

Influence of Warming and Atmospheric Circulation Changes on Multidecadal European Flood Variability

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Supplementary Table S1

Supplementary Figures S1, S2, S3, S4 S5

Supplementary Tables

Supplementary Table S1: Streamflow series used in the paper with their hydrological characteristics, as well as the precipitation station used for comparison. The 14 long series shown in Fig. 1 are in highlighted bold. Columns r(ann) and r(seas) show the correlation between the streamflow series and the Rx5d series year-round and for seasons, italics denote $p < 0.05$.

GRDC station number	river name	station name	Cluster #	country code (ISO 3166)	latitude, decimal degree	longitude, decimal degree	catchment size, km ²	height of gauge zero, m above sea level	data available from year	data available until year	long-term average discharge, cubic kilometre per second	Precipitation station	latitude, decimal degree	longitude, decimal degree	r(ann)	r(seas)
6935300	Aare	Untersiggental/Stilli	4	CH	47.5166	8.2348	17601	373.41	1904	2016	558.2	Bern	46.99	7.46	<i>0.58</i>	<i>0.59</i>
6337502	Aller	Celle	7	DE	52.622	10.063	4374	31.8	1890	2016	27.0	Clausthal	51.79	10.35	<i>0.35</i>	<i>0.33</i>
6731215	Bjerkreimselva	Bjerkreim	2	NO	58.58	6.08	633	55	1897	2015	50.9	Soyland	58.68	5.98	<i>0.56</i>	<i>0.49</i>
6142200	Danube	Achleiten	3	DE	48.5824	13.5044	76653	287.7	1900	2015	1421.1	Passau	48.58	13.42	<i>0.44</i>	<i>0.51</i>
6342800	Danube	Bratislava	3	SK	48.1396	17.1092	131331	128	1900	2017	2045.5	Vienna	48.23	16.35	<i>0.23</i>	<i>0.29</i>
6342900	Danube	Hofkirchen	3	DE	48.6766	13.1152	47496	299.6	1900	2016	636.9	Munich	48.17	11.5	<i>0.22</i>	<i>0.43</i>
6140700	Divoka Orlice	Nekor	6	CZ	50.0651	16.5404	182.4	431.19	1906	2018	3.7	Görlitz	51.16	14.95	<i>0.25</i>	<i>0.25</i>
6340120	Elbe	Barby	6	DE	51.9901	11.8826	94060	46	1899	2016	551.3	Jena	50.93	11.58	0.13	0.16
6340110	Elbe	Decin	6	CZ	50.7822	14.2096	51120.3	120.07	1887	2018	309.3	Prague	50.09	14.42	0.12	0.05
6140400	Elbe	Dresden	6	DE	51.0597	13.7385	53096	102.73	1806	2016	332.2	Chemnitz	50.79	12.87	<i>0.28</i>	<i>0.04</i>
6340140	Elbe	Neu-Darchau	6	DE	53.2323	10.8888	131950	5.68	1874	2016	705.9	Marnitz	53.32	11.93	<i>0.04</i>	<i>0.06</i>
6340150	Elbe	Wittenberge	6	DE	52.9908	11.7598	123532	17	1899	2016	677.2	Berlin	52.46	13.3	0.15	0.10
6338120	Ems	Greven	8	DE	52.094	7.603	2842	32.71	1900	2016	26.1	Münster	51.95	7.59	<i>0.38</i>	<i>0.31</i>
6731403	Glomma	Solbergfoss	-	NO	59.6373	11.1535	40540	101	1901	2013	690.6	Orje	59.48	11.65	0.10	0.08
6342200	Iller	Kempton	3	DE	47.7304	10.3169	954.6	656	1900	2016	46.4	Kempton	47.72	10.34	<i>0.50</i>	<i>0.49</i>
6342830	Ilz	Kalteneck	7	DE	48.6889	13.4519	762	327.97	1900	2016	16.1	Riedlhütte	48.89	13.43	<i>0.51</i>	<i>0.48</i>
6343100	Inn	Martinsbruck	-	CH	46.8858	10.4654	1945	1076.537	1904	2016	55.9	Bever	46.5	9.85	<i>0.35</i>	<i>0.32</i>
6943100	Inn	Wasserburg	3	DE	48.0593	12.2342	11983	420.45	1826	2016	354.2	Ebersberg	48.1	11.99	<i>0.48</i>	<i>0.49</i>
6607830	Lea	Feildes Weir	1	GB	51.7642	0.0139	1036	27.7	1879	2018	4.4	Rothamsted	51.81	0.36	<i>0.24</i>	<i>0.14</i>
6342513	Lech	Landsberg	3	DE	48.0415	10.8751	2295	584.41	1900	2016	82.4	Hohenpeissenberg	47.8	11.01	<i>0.51</i>	<i>0.44</i>
6335500	Main	Schweinfurt	7	DE	50.0312	10.2208	12715	201.16	1844	2016	103.2	Bamberg	49.88	10.92	<i>0.17</i>	<i>0.18</i>
6335301	Main	Würzburg	7	DE	49.796	9.926	14031	164.55	1823	2016	108.9	Bamberg	49.88	10.92	<i>0.19</i>	<i>0.23</i>

6336050	Moselle	Cochem	8	DE	50.1434	7.1683	27088	77	1900	2016	313.8	Karlsruhe	49.04	8.36	0.31	0.30
6731217	Ognaelvi	Helleland	2	NO	58.5336	6.1503	185	86	1896	2015	13.7	Soyland	58.68	5.98	0.42	0.30
6935310	Reuss	Mellingen	4	CH	47.421	8.2713	3382	392.631	1904	2016	139.2	Engelberg	46.8	8.4	0.43	0.46
not from GRDC	Rhine	Basel/Schifflande	4	CH	47.5599	7.5884	35905	292.887	1808	1995	1042.4	Basel	47.53	7.58	0.43	0.48
6935051	Rhine	Domat/Ems	-	CH	46.8377	9.4561	3229	622.884	1899	2016	117.4	Bad Ragaz	47	9.5	0.30	0.30
6935052	Rhine	Düsseldorf	8	DE	51.2255	6.7702	147680	24.48	1900	2016	2126.9	Karlsruhe	49.04	8.36	0.29	0.29
6935145	Rhine	Köln	8	DE	50.937	6.9633	144232	34.97	1816	2016	2085.4	Karlsruhe	49.04	8.36	0.28	0.29
6335050	Rhine	Lobith	8	NL	51.84	6.11	160800	8.53	1901	2017	2214.1	Roermond	51.18	5.97	0.18	0.18
6435060	Rhine	Neuhausen	-	CH	47.6823	8.6259	11887	429.577	1904	2016	369.4	St. Gallen	47.4	9.4	0.25	0.27
6935054	Rhine	Rees	8	DE	51.7569	6.3954	159300	8	1814	2016	2252.0	Roermond	51.18	5.97	0.15	0.15
6935055	Rhine	Rekingen	-	CH	47.5704	8.33	14718	370.174	1904	2016	441.2	Zurich	47.38	8.57	0.46	0.46
not from GRDC	Rhône	Beaucaire	5	FR	43.92	4.67	95590	3	1816	2017	1692.6	Montélimar	44.58	4.73	0.35	0.39
6939200	Rhône	Chancy	5	CH	46.153	5.9707	10323	388.729	1904	2016	340.6	Geneva	46.2	6.15	0.35	0.34
6939050	Rhône	Porte-du-Scex	-	CH	46.3495	6.8886	5244	428.582	1905	2016	180.6	Sion	46.22	7.33	-0.06	-0.06
6343560	Saalach	Unterjettenberg	3	DE	47.6812	12.8228	927.3	494	1900	2016	38.2	Schneizhreuth	47.67	12.77	0.65	0.64
6343500	Salzach	Burghausen	3	DE	48.1586	12.8343	6649	352	1826	2016	258.8	Kremsmünster	48.06	14.13	0.60	0.62
6607651	Thames	Kingston	1	GB	51.4154	-0.3077	9948	4.7	1883	2018	78.9	Oxford	51.76	-1.26	0.16	0.15
6935400	Thur	Andelfingen	4	CH	47.5965	8.682	1696	402.751	1904	2016	46.9	Säntis	47.25	9.35	0.29	0.32
6731371	Tovdalselva	Flaksvatn	2	NO	58.3305	8.2031	1780.6	19	1899	2014	61.0	Mestad	58.22	7.89	0.48	0.53
6337100	Weser	Bodenwerder	7	DE	51.973	9.516	15924	69.39	1839	2016	145.6	Göttingen	51.56	9.85	0.29	0.27
6337400	Weser	Hann. Münden	7	DE	51.426	9.641	12442	114.95	1831	2016	109.8	Creuzburg	51.06	10.25	0.22	0.28
6337514	Weser	Intschede	7	DE	52.964	9.125	37720	4.79	1857	2016	320.5	Rotenburg	53.13	9.34	0.04	0.07
6337200	Weser	Vlotho	7	DE	52.176	8.862	17618	41.66	1820	2016	170.7	Göttingen	51.56	9.85	0.27	0.24

Supplementary Figures

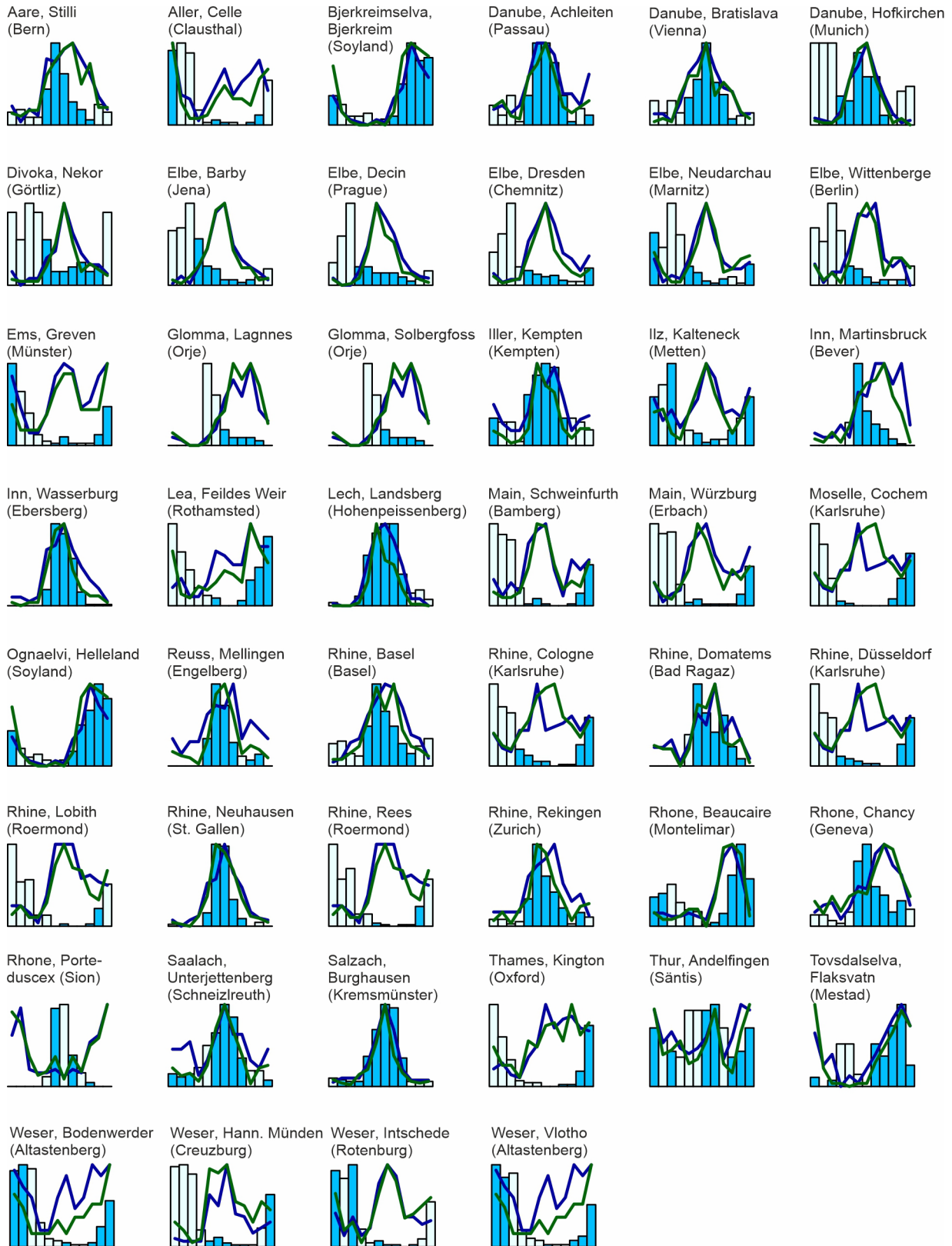


Fig. S1: Seasonality of annual peak streamflow (bars), Rx5day (blue) and Rx20day (green). The streamflow bars pertaining to the six months with highest Rx5day are marked in blue. Lines and bars are scaled between 0 and the maximum.

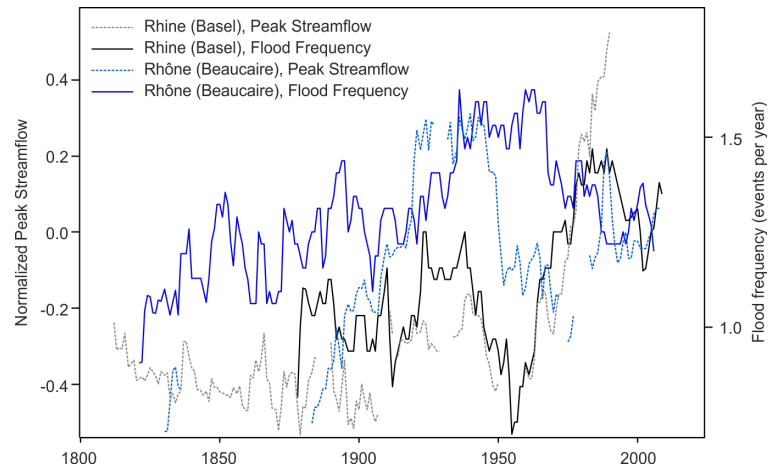


Fig. S2: Time series of flood intensity (normalized peak stream flow) and flood frequency (exceedance of 98th percentile after declustering) in the daily series from the Rhône (Beaucaire) and Rhine (Basel), smoothed with a 30-yr moving average.

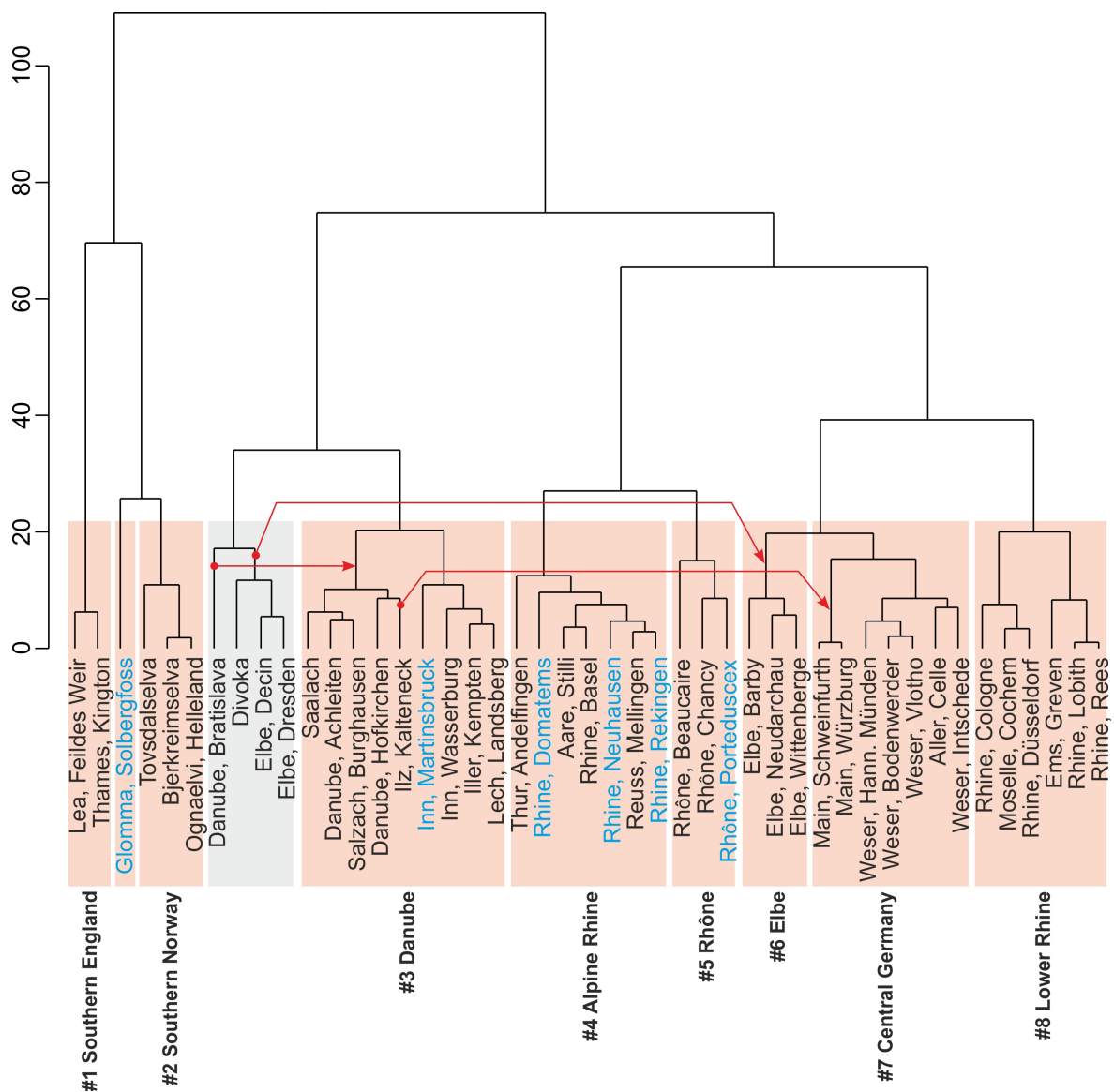


Fig. S3: Dendrogram of Ward cluster analysis and chosen regionalization (boxes – the grey cluster was split). Red points and arrows: Streamflow series that were assigned to another cluster (blue: series shown in Fig. 2).

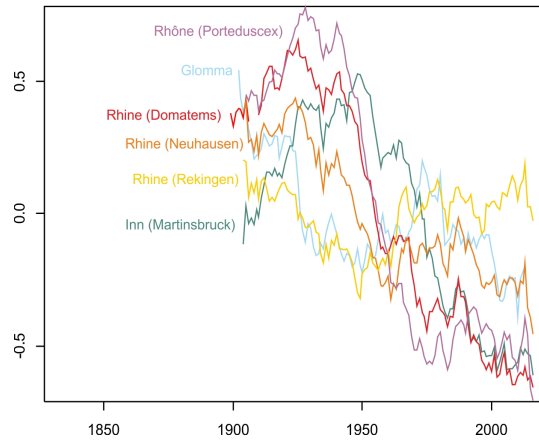
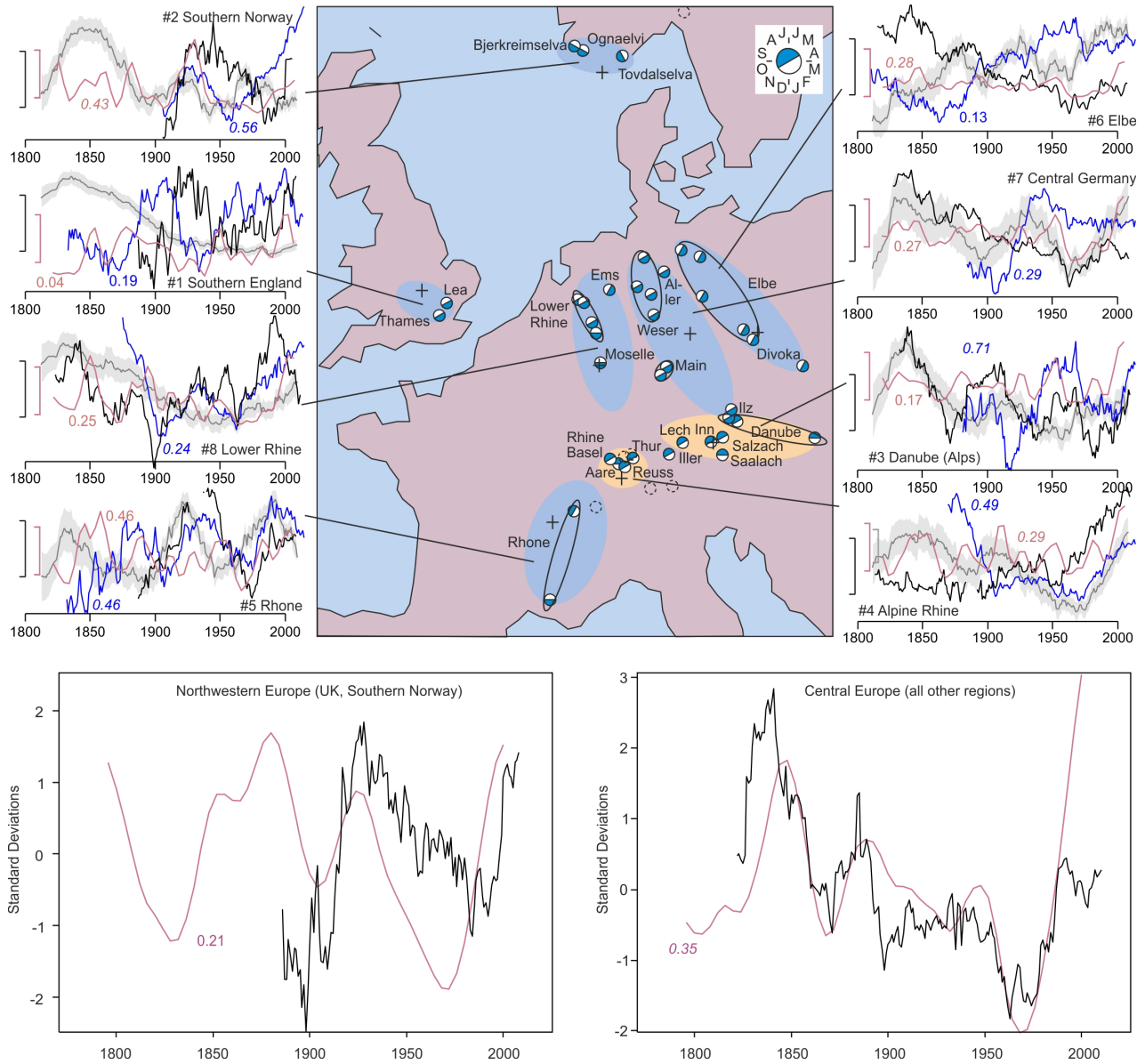
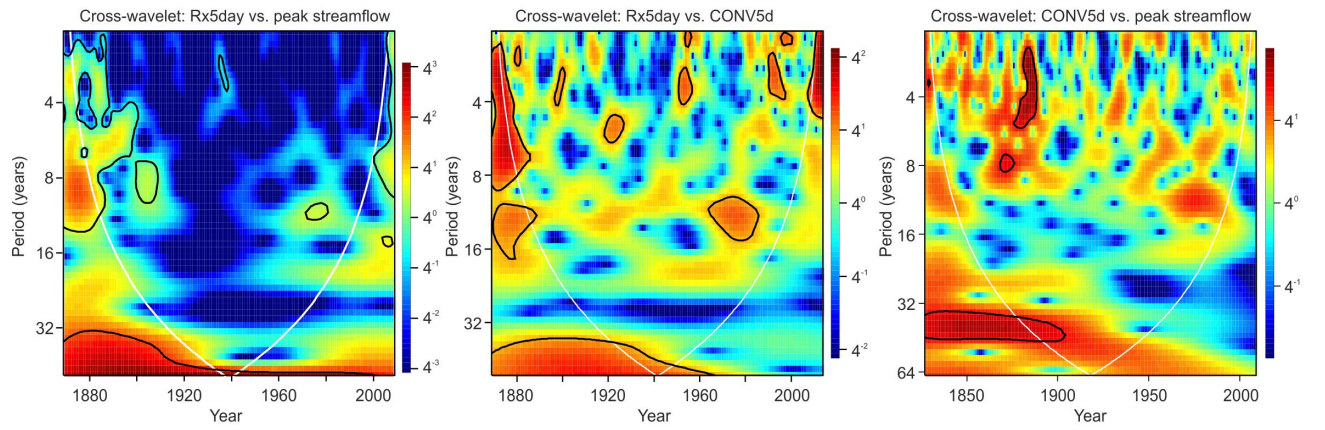


Fig. S4: Streamflow series (normalized, smoothed with a 30-yr moving average) that were excluded from the main analysis (see Section 2.2 and Fig. 2).



Same selection as Fig. 5a (min. 4 regions must have data)



Longest possible period

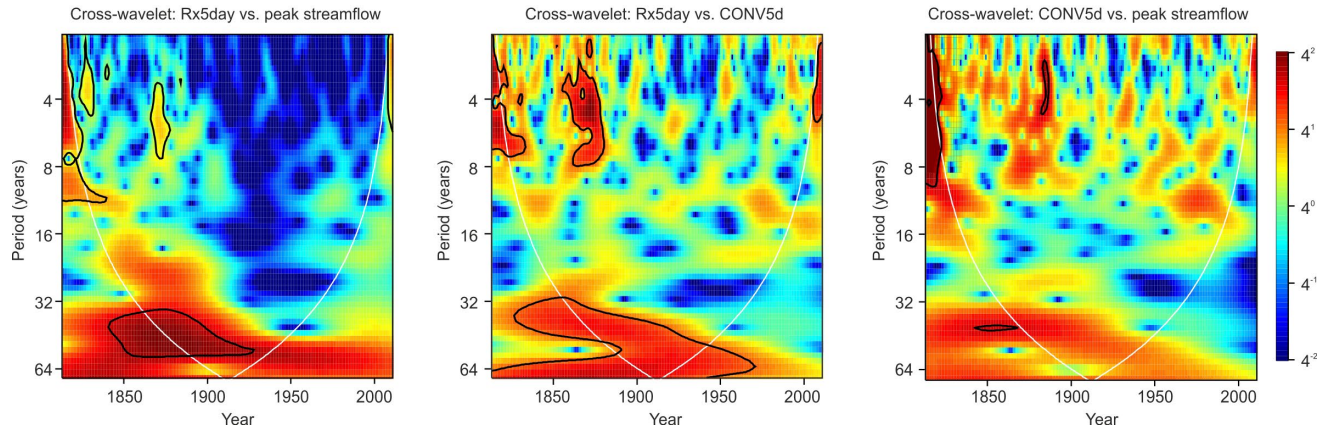


Fig. S6: Cross-wavelet analysis of Rx5day, flood intensity (normalized peak streamflow) and CONV5d averaged over all regions for (top) the time period in which at least 4 series have data and (bottom) the period after 1832 (note that the number of contributing regions can drop below 4).

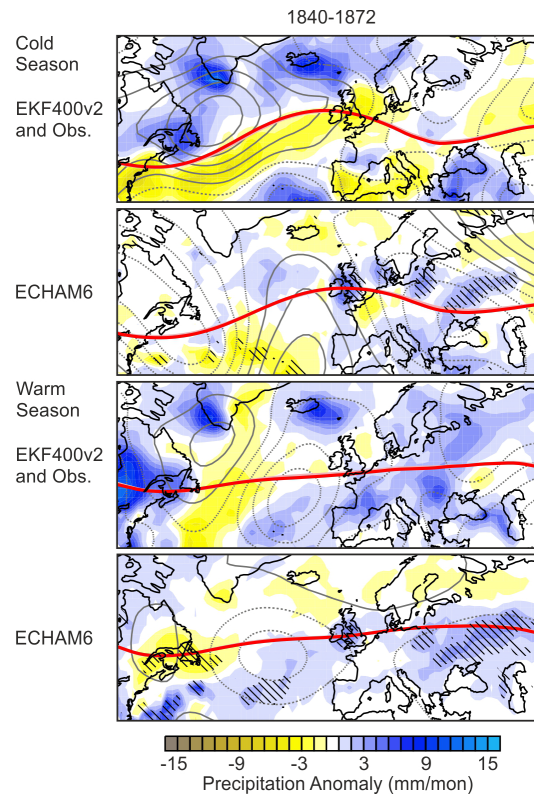


Fig. S7. Same as Fig. 8, but for the period 1840-1872. Note that ECHAM6 simulations start only in 1851.