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Regional, multi-decadal analysis on the Loire River basin reveals that stream temperature increases faster than air temperature

Hanieh Seyedhashemi et al.

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Supplementary material for “Regional, multi-decadal analysis on the Loire River basin reveals that stream temperature increases faster than air temperature”

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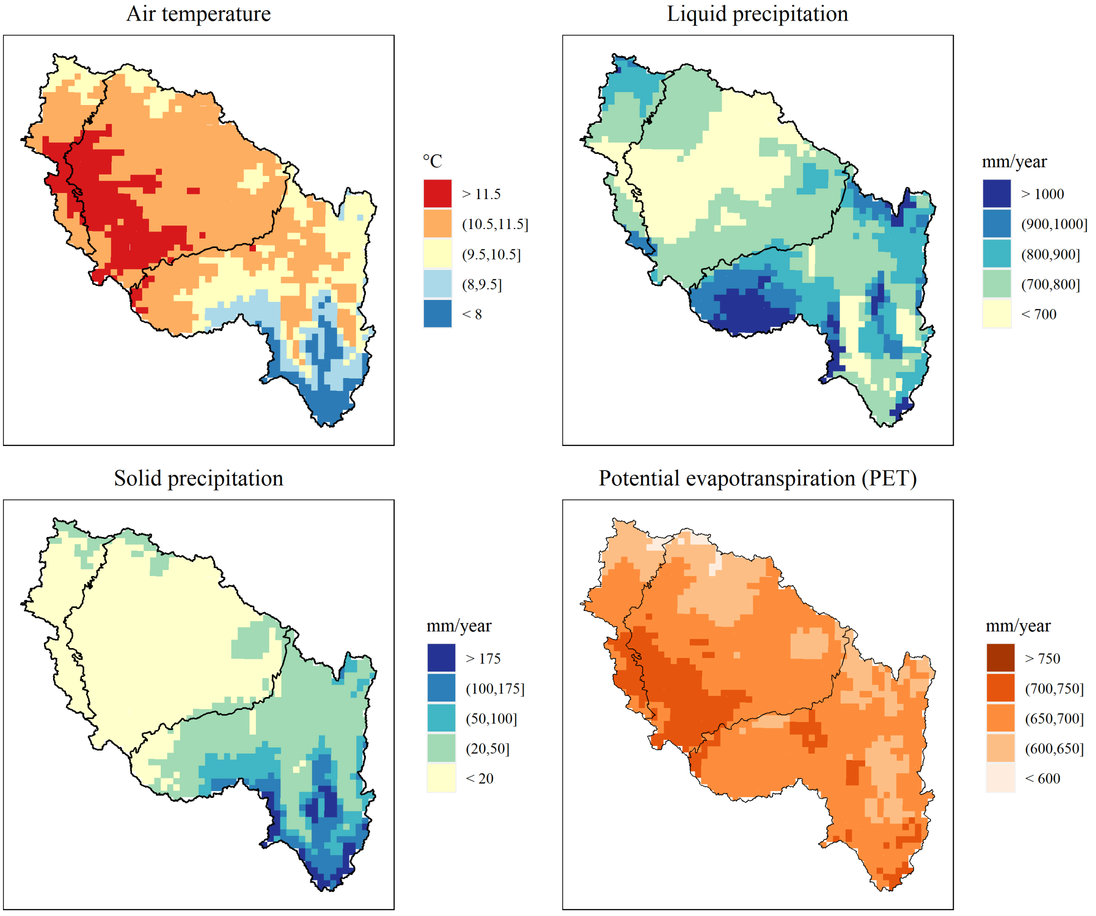

Figure S1. Annual mean air temperature (Ta), liquid and solid precipitation (P), and potential evapotranspiration (PET) over the 1958–2019 period. These data are derived from the Safran reanalysis data (Quintana-Segui et al., 2008; Vidal et al., 2010).

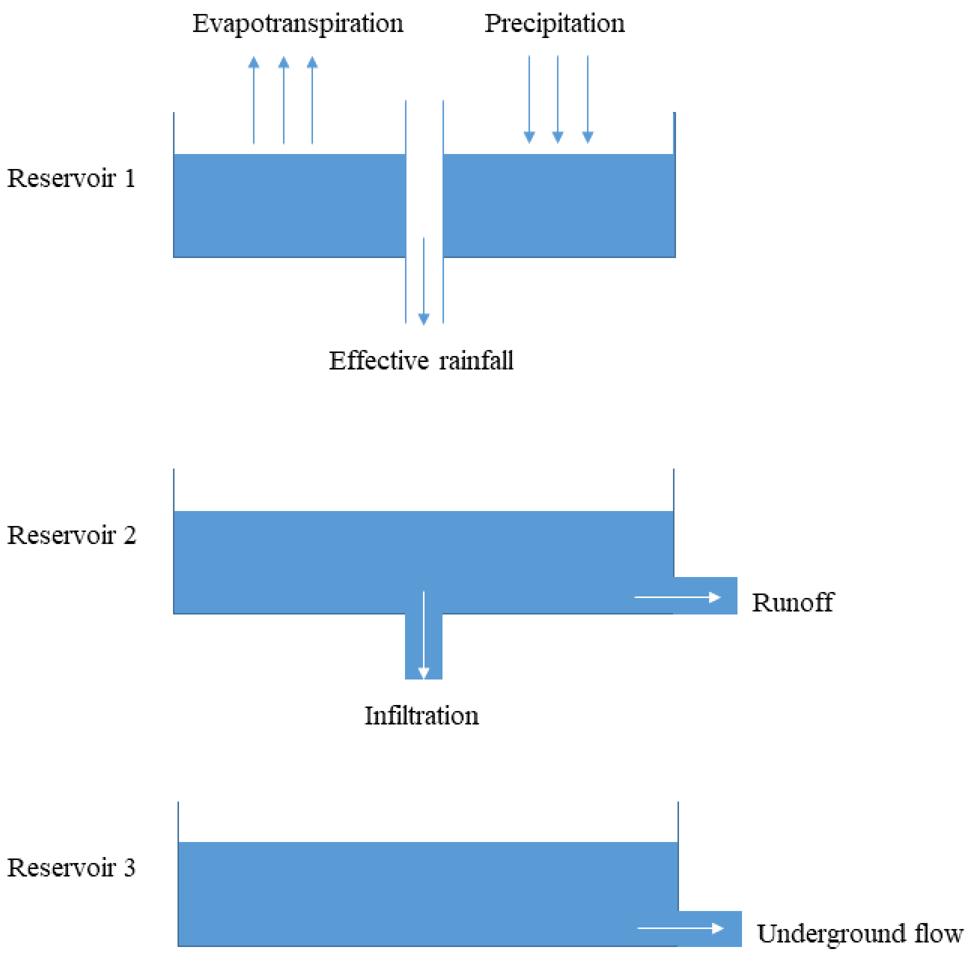

Figure S2. Schematic figure of the EROS model operation for each sub-basin. The water balance in the sub-basin is modeled by a lumped model using three reservoirs as follows: i) the first reservoir represents the soil that is subjected to evapotranspiration and precipitation; ii) the second non-linear reservoir represents the vadose zone, models the percolation time, and determines the partition between runoff and infiltration; iii) the third reservoir represents the underlying aquifer characterized by a recession time, and characterizes the groundwater flow. The contribution flow of each sub-basin is the sum of the runoff and the groundwater flow. The total flow at the outlet of each sub-basin is the sum of its contribution and the total flow of the upstream sub-basins (delayed by a transfer function representing their propagation time).

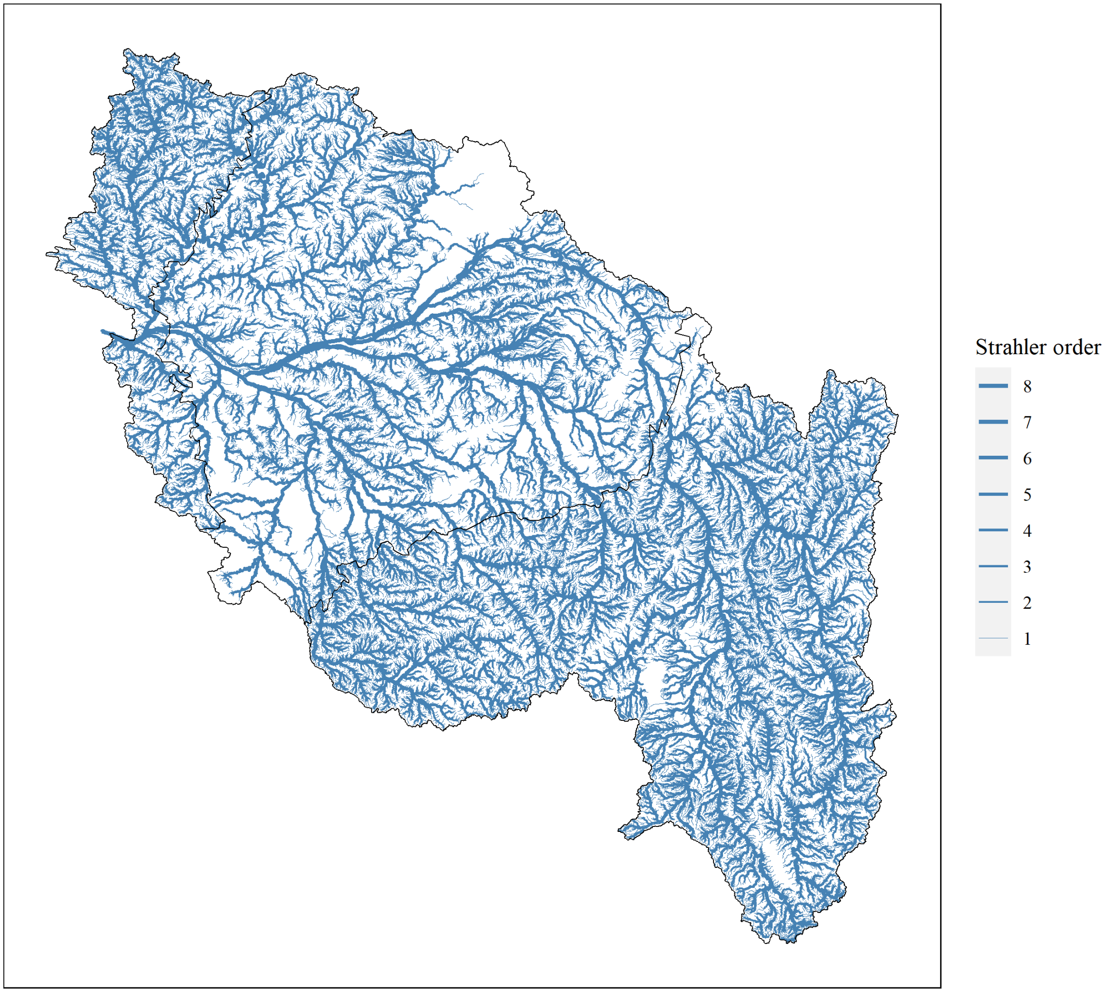

Figure S3. The detailed hydrographic network of the T-NET model over the Loire basin consisting of 52 278 reaches.

Table 1. Vegetation species and their approximated height (extracted from: Otto (1998); Aulinger et al. (2005); Allaby (2019); https://cms.geobretagne.fr/; www.polebocage.fr).

Species	Height (m)
Wood forest	25
Coniferous forest	25
Deciduous forest	25
Open forest	20
Mixed forest	25
Poplar grove	25
Bocage	15
Mixed woody vegetation	20
Shrub	10
Grass	0

Table 2: Hydrometric stations used for calibrating the EROS model. The coordinate system is Lambert 93.

Code	X	Y	Code	X	Y	Code	X	Y
K0030010	782951.5	6414192.53	K2994010	736672.91	6540594.87	L5323010	545858.81	6574379.22
K0100020	772656.16	6421130.17	K3030810	735469.79	6551442.81	L5401810	541026.08	6577325.24
K0114020	782012.53	6425971.35	K3060310	736668.98	6557845.24	L5411810	536388.26	6593688.03
K0120020	772342.34	6433586.37	K3074010	734989.94	6559798.81	L5511910	566061.64	6601927.25
K0214010	777234.49	6435320.18	K3153010	727642.86	6580048.82	L5561910	553958.69	6609399.05
K0253010	771322.79	6440119.92	K3222010	688282.05	6525966.37	L5623010	566129.59	6585376.24
K0260020	771122.62	6441373.46	K3273010	677001.58	6531871.31	L5733020	545749.08	6600837.33
K0274010	775767.88	6440265.03	K3292020	684155.16	6541572.7	L5741910	541210.53	6616557.38
K0323010	764733.08	6463225.53	K3302010	692376.4	6547771.09	L6020710	525254.72	6648032.12
K0333010	769051.99	6456732.82	K3322010	707289.97	6557394.06	L6202030	534042.26	6647476.55
K0433010	793328.79	6452049.75	K3373010	717470.43	6573726.36	L6216920	534804.39	6655744.8
K0454020	804549.45	6458743.05	K3382010	722819.39	6578859.87	L7024030	512558.18	6674243.89
K0513010	769765.95	6475999.17	K3400810	724449.11	6589153.6	L7123001	494104.55	6674771.59
K0550010	787629.76	6466827.68	K3450810	724945.61	6606875.99	L8000010	478654.44	6683523.68
K0567530	806852.21	6467648.28	K3464010	722732.58	6609889.92	L8000020	465026.76	6691030.66
K0614010	798209.5	6492243.69	K3533010	711630.41	6615778.6	L8102120	449468.79	6620233.71
K0624510	792741.2	6486346.52	K3553010	711291.92	6620523.47	L8134020	456571.82	6635375.61
K0643110	788306.28	6488474.34	K3570810	702854.72	6630134.65	L8134030	454221.47	6630380.96
K0663310	818834.02	6504313.2	K3603010	700318.51	6624148.77	L8142110	460974.38	6647372.85
K0690010	795444.71	6505606.35	K3650810	705312.18	6649600.15	L8213010	456845.66	6651016.08
K0700010	794011.24	6516916.61	K4000010	705478.14	6657309.81	L8222110	457351.54	6655168.68
K0704510	800844.99	6509017.36	K4013010	694860.63	6643833.83	L8343010	445025.5	6660677.07
K0733220	767468.69	6511172.29	K4073110	692174.97	6685604.64	L8503010	470917.08	6645472.99
K0744010	775055.52	6517711.39	K4080010	689932.68	6693437.73	L8523010	465646.45	6670831.16
K0753210	777764.72	6516595.07	K4094010	699774.98	6695047.52	L8602110	466404.46	6684947.45
K0773210	789867.36	6514831.69	K4180001	671170.55	6731766.36	L8700010	434438.96	6708084.56
K0813020	777866.55	6526232.8	K4350010	620421.84	6755955.81	L9113020	472674.57	6705504.14
K0910010	783495.88	6548195.42	K4383110	619581.93	6750919.04	L9213010	456751.85	6711149.44
K0943010	803043.67	6543369.82	K4414010	601734.76	6745208.3	M0014110	511124.95	6830559.2
K0974010	791941.72	6540145.1	K4470010	567715.82	6711930.06	M0050620	476191.8	6813716.45
K0983010	786635.94	6542928.86	K4672210	582000.2	6715910.7	M0064310	474030.15	6816704.98
K1063010	789033.35	6561789.47	K4793010	568727.89	6712260.08	M0104010	471084.96	6812816.82
K1173210	780716.65	6584764.08	K4800010	563737.76	6711029.54	M0114910	466609.04	6807989.92
K1180010	775416.87	6598045.25	K4843010	567279.26	6717758.14	M0124010	470175.53	6803608.36
K1211810	805741.33	6668125.12	K4853000	546701.73	6705808.19	M0134010	474407.73	6800822.25
K1243010	807709.22	6658665.57	K4856020	548382.99	6708030.58	M0153010	492525.81	6804453.09
K1251810	800395.36	6656379.63	K4873110	541692.62	6718434.37	M0250610	492076.05	6780273.93

Table – continued from previous page

Code	X	Y	Code	X	Y	Code	X	Y
K1273110	795640	6655320.94	K4900030	522757.55	6701739.51	M0301510	519962.6	6821670.61
K1314010	796369.69	6641255.62	K4923030	523091.01	6708333.55	M0361510	537960.4	6804263.49
K1321810	790857.92	6639718.73	K5083010	667880.44	6563896.54	M0365010	538447.41	6803460.97
K1363010	801601.89	6614847.57	K5090910	665099.49	6564156	M0401510	524785.82	6787488.02
K1414010	772221.98	6591042.11	K5143110	644188.08	6567616.83	M0421510	506671.93	6774450.03
K1440010	758704.68	6604553.88	K5210910	669411.79	6579236.14	M0424810	506092.38	6770111.79
K1503010	752595.8	6558819.46	K5220910	669548.89	6588291.52	M0434010	498419.79	6774479.36
K1524010	751666.96	6566505.43	K5333110	692450.33	6600889.29	M0500610	486747.44	6760780.35
K1533010	749768.8	6569862.16	K5336010	669263.45	6591861.1	M0504510	490897.76	6763220.33
K1533020	748477.97	6574001.65	K5343210	681138.37	6579271.36	M0514010	487154.66	6757938.95
K1563010	751628.12	6600038.56	K5363210	686719.93	6589600.12	M0525210	482025.47	6762082.49
K1713010	748787.77	6662603.36	K5383010	675020.6	6603279.23	M0535010	472687.35	6760559.71
K1753110	751861.52	6638555.88	K5383020	677965.98	6600877.38	M0556030	460428.43	6757116.3
K1764020	749737.8	6646177.95	K5400920	661103.5	6625234.75	M0583020	458486.1	6759214.86
K1773010	743874.58	6639242.04	K5424010	676883.18	6626098.63	M0613010	452888.25	6786541.34
K1775510	741035.94	6646341.56	K5433020	671240.68	6625260.44	M0624010	450428.1	6763632.24
K1810310	741012.7	6619277.05	K5490910	628944.68	6680176.26	M0633010	448822.96	6760568.59
K1833010	732963.62	6631860.24	K5543010	668077.37	6656775.46	M0653110	447343.66	6757373
K1900010	719237.65	6648564.3	K5552300	667365.24	6661087.75	M0680610	446696.74	6749682.71
K1914510	725491.38	6651469.17	K5574100	656041.58	6669124.65	M1021610	579516.95	6789386.02
K1930010	712538.91	6653662.98	K5623010	673373.21	6633957.63	M1024810	580451.65	6796363.89
K1943010	715762.14	6670786.66	K6102420	636675.4	6639122	M1025510	581897.5	6794662.95
K1954010	719177.03	6670488.02	K6192410	626433.44	6673961.09	M1034020	577257.18	6791139
K1963010	715420.36	6662497.85	K6220910	587480.35	6686733.37	M1041610	582396.96	6784692.43
K2064010	768036.92	6403973.02	K6332520	644267.59	6718465.63	M1073010	583350.4	6780367.07
K2070810	770083.71	6399656.73	K6334010	657517.29	6710286.25	M1114011	570170.99	6770401.64
K2090810	758148.9	6415950.36	K6373020	647624.24	6705374.95	M1124810	573547.14	6766372.66
K2134010	759282.77	6403083.65	K6402510	620801.04	6699709.72	M1151610	541989.11	6741998.37
K2143020	756470.79	6407837.48	K6593010	583594.56	6685964.02	M1214010	539428.53	6774705.01
K2163110	750376.37	6410166.94	K6720910	510073.62	6696866.37	M1233040	535834.49	6755628.4
K2173010	758159.03	6415730.36	K6888888	504041.49	6694278.9	M1244010	531409.95	6756250.32
K2210810	750948.31	6430038.27	K7202610	610704.55	6627512.79	M1254010	525400.73	6747168.55
K2223020	749804.25	6422237.32	K7207510	600095.52	6637984.3	M1313010	515673.46	6746916.44
K2223030	749311.88	6424262.58	K7424010	564519.64	6677363.99	M1324010	517754.69	6748807.85
K2233020	750199.11	6430049.61	K7433030	555863.05	6677229.2	M1341610	511637.74	6738259.97
K2240810	747038.82	6436626.23	K7542610	502619.83	6690088.81	M1424410	490523.01	6722732.01
K2254010	743424.21	6430371.73	L0050630	603177.5	6515649.78	M1463020	482667.09	6738625.62
K2283110	741942.66	6441592.78	L0093010	587609.27	6519590.89	M1531610	456567.93	6734782.88
K2300810	738585.41	6446506.65	L0123030	604380.98	6525491.5	M1534510	458785.53	6740138.78
K2316210	734438.48	6449249.22	L0140610	576145.81	6532951	M3014010	453612.63	6820615.89
K2330810	732040.25	6462428.39	L0201510	618636.04	6532588.99	M3020910	452174.43	6825773.09
K2335510	728022.81	6460287.35	L0231510	610747.58	6544738.61	M3040910	447668.6	6828522.79
K2363020	739462.55	6456890.63	L0244510	600487.85	6545634.7	M3060910	434868.21	6822130.27
K2383110	739912.58	6461547.54	L0321510	575843.52	6533490.79	M3103010	430255.32	6838319.86
K2430810	727435.69	6476843.28	L0400610	570147.12	6530328.32	M3133010	428554.3	6828213.29
K2450810	726195.18	6481053.92	L0513010	570349.3	6515621.48	M3213010	418513.95	6822516.47
K2514020	694743.48	6458879.82	L0700610	552429.56	6528656.45	M3223010	428711.63	6813063.8
K2534010	714375.85	6460229.81	L0914010	534207.87	6530397.57	M3230910	430888.44	6804093.78
K2544010	715468.34	6461353.55	L0920610	529943.29	6532328.48	M3230920	434588.61	6811582.43
K2623010	714870.72	6481211.54	L0940610	519849.45	6548569.75	M3253110	431126.77	6802693.75
K2644010	727901.38	6502651.18	L1400610	523453.59	6591969.92	M3313010	408122.91	6806599.73
K2654010	708674.33	6494591.89	L2103020	488108.96	6587342.19	M3340910	421176.35	6774584.46
K2674010	708164.13	6498657.58	L2201610	488630.6	6587674.22	M3403010	441603.26	6789384.4
K2680810	715735.12	6506906.31	L2253010	481675	6596691.33	M3504010	418107.23	6772123.37
K2680820	716477.96	6501759.58	L2313050	491289.01	6596307.13	M3600910	423731.17	6752857.52
K2698210	710133.51	6510984.05	L2321610	491719.94	6596952.98	M3630910	423426.88	6737493.86
K2714010	721763.96	6523835.51	L2334010	495969.1	6609112.42	M3711810	406840.23	6766673.64
K2724220	713392.14	6521811.04	L2341620	496739.53	6611765.37	M3771810	406013.34	6748828.88
K2753010	704428.32	6547200.87	L2404030	491240.93	6612485.33	M3774010	401606.08	6750125.13
K2763110	708494.65	6525024.99	L2501610	503121.22	6625741.29	M3813010	394514.86	6741073.7
K2773120	723923.21	6534263.06	L3100610	512198.52	6637247.61	M3823010	403638.95	6738341.8
K2774020	717395.71	6532278.12	L3123010	511933.5	6637334.43	M3834030	409826.02	6734380.84
K2783010	723969.22	6534304.3	L3200610	514769.47	6645514.6	M3851810	410467.31	6738856.38
K2784510	725208.73	6535865.96	L4110710	624824.04	6558635.88	M3861810	417514.43	6736439.21
K2790810	734729.01	6541118.88	L4210710	616674.31	6569122.11	M3910910	428330.25	6721795.82
K2821910	758348.62	6476155.94	L4523010	593324.14	6587527.46	M4101921	432023.02	6713951.14
K2834010	749296.63	6483211.34	L4530710	593549.12	6595922.69	M4114010	428242.6	6716846.14
K2851910	756980.86	6494073.44	L4653010	595016.65	6619337.52	M5014220	435287.67	6703144.21

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Code	X	Y	Code	X	Y	Code	X	Y
K2884010	746234.72	6511569.07	L4710710	569129.59	6616131.21	M5124310	436601	6686179.05
K2944010	742758.8	6517314.35	L5301810	541790.51	6566963.28	M5214020	426482.73	6695431.4
K2981910	737043.05	6532500.7	L5301811	581228.04	6559554.67	M5300010	408857.48	6706221.26

Table 3. List of hydrometric stations influenced by dams. The time series of these stations are naturalized by French Electricity (EDF).

Code	Location
K0100020	La Loire at Goudet
K0120020	La Loire at Coubon
K0260020	La Loire at Chadrac
K0550010	La Loire at Bas-en-Basset
K0690010	La Loire at Montrond-les-Bains
K0700010	La Loire at Feurs
K0910010	La Loire at Villerest
K1180010	La Loire at Digoin
K1440010	La Loire at Gilly-sur-Loire
K1900010	La Loire at Imphy
K1930010	La Loire at Nevers
K2240810	L'Allier at Prades
K2300810	L'Allier at Langeac
K2330810	L'Allier at Vieille-Brioude
K2430810	L'Allier at Agnat
K2680810	L'Allier at Vic-le-Comte
K2790810	L'Allier at Limons
K3030810	L'Allier at Saint-Yorre
K3400810	L'Allier at Chatel-de-Neuvre
K3450810	L'Allier at Moulins
K3570810	L'Allier at Livry
K3650810	L'Allier at Cuffy
K4000010	La Loire at Cours-les-Barres
K4080010	La Loire at Saint-Satur
K4180010	La Loire at Gien

Table 4: Hydrometric stations with long-term continuous daily data located on the Reference Hydrometric Network. The coordinate system is Lambert 93.

Code	**X**	**Y**	**Code**	**X**	**Y**	**Code**	**X**	**Y**
K0010010	791375.44	6408562.73	K2871910	747510.65	6510159.49	L2443010	490191.09	6617355.1
K0403010	802401.56	6440678.06	K3264010	674712.2	6530166.07	L4220710	598477.39	6587347.52
K0454010	795337.61	6458003.17	K3374710	715272.82	6571544.75	L4321710	623221.41	6584565.78
K0523010	773565.84	6468033.13	K4443010	599274.27	6739425.6	L4411710	599253.63	6588169.36
K0567520	798002.01	6469025.4	K5183010	655710.56	6565553.43	L5034010	583787.34	6556316.2
K0673310	807203.23	6501839.54	K5200910	664208.83	664208.83	L5101810	578997.01	6558306.51
K1284810	790906.06	6656780.1	K5653010	655005.78	6660896.66	L5134010	556619.25	6562905.24
K1341810	779283.4	6604359.27	K6492510	587732.21	6687266.69	L5223020	546585.47	6562341.84
K1383010	783354.72	6597220.43	K7312610	557740.57	6659092.39	L7000610	513799.08	6664712.54
K1724210	758122.06	6645915.05	K7414010	566649.23	6672109.22	M0243010	492217.25	6788044.53
K2363010	740999.39	6455503.89	K7514010	535046.72	6685285.32	M1213010	537414.42	6770526.61
K2514010	700546.24	6448347.57	L0314010	589894.82	6540597.58	M1354020	510446.79	6725644.89
K2523010	702148.01	6451101.5	L0563010	563206.59	6518987.08	M3323010	419385.98	6791915.44
K2593010	720781.8	6476056.23	L0813010	538441.77	6536959.68	M3423010	423967.87	6776825.99
M3423010	423967.87	6776825.98	M5102010	444579.08	6682426.15	M5222010	425705.89	6696960.64

Table 5. 67 stations with continuous daily Tw over the 2010–2014 period. Only 53 stations are presented here. The rest of the stations with the long-term time series are presented in Table 1. Tw data provided by OFB can be downloaded from http://www.naiades.eaufrance.fr/. The rest of Tw data are not archived for the public use.

Code	X	Y	Source	Code	X	Y	Source	Code	X	Y	Source
4021250	768551.46	6582925.45	OFB	4108425	522514.35	6758807.33	OFB	K3264010	674697.42	6530180.8	DREAL Auvergne
4022210	750110.42	6567622.41	OFB	4110700	513471.06	6839787.44	OFB	K3374710	715272.17	6571519.72	DREAL Auvergne
4024060	742853.03	6601451.83	OFB	Ance–Pontempeyrat	770634.03	6472338.5	FD	Lignon–Amont–pt–Neuf	769826.03	6509777.54	FD
4040150	750076.45	6547335.74	OFB	Andrable–Cacharat	778486.46	6473447.73	FD	Lignon–Le–Sagnat	764366.56	6514393.27	FD
4042100	717421.83	6573732.71	OFB	Andrable–Jamillard	776741.26	6485606.63	FD	Loir–amont–Illiers–Combray	569466.08	6801913.12	FD
4043100	723856.48	6582328.33	OFB	Anzon–La–Rivalsupt	759531.05	6522835.44	FD	Loise–La–Vieille–Cure	803799.46	6518110.1	FD
4043800	716195.96	6604025.33	OFB	Anzon–Memos	768923.3	6523301.84	FD	Loise–Mayoliere	797237.85	6517215.29	FD
4044400	700335.81	6622069.6	OFB	Bonson–Fournier	785171	6478216.56	FD	4046800	690032.61	6693063.16	OFB
Coise–Moulin–Trunel	811669.85	6503644.36	FD	4048550	672642.83	6718155.67	OFB	Cotatay–Pre–Farost	811005.95	6474769.13	FD
Mare–Aval–double	794690.71	6502945.34	FD	4049625	649245.79	6740290.73	OFB	Couzon–Cote–ratier	813440.51	6500195.76	FD
Mare–Le–Moulin	775439.77	6493299.75	FD	4060500	670482.64	6603987.08	OFB	Curraize–Les–Jaquets	791378.88	6498627.34	FD
Mare–Molley	783867	6490448.55	FD	4060900	686607.74	6599111.86	OFB	Jarnossin–Marpin	792775.66	6555226.46	FD
Semene–Croquet	807438.4	6468339.39	FD	4061400	686432.76	6591216.48	OFB	Jarnossin–Rajasse	785566.65	6559374.2	FD
Semene–Le–Mas	812546.33	6472340.79	FD	4065000	635690.14	6674511.28	OFB	K2365510	739522.27	6455843.93	DREAL Auvergne
St–Suzanne–Ferchaux	554815.66	6789239.01	FD	4075700	628112.91	6510868.98	OFB	K2383110	739886.87	6461522.71	DREAL Auvergne
Trambouze–La–Tombee	796161.92	6545177.28	FD	4082550	489936.27	6584120.9	OFB	Valcherie–Bois–de–la–Montat	804888.18	6476441.36	FD
4086060	524079.4	6624818.57	OFB	Vizezy–Bullieu	786148.4	6505085.3	FD	4091400	576556.7	6616444.39	OFB
Vizezy–Vizezy	789749.18	6514600.24	FD	Yerre–amont	548898.86	6782924.30	FD				

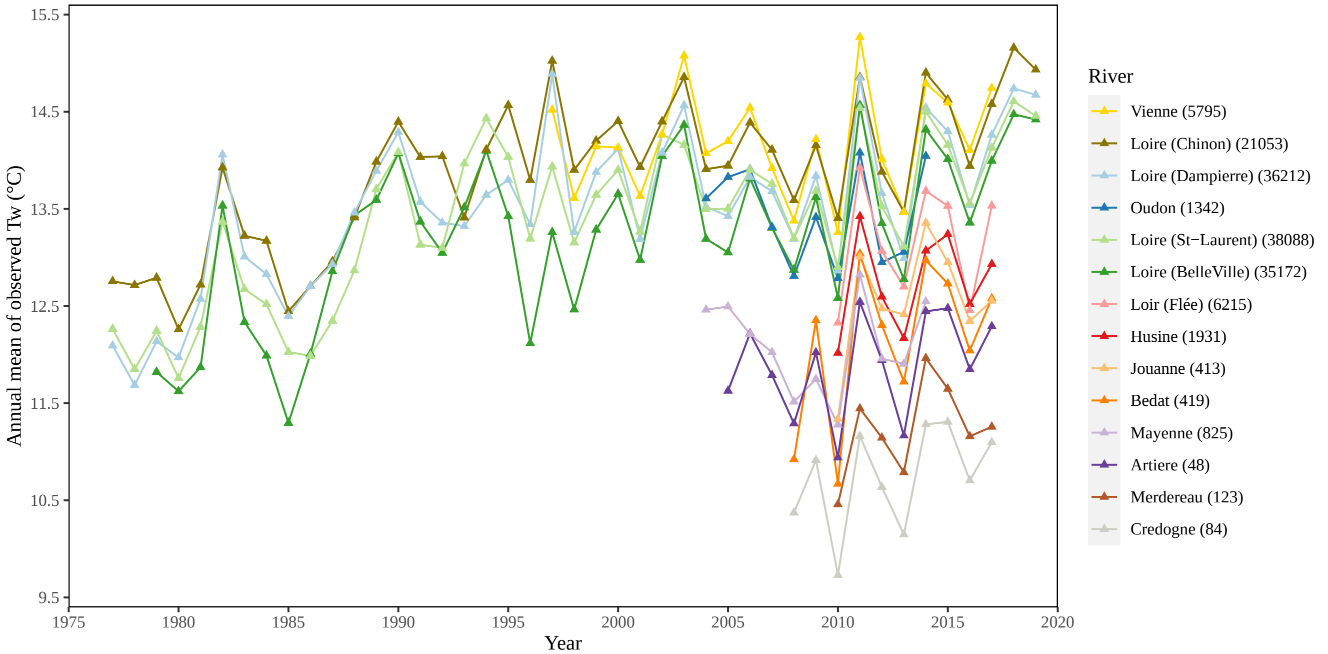

Figure S4. The annual mean of observed Tw at the 14 stations with long-term data between 1977 and 2019 (see Table 1). The numbers within the parentheses show the river catchment area (km^2).

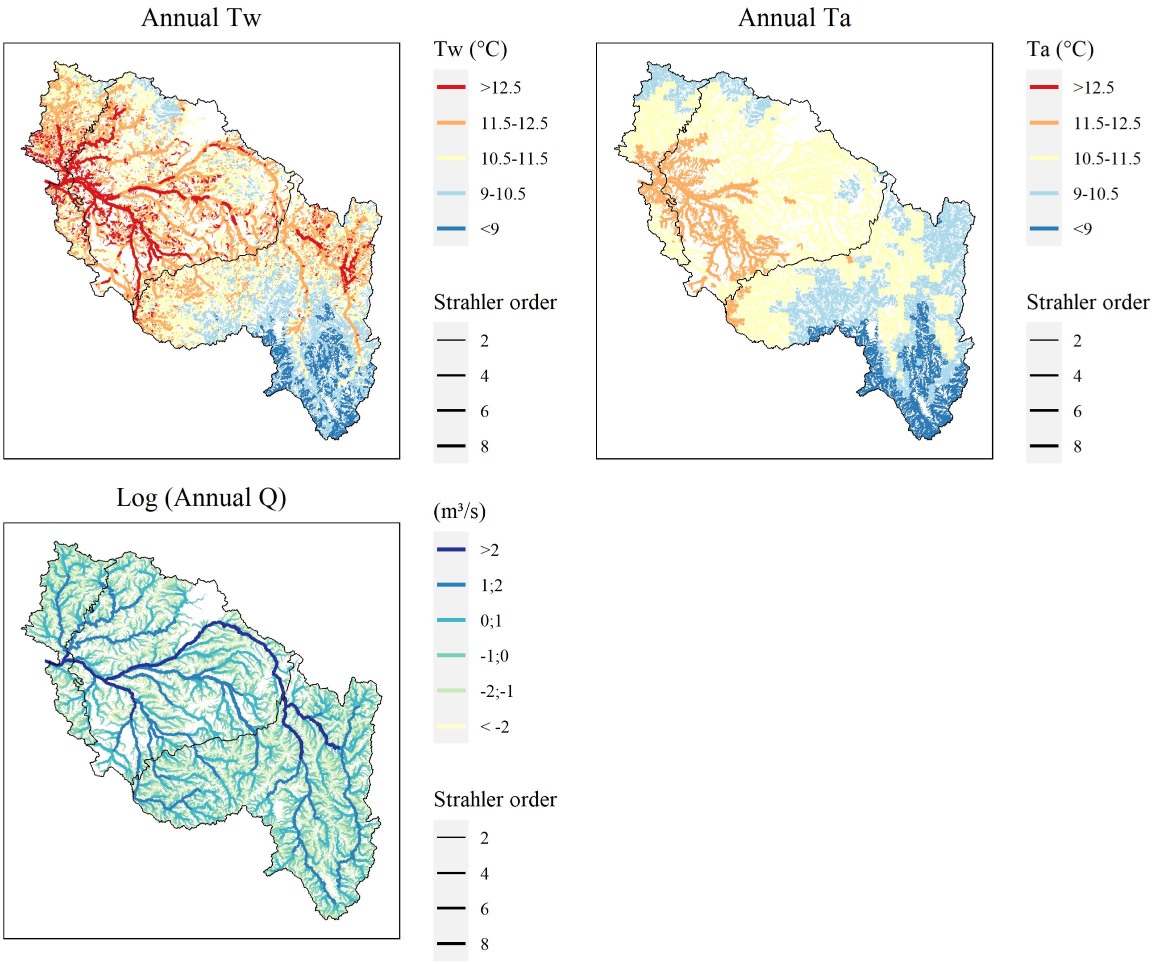

Figure S5. Map of annual mean Tw, Ta and Q over the 1963–2019 period. Please note that for Q, log(annual Q) are presented.

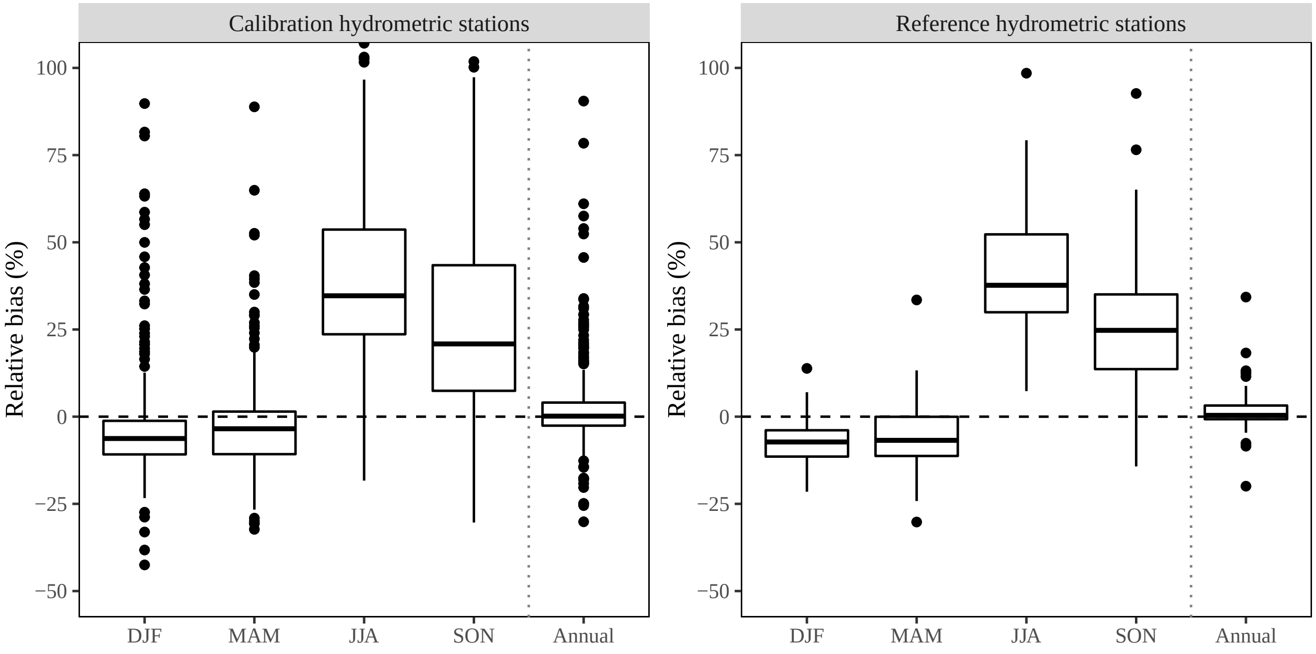

Figure S6. Relative bias of the EROS hydrological model at (left) 352 calibration stations between 1975 and 2018, and at (right) 44 stations from the Reference Hydrometric Network (RHN) over the 1968–2019 period. Relative bias at seasonal (DJF = winter; MAM = spring; JJA = summer; SON = fall) and annual scale are presented separately.

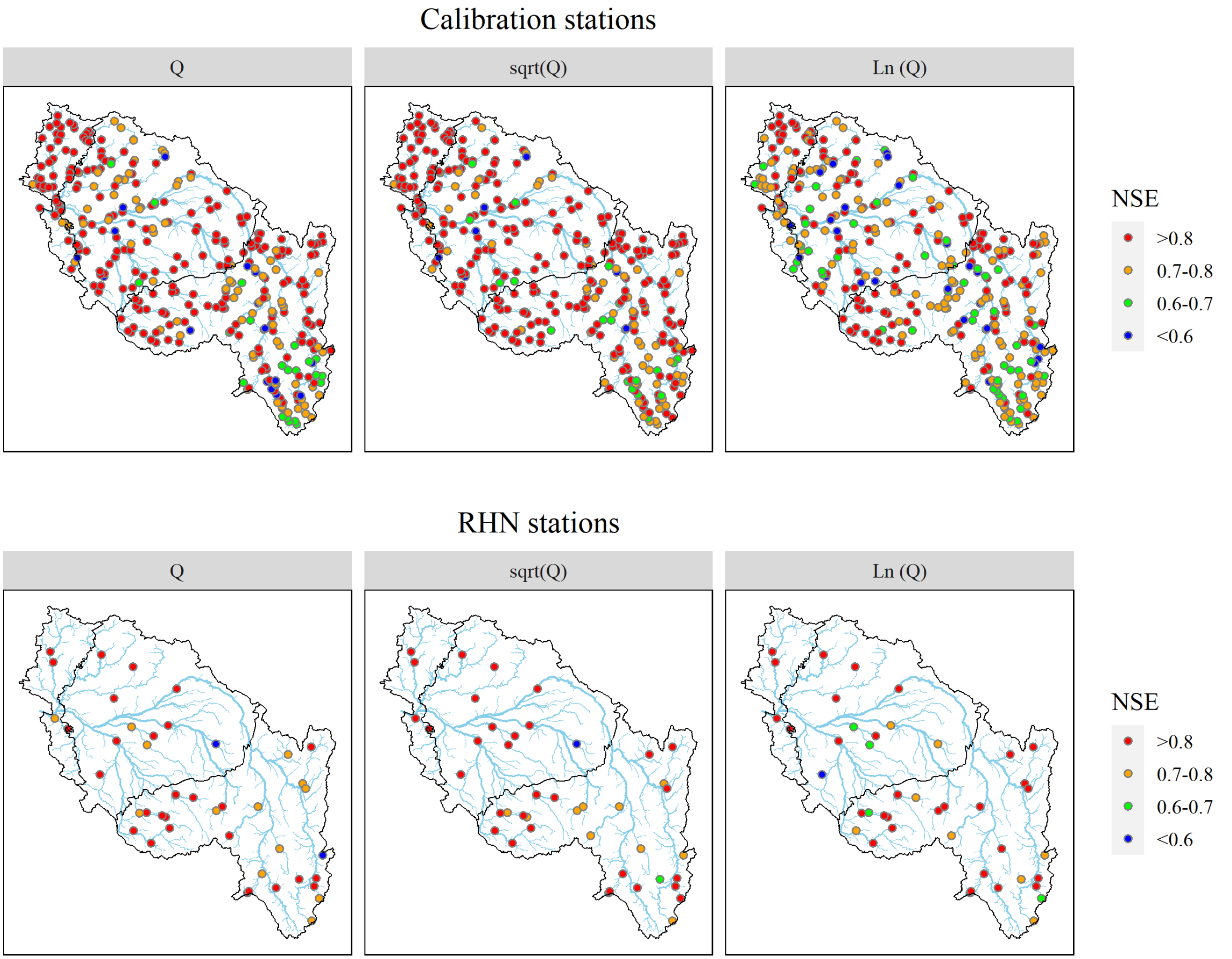

Figure S7. NSE values of simulated daily Q for Q, $\sqrt{Q}$ and $\ln(Q)$ at (top) 352 calibration stations between 1975 and 2018, and at (bottom) 44 RHN stations over the 1968–2019 period.

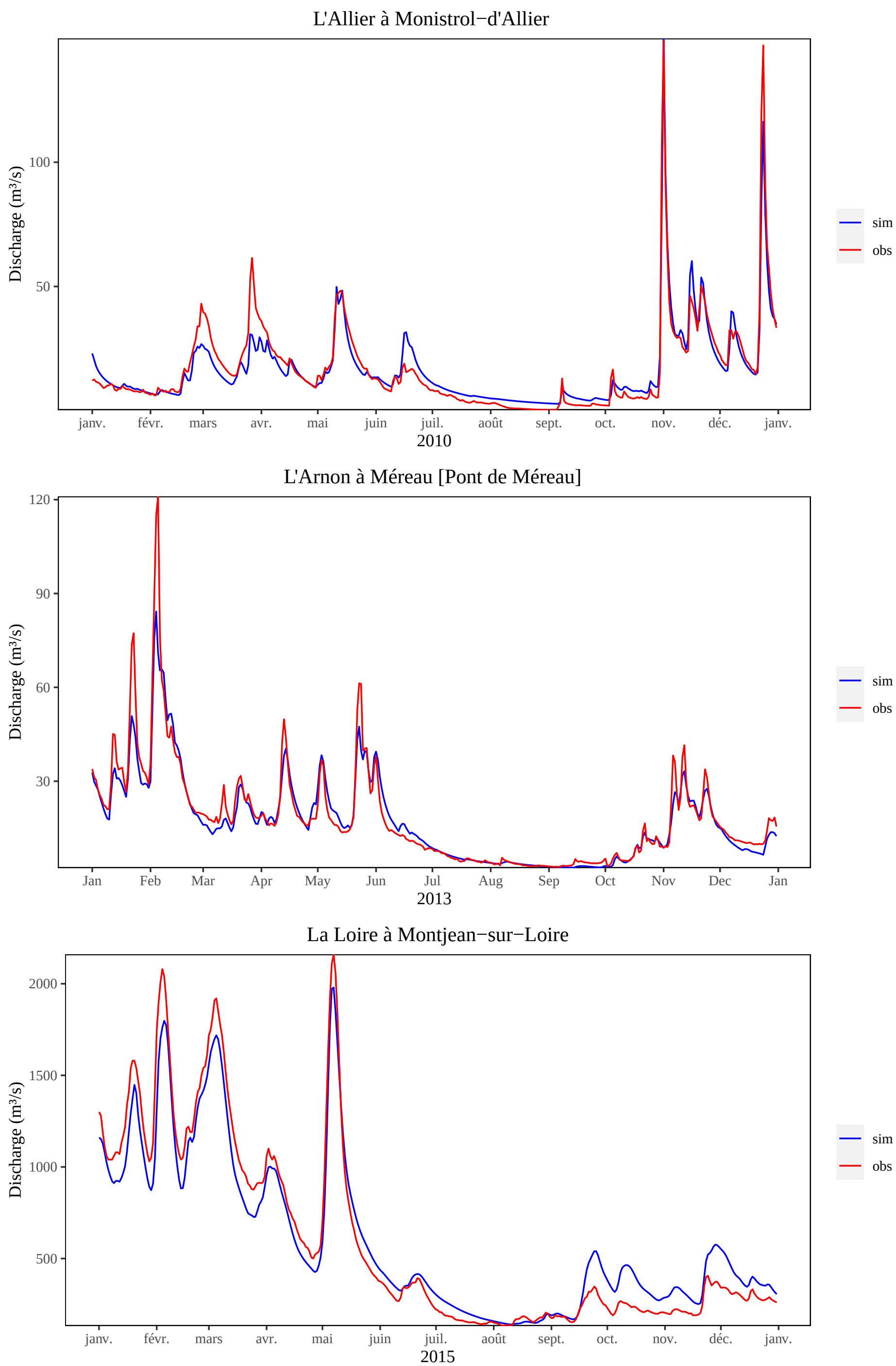

Figure S8. Simulated and observed daily Q at three different hydrometric stations: (top) in the upstream (L'Allier à Monistrol-d'Allier), (middle) in the middle (L'Arnon à Méreau [Pont de Méreau]), and (bottom) in the downstream part (La Loire à Montjean-sur-Loire) of the Loire River basin.

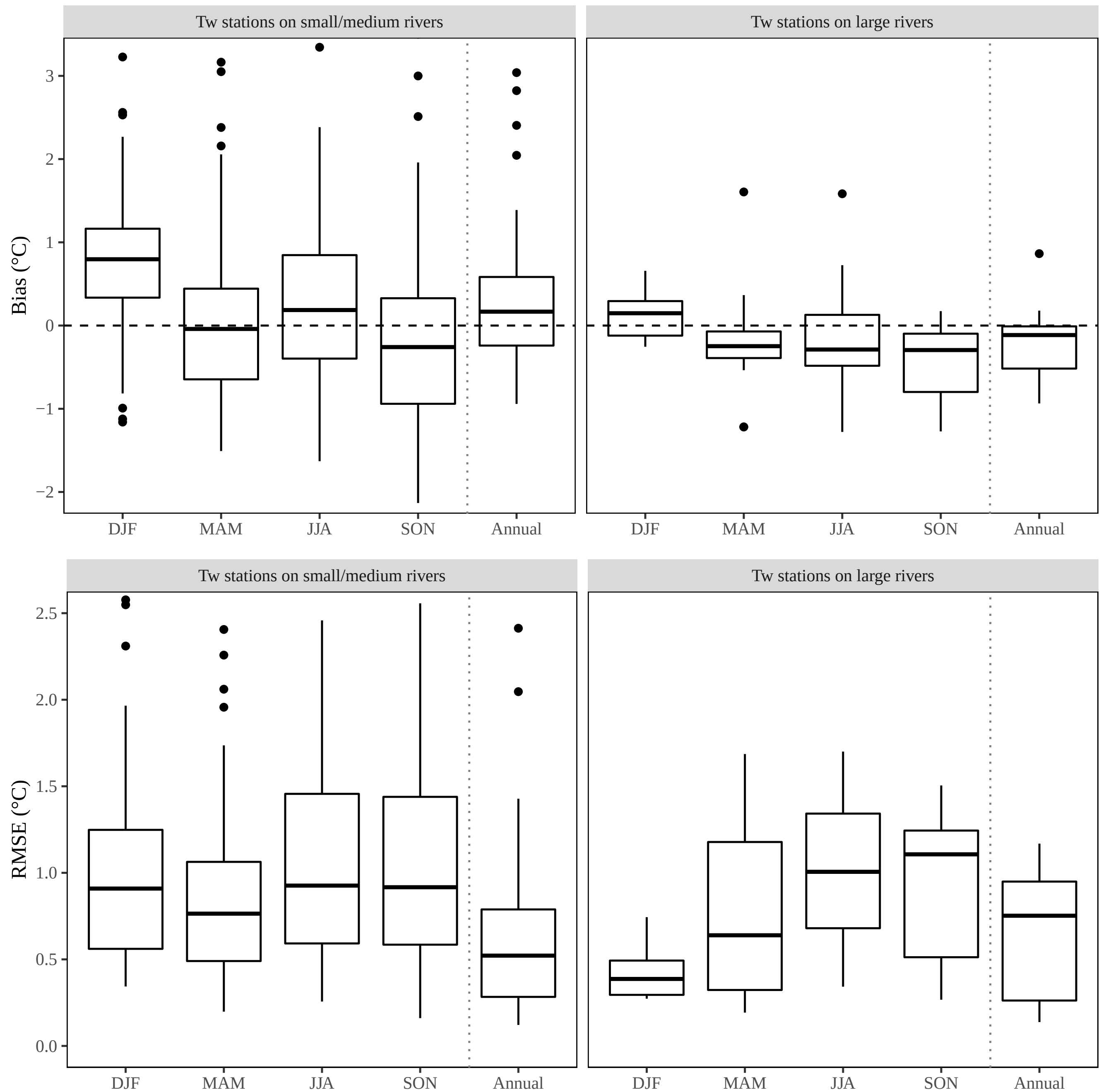

Figure S9. (top) Absolute bias and (bottom) RMSE of the TNET thermal model at 67 observed Tw stations (55 on small and medium rivers, left; 12 on large rivers, right) over the 2010–2014 period. Absolute bias and RMSE at seasonal (DJF = winter; MAM = spring; JJA = summer; SON = fall) and annual scales are presented separately.

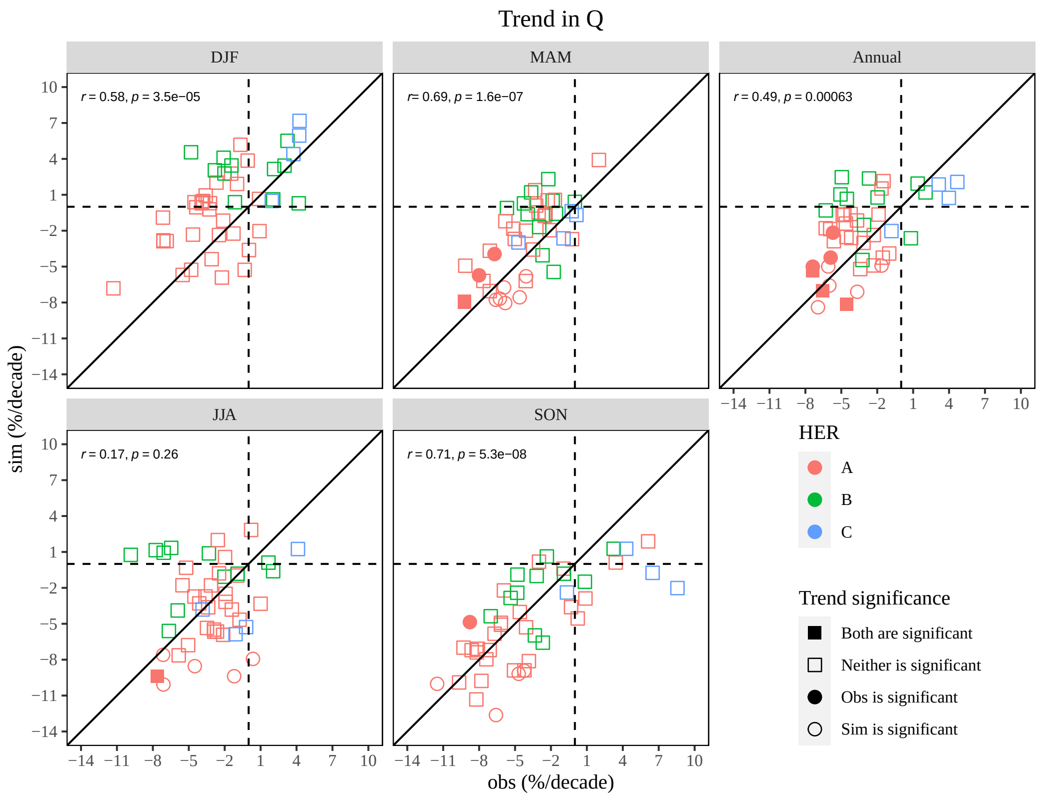

Figure S10. Relationships between long-term trends (over the 1968–2019 period) in observed and simulated Q for 44 RHN stations, at the seasonal (DJF = winter; MAM = spring; JJA = summer; SON = fall) and annual scale. Point shapes indicate whether trends are significant or not at the 95% confidence level for observations and simulations according to the Mann-Kendall test. Colors refer to the Hydro-Ecoregion (HER) where the station is located (see Fig. 1).

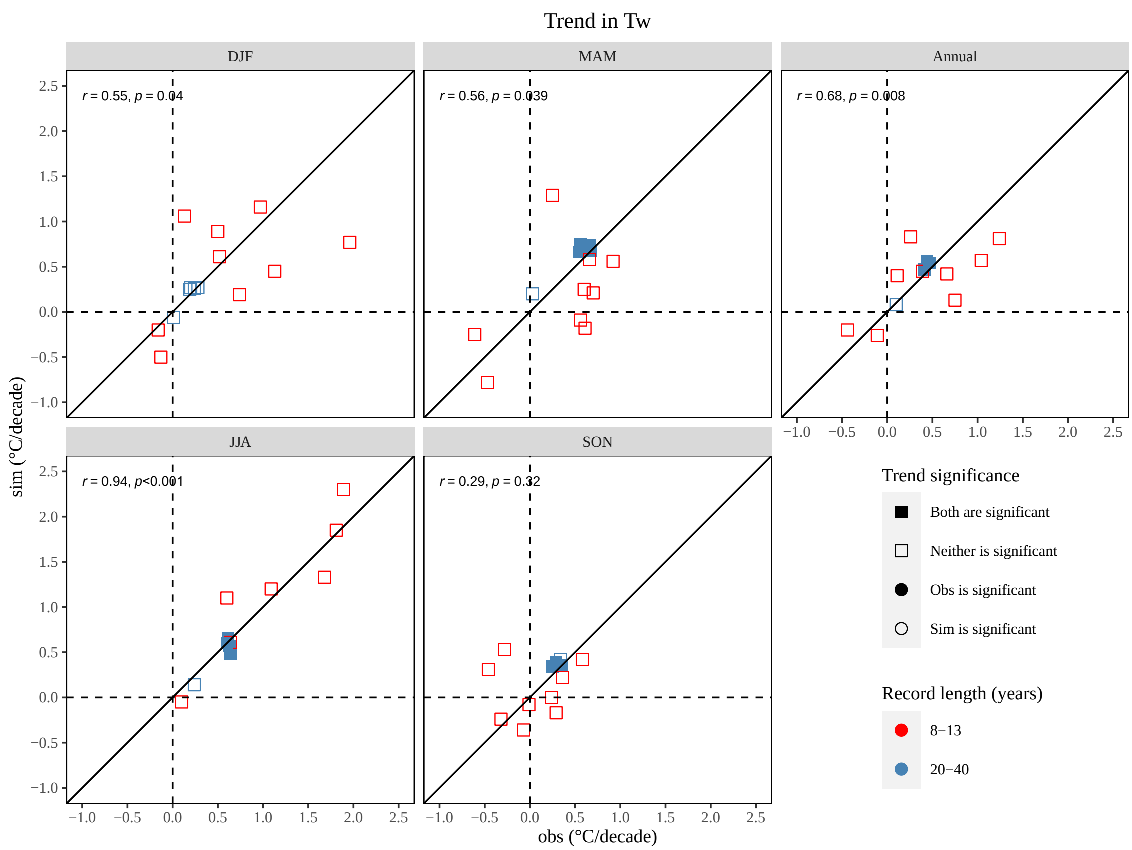

Figure S11. Relationships between trends in observed and simulated Tw for 14 stations, including 5 stations with long-term data (20-40 years, blue) and 9 stations with 8-13 years of data (red). Colors refer to total number of years with data. Point shapes indicate whether trends are significant or not at the 95% confidence level for observations and simulations according to the Mann-Kendall test. The trends in observed and simulated Tw were either both significant or neither was significant. Trends are presented at seasonal (DJF = winter; MAM = spring; JJA = summer; SON = fall) and annual scale separately.

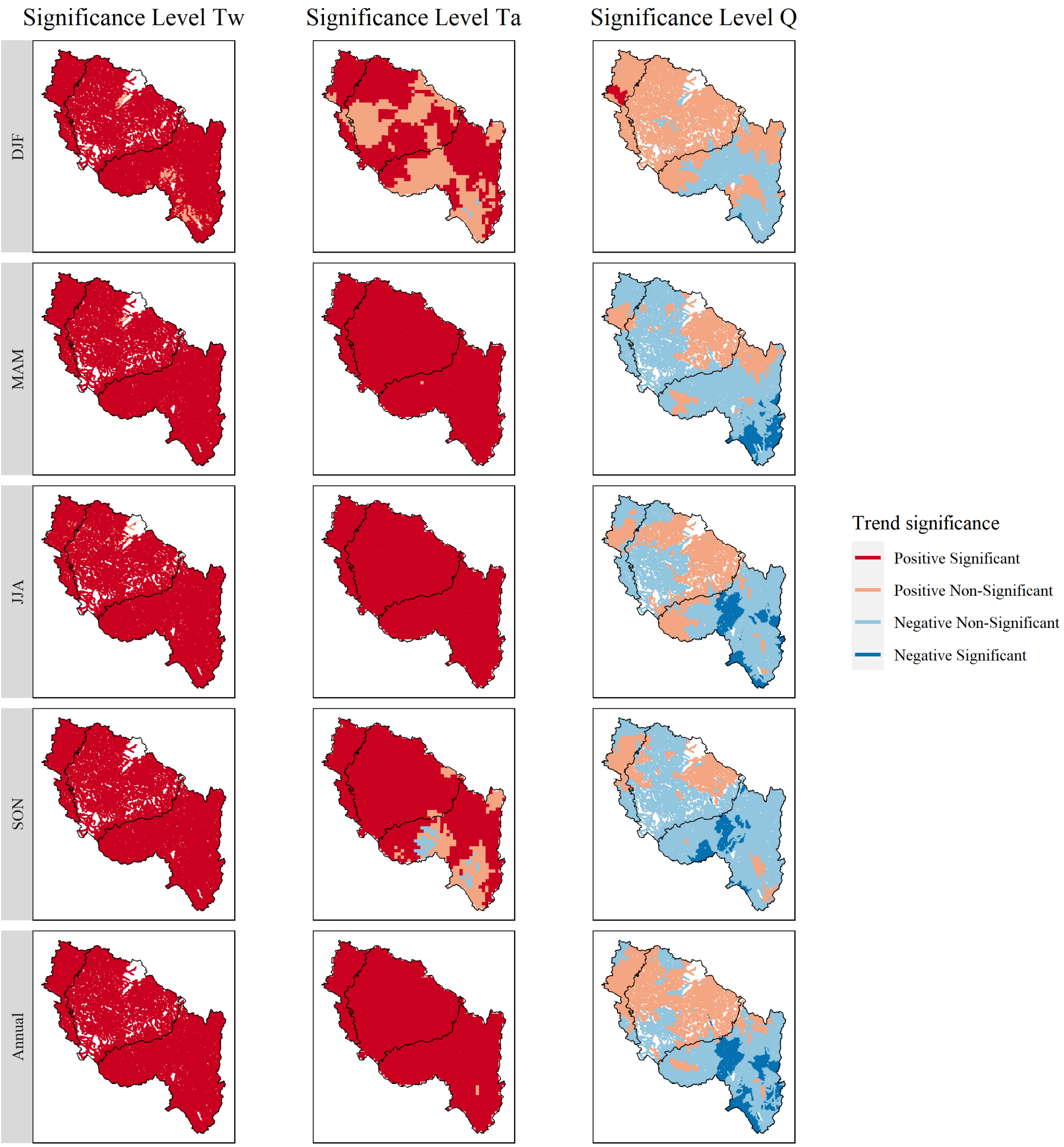

Figure S12. Spatial variability of the significance of trends in seasonal and annual Tw, Ta and Q over the 1963–2019 period, based on a Mann-Kendall test at the 95% confidence level. Solid black lines show the Hydro-Ecoregion delineation (see Fig. 1).

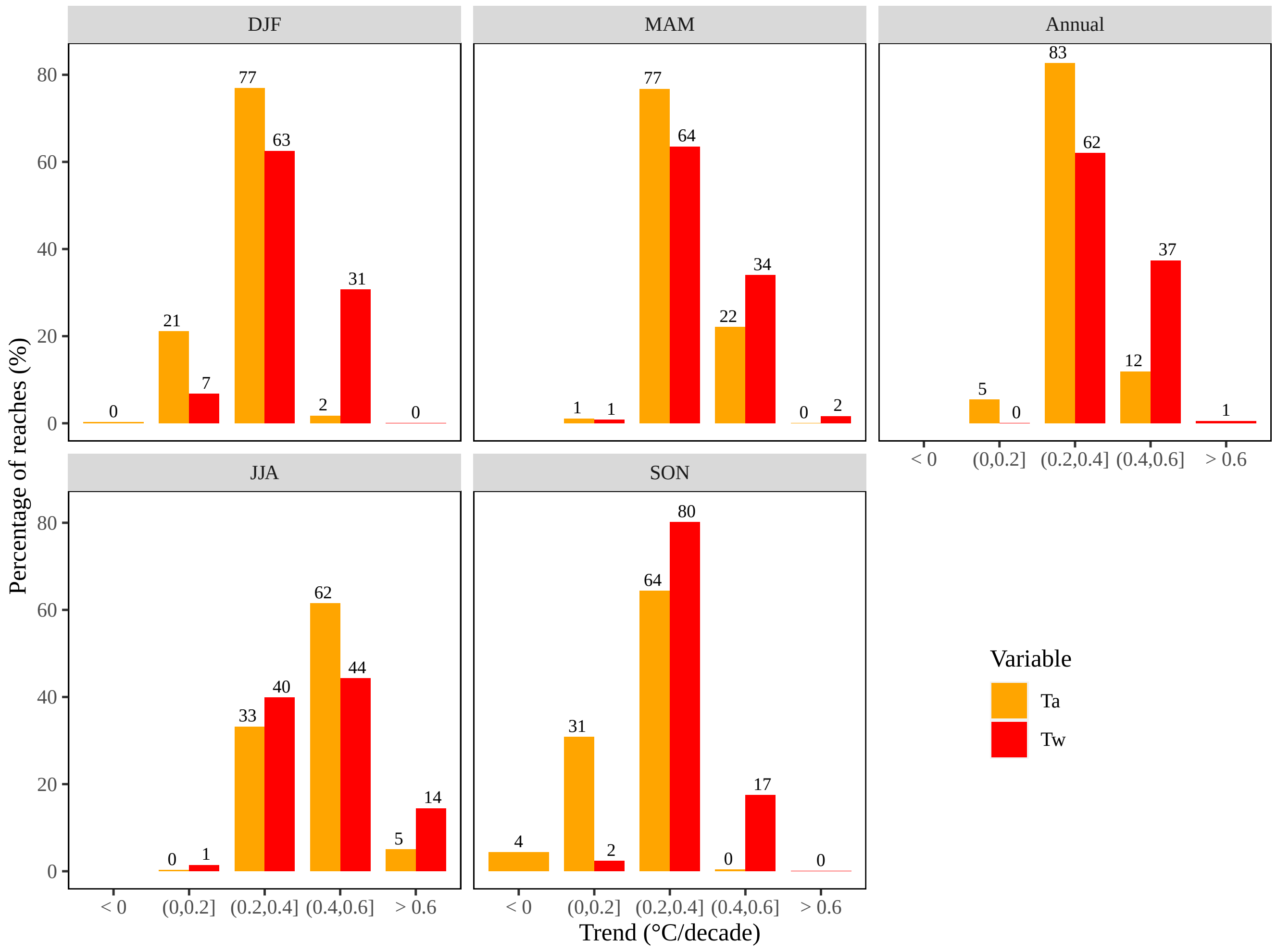

Figure S13. The range of the seasonal and annual Tw and Ta trends for all 52 278 reaches over the 1963–2019 period. This representation includes both significant and non-significant trends.

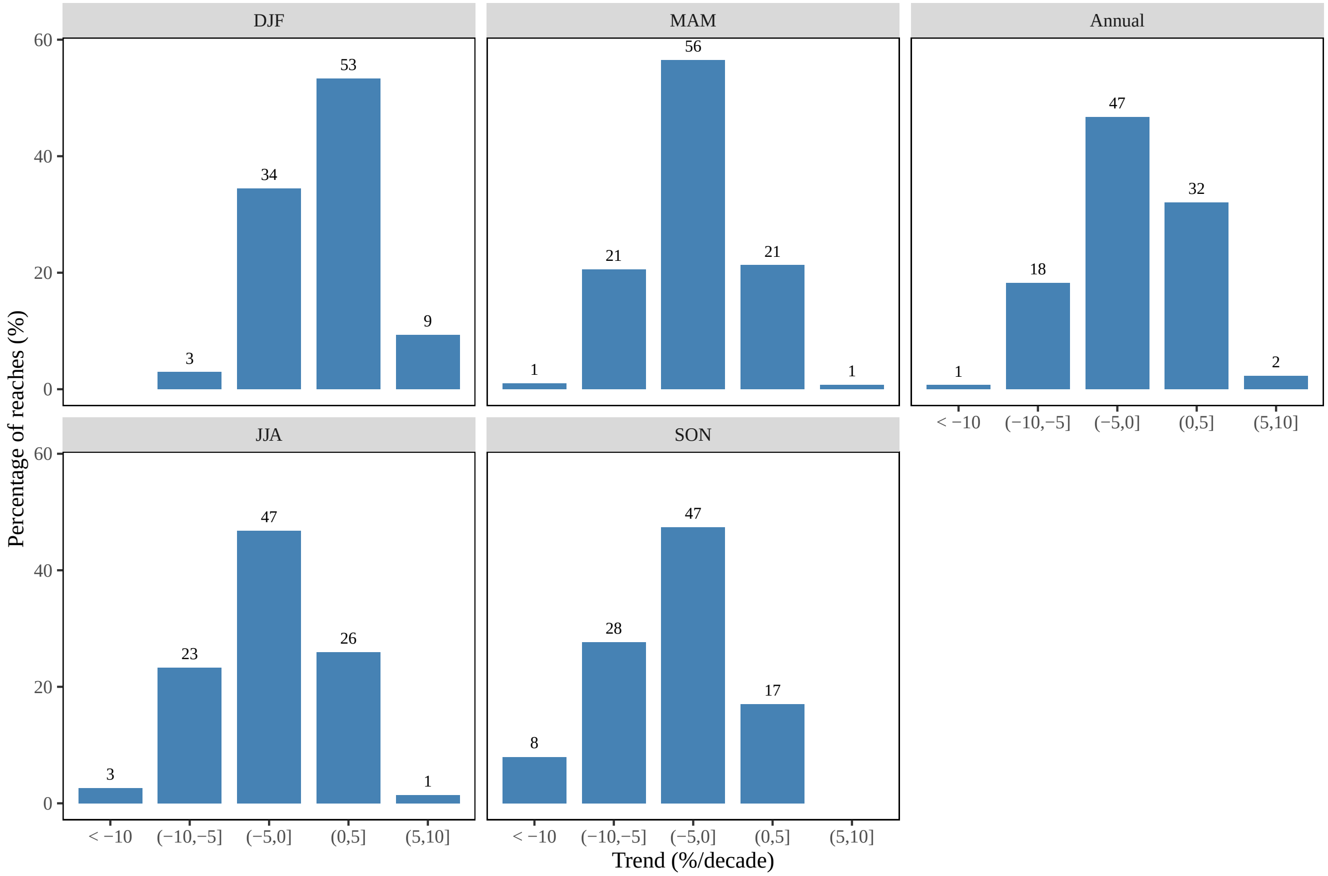

Figure S14. The range of the seasonal and annual Q trends for all 52 278 reaches over the 1963–2019 period. This representation includes both significant and non-significant trends.

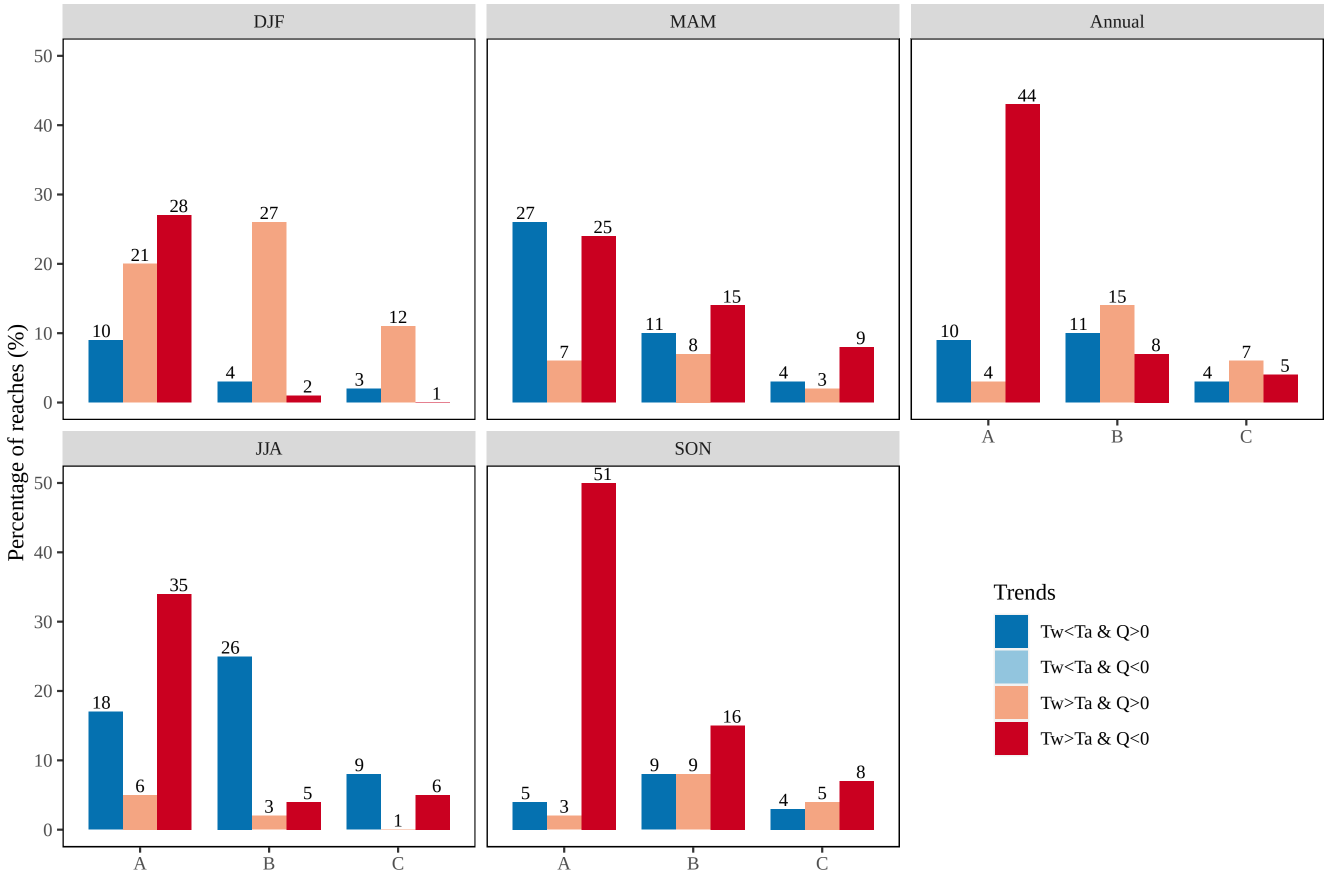

Figure S15. Percentage of reaches in each HER with consistent trends (significant and non-significant) in Tw, Ta, and Q, categorised with respect to two criteria: (1) comparison between Tw and Ta trends, and (2) sign of Q trend. Sen's slope is used as trend value estimate. Please note that the percentages are calculated with respect to the whole basin, which means that the sum of them in each season is equal to 100 %.

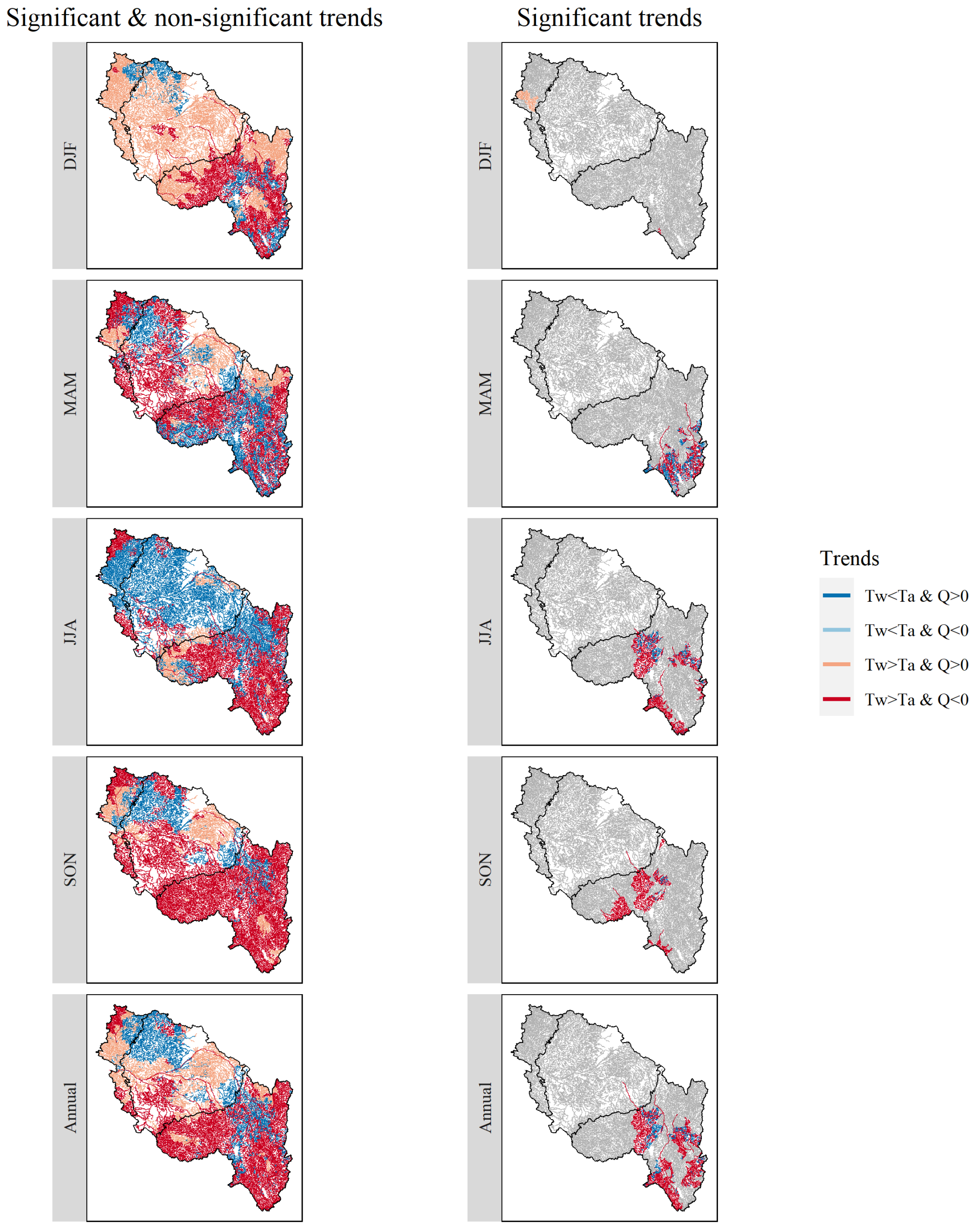

Figure S16. Map of reaches with trends in Tw, Ta, and Q, categorised with respect to two criteria: (1) comparison between Tw and Ta trends, and (2) sign of Q trend. Sen's slope is used as trend value estimate. (left) All reaches with significant and non-significant trends in Tw, Ta and Q. (right) Only reaches with significant trends in Tw, Ta, and Q.

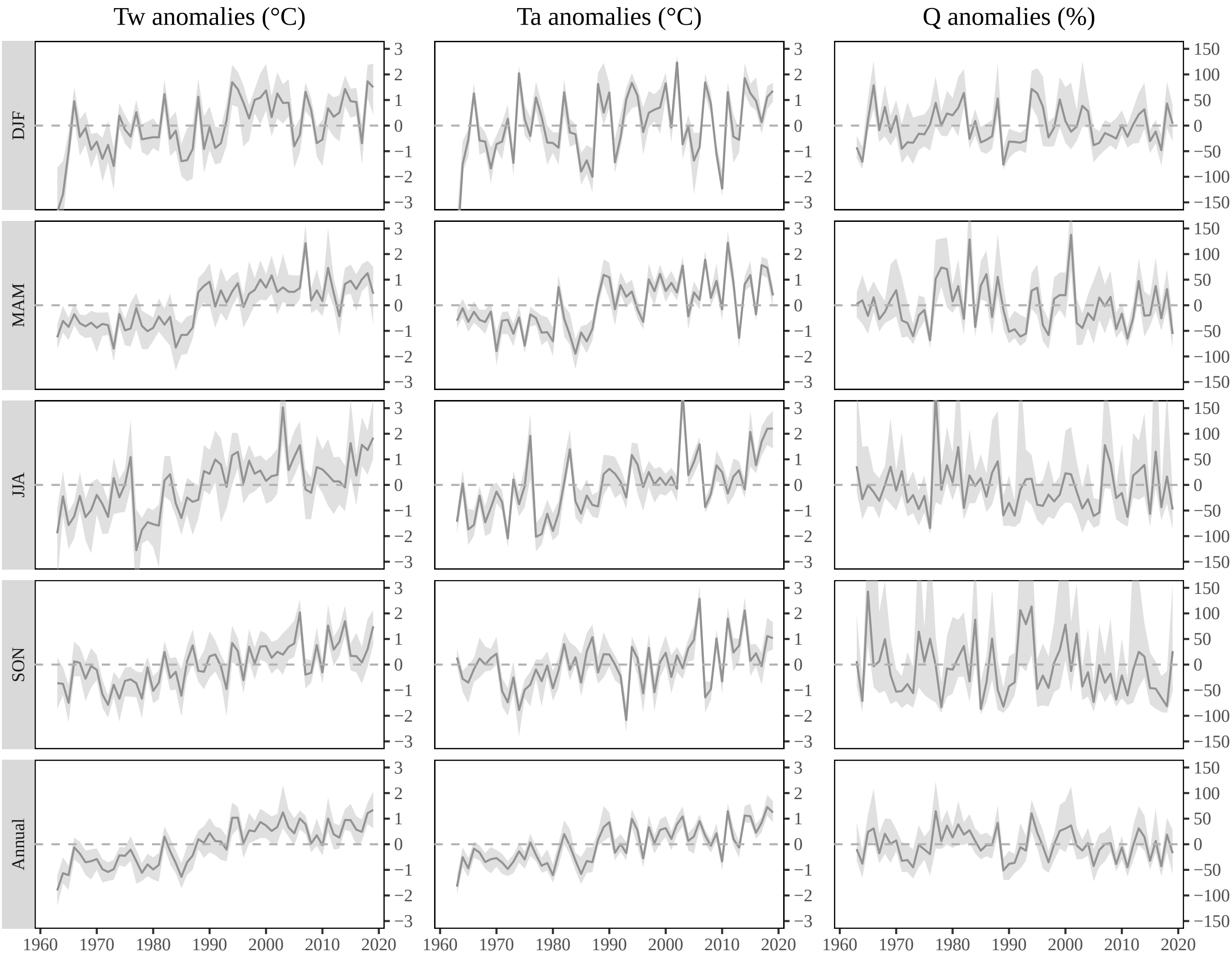

Figure S17. Seasonal and annual times series of anomalies in Tw (°C), Ta (°C) and relative Q (%) with respect to 1963–2019 averages. Grey intervals show the 5th and 95th percentiles across reaches, and the solid grey line depicts the median value. Note that Ta and Tw have the same scale.

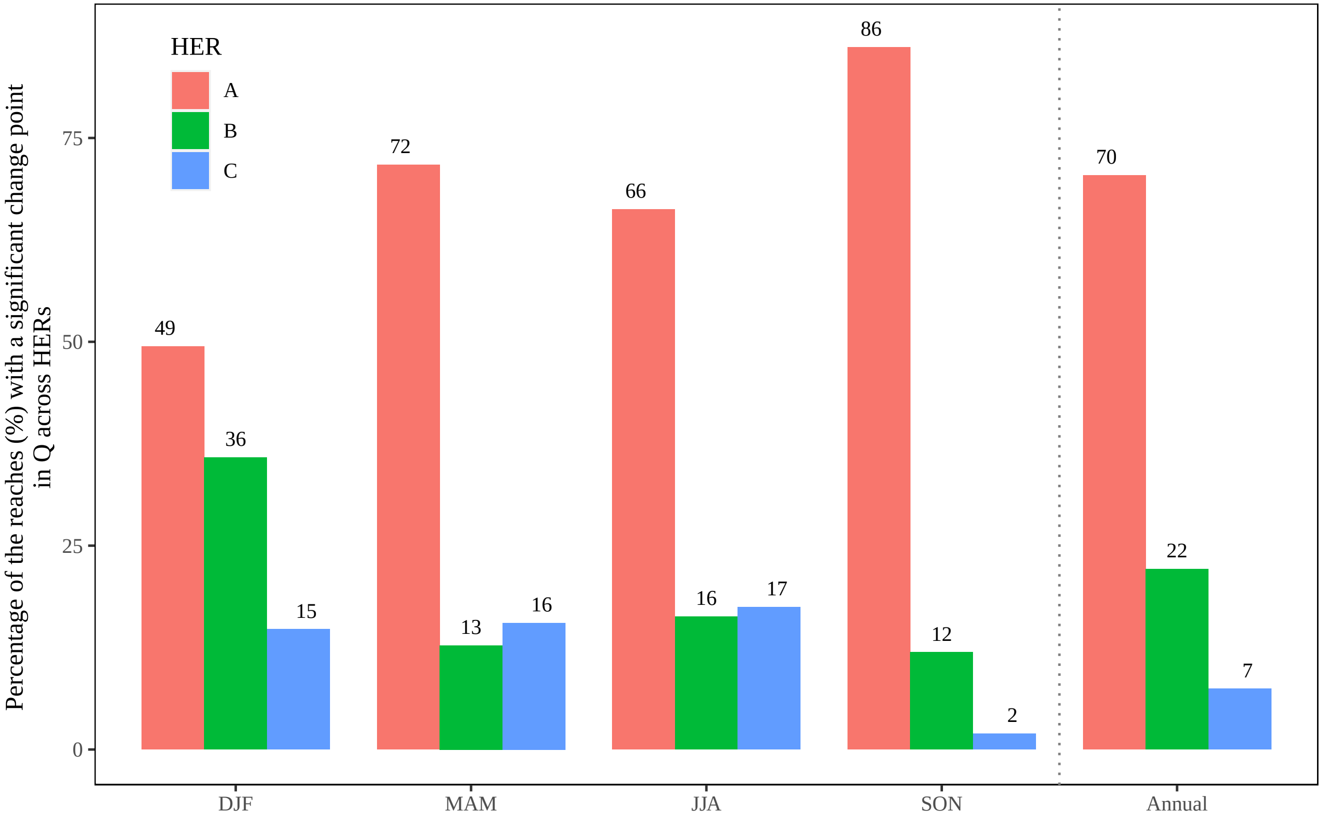

Figure S18. Percentage of reaches with the detected significant change-point in Q time series across HERs. Note that, in this figure, the percentage has been calculated over the reaches with the significant change-point, not over whole 52 278 reaches.

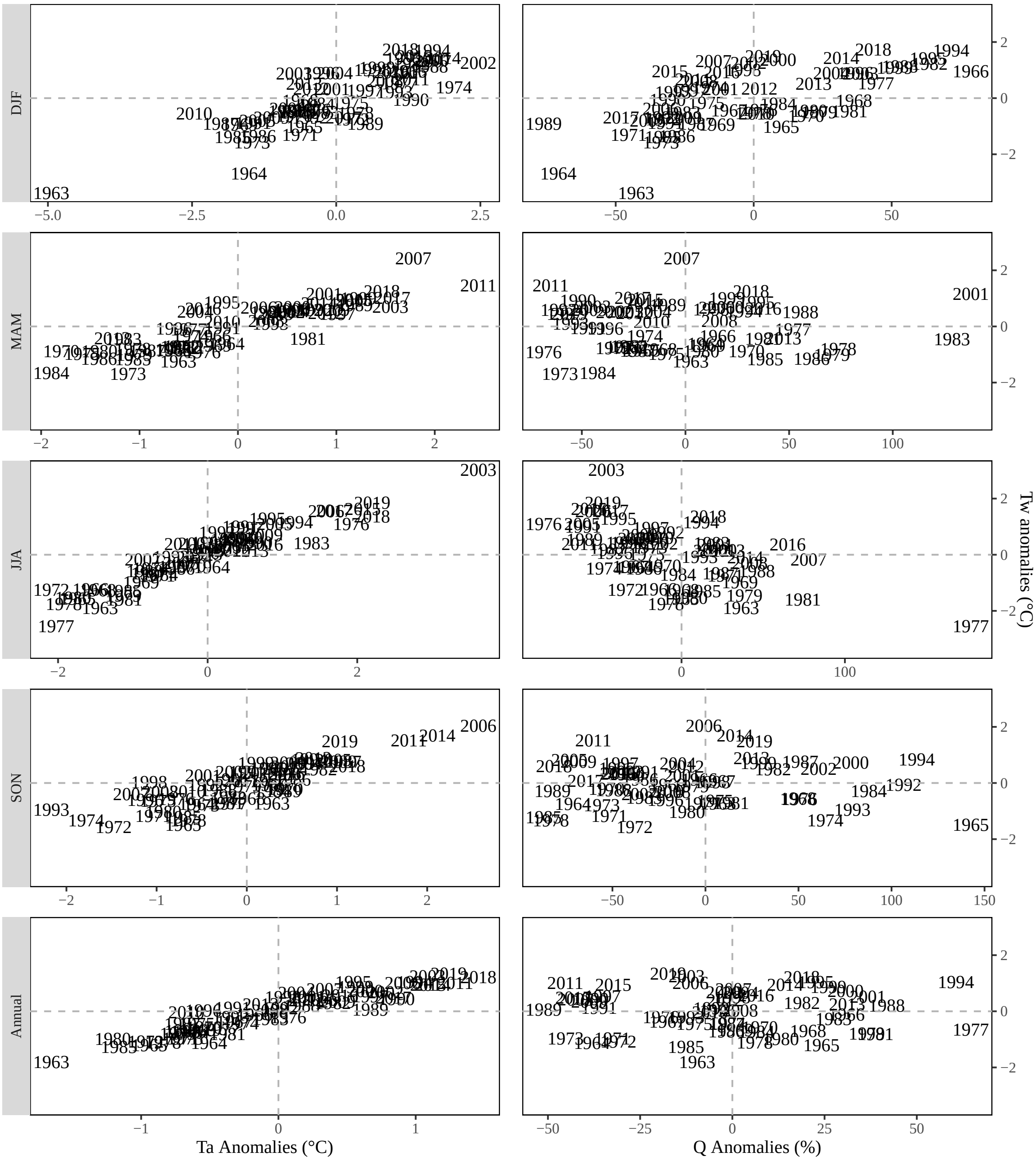

Figure S19. Synchronicity of Tw anomalies with Ta anomalies and Q anomalies at seasonal and annual scale. The labels indicate the median anomalies of 52 278 reaches for each year.

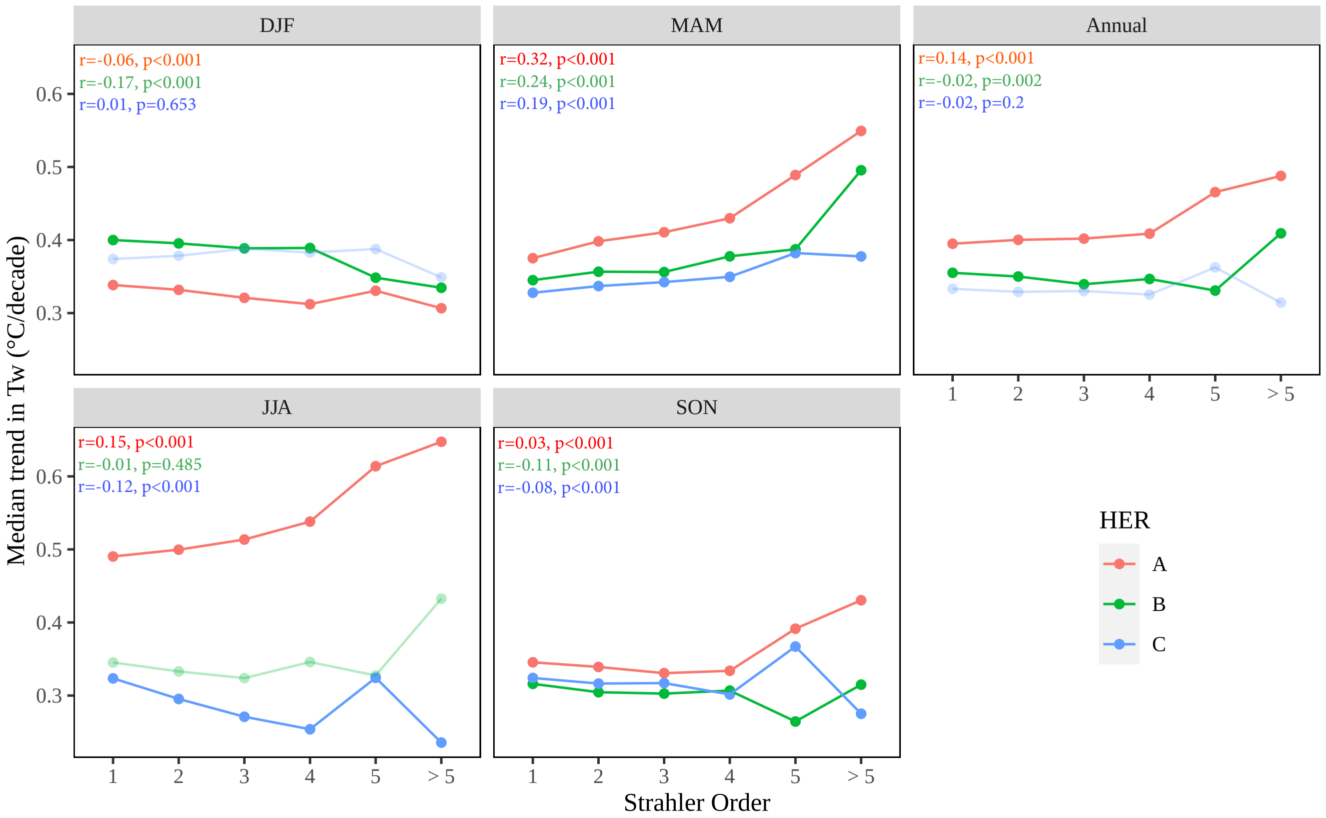

Figure S20. Relationships between reach size and median trends in Tw across reaches over the 1963–2019 period, by HER and by season. Correlations and associated p-values are shown in the top-left corner of each graph, and significant relationships at the 95 % confidence level are identified by full solid lines.

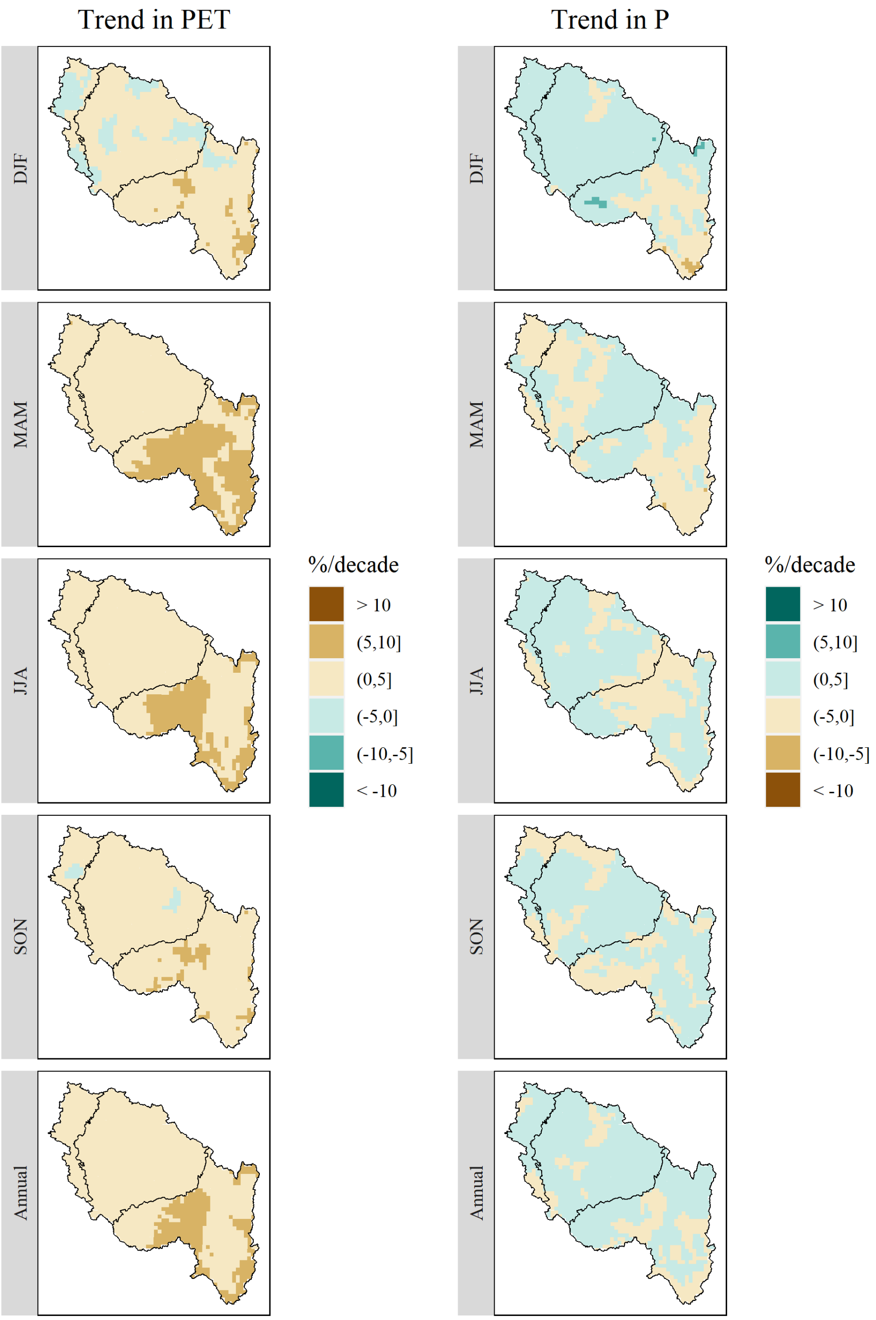

Figure S21. The spatial variability of trends in seasonal and annual potential evapotranspiration (PET) and total precipitation (P) over the 1963–2019 period. The solid black lines are showing the borders of HER (see Fig. 1).

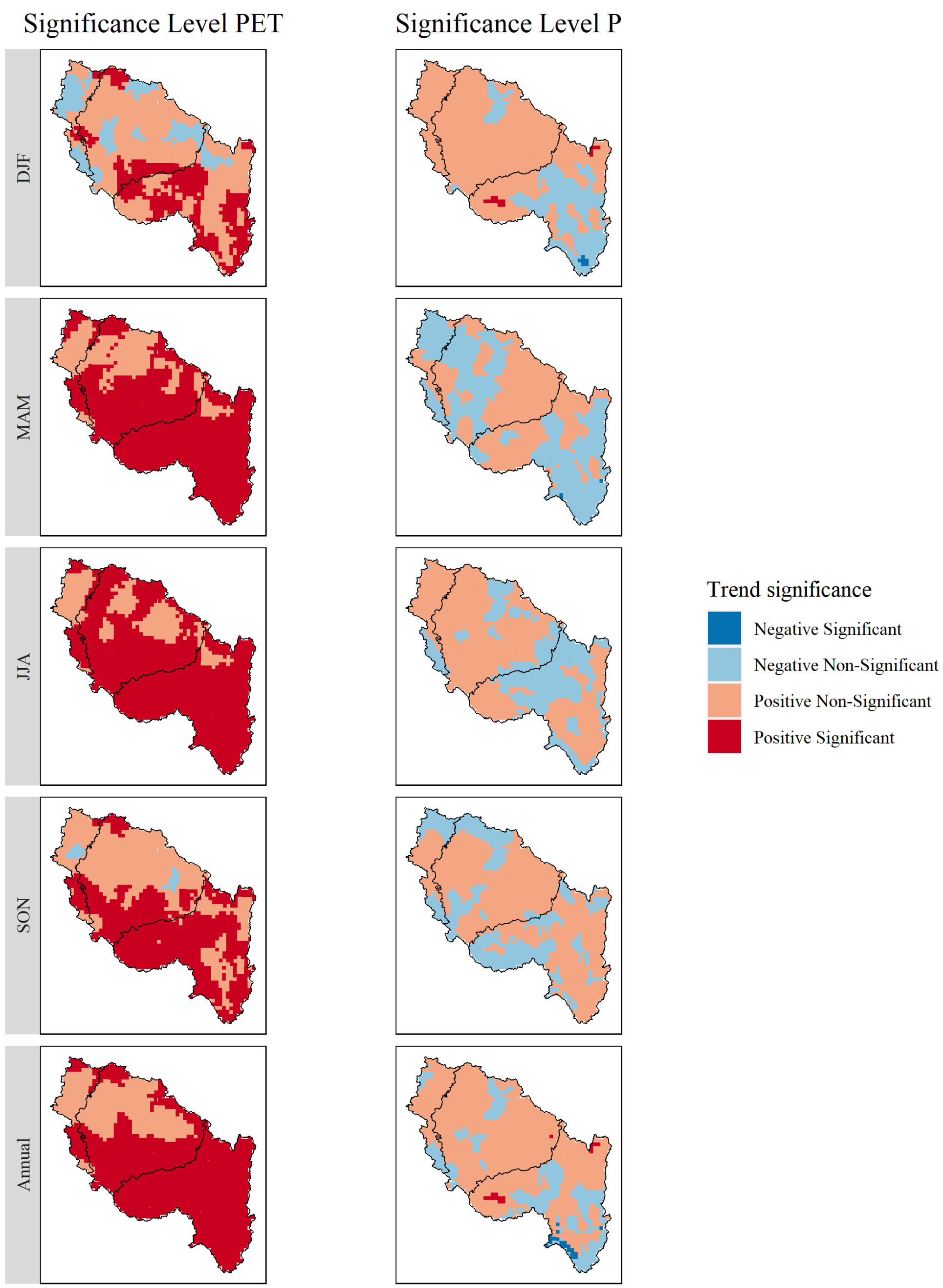

Figure S22. The spatial significance level of trends in seasonal and annual P and PET the 1963–2019 period. The solid black lines are showing the borders of HERs.

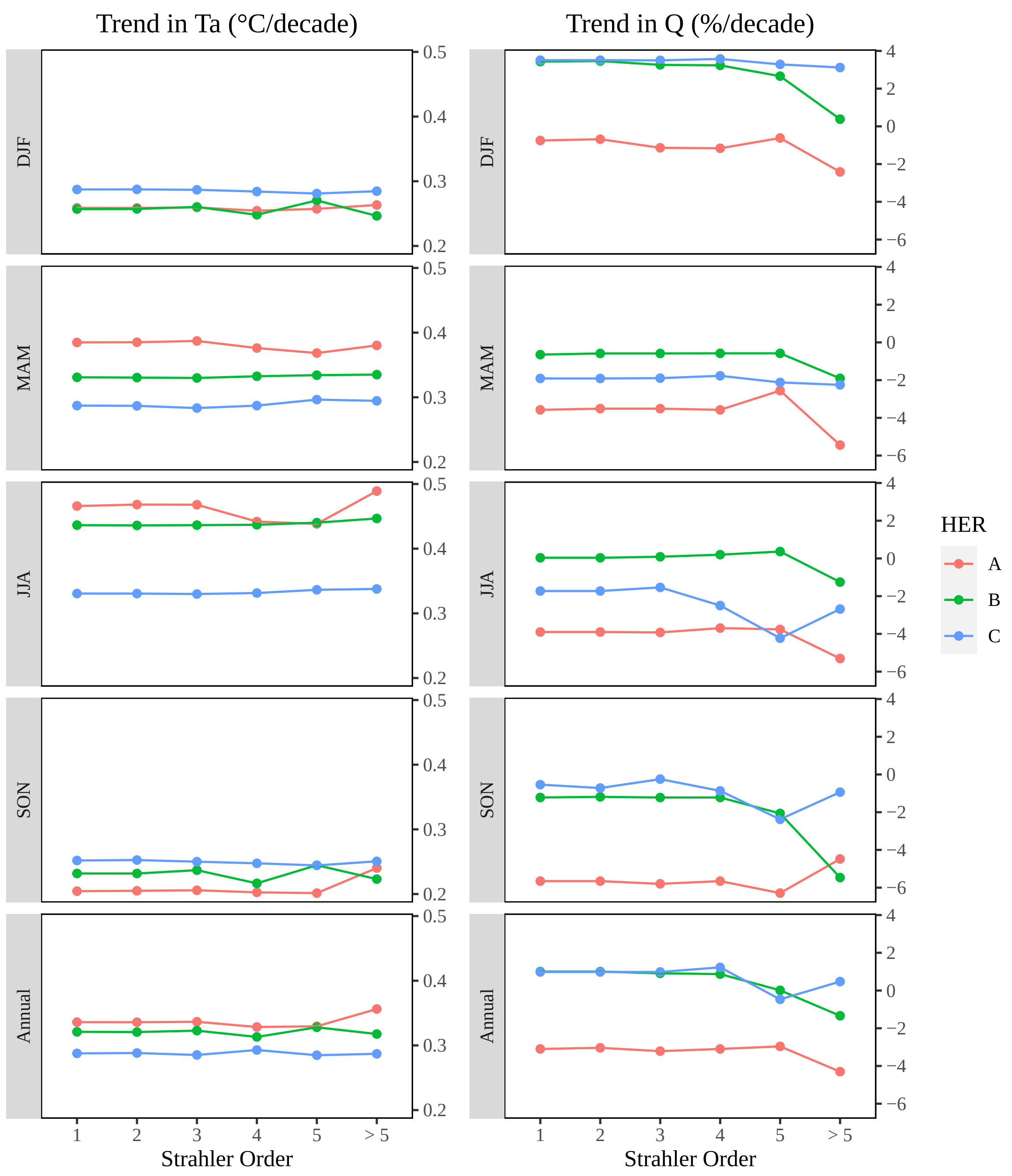

Figure S23. Relationships between median trends in Ta and Q over the period 1963—2019 and reach size (Strahler order; 1=small streams, > 5=large rivers). The relationships are shown by HER and by season (DJF=winter; MAM=spring; JJA=summer; SON =fall).