Stream temperature evolution in Switzerland over the last 50 years Supplementary Materials

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Abstract. The present supplementary material is complementing the key elements of the study presented in the main part of this work. It either expands on results which were too voluminous for the main article or gives elements for better understanding and potential reproduction of the results. Often, the article only shows pertinent examples while the larger body of corresponding results is included here. The first part is a collection of additional tables and figures related to the data and methods presented (Section S1), followed by more figures, detailing and complementing the main results in the article (Section S2). All descriptions and explanations necessary to understand the material below, as well as all the general conclusions, are provided in the text of the paper. The availability of the data and code are also mentioned and discussed in the article.

S1 Data and methods supplementary materials

S1.1 Excluded catchments

Some catchments have been excluded from the analysis for various reasons. They are listed below in Table S1.

Table S1. River measurement stations removed from the study and justifications. The hydrological regimes are Swiss Plateau and Jura regime (SPJ), Alpine regime (ALP), Downstream lake regime (DLA), and Regime strongly influenced by hydropeaking (HYP). The data providers are the Swiss Federal Office for the Environment (FOEN), the Office for water and waste of the Canton of Bern (AWA) and the Office for waste, water, energy and air of the Canton Zurich (AWEL).

River	Temperature measurement	Discharge measurement	Hydrological regime	Data provider	Reason for removal
Foul in Moutier	1995-2018	1995-2018	SPJ	AWA	Issues in temperature values (no annual cycle)
Birse in Court, Pont de la STEP	1996-2018	1996-2018	SPJ	AWA	Below a water-treatment plant
Louibach in Gstaad, Badweidli	1995-2018	1994-2018	ALP	AWA	1.5 year gap in water temperature, temperature only every 2 hours before 2000
Suze in Péry, Vigier Ciment	1996-2018	1992-2018	SPJ	AWA	Disturbance because of a cement factory
Urtenen in Kernenried	1997-2018	1997-2018	SPJ	AWA	Below a water-treatment plant
Chalière in Moutier, Pont de la STEP	1997-2018	1997-2018	SPJ	AWA	1.5 year gap in water temperature
Entschlige in Frutigen, Tropenhaus	1998-2018	1998-2018	ALP	AWA	Multiple gaps in the time series
Rhein in Weil, Palmrainbrücke	1995-2018	1992-2018	DLA	FOEN	Data only since 1995, already many sations on the Rhein

S1.2 MeteoSwiss stations details

Table S2 summarizes information about the MeteoSwiss stations used.

Table S2. Details of MeteoSwiss stations used including the periods for air temperature, precipitation, homogeneous air temperature and homogeneous precipitation time series.

Station Name	Station Abbreviation	Station Elevation	Easting Coordinates	Northing Coordinates	Air temp. measurement	Hom. air temp. measurement	Precipitation measurement	Hom. precipitation measurement
Adelboden	ABO	609350	149001	1322	1959-2018	-	1950-2018	-
Altdorf	ALT	690180	193564	438	1950-2018	1950-2018	1950-2018	1950-2018
Basel-Binningen	BAS	610908	265611	316	1950-2018	1950-2018	1950-2018	1950-2018
Passo-del-Bernina	BEH	798422	143020	2260	1972-2018	-	1950-2018	-
Bern-Zollikofen	BER	601933	204409	552	1950-2018	1950-2018	1950-2018	1950-2018
La-Chaux-de-Fonds	CDF	550919	214861	1017	1950-2018	1950-2018	1950-2018	1950-2018
Chasseral	CHA	570845	220157	1599	1981-2018	-	1981-2018	-
Chur	CHU	759465	193152	556	1950-2018	-	1950-2018	-
Delémont	DEM	593269	244543	439	1959-2018	-	1950-2018	-
Einsiedeln	EIN	699982	221068	910	1950-2018	-	1950-2018	-
Elm	ELM	732265	198425	957	1950-2018	1950-2018	1950-2018	1950-2018
Engelberg	ENG	674160	186069	1035	1950-2018	1950-2018	1950-2018	1950-2018
Glarus	GLA	723755	210567	516	1950-2018	-	1950-2018	-
Grächen	GRC	630738	116062	1605	1950-2018	1950-2018	1950-2018	1950-2018
Grimsel-Hospiz	GRH	668583	158215	1980	1950-2018	1950-2018	1950-2018	1950-2018
Col-du-Grand-St-Bernard	GSB	579192	79753	2472	1950-2018	1950-2018	1950-2018	-
Genève-Cointrin	GVE	498904	122631	410	1954-2018	1954-2018	1950-2018	1954-2018
Hallau	HLL	677456	283472	419	1959-2018	-	1950-2018	-
Interlaken	INT	633023	169092	577	1950-2018	-	1950-2018	-
Zurich-Kloten	KLO	682710	259338	426	1950-2018	-	1950-2018	-
Koppigen	KOP	612662	218664	485	1961-2018	-	1961-2018	-
Langnau-i.E.	LAG	628003	198793	743	1950-2018	-	1950-2018	-
Luzern	LUZ	665543	209849	454	1950-2018	1950-2018	1950-2018	1950-2018
Meiringen	MER	655844	175930	588	1950-2018	1950-2018	1950-2018	1950-2018
Mühleberg	MUB	587792	202479	479	1988-2018	-	1988-2018	-
Napf	NAP	638136	206078	1403	1978-2018	-	1978-2018	-
Neuchâtel	NEU	563086	205559	485	1950-2018	-	1950-2018	-
Locarno-Monti	OTL	704172	114342	366	1950-2018	1950-2018	1950-2018	1950-2018
Payerne	PAY	562131	184611	490	1965-2018	-	1965-2018	-
Bad-Ragaz	RAG	756910	209350	496	1950-2018	1950-2018	1950-2018	-
Santis	SAE	744183	234918	2502	1950-2018	-	1950-2018	1950-2018
Samedan	SAM	787249	155685	1708	1979-2018	-	1980-2018	1979-2018
S.Bernardino	SBE	734115	147294	1638	1968-2018	1968-2018	1968-2018	1968-2018
Segl-Maria IA	SIA	778574	144976	1804	1950-2018	-	1950-2018	1950-2018
Sion	SIO	591633	118583	482	1958-2018	1958-2018	1958-2018	1958-2018
Zurich-Fluntern	SMA	747865	254588	775	1866-2017	1866-2017	1890-2017	1866-2017
St.Gallen	STG	747865	254588	775	1950-2018	1950-2018	1950-2018	1950-2018
Aadorf-Tänikon	TAE	710517	259824	539	1971-2018	-	1970-2018	-
Vaduz	VAD	757722	221699	457	1971-2018	-	1971-2018	-
Wädenswil	WAE	693847	230744	485	1981-2018	-	1961-2018	-
Wynau	WYN	626404	233848	422	1978-2018	-	1978-2018	-

S1.3 STL analysis details

In this section, some examples of output of the STL analysis are presented. Figures S1 to S4 show the three different components of the STL (seasonal, trend, residuals) for the FOEN water station Reuss-Meillingen and for the MeteoSwiss station of Luzern. As we can see, the seasonal removal works correctly for water temperature, for discharge and for air temperature. For precipitation, the effect is negligible. The STL has been applied here with $n_s = 37$.

In Figures S5 and S6, the ACF and PACF of the residuals time series are shown (also with $n_s = 37$). If some seasonal signal still exists in the ACF, it is absent in the PACF, meaning that the data at one-year lag in time have no explanatory power on the current data, which is the goal to be achieved. In addition, this plot shows the absence of strong seasonality in the precipitations, especially, as we can expect, in the PACF, justifying the usage of these time series even if the STL has almost no effect.

Finally, in figures S7 and S8 the evolution of ACF and PACF for stream and air temperature residuals time series and for discharge and precipitation residuals time series for varying values of n_s are shown.

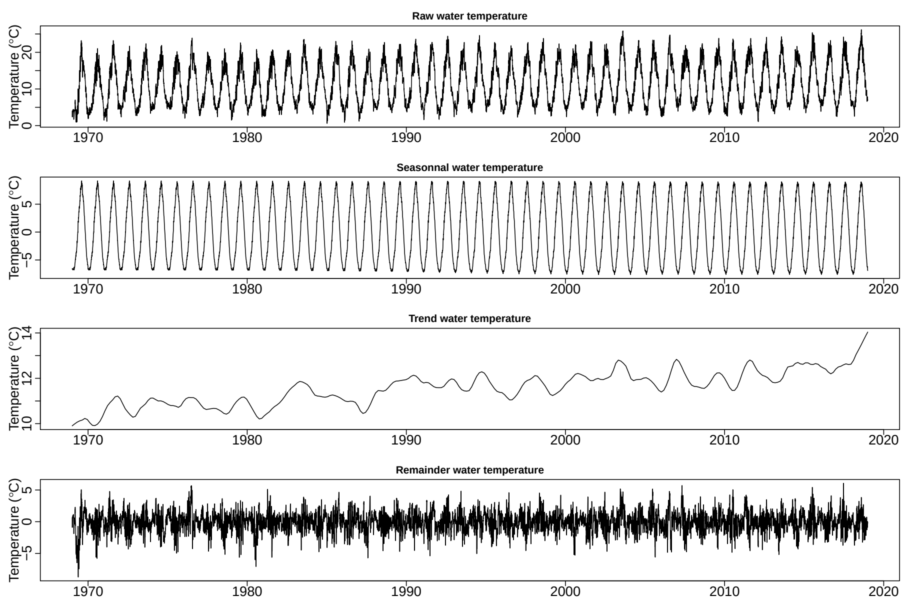

Figure S1. STL decomposition for water temperature for the Reuss river at the FOEN measurement station of Mellingen. Top: Raw data; 2nd row: seasonal part; 3rd row: trend part; bottom: residuals. Series obtained with $n_s = 37$.

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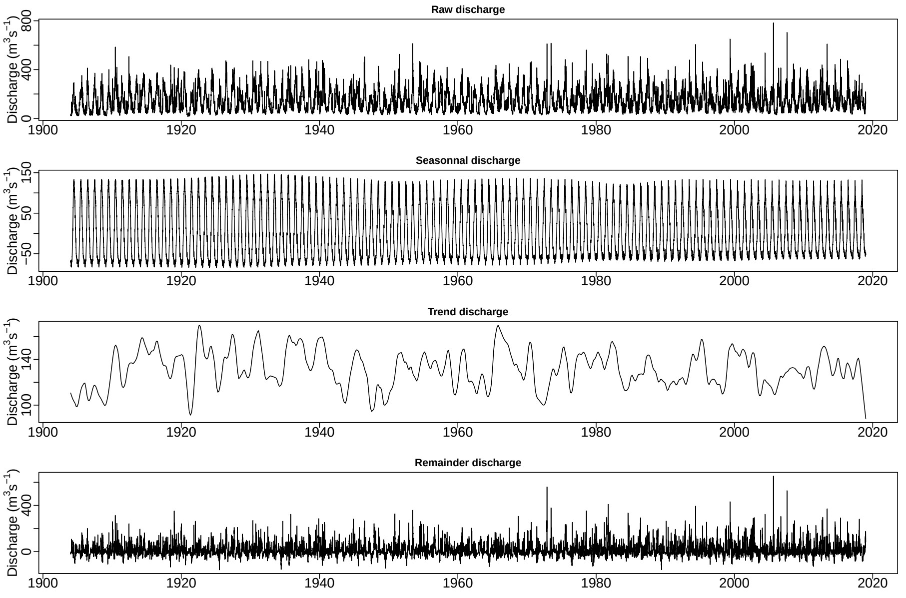

Figure S2. STL decomposition for discharge for the Reuss river at the FOEN measurement station of Mellingen. Top: Raw data; 2nd row: seasonal part; 3rd row: trend part; bottom: residuals. Series obtained with $n_s = 37$.

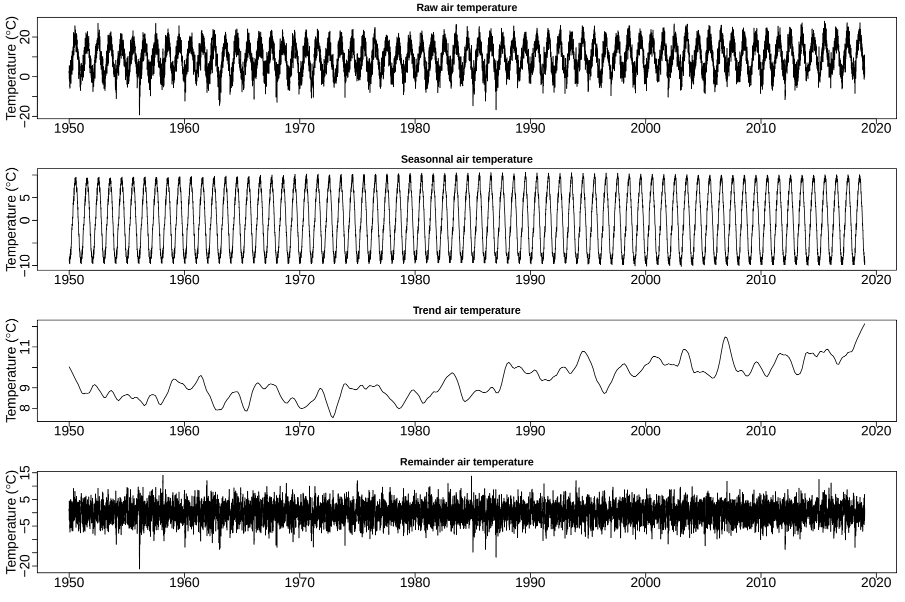

Figure S3. STL decomposition for air temperature for the MeteoSwiss measurement station of Luzern. Top: Raw data; 2nd row: seasonal part; 3rd row: trend part; bottom: residuals. Series obtained with $n_s = 37$.

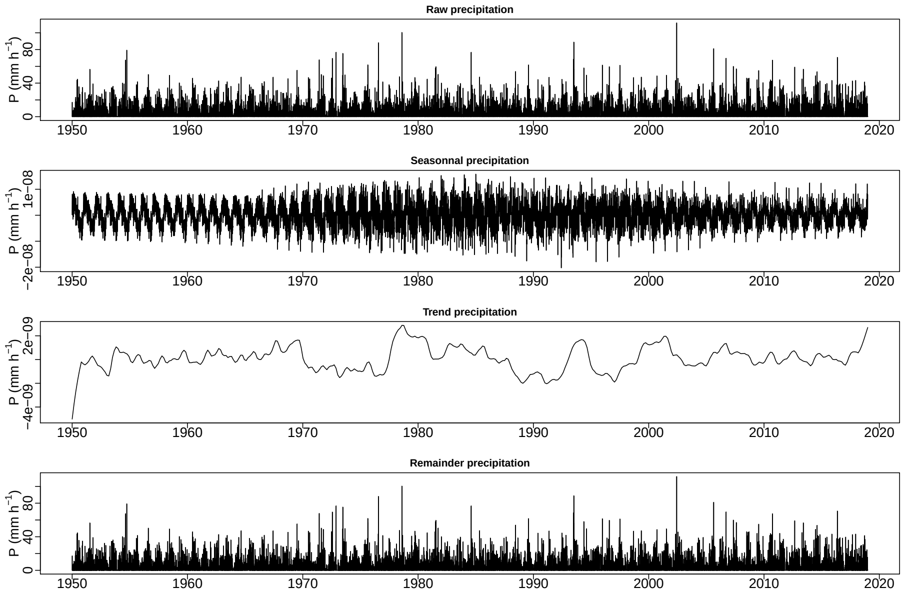

Figure S4. STL decomposition for precipitation for the MeteoSwiss measurement station of Luzern. Top: Raw data; 2nd row: seasonal part; 3rd row: trend part; bottom: residuals. Series obtained with $n_s = 37$.

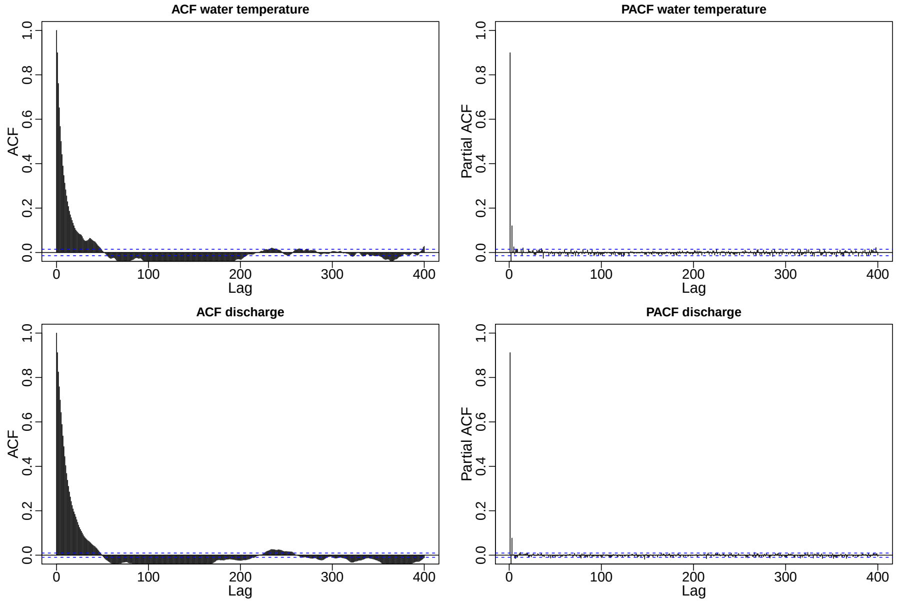

Figure S5. ACF and PACF of the residuals time series of the STL analysis for water temperature (top) and discharge (bottom) for the Reuss river at the FOEN measurement station of Mellingen.

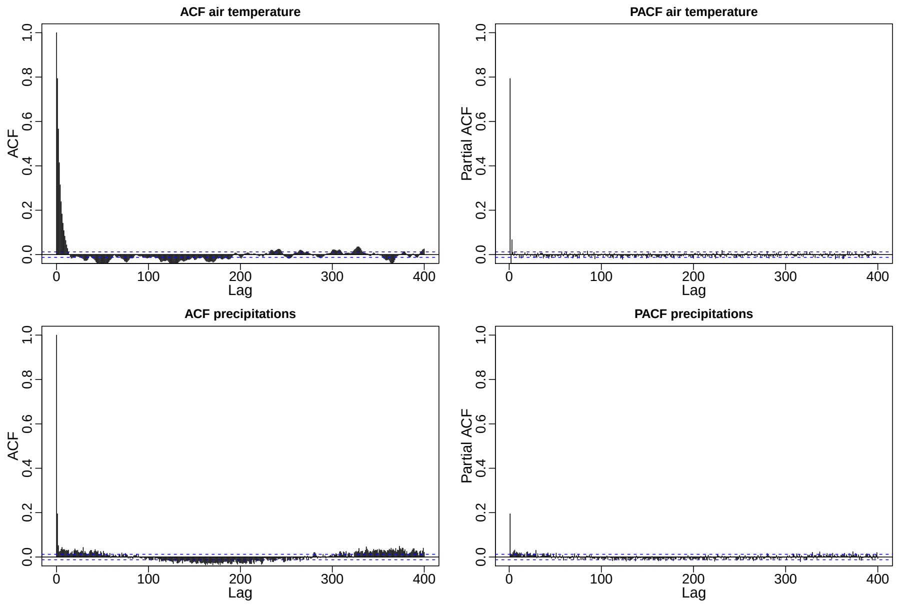

Figure S6. ACF and PACF of the residuals time series of the STL analysis for air temperature (top) and precipitation (bottom) for the MeteoSwiss measurement station of Luzern.

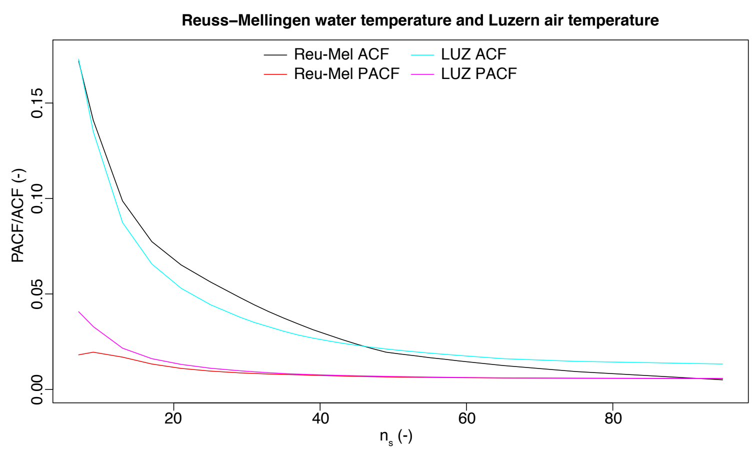

Figure S7. Evolution of the ACF and PACF of the residuals time series of the STL analysis for varying values of n_s for the Reuss water temperature at the FOEN measurement station of Mellingen and for air temperature at the MeteoSwiss measurement station of Luzern.

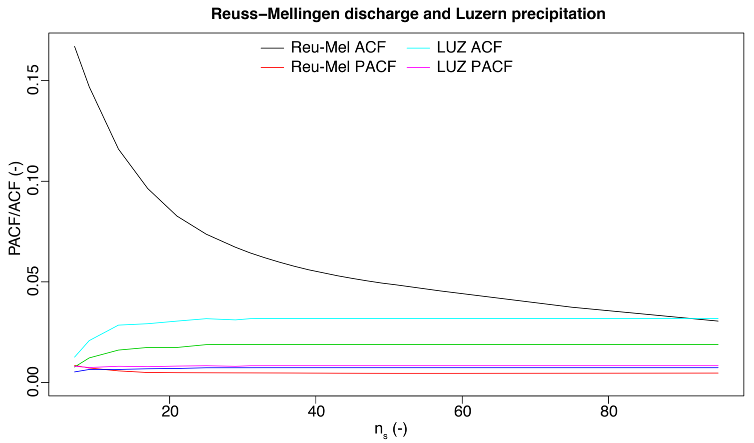

Figure S8. Evolution of the ACF and PACF of the residuals time series of the STL analysis for varying values of n_s for the Reuss discharge at the FOEN measurement station of Mellingen and for precipitation at the MeteoSwiss measurement station of Luzern.

S2 Supplementary material additional results

S2.1 long-term and trend analysis

This Section presents additional results for Sections 4.1 and 4.2 of the main article. Figure S9 shows the decadal mean of air temperature anomaly (similar to Figure 2 bottom panel and Figure 4 in the main text).

Figure S10 show the evolution of the climatic indices used in Lehre Seip et al. (2019). These indices are the North Atlantic Oscillation (NAO) (Jones et al., 1997) and the Atlantic Multi-decadal Oscillation (AMO) (Enfield et al., 2001). Data are obtained from the NOAA website. In the Figure, long-term decadal anomalies in precipitation and discharges are shown for comparison.

Tables S3 and S4 show the trends for air temperature and precipitation for the MeteoSwiss station used (see Table S2), for the periods 1999-2018 and 1979-2018. They are similar to Tables A1 and A2 for water temperature and discharge in the Appendix of the main text. Figures S11 and S12 show the same as Figures 5 and 6 in the main text, but for the period 1979-2018.

Finally, Figure S13 shows the distribution of area for the four different alpine regimes and the distribution of the SPJ water temperature trends as function of the catchment area, showing that there is no correlation between the observed water temperature trend and the catchment area (only SPJ catchments are plotted to separate the effect of regime and the effect of area).

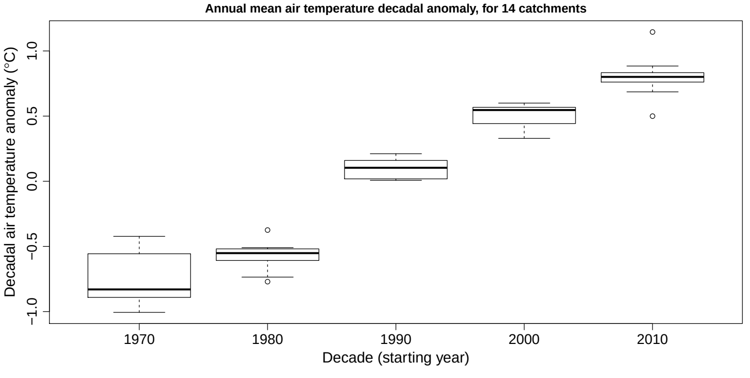

Figure S9. Air temperature anomalies per decade with respect to the 1970-2018 mean, for the 14 catchments with data available since 1970 (same catchments as for water temperature in Figure 2 bottom panel in main text).

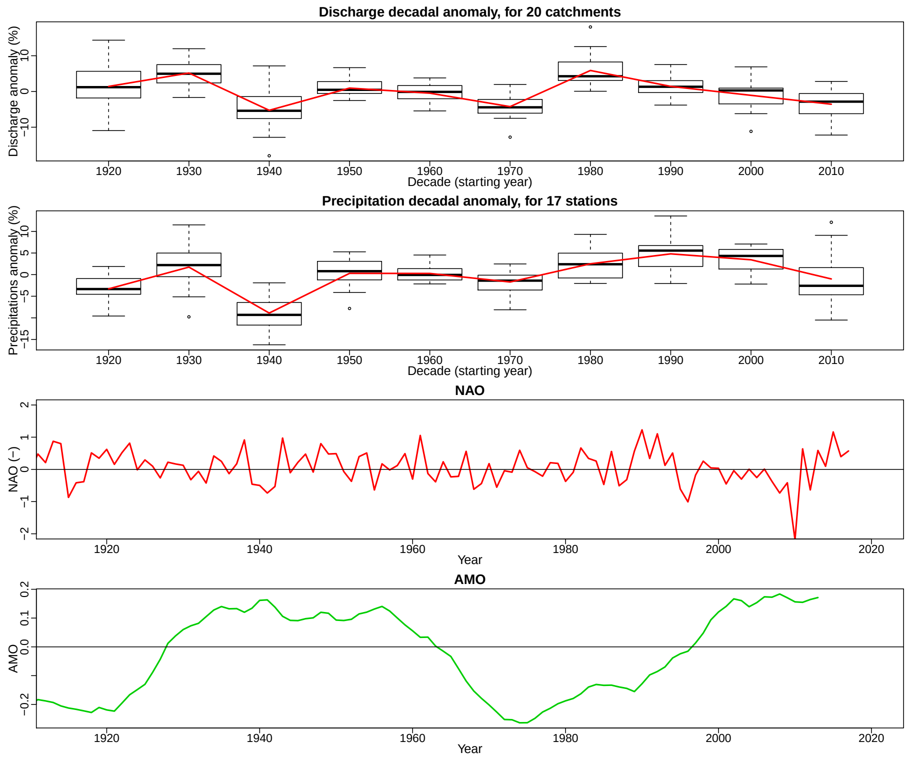

Figure S10. Relative discharge and precipitation decadal means of anomalies with respect to the 1920-2018 average for 20 catchments and 22 MeteoSwiss homogeneous stations with data available since 1920 (upper two plots). Yearly mean of the NAO and AMO (lower two plots).

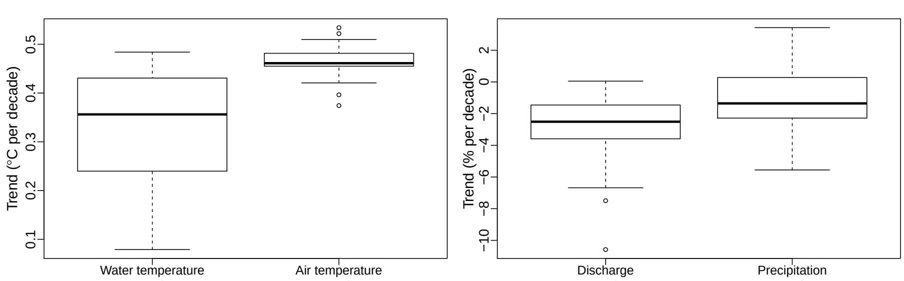

Figure S11. Distributions of trends of water and air temperature (left) , and normalized discharge and normalized precipitation (right), for the periods 1979-2018 for the 27 catchments where data are available for temperature and discharge (see Table 1 in main text).

Table S3. Air temperature (left part) and precipitation (right part) annual and seasonal trends for all the MeteoSwiss stations presented in Table S2 over the period 1999-2018. The numbers in brackets indicate the standard error of the computed trends based on linear regression.

	Water temperature trend (° per decade)					Discharge trend (% per decade)				
River Name	**Annual**	**Winter**	**Spring**	**Summer**	**Fall**	**Annual**	**Winter**	**Spring**	**Summer**	**Fall**
ABO	0.44 (0.08)	0.32 (0.63)	0.15 (0.39)	0.56 (0.40)	0.61 (0.43)	-6.9 (4.1)	-3.1 (14.5)	-7.4 (11.5)	-11.7 (8.1)	-10.8 (11.4)
ALT	0.33 (0.07)	0.20 (0.45)	0.13 (0.35)	0.49 (0.39)	0.43 (0.37)	-8.9 (4.5)	-6.4 (13.4)	-13.3 (11.5)	-6.2 (8.1)	-16.6 (14.3)
BAS	0.35 (0.07)	0.09 (0.54)	0.14 (0.40)	0.70 (0.43)	0.35 (0.35)	-8.5 (4.5)	18.2 (10.6)	-8.5 (15.5)	-10.5 (11.9)	-28.6 (14.3)
BEH	0.13 (0.08)	0.26 (0.63)	-0.23 (0.46)	0.01 (0.52)	0.40 (0.38)	-37.7 (5.3)	-39.9 (41.3)	-55.1 (23.4)	-9.7 (10.7)	-43.1 (20.2)
BER	0.42 (0.07)	0.22 (0.50)	0.17 (0.37)	0.75 (0.38)	0.44 (0.34)	-12.5 (4.5)	13.4 (10.9)	-16.3 (14.8)	-17.1 (10.4)	-25.5 (12.6)
CDF	0.51 (0.08)	0.35 (0.57)	0.41 (0.39)	0.69 (0.38)	0.50 (0.43)	-9.2 (4)	5.1 (11.8)	-10.1 (15.1)	-8.8 (10.8)	-28.8 (13.5)
CHA	0.53 (0.09)	0.25 (0.62)	0.43 (0.46)	0.60 (0.46)	0.66 (0.49)	-3.1 (4.3)	-21.3 (14.3)	-5.7 (17.1)	14.4 (14.5)	-6.0 (14.5)
CHU	0.50 (0.07)	0.43 (0.57)	0.20 (0.37)	0.73 (0.42)	0.58 (0.42)	-12.0 (5.2)	-9.0 (17.2)	-11.4 (15.2)	-15.3 (10.3)	-20.3 (13.9)
DEM	0.01 (0.07)	-0.07 (0.53)	-0.23 (0.39)	0.27 (0.40)	0.00 (0.35)	-16.4 (4.5)	0.0 (10.1)	-18.4 (14.9)	-12.4 (10.1)	-36.2 (16)
EIN	0.49 (0.08)	0.32 (0.57)	0.28 (0.40)	0.71 (0.39)	0.52 (0.40)	-16.0 (4)	-21.6 (12.3)	-21.2 (9.9)	-11.6 (9.1)	-18.1 (11.7)
ELM	0.52 (0.08)	0.46 (0.57)	0.36 (0.39)	0.61 (0.37)	0.59 (0.43)	-10.8 (4)	-13.5 (13.1)	-11.8 (10.1)	-10.3 (8.3)	-16.3 (12.8)
ENG	0.51 (0.08)	0.41 (0.58)	0.28 (0.39)	0.63 (0.38)	0.61 (0.42)	-5.1 (3.9)	-6.4 (13)	-7.4 (9.9)	-3.6 (7.4)	-9.9 (12)
GLA	0.43 (0.07)	0.30 (0.55)	0.29 (0.39)	0.58 (0.39)	0.42 (0.38)	-9.5 (4.1)	-7.4 (13.9)	-15.8 (11.2)	-8.1 (9.1)	-15.0 (11.8)
GRC	0.50 (0.07)	0.33 (0.59)	0.27 (0.39)	0.67 (0.39)	0.63 (0.40)	-14.1 (6.2)	8.0 (16.9)	-10.6 (13.6)	-17.7 (12.7)	-37.2 (24.5)
GRH	0.43 (0.08)	0.50 (0.61)	0.25 (0.40)	0.41 (0.37)	0.52 (0.45)	-6.0 (4.2)	-12.1 (18.3)	5.6 (9.4)	-7.7 (9)	-13.1 (12.5)
GSB	0.45 (0.08)	0.22 (0.58)	0.21 (0.37)	0.59 (0.40)	0.65 (0.35)	-10.5 (4.3)	2.1 (13.7)	-8.8 (8.1)	-22.7 (10.5)	-18.2 (14.3)
GVE	0.33 (0.06)	0.17 (0.45)	0.14 (0.37)	0.54 (0.45)	0.41 (0.35)	-16.0 (4.8)	11.1 (11.4)	-16.6 (16)	-21.1 (9.9)	-35.3 (12.9)
HLL	0.13 (0.07)	0.07 (0.48)	-0.19 (0.39)	0.37 (0.41)	0.19 (0.32)	-25.4 (4.5)	-20.0 (10.4)	-30.4 (15.4)	-17.3 (10.8)	-35.6 (12.9)
INT	0.51 (0.06)	0.39 (0.43)	0.35 (0.34)	0.71 (0.36)	0.52 (0.29)	-3.6 (4.3)	1.9 (13.8)	-3.8 (10.9)	-5.5 (11.1)	-11.9 (12.6)
KLO	0.41 (0.07)	0.17 (0.49)	0.14 (0.36)	0.73 (0.41)	0.49 (0.33)	-14.7 (4.4)	-2.7 (9.6)	-18.5 (13.8)	-15.7 (10.2)	-24.6 (12)
KOP	0.13 (0.07)	0.05 (0.51)	-0.16 (0.35)	0.43 (0.38)	0.12 (0.33)	-13.2 (4.4)	1.3 (9.7)	-9.7 (14.8)	-15.8 (11.1)	-28.1 (14)
LAG	0.25 (0.07)	0.00 (0.51)	0.07 (0.37)	0.65 (0.35)	0.18 (0.36)	-11.2 (4.2)	1.1 (9.8)	-9.1 (11.4)	-15.3 (9.7)	-18.4 (10.7)
LUZ	0.39 (0.07)	0.23 (0.46)	0.17 (0.37)	0.63 (0.41)	0.45 (0.32)	-2.0 (4.3)	19.9 (10.4)	-0.4 (12.2)	-9.9 (9.2)	-7.4 (10.4)
MER	0.46 (0.07)	0.38 (0.47)	0.34 (0.35)	0.57 (0.35)	0.45 (0.35)	-10.5 (4.2)	-11.7 (15.4)	-15.1 (11.2)	-7.5 (8)	-14.4 (14.7)
MUB	0.40 (0.06)	0.10 (0.48)	0.19 (0.37)	0.77 (0.39)	0.49 (0.33)	-7.6 (4.5)	13.3 (10)	-10.8 (14.9)	-10.9 (13.4)	-18.3 (13.6)
NAP	0.53 (0.09)	0.35 (0.65)	0.34 (0.46)	0.64 (0.47)	0.64 (0.51)	-8.3 (4)	2.8 (14.6)	-11.5 (10.7)	-11.5 (9.4)	-12.6 (13.2)
NEU	0.38 (0.07)	0.13 (0.49)	0.18 (0.42)	0.63 (0.44)	0.50 (0.34)	-9.9 (4.6)	8.0 (10.6)	-3.7 (17.9)	-15.6 (13.3)	-30.1 (13.5)
OTL	0.47 (0.06)	0.40 (0.36)	0.24 (0.40)	0.61 (0.43)	0.61 (0.25)	-9.1 (5.8)	22.2 (27.4)	-1.4 (15.4)	-17.9 (13.3)	-20.1 (18)
PAY	0.31 (0.07)	0.13 (0.49)	0.05 (0.36)	0.54 (0.42)	0.43 (0.33)	-10.4 (4.7)	16.7 (12.3)	-17.3 (15.2)	-9.5 (11.9)	-26.7 (14.2)
RAG	0.30 (0.08)	0.46 (0.60)	0.04 (0.40)	0.37 (0.39)	0.23 (0.42)	-0.2 (4.7)	-6.1 (15.4)	5.1 (12.7)	-6.0 (9.9)	-3.9 (14.6)
SAE	0.39 (0.09)	0.24 (0.60)	0.24 (0.40)	0.63 (0.39)	0.41 (0.51)	-7.8 (3.9)	-1.1 (14.2)	-17.1 (14.6)	-7.4 (8.1)	-14.2 (13)
SAM	0.38 (0.07)	0.84 (0.61)	-0.01 (0.32)	0.35 (0.31)	0.36 (0.37)	-8.6 (5.7)	24.5 (22.2)	0.0 (12)	-7.3 (10.5)	-34.5 (17.5)
SBE	0.48 (0.06)	0.35 (0.48)	0.32 (0.38)	0.52 (0.37)	0.62 (0.32)	0.0 (5)	27.6 (25.9)	7.0 (12.8)	-2.9 (10.6)	-16.4 (17.8)
SIA	0.42 (0.06)	0.51 (0.51)	0.19 (0.33)	0.56 (0.32)	0.40 (0.31)	-12.5 (5.4)	6.3 (21.5)	-7.1 (12.6)	-11.9 (9.6)	-28.5 (18.8)
SIO	0.67 (0.06)	0.42 (0.50)	0.37 (0.33)	1.03 (0.37)	0.78 (0.32)	-4.9 (5.6)	23.2 (15)	-8.3 (17.9)	-19.1 (11.3)	-21.7 (18.2)
SMA	0.38 (0.07)	0.10 (0.53)	0.15 (0.42)	0.70 (0.43)	0.46 (0.35)	-11.7 (4.4)	-1.1 (10.1)	-21.1 (12.9)	-5.3 (9.9)	-23.2 (12)
STG	0.33 (0.08)	0.17 (0.64)	0.14 (0.43)	0.50 (0.41)	0.40 (0.41)	0.3 (4.4)	22.5 (12.2)	-8.8 (11.4)	-0.4 (8.2)	-7.9 (11)
TAE	0.42 (0.07)	0.24 (0.51)	0.11 (0.34)	0.71 (0.38)	0.49 (0.35)	-9.9 (4.2)	-1.3 (9.7)	-17.6 (12.5)	-5.0 (8.9)	-18.1 (14.2)
VAD	0.52 (0.08)	0.35 (0.60)	0.24 (0.39)	0.79 (0.39)	0.55 (0.42)	-8.0 (4.9)	-9.6 (13.8)	-9.0 (11.8)	-9.6 (6.6)	-10.2 (13.4)
WAE	0.46 (0.07)	0.32 (0.50)	0.20 (0.39)	0.68 (0.42)	0.54 (0.34)	-9.5 (4.2)	-0.7 (11.1)	-15.8 (11.4)	-7.0 (9.1)	-20.8 (11.8)
WYN	0.43 (0.06)	0.28 (0.49)	0.20 (0.34)	0.69 (0.40)	0.47 (0.34)	-8.1 (4.4)	4.5 (11.3)	-5.4 (15.3)	-8.9 (9.4)	-23.8 (12.4)

Table S4. Air temperature (left part) and precipitation (right part) annual and seasonal trends for all the MeteoSwiss stations presented in Table S2 over the period 1979-2018. The numbers in brackets indicate the standard error of the computed trends based on linear regression.

River Name	Water temperature trend (° per decade) Annual	Winter	Spring	Summer	Fall	Discharge trend (% per decade) Annual	Winter	Spring	Summer	Fall
ABO	0.36 (0.03)	0.14 (0.21)	0.60 (0.14)	0.46 (0.12)	0.22 (0.14)	-3.9 (1.4)	-9.5 (4.4)	-1.8 (3.4)	-0.9 (2.6)	-7.9 (4.2)
ALT	0.48 (0.02)	0.28 (0.17)	0.64 (0.12)	0.61 (0.12)	0.35 (0.12)	0.3 (1.6)	-4.5 (4.3)	-0.2 (3.7)	3.1 (2.6)	-1.9 (4.8)
BAS	0.49 (0.03)	0.34 (0.20)	0.59 (0.13)	0.66 (0.13)	0.35 (0.12)	1.1 (1.6)	0.1 (4)	1.8 (5)	1.7 (3.8)	-0.8 (4.6)
BEH	0.26 (0.03)	0.28 (0.21)	0.48 (0.17)	0.18 (0.15)	0.11 (0.14)	-8.6 (1.9)	-4.1 (11.1)	-20.8 (7.5)	-3.0 (4.7)	-5.5 (6.5)
BER	0.48 (0.02)	0.28 (0.18)	0.61 (0.13)	0.65 (0.11)	0.34 (0.11)	-3.9 (1.6)	-2.4 (4.3)	-3.5 (4.5)	-2.6 (3.9)	-8.8 (4.1)
CDF	0.49 (0.03)	0.23 (0.20)	0.73 (0.13)	0.63 (0.12)	0.34 (0.14)	-4.6 (1.4)	-5.4 (4.2)	-5.4 (4.7)	-1.2 (3.7)	-8.7 (4.5)
CHA	0.36 (0.03)	0.06 (0.24)	0.66 (0.16)	0.50 (0.15)	0.22 (0.18)	-0.4 (1.6)	-11.5 (5.8)	1.9 (5.9)	11.6 (5.2)	-4.9 (5.5)
CHU	0.59 (0.03)	0.40 (0.20)	0.72 (0.13)	0.76 (0.13)	0.45 (0.13)	-0.9 (1.9)	-4.1 (5.7)	-2.9 (4.9)	0.9 (3.9)	-1.8 (5.2)
DEM	0.43 (0.03)	0.32 (0.20)	0.54 (0.14)	0.54 (0.12)	0.26 (0.12)	-4.4 (1.5)	-6.2 (3.6)	-7.4 (4.7)	-0.2 (3.4)	-6.1 (5)
EIN	0.43 (0.03)	0.28 (0.20)	0.60 (0.14)	0.54 (0.12)	0.26 (0.13)	-4.9 (1.4)	-8.6 (3.9)	-3.4 (3.4)	-3.1 (2.9)	-7.7 (4.2)
ELM	0.48 (0.03)	0.30 (0.20)	0.70 (0.13)	0.56 (0.11)	0.31 (0.14)	-2.3 (1.4)	-4.9 (4.3)	-2.9 (3.4)	-0.4 (2.9)	-3.6 (4.6)
ENG	0.43 (0.03)	0.21 (0.20)	0.61 (0.14)	0.56 (0.12)	0.30 (0.14)	0.1 (1.4)	-4.4 (3.9)	2.2 (3.1)	2.4 (2.3)	-3.4 (4.2)
GLA	0.44 (0.03)	0.27 (0.18)	0.61 (0.13)	0.57 (0.12)	0.27 (0.12)	-0.6 (1.4)	-4.4 (4.6)	-1.2 (3.7)	1.0 (2.9)	-1.4 (4.2)
GRC	0.45 (0.03)	0.12 (0.20)	0.75 (0.14)	0.60 (0.12)	0.30 (0.13)	-7.1 (2.2)	-10.8 (5.5)	-10.1 (5.3)	1.9 (4.2)	-12.1 (6.9)
GRH	0.43 (0.03)	0.22 (0.20)	0.68 (0.14)	0.58 (0.12)	0.20 (0.15)	-2.8 (1.5)	-6.6 (5.4)	-1.6 (3.4)	-1.3 (3)	-0.7 (4.7)
GSB	0.41 (0.03)	0.17 (0.20)	0.66 (0.14)	0.57 (0.12)	0.22 (0.14)	-2.5 (1.5)	-0.5 (4.5)	-4.5 (3.8)	-0.9 (3.7)	-4.9 (4.7)
GVE	0.46 (0.02)	0.21 (0.16)	0.62 (0.12)	0.60 (0.13)	0.34 (0.11)	-5.6 (1.7)	-9.5 (4.6)	-4.7 (5.2)	-1.3 (4.6)	-8.5 (5.1)
HLL	0.41 (0.02)	0.38 (0.18)	0.48 (0.14)	0.44 (0.13)	0.30 (0.11)	-6.9 (1.6)	-10.3 (4.3)	-5.8 (5.4)	-0.2 (3.8)	-13.1 (4.6)
INT	0.52 (0.02)	0.26 (0.15)	0.70 (0.11)	0.69 (0.11)	0.40 (0.10)	0.1 (1.5)	-3.7 (4.5)	1.0 (3.3)	3.1 (3.4)	-3.8 (4.4)
KLO	0.45 (0.02)	0.34 (0.18)	0.56 (0.13)	0.57 (0.12)	0.28 (0.11)	1.8 (1.6)	-0.9 (4)	4.4 (5.1)	3.5 (3.6)	-3.3 (4.6)
KOP	0.34 (0.02)	0.28 (0.19)	0.44 (0.13)	0.38 (0.12)	0.21 (0.11)	-5.0 (1.5)	-10.1 (3.7)	-4.2 (4.4)	-1.0 (3.8)	-8.2 (4.6)
LAG	0.31 (0.02)	0.23 (0.18)	0.45 (0.13)	0.32 (0.11)	0.19 (0.11)	-6.8 (1.4)	-12.2 (3.8)	-4.9 (3.9)	-3.5 (3.2)	-10.2 (3.6)
LUZ	0.48 (0.02)	0.28 (0.17)	0.63 (0.13)	0.62 (0.12)	0.33 (0.11)	2.4 (1.5)	-1.1 (4)	4.8 (3.7)	4.4 (3.2)	-2.4 (3.7)
MER	0.50 (0.02)	0.36 (0.17)	0.67 (0.12)	0.57 (0.11)	0.33 (0.11)	-1.2 (1.5)	-9.1 (4.3)	-1.7 (3.5)	3.5 (2.5)	-2.3 (4.8)
MUB	-	-	-	-	-	-	-	-	-	-
NAP	0.44 (0.03)	0.12 (0.22)	0.72 (0.15)	0.63 (0.15)	0.24 (0.17)	4.5 (1.4)	4.6 (5.5)	7.5 (3.8)	4.7 (3.2)	-0.3 (4.3)
NEU	0.41 (0.02)	0.24 (0.17)	0.57 (0.14)	0.50 (0.14)	0.29 (0.11)	-2.3 (1.6)	-3.8 (3.9)	-0.7 (5.4)	2.1 (4.8)	-9.7 (4.4)
OTL	0.52 (0.02)	0.30 (0.12)	0.72 (0.13)	0.61 (0.12)	0.43 (0.08)	-1.5 (2.1)	6.4 (7.9)	-6.8 (5.7)	-2.8 (5.1)	1.0 (6.6)
PAY	0.44 (0.02)	0.26 (0.17)	0.55 (0.13)	0.59 (0.12)	0.30 (0.11)	-3.9 (1.7)	-7.0 (5.2)	-3.1 (4.9)	-2.3 (4.2)	-6.1 (4.7)
RAG	0.45 (0.03)	0.35 (0.21)	0.58 (0.14)	0.53 (0.12)	0.29 (0.13)	-1.4 (1.7)	-4.7 (5)	0.1 (4.4)	-2.6 (3.1)	-0.5 (4.9)
SAE	0.35 (0.03)	0.08 (0.22)	0.62 (0.14)	0.54 (0.13)	0.13 (0.17)	-1.0 (1.4)	1.4 (4.6)	-3.1 (4.6)	0.8 (2.4)	-5.1 (5.2)
SAM	0.52 (0.03)	0.59 (0.20)	0.60 (0.14)	0.51 (0.10)	0.39 (0.12)	-2.6 (2.1)	-0.8 (6.5)	-6.9 (6.6)	-1.3 (3.8)	-3.7 (6.3)
SBE	0.39 (0.02)	0.20 (0.17)	0.66 (0.13)	0.48 (0.11)	0.22 (0.11)	-0.5 (1.8)	2.4 (7.5)	-6.9 (5.5)	2.3 (4.3)	0.2 (6.1)
SIA	0.45 (0.02)	0.40 (0.16)	0.64 (0.13)	0.42 (0.10)	0.33 (0.11)	-2.9 (1.9)	-2.4 (6.3)	-10.2 (5.8)	-1.2 (3.9)	-0.5 (6.4)
SIO	0.63 (0.02)	0.33 (0.16)	0.74 (0.12)	0.80 (0.11)	0.61 (0.10)	-4.2 (2)	-4.9 (5.8)	-1.8 (5.3)	2.8 (3.9)	-16.7 (5.3)
SMA	0.46 (0.03)	0.29 (0.19)	0.61 (0.14)	0.60 (0.13)	0.31 (0.12)	-0.9 (1.5)	-4.0 (3.7)	1.8 (4.7)	1.6 (3.8)	-6.5 (4.6)
STG	0.47 (0.03)	0.29 (0.22)	0.66 (0.15)	0.61 (0.13)	0.28 (0.13)	1.6 (1.5)	3.1 (4.1)	0.7 (3.7)	2.5 (2.4)	-0.7 (4.2)
TAE	0.46 (0.03)	0.36 (0.19)	0.56 (0.13)	0.59 (0.12)	0.31 (0.11)	-1.7 (1.5)	-5.0 (3.9)	0.3 (4.5)	2.0 (3.1)	-7.4 (5)
VAD	0.56 (0.03)	0.43 (0.20)	0.69 (0.13)	0.69 (0.12)	0.37 (0.13)	0.3 (1.7)	-5.4 (4.6)	4.0 (3.9)	0.5 (2.4)	-1.9 (5.1)
WAE	0.46 (0.03)	0.41 (0.19)	0.58 (0.15)	0.53 (0.14)	0.33 (0.13)	-2.3 (1.5)	-6.1 (4)	-2.1 (4.1)	1.0 (3)	-6.3 (4.3)
WYN	0.44 (0.02)	0.29 (0.18)	0.55 (0.12)	0.60 (0.12)	0.30 (0.11)	-1.2 (1.6)	-5.2 (4.3)	1.6 (5)	2.6 (3.3)	-6.7 (4.7)

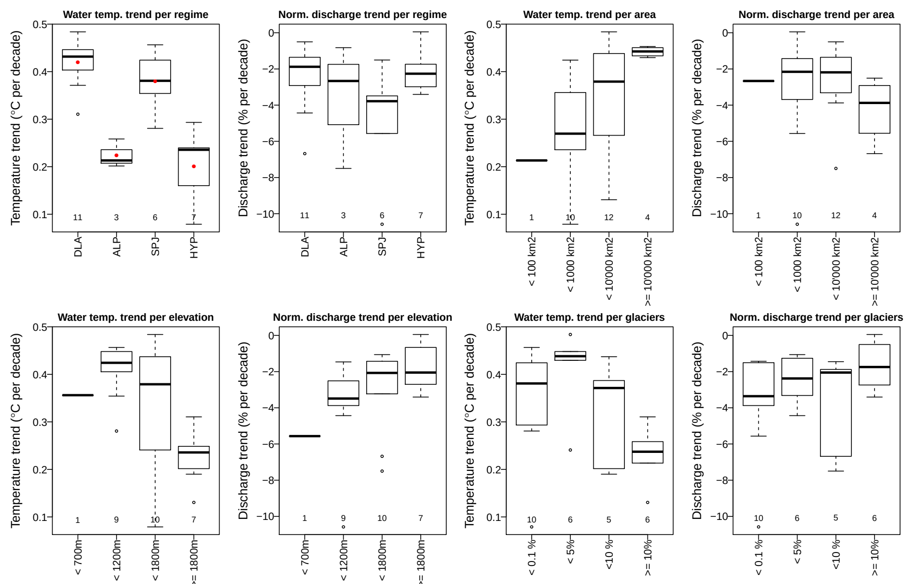

Figure S12. Water temperature and discharge trends for the period 1979-2019 for the 27 catchments where data are available for temperature and discharge (see Table 1 in main text). Top left: classified according to the four different hydrological regimes (DLA = downstream lake regimes, ALP = alpine regimes, SPJ = Swiss Plateau/Jura regimes and HYP = strong influence from hydropeaking). Top right: Classified according to catchment area. Bottom left: Classified according to the catchment elevation. Bottom right: Classified according to the glacier coverage.

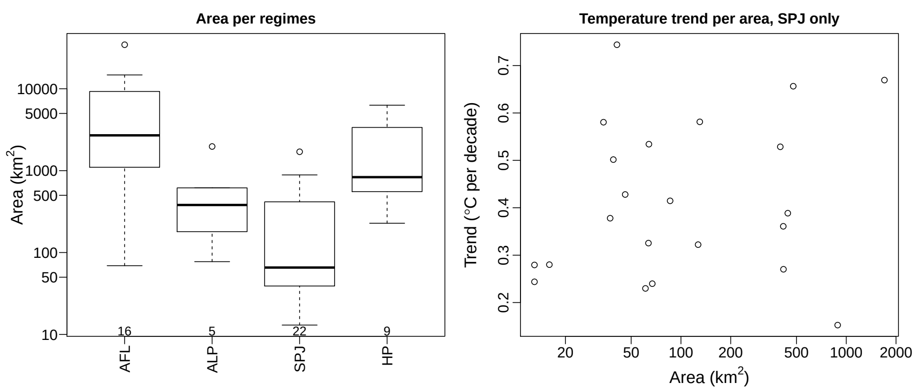

Figure S13. Left: Distribution of catchment area for four different regimes (DLA = downstream lake regimes, ALP = alpine regimes, SPJ = Swiss Pateau/Jura regimes and HYP = strong influence from hydropeaking). Right: Temperature trends for SPJ regime catchments only.

S2.2 Lake effect

This Section presents plots for the four lakes not shown in the main text Section 4.3: Lake Walen (Figure S14), Lake Luzern (Figure S15), Lakes Brienz and Thun (Figure S16), and Lake Biel (Figure S17). The values for the various trends presented are shown in Table 3 in the main text.

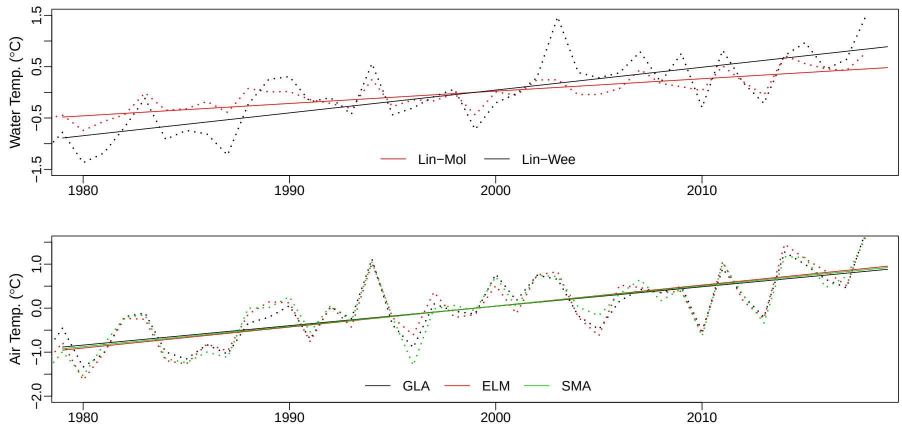

Figure S14. Lake Walen: Water temperature anomalies and trends for inflow and outlet stations (top), air temperature anomalies and trends for surrounding MeteoSwiss stations (bottom). The period for trend computations is 1979-2018. The abbreviation for water gauging stations and for MeteoSwiss stations are given in Table 1 in main text and in Table S2.

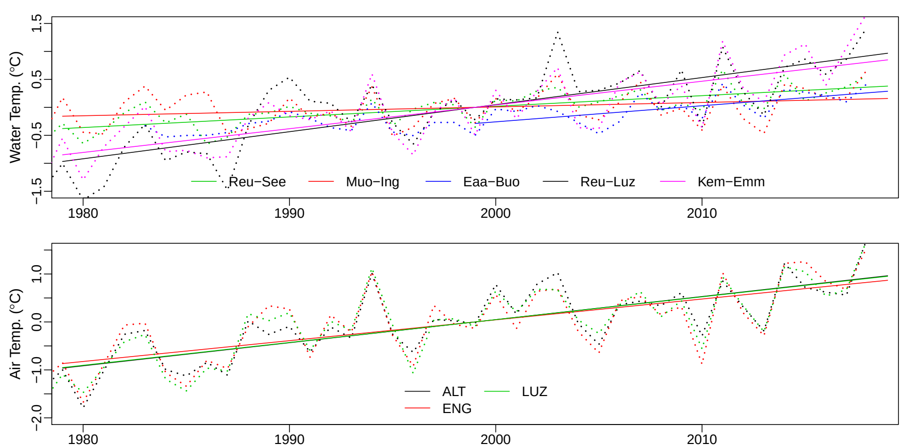

Figure S15. Lake Luzern: Water temperature anomalies and trends for inflow and outlet stations (top), air temperature trends for surrounding MeteoSwiss stations (bottom). The period for trend computations is 1979-2018.The abbreviation for water gauging stations and for MeteoSwiss stations are given in Table 1 in main text and in Table S2.

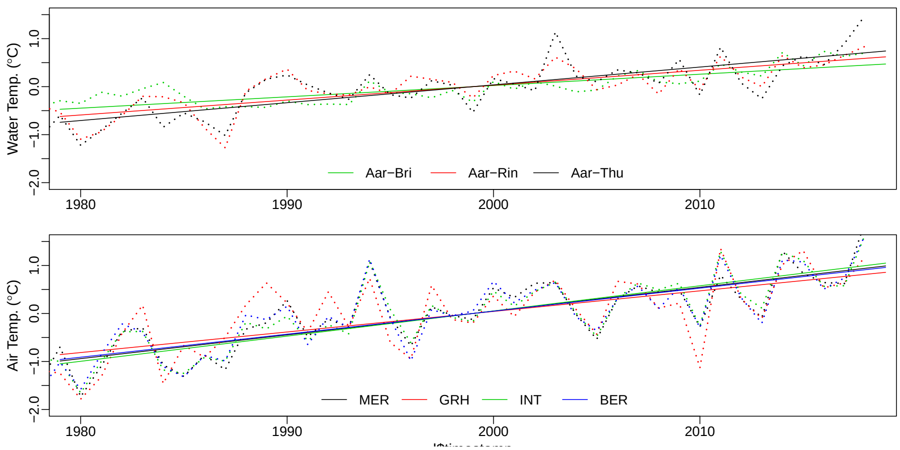

Figure S16. Lakes Brienz and Thun: Water temperature anomalies and trends for inflow and outlet stations (top), air temperature anomalies and trends for surrounding MeteoSwiss stations (bottom). The period for trend computations is 1979-2018. The abbreviation for water gauging stations and for MeteoSwiss stations are given in Table 1 in main text and in Table S2.

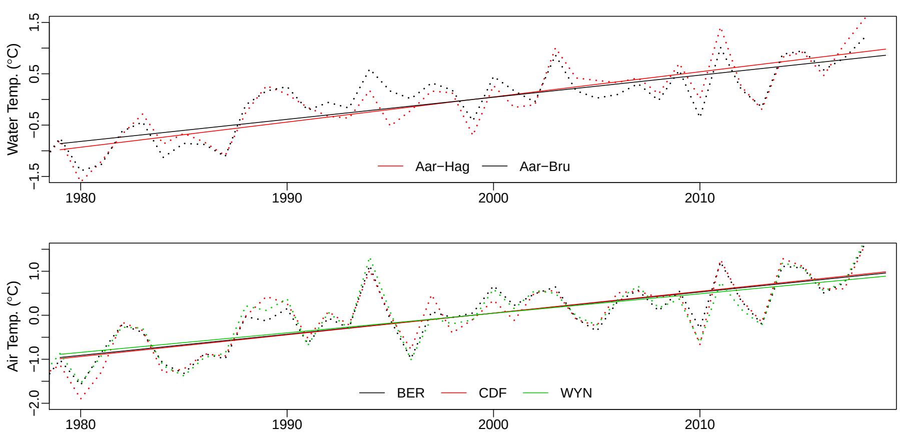

Figure S17. Lake Biel: Water temperature anomalies and trends for inflow and outlet stations (top), air temperature anomalies trends for surrounding MeteoSwiss stations (bottom). The period for trend computations is 1979-2018. The abbreviation for water gauging stations and for MeteoSwiss stations are given in Table 1 in main text and in Table S2.

S2.3 Seasonal trends and relation with air temperature and precipitation

This Section presents additional results related to Section 4 of the main text. Figures S18 and S19 show the decades evolution of air temperature and precipitation for the four seasons, similar to Figures 8 and 9 of the main text for stream temperature and discharge.

Table S5 shows the correlation between trends of various variables. As discussed in the main text, these correlations are mostly not significant and thus not considered in the study. Therefore, the inter-variable and inter-seasonal mechanisms are used with raw values instead of trends.

Figures S20 and S22 show the yearly anomalies in stream temperature, discharge, air temperature and precipitation in winter and fall, similar to Figures 8 and 11 in the main text which present spring and summer.

Finally, Figure S21 shows the snow water equivalent (SWE) at the beginning of various months over the whole country, and Figure S23 shows the evolution of the summer mass balance for 9 Swiss glaciers.

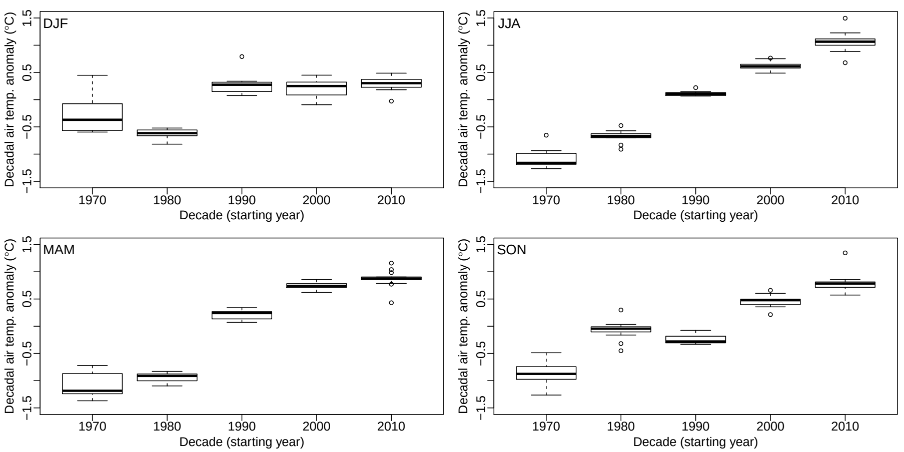

Figure S18. Air temperature seasonal anomalies over the 14 catchments where data are available since 1970 (see Table S2). Anomalies with respect to the 1970-2018 period.

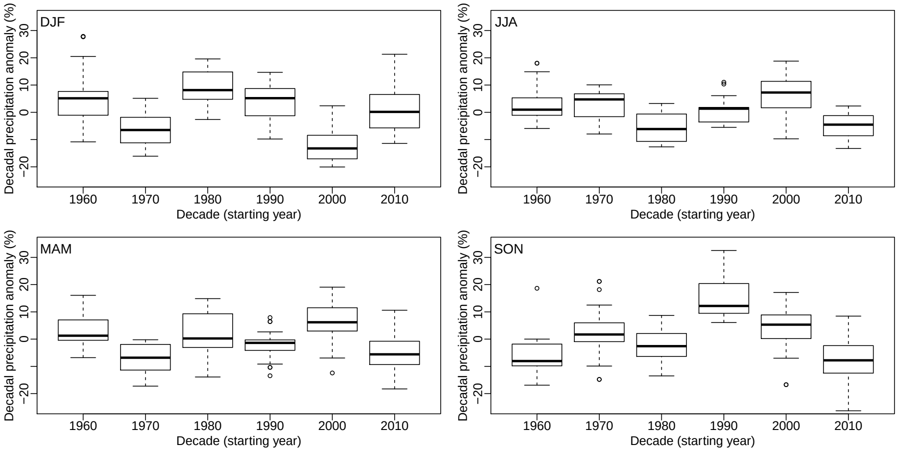

Figure S19. Precipitation seasonal relative anomalies over the 26 stations where data are available since 1960 (see Table S2). Anomalies with respect to 1960-2018 period.

Table S5. Correlation between the trends of water and air temperature (left), water temperature and discharge (middle) and discharge and precipitation (right). Correlations are computed between annual and seasonal trends, and by taking one value per catchment and constructing ordered vectors of values. The number in parenthesis indicates the p-value of the null-hypothesis (no correlation). Since the computation here is different to the one in Table 4 in main text (where correlation is computed from full time series and then averaged between catchment), the two tables cannot be compared.

Water and air temperature trends		**Water temperature and discharge trends**		**Discharge and precipitation trends**	
Period	**cor.**	**Period**	**Cor.**	**Period**	**Cor.**
Yearly	-0.18 (0.19)	Yearly	-0.25 (0.08)	yearly	0.08 (0.01)
Winter	-0.13 (0.36)	Winter	-0.50 (<0.01)	Winter	0.36 (0.02)
Spring	0.02 (0.87)	Spring	-0.35 (0.01)	Spring	0.11 (0.43)
Summer	-0.09 (0.51)	Summer	-0.05 (0.72)	Summer	0.33 (0.01)
Fall	-0.26 (0.07)	Fall	-0.26 (0.06)	Fall	0.34 (0.58)

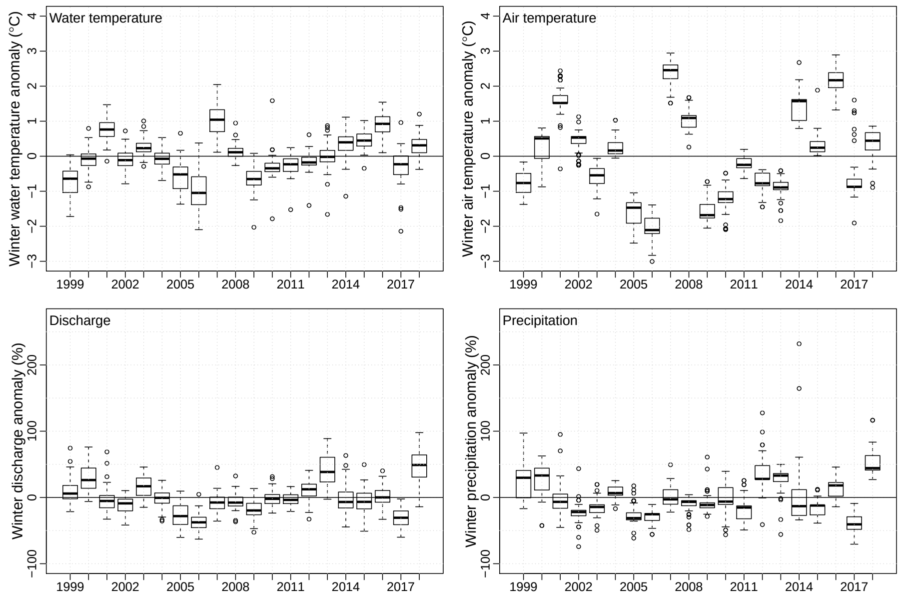

Figure S20. Winter anomalies in stream temperature, air temperature, relative discharge and relative precipitation for all catchments. Anomalies are computed with respect to the 1999-2018 mean for each catchment.

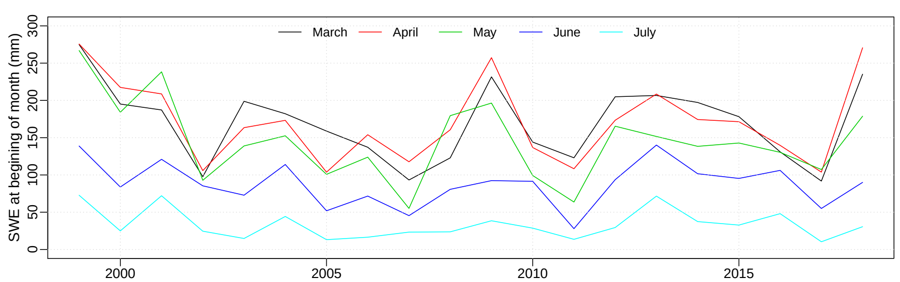

Figure S21. Snow water equivalent in spring in Switzerland at the beginning of the months, from March to July. Obtained from Magnusson et al. (2014) and provided by the WSL Institute for Snow and Avalanche Research (SLF).

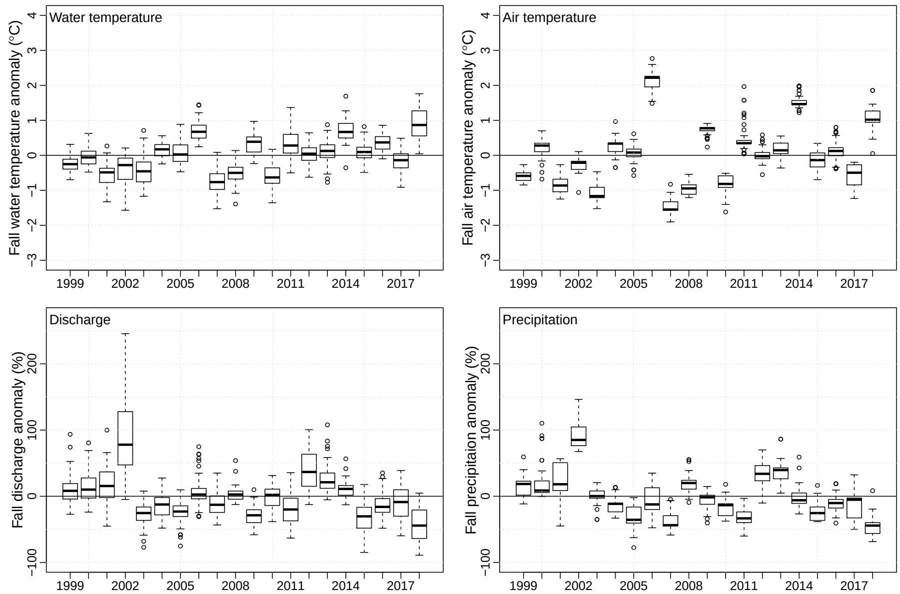

Figure S22. Fall anomalies in stream temperature, air temperature, relative discharge and relative precipitation for all catchments. Anomalies are computed with respect to the 1999-2018 mean for each catchment.

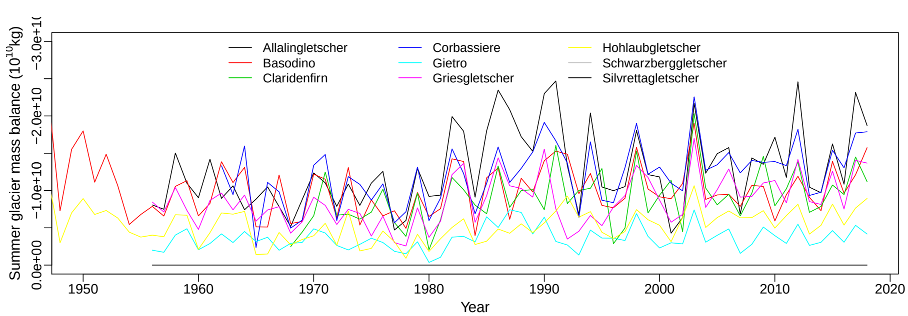

Figure S23. Summer mass balance for 9 Swiss glaciers, from (GLAMOS, 2018).

S2.4 Ecological indicators

This Section presents an additional Figure related to Section 4.5 of the main text. Figure S24 shows the summer runoff anomaly for the same catchments as the ones used in Figure 17 in the main text.

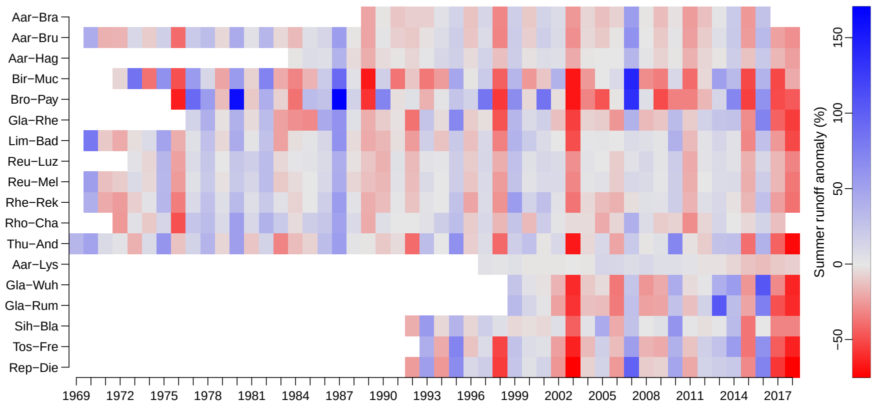

Figure S24. Summer relative runoff anomaly (with respect to the 1999-2018 period) for the catchments in which the 25°C threshold is reached (see Figure 17 in main text).

Code and data availability. TEXT

The aim is to share the data set collected in the context of this paper, discussions are still going on with data providers to find an agreement. If successful, the dataset will be made available on EnviDat.ch.

The code will also be available in a well commented and comprehensive form at publication time.

For the time being (review) documented code and data are available at: https://drive.switch.ch/index.php/s/9BEqpBWFkNWoTSU The main author should be contacted to obtain the password (adrien.michel@epfl.ch).

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