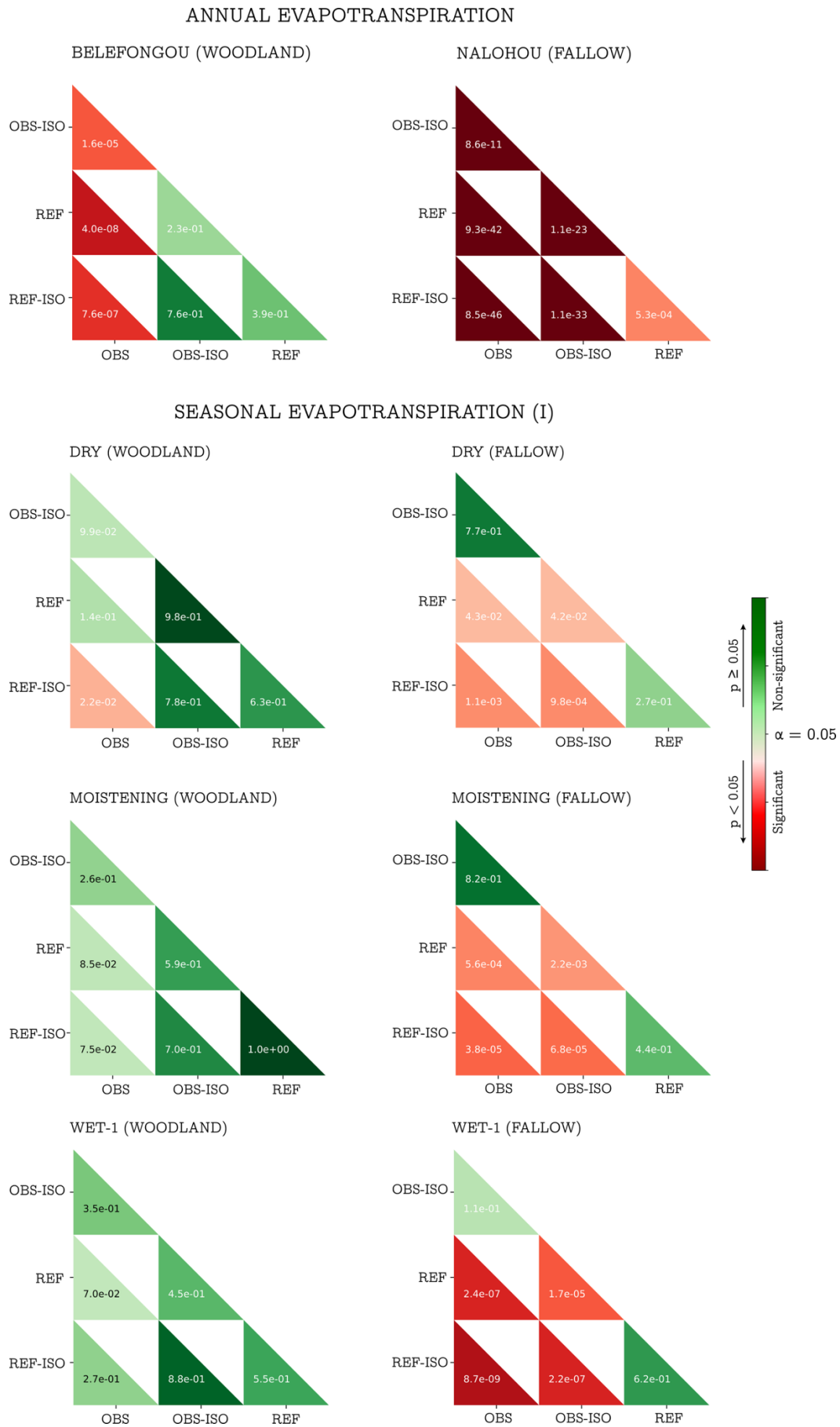


Figure S6. Statistical comparison of of mean annual evapotranspiration (ET) and seasonal ET (2018–2022) across simulation scenarios. Triangles show Wilcoxon-Mann-Whitney (WMW) test p-values. Green tones indicate $p \geq 0.05$ (no significant difference) and red tones indicate $p < 0.05$ (significant difference).

SEASONAL EVAPOTRANSPIRATION (II)

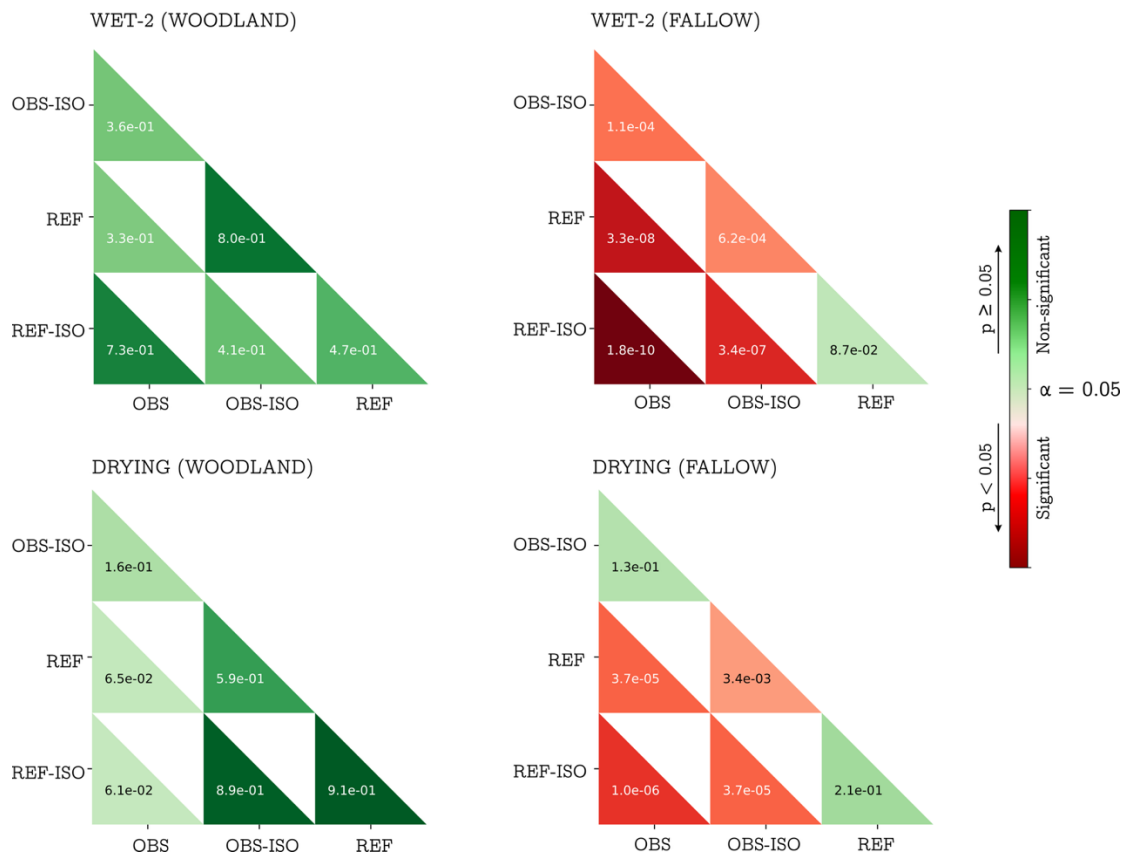


Figure S6. (continued).

MAIN WATER BUDGET COMPONENTS

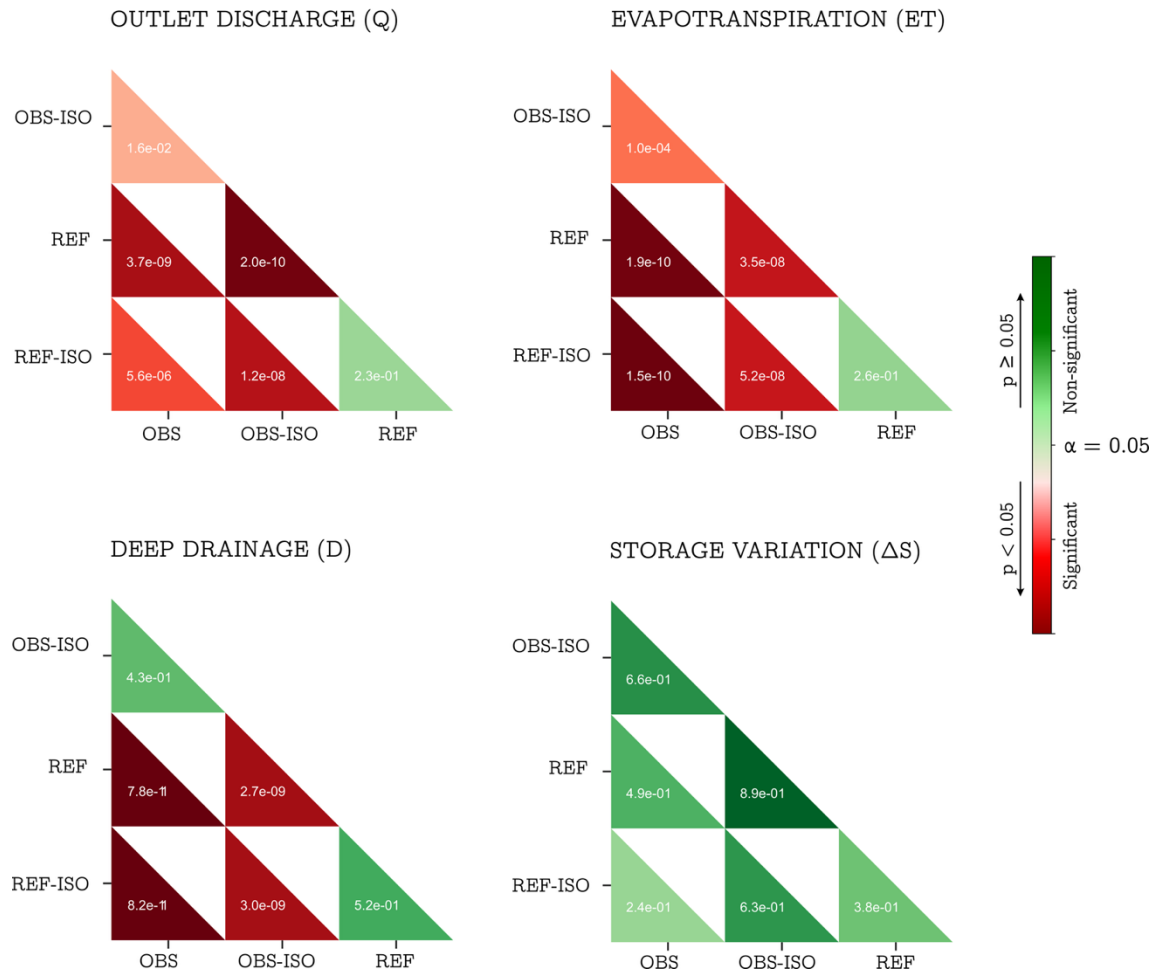


Figure S7. Statistical comparison of water budget components and subcomponents (2018–2022) across simulation scenarios. Triangles show Wilcoxon-Mann-Whitney (WMW) test p -values. Green tones indicate $p \geq 0.05$ (no significant difference) and red tones indicate $p < 0.05$ (significant difference).

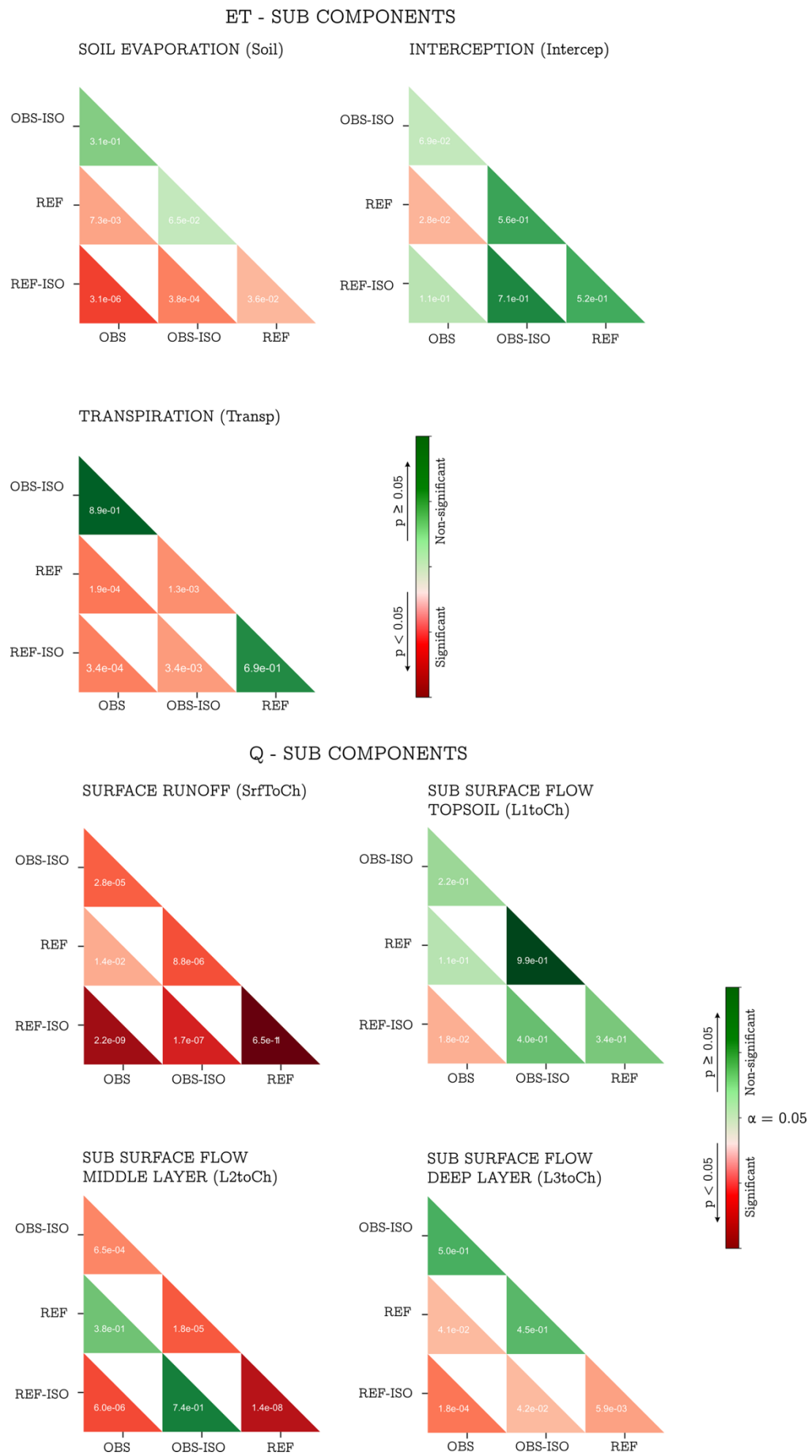


Figure S7. (continued).

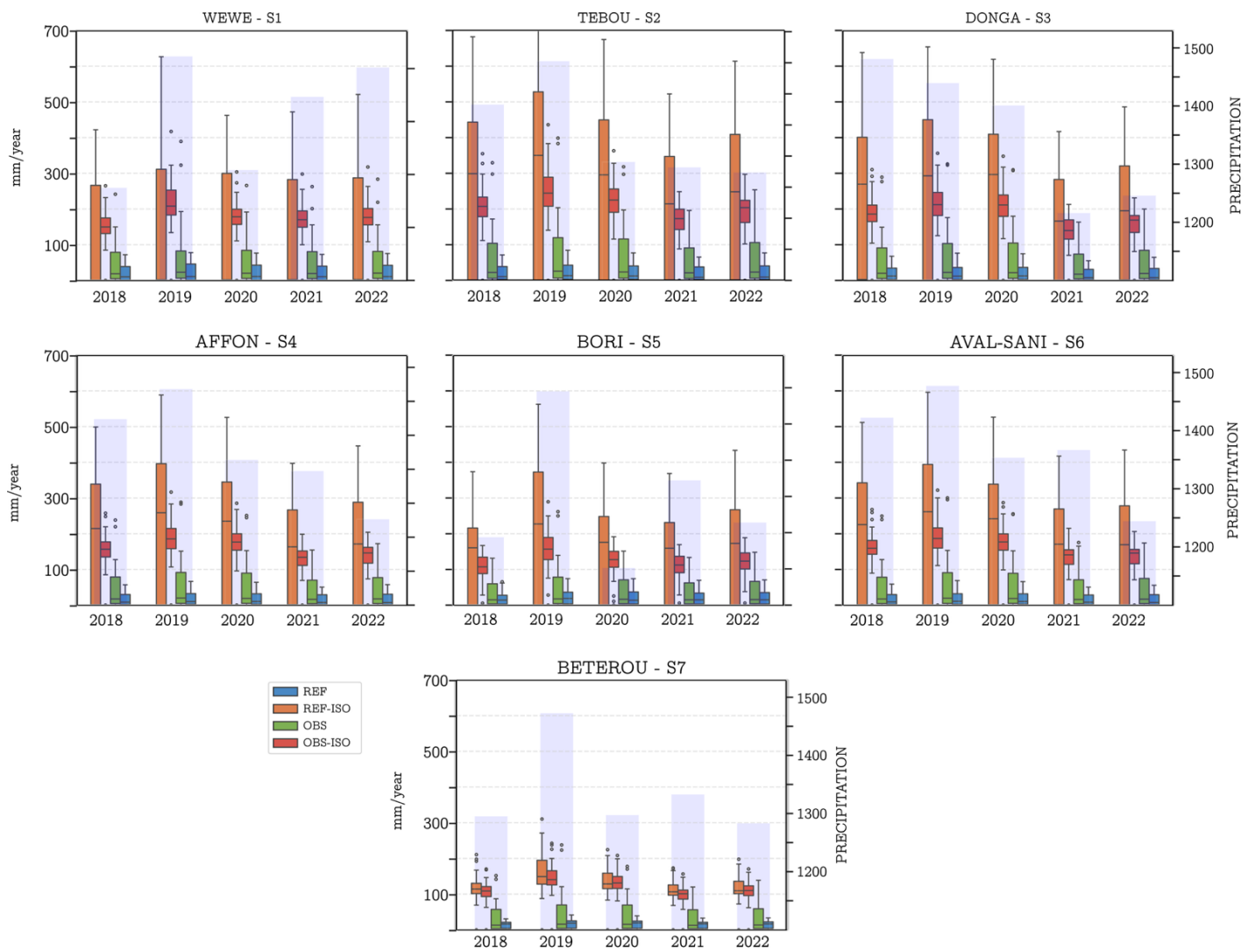


Figure S8. Mean annual simulated specific baseflow for 2018-2022 at the sub-basin stations (S1-S6) and the basin outlet (S7) across calibration scenarios. Light blue bars indicate mean annual precipitation at each sub-basin.

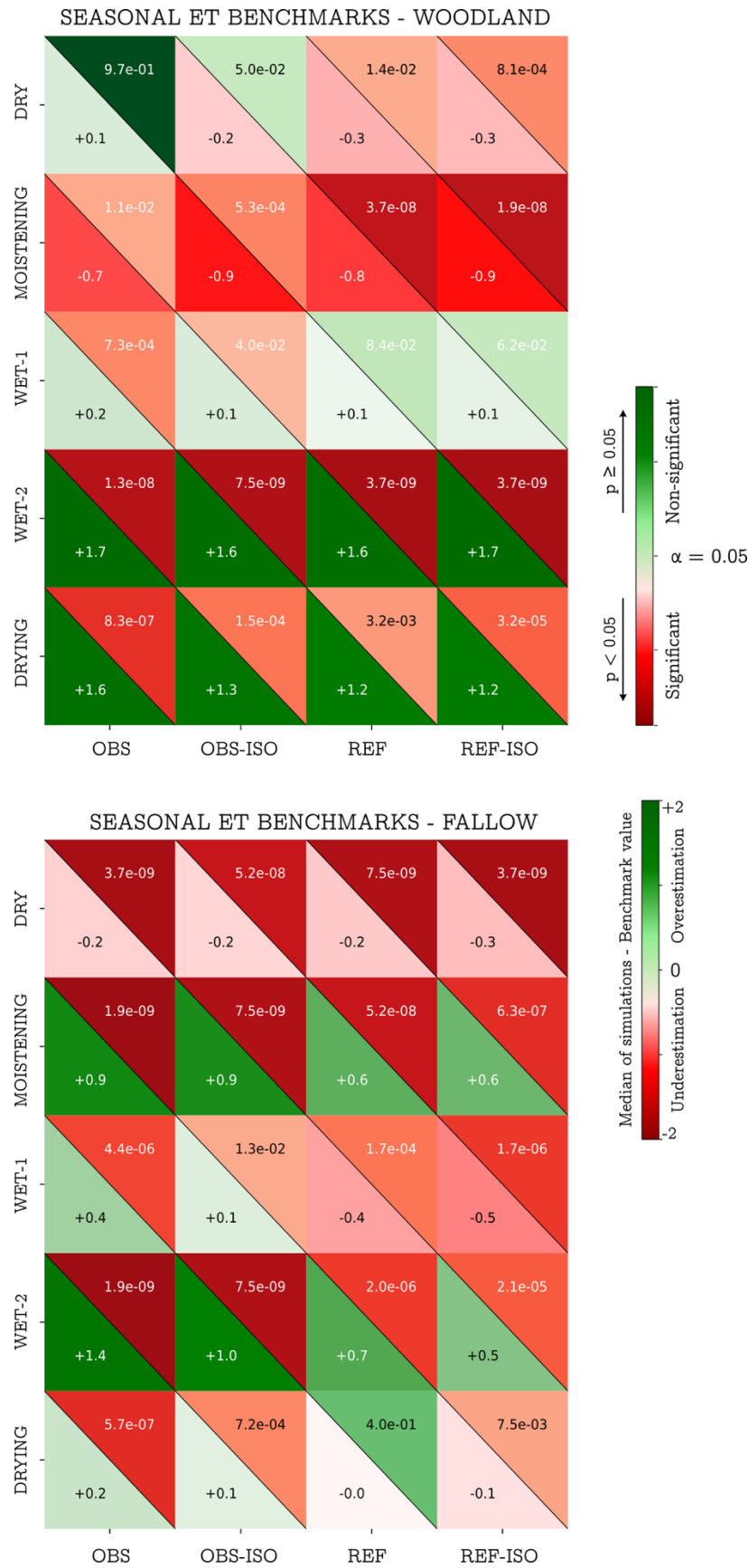


Figure S9. Statistical comparison of benchmark values and simulation ensembles (2018–2022) using the one-sample Wilcoxon signed-rank test for seasonal and annual evapotranspiration (ET) at model pixels representing the Béléfongou (Woodland) and Nalohou (Fallow) sites. Green tones indicate $p \geq 0.05$ (no significant difference) and red tones $p < 0.05$ (significant difference); the lower triangle shows the difference between ensemble median and benchmark values, with red and green tones indicating negative and positive biases, respectively.

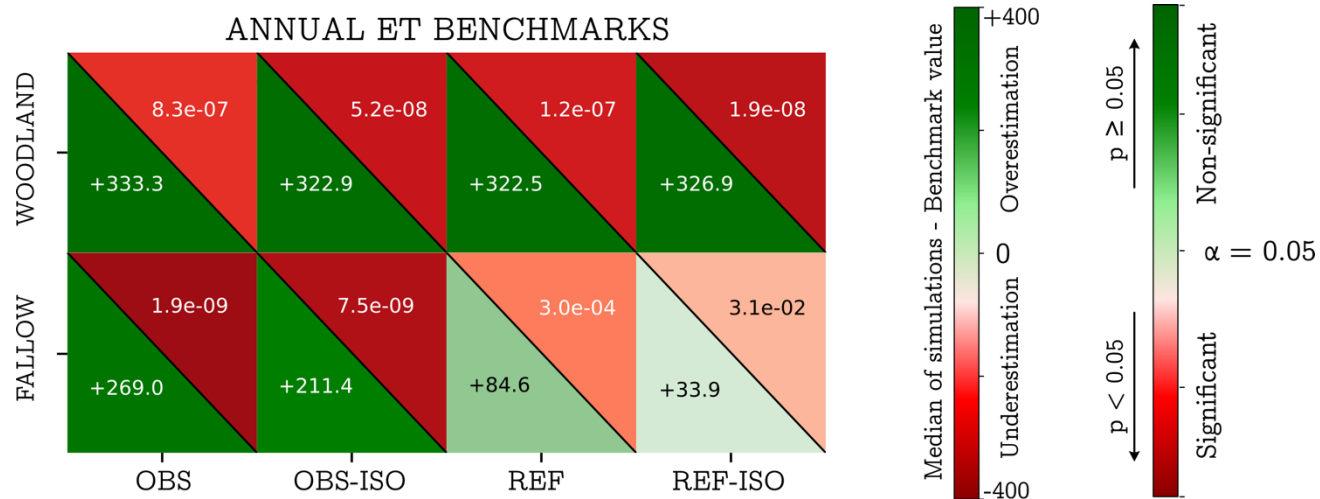


Figure S9. (continued).

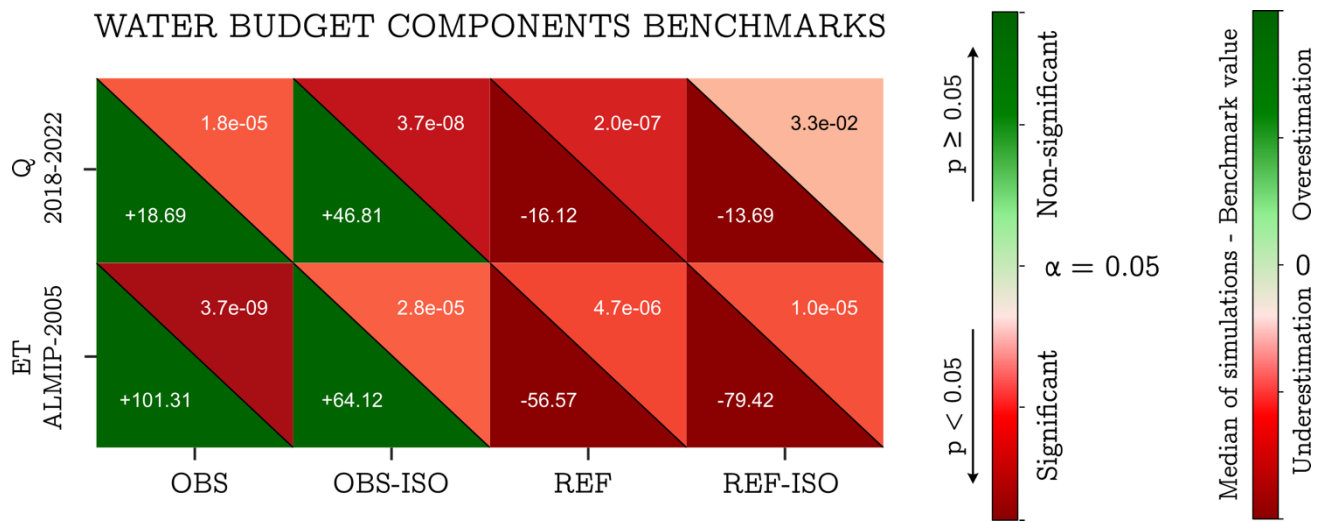


Figure S10. Statistical comparison of benchmark values and simulation ensembles (2018–2022) using the one-sample Wilcoxon signed-rank test for the main water budget components, including outlet discharge (Q) and evapotranspiration (ET). Green tones indicate $p \geq 0.05$ (no significant difference) and red tones $p < 0.05$ (significant difference); the lower triangle shows the difference between ensemble median and benchmark values, with red and green tones indicating negative and positive biases, respectively.

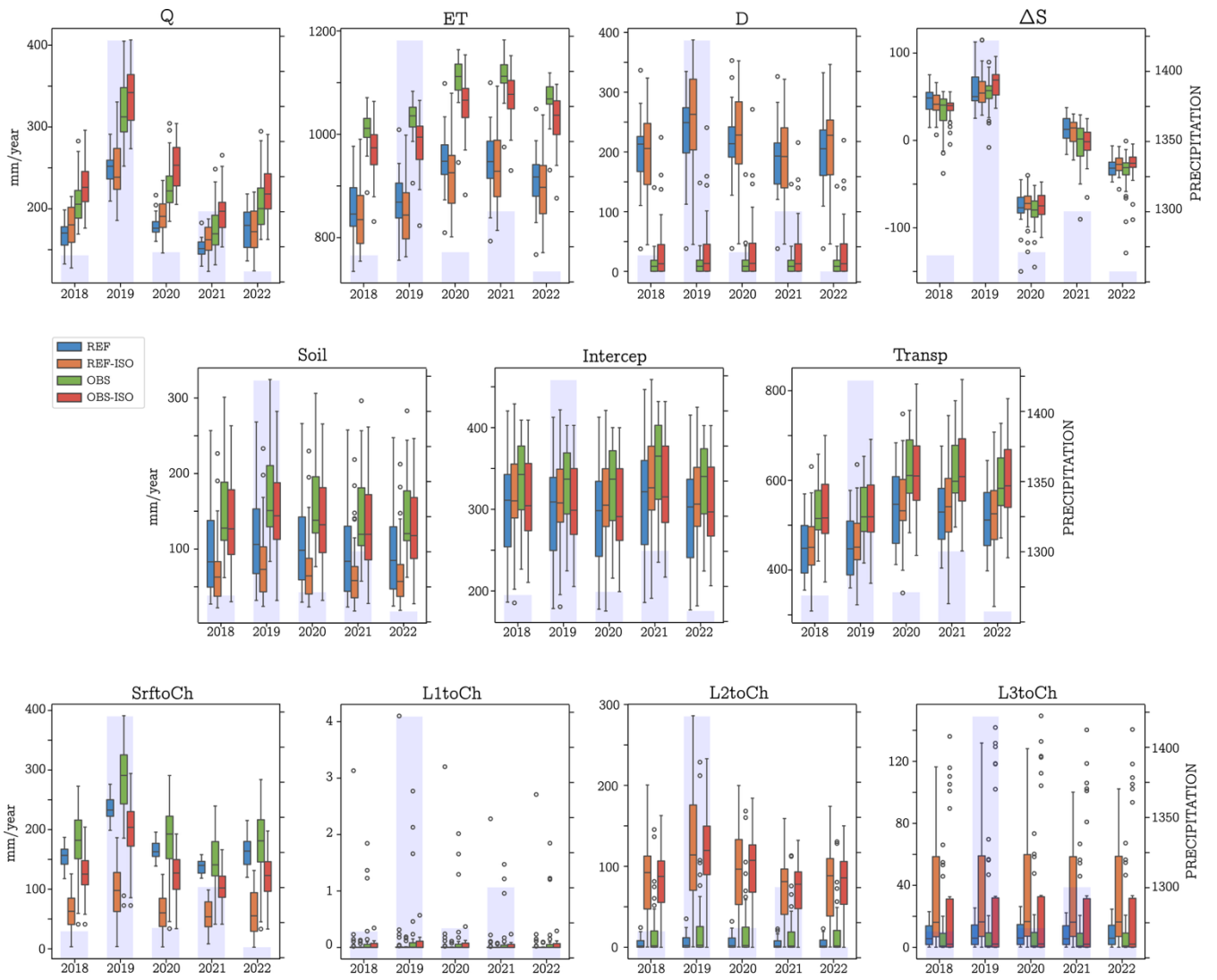


Figure S11. Basin-scale annual water budget components for 2018–2022 for each calibration scenario. Components include annual evapotranspiration (ET), with subcomponents soil evaporation ($Soil$), interception ($Intercep$), and transpiration ($Transp$); annual discharge (Q), with subcomponents surface-runoff ($SrfToCh$) and subsurface-flow from the topsoil ($L1toCh$), middle ($L2toCh$), and deepest ($L3toCh$) layers; deep drainage (D); and annual storage change (ΔS). Light blue bars indicate mean basin-scale annual precipitation.

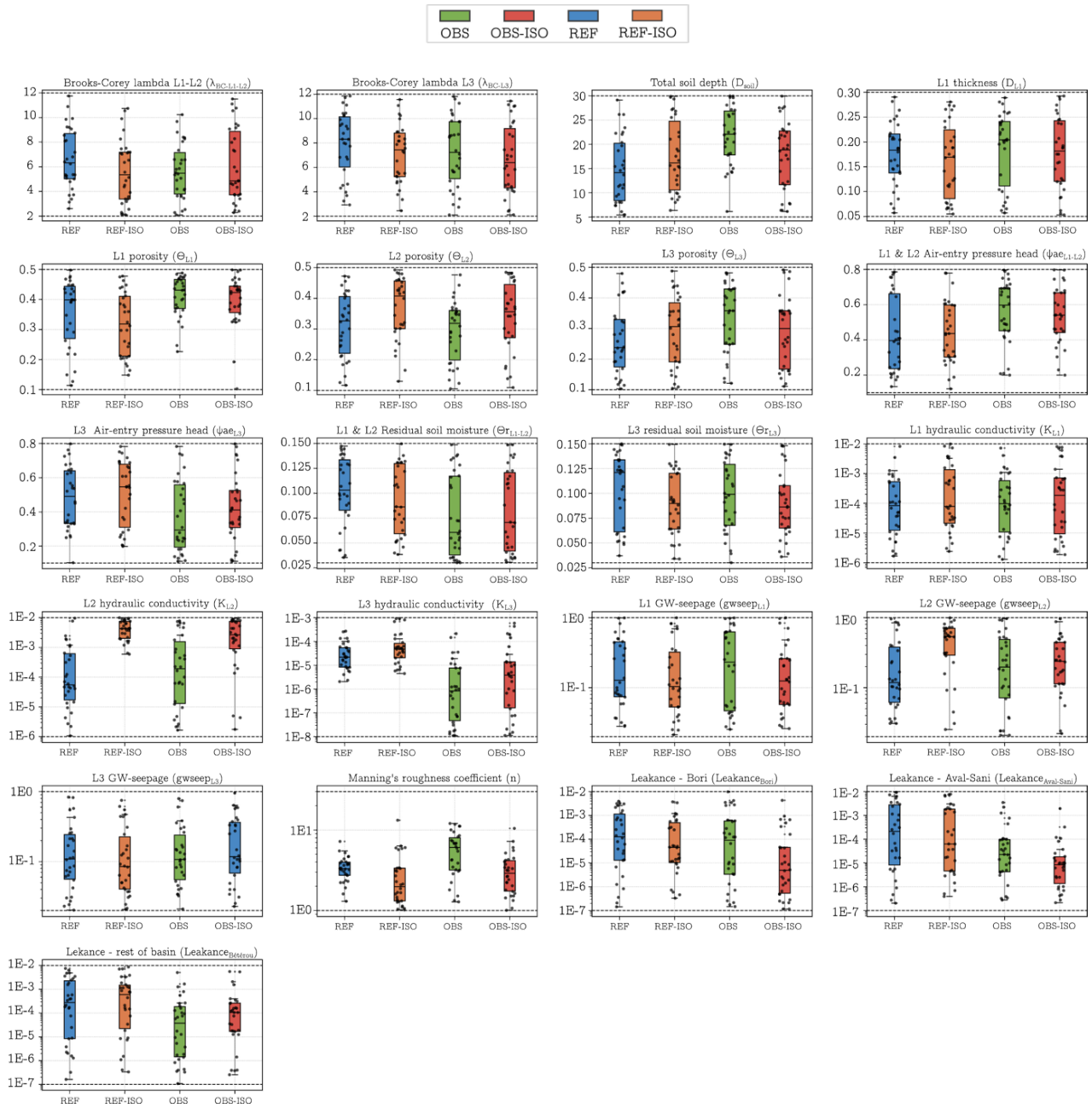


Figure S12. Soil physical and vegetation parameter distributions by calibration scenario for the 30 selected simulations. Individual parameter values are shown as black points.

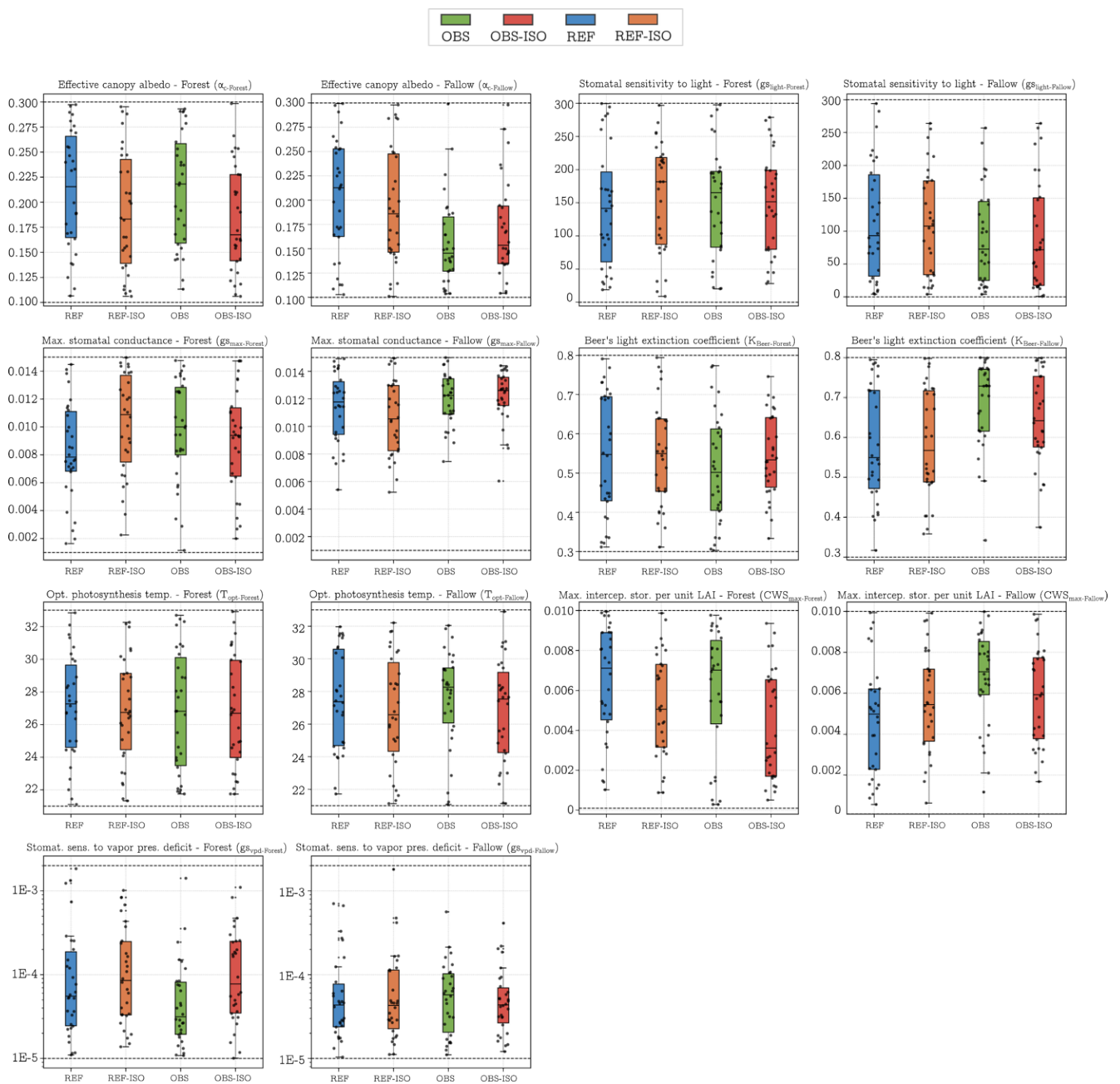


Figure S12. (continued).

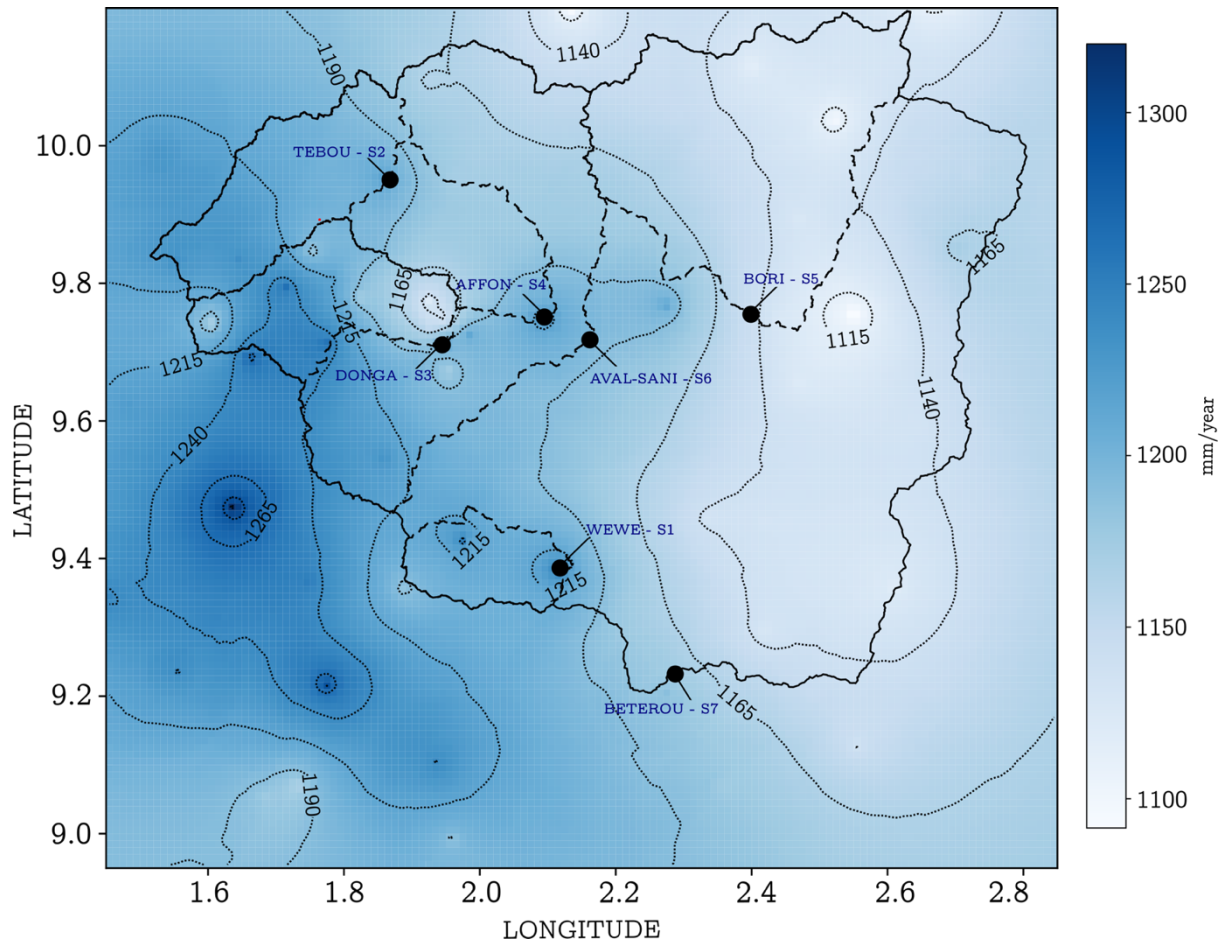


Figure S13. Map of mean annual isohyets showing precipitation distribution across the Bétérou basin and its sub-basins. The map was derived from 1999–2012 rainfield data at a 5-minute temporal resolution and 0.01° spatial resolution (Ali et al., 2003; Vischel et al., 2011).

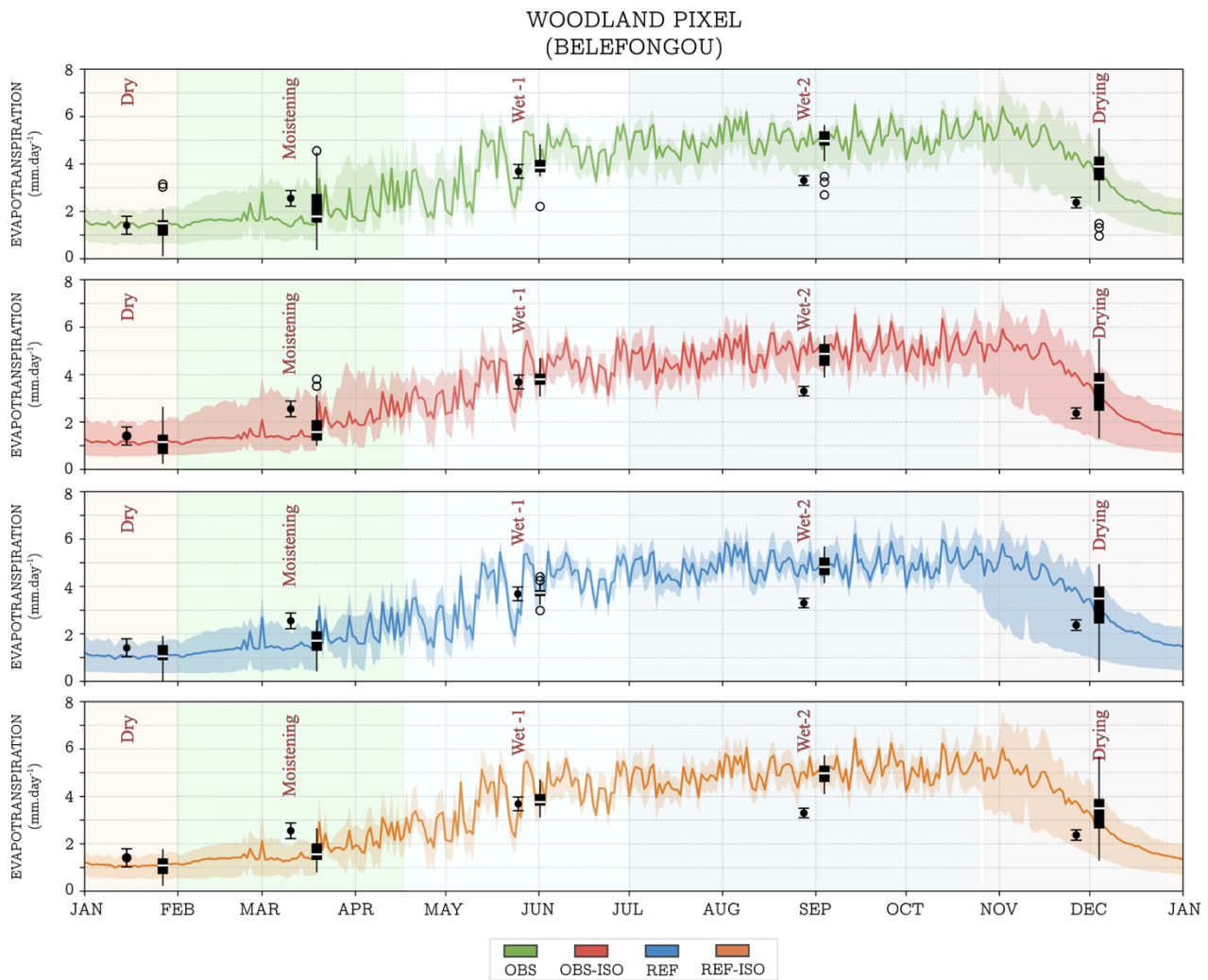


Figure S14. Mean evapotranspiration time series (2018–2022) across calibration scenarios at the woodland pixel (Béléfongou) and the fallow pixel (Nalohou). Shaded envelopes show the 10th to 90th percentile range of simulations, with solid lines marking the median. The year was divided into five periods following Mamadou et al. (2016), using the mean starting day of year and mean number of days reported for 2008–2010. Black circles with error bars show the measured mean evapotranspiration and its uncertainty for each period, based on 2008–2010 observations. Black boxplots show the distribution of the simulated mean evapotranspiration for each period.

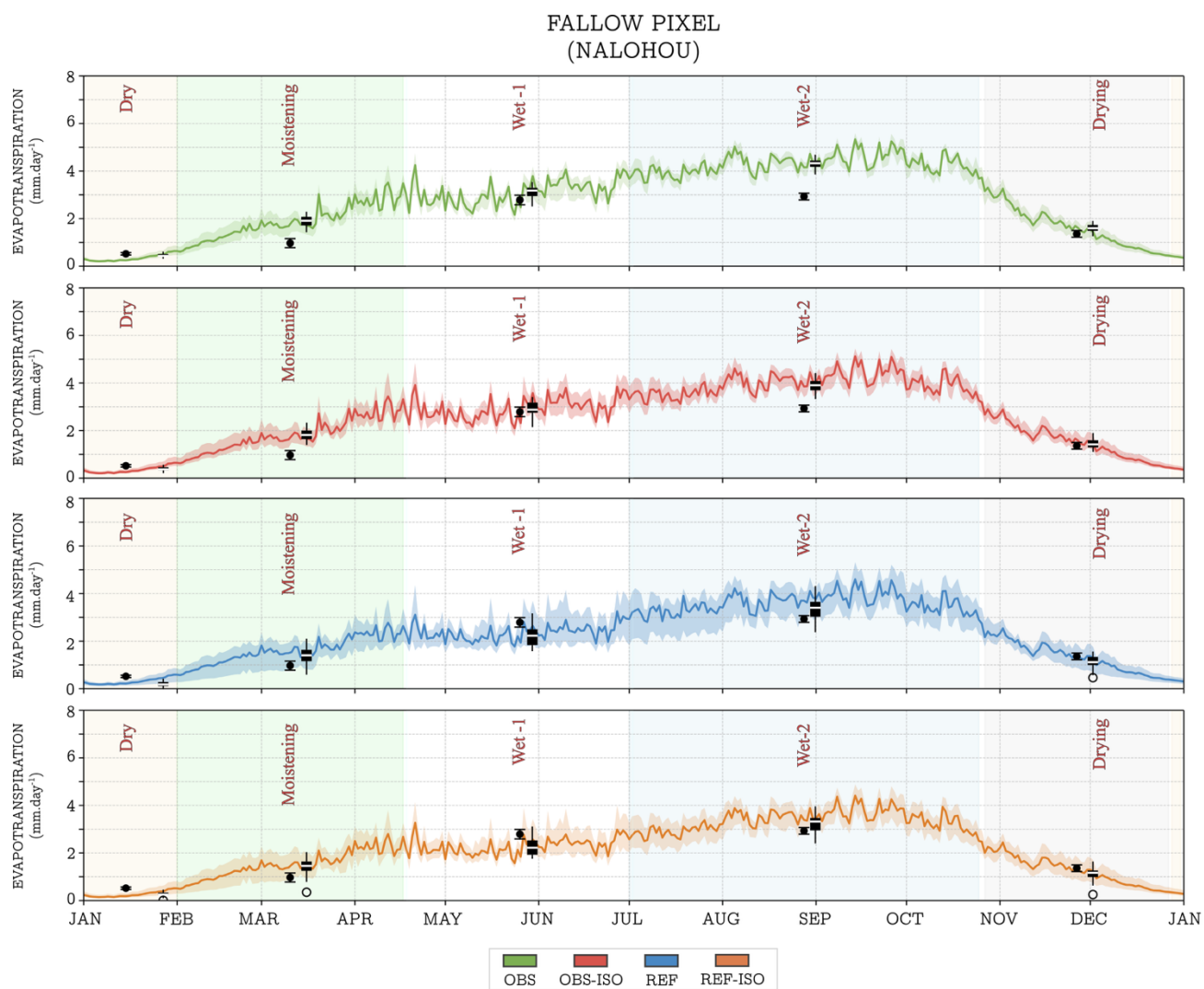


Figure S14 (continued).

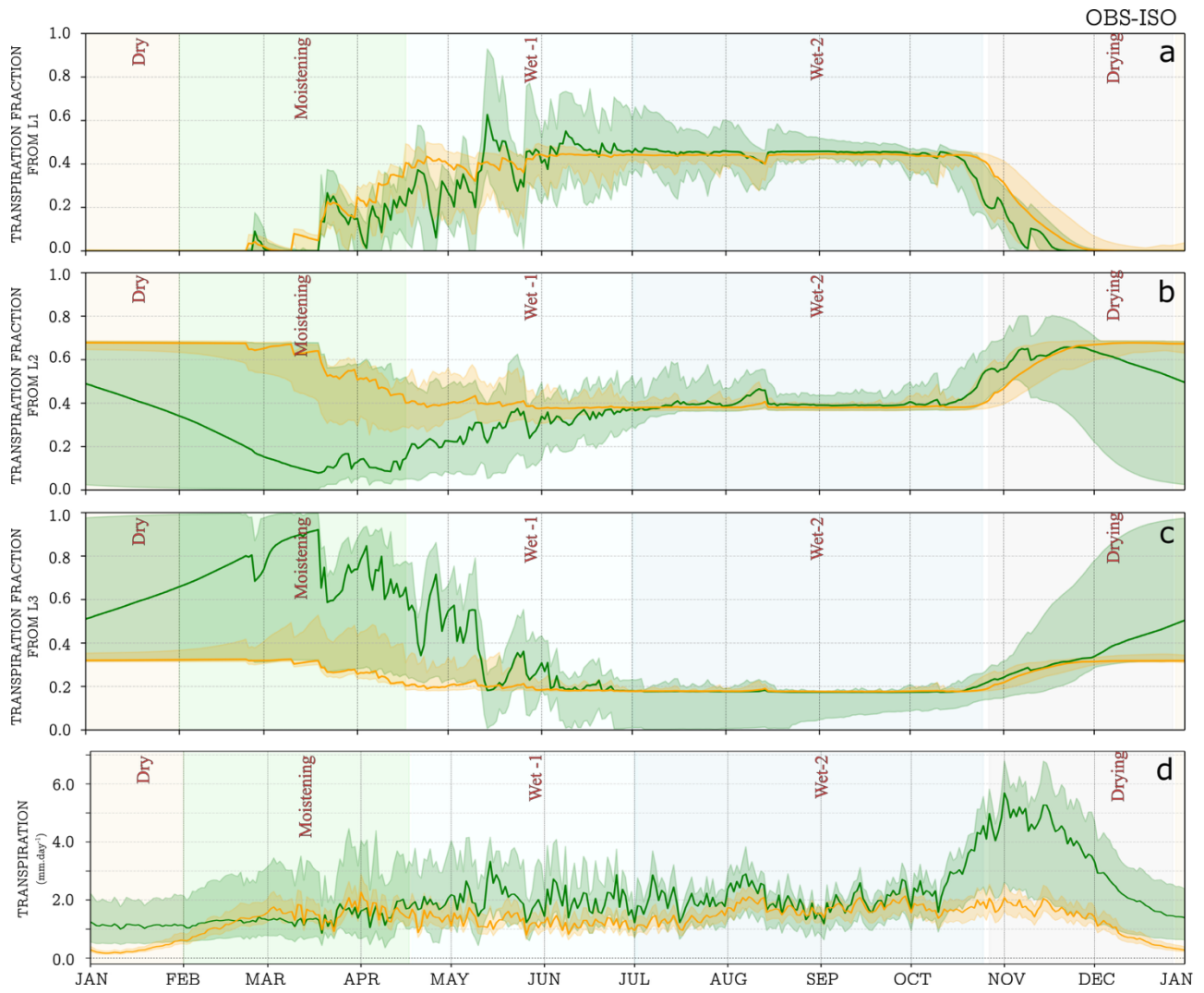


Figure S15. Mean daily time series (2018 to 2022) for (a to c) the fraction of transpiration extracted from the topsoil (L1), middle (L2), and deep (L3) layers and (d) total transpiration. Green and yellow denote Woodland and Fallow, respectively, each shown with shaded envelopes indicating the 10th to 90th percentile range of simulations and solid lines inside representing the median.

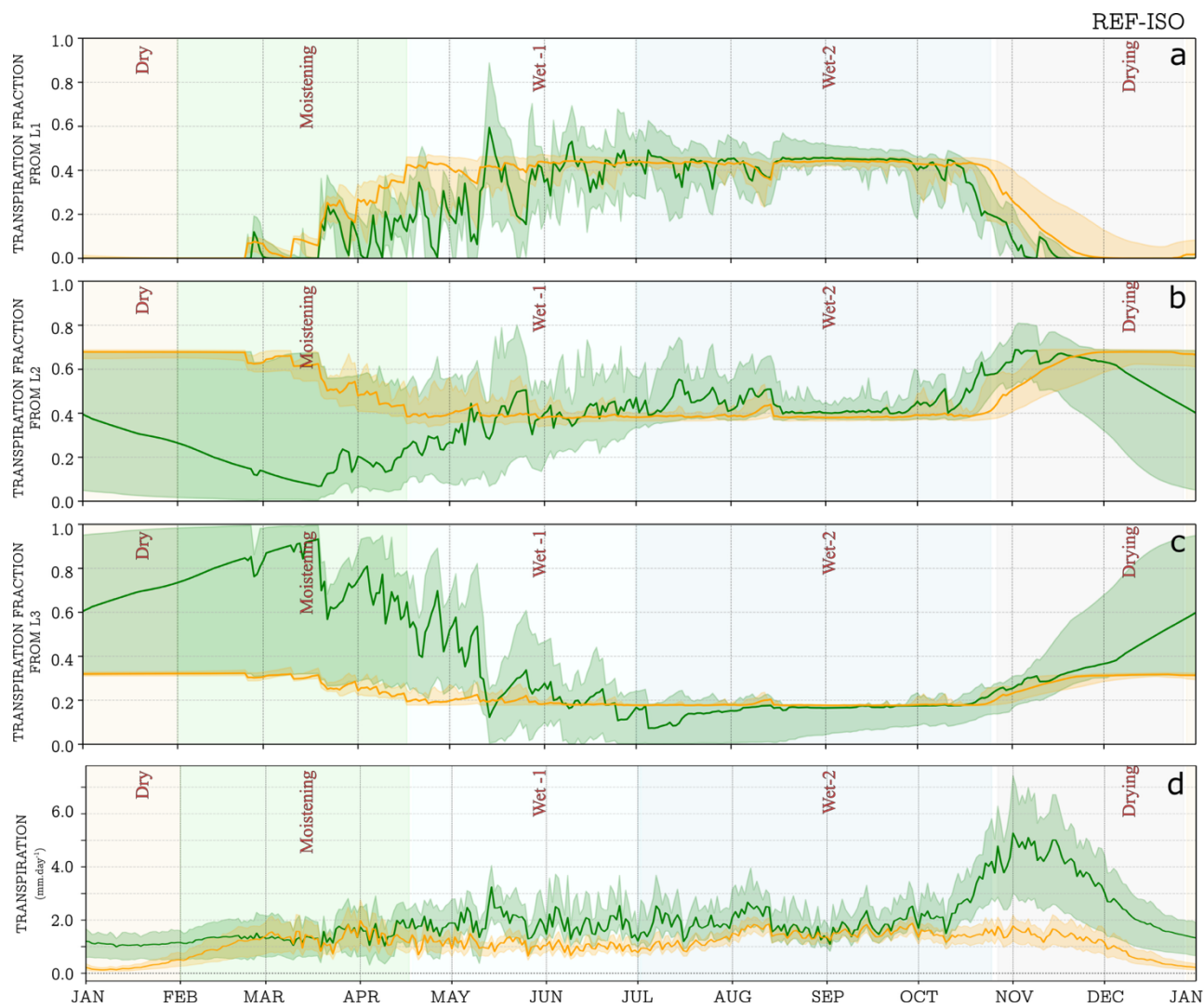


Figure S15 (continued).

Table S1. Rain gauge stations of the Bétérou basin, part of the AMMA-CATCH monitoring network.

ID	Name	Location		Elevation (m)	Mean Precipitation (mm/year)
		E	N		
O-1	AFFON	2°5'38"	9°44'54"	334	1344
O-2	BELEFOUNGOU	1°42'51"	9°47'43"	433	1325
O-3	BEMBEREKE	2°40'25"	10°14'8"	420	1228
O-4	BETEROU_C	2°16'31"	9°12'7"	287	1283
O-5	BIRNI	1°31'48"	9°59'24"	459	1297
O-6	COPARGO	1°33'10"	9°49'47"	532	1231
O-7	DAENON	2°27'58"	9°39'21"	319	1406
O-8	DJOUGOU	1°39'42"	9°41'31"	454	1346
O-9	DONGA	1°56'55"	9°42'40"	349	1184
O-10	FO_BOURE	2°23'58"	10°6'56"	425	1449
O-11	GANGAMOU	1°51'4"	9°50'50"	419	1411
O-12	MOMONGOU	1°51'35"	9°32'48"	406	1269
O-13	MONOBANSON	2°25'12"	9°27'12"	306	1491
O-14	NASSOU	1°55'20"	10°5'31"	405	1219
O-15	N_DALI	2°42'0"	9°50'60"	393	1475
O-16	PARAKOU	2°36'45"	9°21'27"	427	1308
O-17	SARMANGA	1°46'25"	9°13'2"	410	1331
O-18	SIRAROU	2°38'54"	9°35'29"	347	1509
O-19	SONOUMON	2°16'26"	9°46'9"	406	1118
O-20	TCHATCHOU	2°33'19"	9°7'37"	381	1301
O-21	TEME	2°28'12"	9°53'40"	329	1317
O-22	TOBRE	2°8'1"	10°11'57"	371	1231
O-23	WEWE	2°6'58"	9°23'5"	318	1343
O-24	NALOHOU_3	1°36'23"	9°44'33"	500	1384

Table S2. Benchmark evapotranspiration values from Mamadou et al. (2016). Seasonal and annual totals (mm $\pm$ SE) were converted to daily rates (mm d⁻¹) by dividing the mean and standard error by the corresponding period duration, then combined across the two hydrological years using an inverse variance weighted mean with propagated uncertainties. Representative start dates were selected as the calendar date closest to the mean day-of-year of the two original start dates, and representative end dates were obtained by adding the mean duration to the representative start date.

Period	Start date	End date	Duration (days)	Woodland		Fallow	
				Season	Daily	Season	Daily
Dry 2008/2009	27-Dec-08	26-Jan-09	31	46 $\pm$ 28	1.48 $\pm$ 0.90	15 $\pm$ 2.4	0.48 $\pm$ 0.08
Dry 2009/2010	27-Dec-09	05-Feb-10	41	57 $\pm$ 17	1.39 $\pm$ 0.41	22.5 $\pm$ 3	0.55 $\pm$ 0.07
Dry Weighted Mean	27-Dec	31-Jan	36	54.0 $\pm$ 14.5	1.41 $\pm$ 0.38	17.9 $\pm$ 1.9	0.52 $\pm$ 0.05
Moistening 2008/2009	27-Jan-09	14-Apr-10	78	203 $\pm$ 31	2.60 $\pm$ 0.40	75.5 $\pm$ 18	0.97 $\pm$ 0.23
Moistening 2009/2010	06-Feb-10	19-Apr-10	73	178 $\pm$ 42	2.44 $\pm$ 0.58	71 $\pm$ 23	0.97 $\pm$ 0.32
Moistening Weighted Mean	01-Feb	17-Apr	76	194.2 $\pm$ 24.9	2.55 $\pm$ 0.33	73.8 $\pm$ 14.2	0.97 $\pm$ 0.19
Wet-1 2008/2009	15-Apr-09	30-Jun-09	78	289 $\pm$ 26	3.71 $\pm$ 0.33	219 $\pm$ 16	2.81 $\pm$ 0.21
Wet-1 2009/2010	20-Apr-10	30-Jun-10	73	272 $\pm$ 45	3.73 $\pm$ 0.62	199 $\pm$ 46	2.73 $\pm$ 0.63
Wet-1. Weighted Mean	18-Apr	30-Jun	75	284.7 $\pm$ 22.5	3.71 $\pm$ 0.29	216.8 $\pm$ 15.1	2.80 $\pm$ 0.20
Wet-2 2008/2009	01-Jul-08	19-Oct-08	111	342 $\pm$ 33	3.08 $\pm$ 0.30	318 $\pm$ 21	2.86 $\pm$ 0.19
Wet-2 2009/2010	01-Jul-09	31-Oct-09	123	428 $\pm$ 33	3.48 $\pm$ 0.27	372 $\pm$ 27	3.02 $\pm$ 0.22
Wet-2 Weighted Mean	01-Jul	25-Oct	117	385.0 $\pm$ 23.3	3.30 $\pm$ 0.20	338.4 $\pm$ 16.6	2.93 $\pm$ 0.14
Drying 2008/2009	20-Oct-08	26-Dec-08	68	167 $\pm$ 16	2.46 $\pm$ 0.24	93 $\pm$ 10	1.37 $\pm$ 0.15
Drying 2009/2010	01-Nov-09	26-Dec-09	56	99 $\pm$ 35	1.77 $\pm$ 0.63	71 $\pm$ 25	1.27 $\pm$ 0.45
Drying Weighted Mean	26-Oct	26-Dec	62	155.2 $\pm$ 14.6	2.37 $\pm$ 0.22	90.0 $\pm$ 9.3	1.36 $\pm$ 0.14
Annual 2008/2009	01-Jul-08	30-Jun-09	366	1047 $\pm$ 62	2.86 $\pm$ 0.17	721 $\pm$ 34	1.97 $\pm$ 0.09
Annual 2009/2010	01-Jul-08	30-Jun-09	366	1034 $\pm$ 80	2.83 $\pm$ 0.22	736 $\pm$ 63	2.01 $\pm$ 0.17
Annual Weighted Mean	01-Jul	30-Jun	366	1042 $\pm$ 49	2.85 $\pm$ 0.13	724 $\pm$ 30	1.98 $\pm$ 0.08

Table S3. Basin-scale water budget components (mm/year) for the 30 behavioural simulations of each calibration scenario, including precipitation (*P*), evapotranspiration (*ET*), discharge (*Q*), deep drainage (*D*), and storage change (ΔS), expressed as the 10th, 50th and 90th percentiles per year over the 2018 to 2022 period, along with the corresponding mean values.

Component	Scenario	2018			2019			2020			2021			2022			Mean		
		10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th
ET	OBS	976	1012	1064	1000	1036	1068	1070	1112	1147	1067	1112	1153	1036	1069	1101	1037	1068	1106
	OBS-ISO	919	974	1019	917	995	1030	995	1066	1115	1018	1077	1121	976	1037	1075	962	1031	1069
	REF	794	846	923	815	869	938	882	948	1003	892	947	1017	860	917	971	857	910	966
	REF-ISO	764	835	933	779	844	954	847	926	1020	858	928	1033	827	897	982	819	888	981
Q	OBS	176	206	250	288	312	364	194	222	266	145	169	209	171	200	255	194	220	266
	OBS-ISO	198	226	264	290	342	380	219	253	282	166	197	231	182	218	263	212	248	281
	REF	150	170	186	230	252	276	167	176	192	137	151	163	144	180	204	169	185	196
	REF-ISO	150	180	213	217	239	294	168	191	219	130	162	183	141	172	214	160	187	220
D	OBS	~0	9	38	~0	9	39	~0	9	39	~0	9	38	~0	9	38	~0	9	38
	OBS-ISO	~0	13	108	~0	13	114	~0	13	119	~0	13	110	~0	13	109	~0	13	112
	REF	131	213	252	176	249	302	158	214	287	128	193	243	137	205	281	150	210	271
	REF-ISO	108	206	286	138	263	375	136	228	315	103	192	258	131	228	290	131	225	292
ΔS	OBS	-3	40	51	26	57	70	-102	-80	-59	-40	2	23	-64	-31	-17	-37	3	3
	OBS-ISO	19	40	49	42	69	81	-100	-75	-54	-20	-2	14	-42	-26	-15	-12	3	4
	REF	32	48	62	36	50	88	-90	-77	-55	-6	13	30	-42	-32	-13	~0	2	5
	REF-ISO	29	41	56	35	54	88	-100	-72	-54	-9	14	26	-39	-27	-13	1	3	5
PRECIPITATION (P)		1268			1421			1270			1301			1258			1304		

Table S4. Basin-scale discharge (Q) subcomponents (mm/year) for the 30 behavioural simulations of each calibration scenario, including surface runoff (SrfToCh) and subsurface flow contributions from the topsoil (L1toCh), middle (L2toCh), and deep (L3toCh) layers, and observed outlet discharge values, expressed as the 10th, 50th and 90th percentiles per year over the 2018 to 2022 period, along with the corresponding mean values.

Q Component	Scenario	2018			2019			2020			2021			2022			Mean		
		10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th
SrfToCh	OBS	176	206	250	288	312	364	194	222	266	145	169	209	171	200	255	130	198	260
	OBS-ISO	88	125	155	144	204	258	77	127	167	70	102	133	73	123	155	92	135	174
	REF	134	157	174	212	233	260	147	163	181	123	140	153	130	164	186	154	169	185
	REF-ISO	27	63	106	32	98	158	22	60	103	27	54	91	21	55	105	25	62	110
L1toCh	OBS	~0	~0	~0	~0	~0	1	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0
	OBS-ISO	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0
	REF	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0
	REF-ISO	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0	~0
L2toCh	OBS	~0	2	75	~0	2	105	~0	2	92	~0	1	66	~0	2	73	~0	2	82
	OBS-ISO	~0	88	128	~0	120	177	~0	107	165	~0	78	113	~0	86	125	~0	95	142
	REF	~0	2	15	~0	2	21	~0	2	18	~0	1	14	~0	1	14	~0	2	16
	REF-ISO	4	92	150	6	114	215	4	97	163	3	81	129	4	88	145	4	96	161
L3toCh	OBS	~0	1	47	~0	1	48	~0	1	49	~0	1	47	~0	1	47	~0	1	47
	OBS-ISO	~0	2	107	~0	2	122	~0	2	123	~0	2	103	~0	2	107	~0	2	112
	REF	1	6	20	1	6	21	1	6	21	1	6	21	1	6	21	~0	6	20
	REF-ISO	1	16	86	1	16	98	1	17	102	1	16	89	1	16	90	~0	16	93
OUTLET DISCHARGE (Q)		183			229			178			216			203			202		

Table S5. Basin-scale evapotranspiration (ET) subcomponents (mm/year) for the 30 behavioural simulations of each calibration scenario, including soil evaporation (Soil), interception (Intercep), and transpiration (Transp), expressed as the 10th, 50th and 90th percentiles per year over the 2018 to 2022 period, along with the corresponding mean values.

ET Component	Scenario	2018			2019			2020			2021			2022			Mean		
		10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th	10th	50th	90th
Soil	OBS	75	128	205	102	151	232	85	138	216	69	119	200	72	120	194	80	130	209
	OBS-ISO	58	127	208	79	144	227	66	132	213	53	119	201	58	118	198	62	128	208
	REF	37	83	212	51	106	223	44	98	220	35	84	207	39	85	199	41	92	212
	REF-ISO	29	63	146	34	73	157	31	64	149	27	58	142	27	57	141	30	63	146
Intercep	OBS	266	343	399	261	337	392	252	337	390	272	365	422	258	340	393	261	344	399
	OBS-ISO	253	304	377	248	299	370	239	291	370	256	315	400	242	297	372	247	302	377
	REF	238	311	359	230	309	353	230	298	353	246	321	382	228	303	356	233	308	360
	REF-ISO	237	310	371	231	308	367	228	305	363	249	326	390	234	306	365	235	311	371
Transp	OBS	455	515	622	466	519	614	546	611	726	543	598	734	525	582	693	507	567	676
	OBS-ISO	422	516	634	419	519	631	488	610	741	506	608	736	482	588	699	463	568	689
	REF	367	448	526	377	447	550	447	547	653	423	529	618	417	512	610	405	498	591
	REF-ISO	383	451	553	392	451	558	456	532	659	443	541	653	437	526	632	426	499	612

Table S6. Proportion of baseflow-contributing seepage cells and woodland cells at the basin and sub-basin scale

ID	Name	Runoff coefficient	Total cells	Number of cells		Proportion of cells (%)	
				Seepage	Woodland	Seepage	Woodland
S1	Wewe	0.15	323	153	22	47.4	6.8
S2	Tebou	0.26	700	318	30	45.4	4.3
S3	Donga	0.21	654	324	48	49.5	7.3
S4	Affon	0.21	1220	561	78	46.0	6.4
S5	Bori	0.11	1667	786	109	47.2	6.5
S6	Aval-Sani	0.21	3422	1593	290	46.6	8.5
S7	Bétérou	0.15	10278	4833	2368	47.0	23.0