



Supplement of

Rain-on-snow events in mountainous catchments under climate change

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Table S1: Selected characteristics of all study catchments. Catchment IDs are set by 1) country: CZ – Czechia (including catchments in Germany), CH – Switzerland, 2) mountain region in Czechia and Germany: 100 – Bohemian and Bavarian Forest, 200 – Ore Mountains, 300 – Western Sudetes, 400 – Central Sudetes, 500 – Eastern Sudetes, 600 – Western Carpathians; in Switzerland: 100 – Jura and Swiss Plateau, 200 – Central Alps, 300 – Southern Alps. Catchments (IDs) are ordered with regard to geographical locations from west to east within individual mountain regions. Climate and snow characteristics represent annual means from the 1980-2010 period valid for mean catchment elevation, based on the modeled values.

ID	Catchment	Gauging station	Area [km ²]	Mean elevation (range) [m a.s.l.]	Annual mean air temperature [°C]	Annual precipitation [mm]	Annual snowfall [mm]	Maximum SWE [mm]
CZ-101	Schwarzach	Höll	59.9	652 (494-1042)	7.1	894	140	70
CZ-102	Weisser Regen	Lohberg	39.3	928 (577-1456)	6.2	1238	257	198
CZ-103	Ostruzna	Kolinec	92.0	755 (541-1165)	6.1	892	112	53
CZ-104	Vydra	Modrava	89.8	1140 (983-1345)	4.6	1279	273	197
CZ-105	Otava	Rejstejn	333.6	1017 (598-1345)	5.7	1205	225	123
CZ-106	Hamerský potok	Antygl	20.4	1098 (978-1213)	5.0	1225	290	139
CZ-107	Spulka	Bohumilice	104.6	804 (558-1131)	7.6	773	129	44
CZ-108	Volynka	Nemetice	383.4	722 (430-1302)	8.3	781	95	45
CZ-109	Teplá Vltava	Lenora	176.0	1010 (765-1314)	4.0	975	183	93
CZ-110	Teplá Vltava	Chlum	347.3	939 (733-1314)	4.6	957	155	75
CZ-111	Stasský potok	Nový Dvůr	9.9	962 (792-1131)	6.2	951	189	76
CZ-112	Saussywasser	Linden	89.7	899 (651-1308)	4.9	950	116	83
CZ-113	Studena Vltava	Černý Kriz	102.4	921 (738-1353)	4.7	971	142	79
CZ-114	Blanice	Blanický Mlýn	85.5	892 (757-1197)	4.2	757	135	59
CZ-115	Blanice	Poděvorský Mlýn	202.8	844 (558-1274)	4.9	731	114	49
CZ-201	Zwota	Klingenthal	55.7	720 (541-943)	5.4	1171	264	96
CZ-202	Rolava	Chaloupky	18.7	902 (826-956)	5.3	1223	260	213
CZ-203	Rolava	Stará Role	125.3	761 (398-994)	5.6	1087	231	131
CZ-204	Natzschung	Rothenthal	76.1	763 (539-921)	5.9	853	148	93
CZ-205	Wilde Weißeritz	Rehefeld	15.4	806 (686-911)	6.1	828	137	80
CZ-206	Wilde Weißeritz	Ammelsdorf	49.3	734 (528-911)	5.5	889	169	119
CZ-301	Jerice	Chrastava	76.0	493 (295-862)	7.7	901	120	58
CZ-302	Černá Nisa	Stráž	18.3	672 (368-850)	6.3	1168	186	134
CZ-303	Černá Nisa	Uhřetická	1.8	816 (786-850)	4.9	1264	285	267
CZ-304	Černá Desná	Jezdecká	4.8	899 (792-1007)	4.5	1490	438	409
CZ-305	Kamenice	Bohunovsko	178.8	699 (345-1069)	5.7	1268	354	178
CZ-306	Luzická Nisa	Proseč	53.8	611 (419-835)	6.7	1085	173	109
CZ-307	Smeda	Bílý potok	26.5	817 (412-1090)	5.0	1219	274	242
CZ-308	Smeda	Frydlant	132.7	588 (297-1113)	6.7	1120	203	121
CZ-309	Mumlava	Janov	51.3	970 (625-1404)	4.7	1517	495	385
CZ-310	Jizera	Dolní Svatava	321.8	771 (399-1404)	5.4	1328	401	246
CZ-311	Jizerka	Dolní Stěpanice	44.2	842 (490-1379)	4.7	1432	418	211
CZ-312	Malá Labe	Proseč	72.8	731 (376-1378)	5.5	1218	306	137
CZ-313	Cista	Hostinné	77.4	594 (358-1322)	6.2	1170	282	93
CZ-314	Modrý potok	Modrý důl	2.6	1297 (1076-1489)	2.2	2103	778	674
CZ-315	Upa	Horní Maršov	82.0	1030 (581-1495)	3.2	1408	477	333
CZ-316	Upa	Horní Stare Mesto	144.8	902 (452-1495)	4.1	1355	411	251

ID	Catchment	Gauging station	Area [km ²]	Mean elevation (range) [m a.s.l.]	Annual mean air temperature [°C]	Annual precipitation [mm]	Annual snowfall [mm]	Maximum SWE [mm]
CZ-317	Metuje	Marsov nad Metuji	94.7	584 (419-786)	5.6	757	113	57
CZ-401	Bela	Castolovice	214.1	491 (269-1104)	7.8	952	174	68
CZ-402	Knezna	Rychnov nad Kneznou	75.4	502 (305-861)	7.9	963	165	63
CZ-403	Zdobnice	Slatina nad Zdobnici	84.1	721 (395-1092)	6.4	1140	232	187
CZ-404	Divoka Orlice	Klasterec nad Orlici	153.6	728 (505-1078)	6.5	1136	207	164
CZ-405	Ticha Orlice	Sobkovice	98.5	622 (459-965)	7.0	900	149	110
CZ-501	Morava	Vlaske	96.5	790 (448-1374)	5.5	979	222	172
CZ-502	Morava	Raskov	350.0	745 (380-1378)	5.6	940	213	170
CZ-503	Krupa	Habartice	109.3	756 (480-1267)	5.7	981	213	193
CZ-504	Telcsky potok	Stare Mesto	21.9	802 (548-1102)	5.4	1176	223	137
CZ-505	Branna	Jindrichov	90.3	794 (474-1378)	5.5	1124	213	123
CZ-506	Desna	Sumperk	246.9	736 (320-1454)	5.5	882	166	96
CZ-507	Stribrny potok	Zulova	21.4	712 (390-1108)	6.0	1083	183	99
CZ-508	Bela	Jesenik	118.0	799 (443-1390)	4.5	1114	264	132
CZ-509	Moravice	Velka Stahle	168.6	800 (549-1415)	4.9	786	138	110
CZ-510	Cerna Opava	Mnichov	51.0	814 (579-1186)	4.4	1146	279	100
CZ-511	Opava	Karlovice	150.9	854 (503-1437)	3.9	1146	295	106
CZ-512	Opava	Krnov	173.3	547 (318-912)	5.7	1024	205	59
CZ-513	Opavice	Krnov	369.2	668 (315-1437)	7.5	728	134	59
CZ-601	Lesti	Solanec	10.4	700 (513-874)	6.4	1131	224	112
CZ-602	Vsetinska Becva	Velke Karlovice	68.3	749 (524-1042)	6.0	1131	252	112
CZ-603	Roznovska Becva	Horni Becva	14.1	745 (568-966)	6.4	1203	274	146
CZ-604	Celadenka	Celadna	31.0	803 (536-1187)	5.9	1264	236	139
CZ-605	Ostravice	Stare Hamry	73.3	707 (542-922)	6.7	1169	257	138
CZ-606	Mohelnice	Raskovice	35.4	765 (473-1209)	6.5	1373	305	148
CZ-607	Moravka	Uspolka	22.2	763 (560-1104)	6.4	1391	309	160
CZ-608	Skalka	Uspolka	18.9	785 (571-1029)	5.6	1234	295	154
CZ-609	Slavic	Slavic	15.1	827 (575-1016)	5.5	1275	304	161
CZ-610	Ropicanka	Reka	12.2	696 (454-1008)	6.4	1180	249	130
CZ-611	Lomna	Jablunkov	69.9	667 (390-1011)	6.2	1180	250	107
CH-101	Mentue	Yvonand	105.3	690 (469-915)	8.8	1115	93	38
CH-102	Sense	Thörisshaus	351.2	1091 (551-2096)	6.6	1480	264	94
CH-103	Gürbe	Belp	116.1	845 (518-2169)	7.7	1272	160	78
CH-104	Emme	Eggiwil	124.4	1308 (770-2022)	5.5	1710	456	155
CH-105	Ilfis	Langnau	187.4	1060 (699-1973)	6.6	1700	360	107
CH-106	Langeten	Huttwil	59.9	770 (632-1032)	7.6	1334	188	62
CH-107	Ergolz	Liestal	261.2	604 (305-1087)	8.9	1126	105	47
CH-108	Kleine Emme	Emmen	478.3	1080 (440-2261)	6.6	1654	330	136
CH-109	Alp	Einsiedeln	46.7	1173 (878-1577)	5.8	2025	388	190
CH-110	Minster	Euthal	59.1	1362 (891-1994)	5.2	2187	594	273
CH-111	Murg	Wängi	80.1	657 (469-930)	8.2	1348	133	59

ID	Catchment	Gauging station	Area [km ²]	Mean elevation (range) [m a.s.l.]	Annual mean air temperature [°C]	Annual precipitation [mm]	Annual snowfall [mm]	Maximum SWE [mm]
CH-112	Rietholzbach	Mosnang	3.2	774 (697-868)	7.8	1556	179	117
CH-113	Necker	Mogelsberg	88.1	970 (649-1372)	6.7	1750	298	129
CH-114	Sitter	Appenzell	74.4	1274 (769-2501)	5.4	1895	421	223
CH-115	Goldach	Goldach	50.4	825 (401-1178)	7.8	1426	197	73
CH-201	Grande Eau	Aigle	131.6	1624 (427-3154)	4.4	1710	526	260
CH-202	Simme	Oberwil	343.7	1632 (776-3242)	3.9	1653	545	231
CH-203	Allenbach	Adelboden	28.8	1930 (1321-2587)	3.4	1666	581	341
CH-204	Krummbach	Klusmatten	19.8	2276 (1795-3269)	1.3	1463	665	554
CH-205	Grosstalbach	Isenthal	43.9	1880 (781-2700)	2.8	1818	710	277
CH-206	Dischmabach	Davos	42.9	2434 (1657-3024)	-0.4	1003	384	330
CH-207	Ova da Cluozza	Zernezh	27.0	2361 (1507-3160)	-0.9	955	292	265
CH-208	Ova dal Fuorn	Zernezh	55.2	2359 (1797-3032)	-0.7	949	385	193
CH-301	Riale di Calneggia	Caverghno	23.9	2079 (881-2827)	3.2	1927	693	437
CH-302	Verzasca	Lavertezzo	185.1	1723 (546-2679)	4.7	2038	455	267
CH-303	Cassarate	Pregassona	75.8	1017 (286-1904)	7.9	1889	227	86

Table S2: Mean seasonal (Nov-Apr) modeled values of all climate and snow characteristics (listed in Table 2 in Section 2.6) for individual projections (Section 2.5). This includes seasonal mean air temperature (T_{mean}), sum of all precipitation (P_{sum}), mean snow water equivalent (SWE_{mean}), maximum snow water equivalent (SWE_{max}), sum of snowfall (S_{sum}) and snowfall fraction (S_f).

Projection		Czech and German catchments						Swiss catchments					
		T_{mean} [°C]	P_{sum} [mm]	SWE_{mean} [mm]	SWE_{max} [mm]	S_{sum} [mm]	S_f [-]	T_{mean} [°C]	P_{sum} [mm]	SWE_{mean} [mm]	SWE_{max} [mm]	S_{sum} [mm]	S_f [-]
T0	P08	-0.5	401	41	109	190	0.46	-0.3	513	72	146	273	0.53
	P09	-0.5	451	48	126	214	0.46	-0.3	578	83	168	308	0.53
	P1	-0.5	501	56	144	237	0.46	-0.3	642	95	191	342	0.53
	P11	-0.5	551	65	161	261	0.46	-0.3	705	107	213	376	0.53
	P12	-0.5	601	73	179	285	0.46	-0.3	770	120	237	410	0.53
T1	P08	0.5	401	25	79	148	0.36	0.7	513	54	113	222	0.44
	P09	0.5	451	29	91	167	0.36	0.7	578	62	130	250	0.44
	P1	0.5	501	34	103	185	0.36	0.7	642	71	147	277	0.44
	P11	0.5	551	40	116	204	0.36	0.7	705	80	165	305	0.44
	P12	0.5	601	45	129	222	0.36	0.7	770	90	183	333	0.44
T2	P08	1.5	401	14	55	111	0.27	1.7	513	39	86	173	0.34
	P09	1.5	451	16	64	125	0.27	1.7	578	46	99	195	0.34
	P1	1.5	501	19	72	139	0.27	1.7	642	52	112	216	0.34
	P11	1.5	551	22	81	152	0.27	1.7	705	59	126	238	0.34
	P12	1.5	601	26	90	166	0.27	1.7	770	66	139	260	0.34
T3	P08	2.5	401	7	38	80	0.20	2.7	513	28	64	129	0.26
	P09	2.5	451	9	44	90	0.20	2.7	578	32	73	146	0.26
	P1	2.5	501	10	49	100	0.20	2.7	642	37	83	162	0.26
	P11	2.5	551	12	55	110	0.20	2.7	705	42	93	178	0.26
	P12	2.5	601	13	61	120	0.20	2.7	770	47	104	194	0.26
T4	P08	3.5	401	4	26	56	0.14	3.7	513	19	47	94	0.19
	P09	3.5	451	4	30	63	0.14	3.7	578	22	54	106	0.19
	P1	3.5	501	5	34	70	0.14	3.7	642	25	61	118	0.19
	P11	3.5	551	6	38	77	0.14	3.7	705	29	68	129	0.19
	P12	3.5	601	7	42	84	0.14	3.7	770	32	76	141	0.19

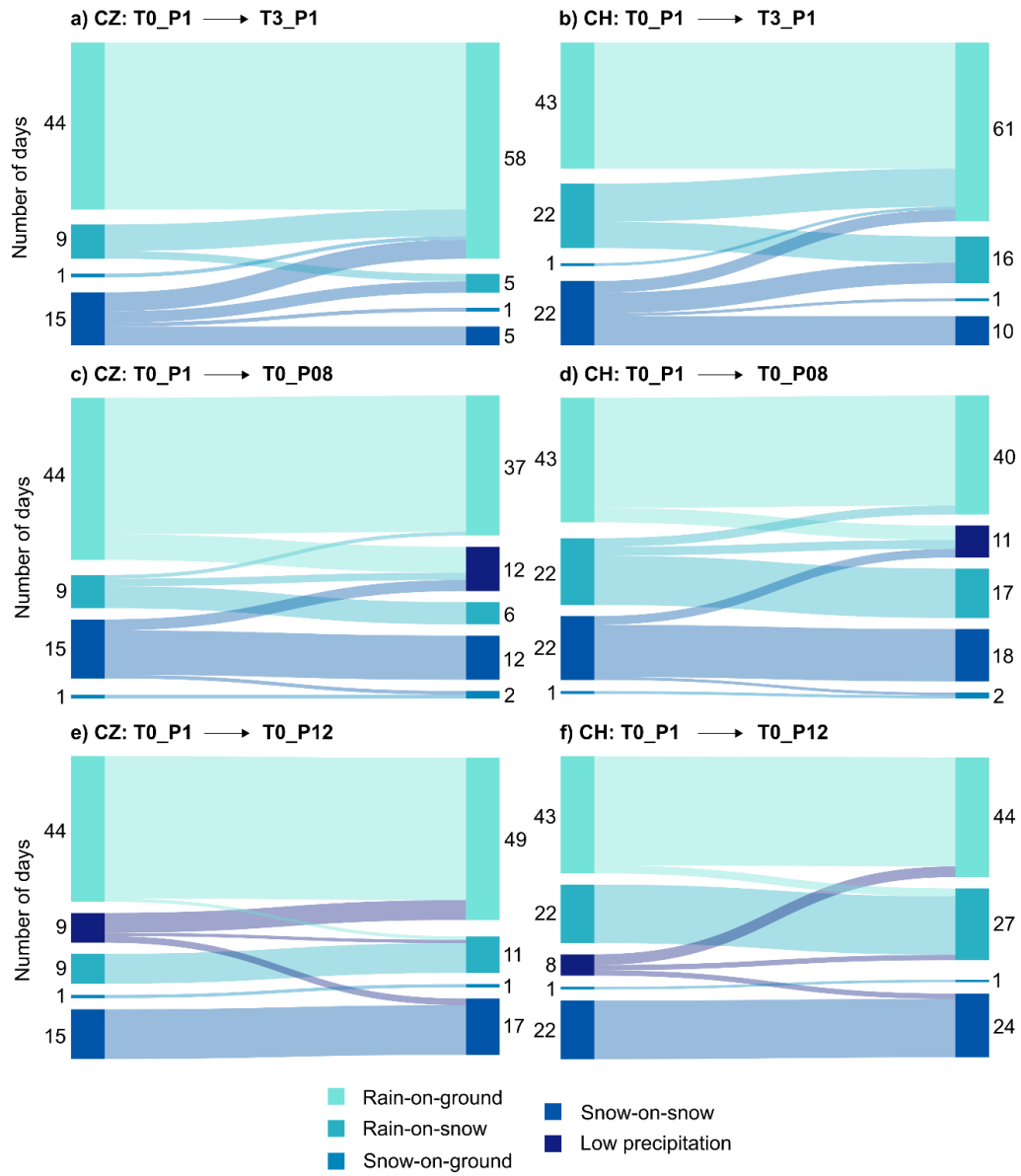
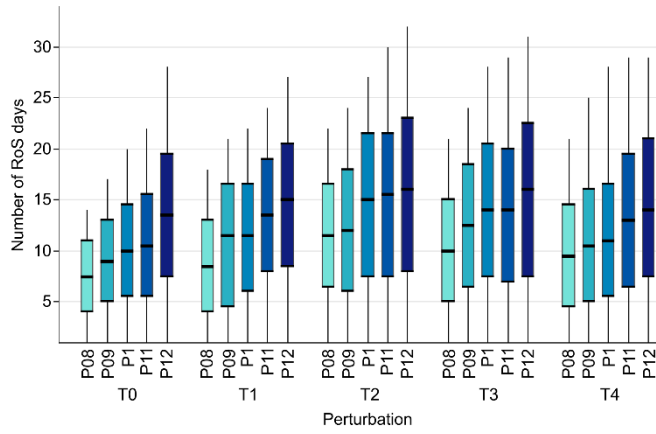
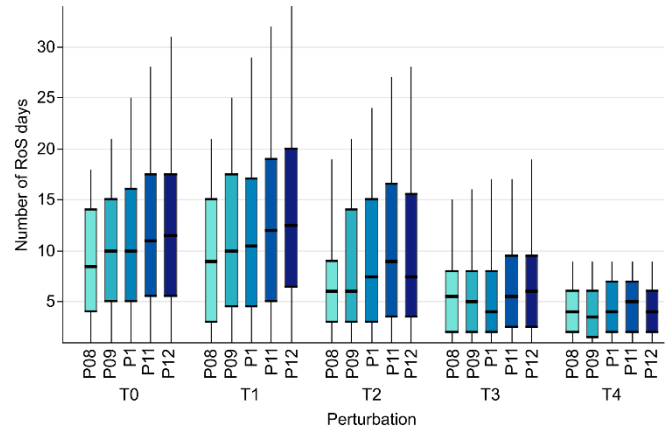


Figure S1: Mean number of categorized days in selected perturbations (T3_P1, T0_P08, T0_P12), compared to reference conditions T0_P1, in both Czech (a, c, e) and Swiss (b, d, f) regions plotted as Sankey diagrams. All precipitation days (with at least 5 mm) were classified into four categories: 1) precipitation classified as rainfall falling on the snow-free ground (rain-on-ground), 2) precipitation classified as rainfall falling on existing snow cover, with SWE of at least 10 mm (rain-on-snow), 3) precipitation classified as snowfall falling on snow-free ground (snow-on-ground), and 4) precipitation classified as snowfall falling on existing snow cover (snow-on-snow). The category “low precipitation” refers to days with precipitation below the threshold of 5 mm. The figure shows the transitions between defined categories.

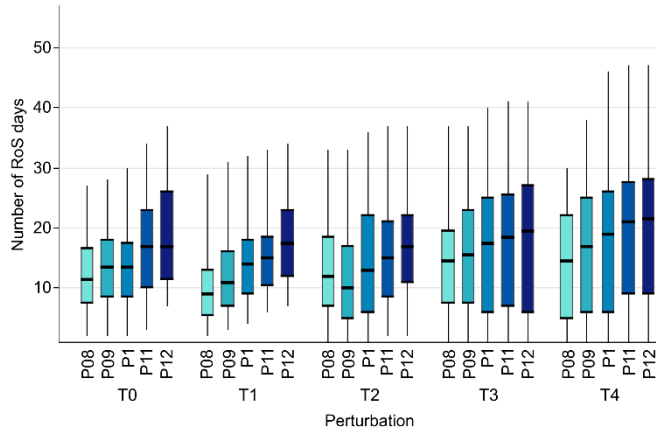
(a) CZ - RoS count in snow-rich season (2005/2006)



(b) CZ - RoS count in snow-poor season (2006/2007)



(c) CH - RoS count in snow-rich season (2008/2009)



(d) CH - RoS count in snow-poor season (2006/2007)

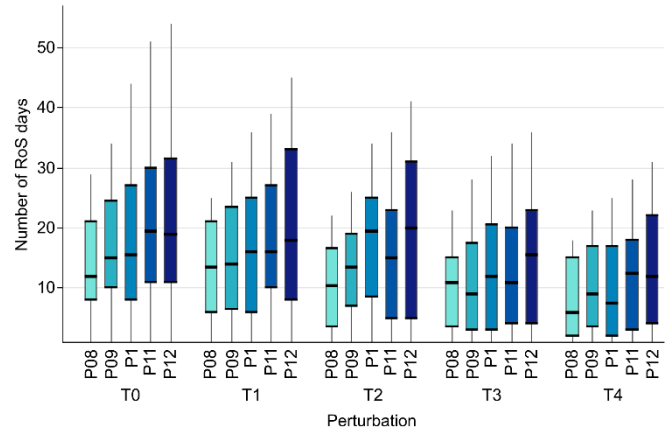
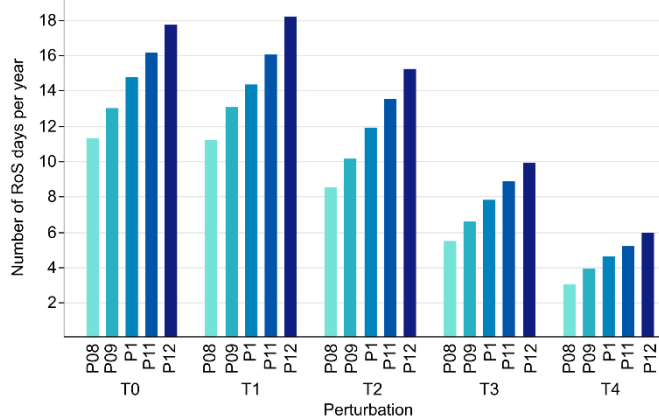
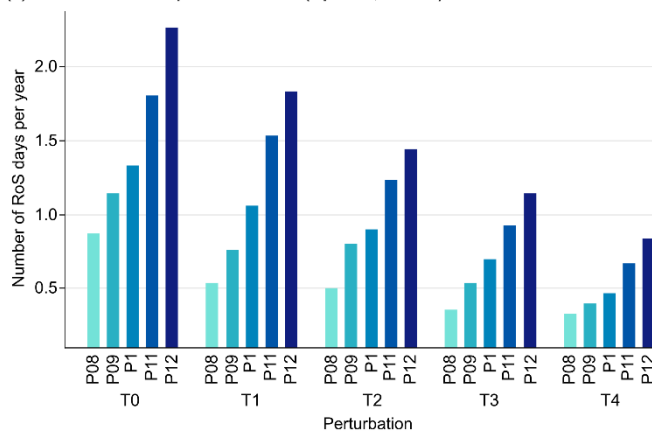


Figure S2: Number of RoS days in both Czech (a, b) and Swiss (c, d) regions for all perturbations for selected contrasting seasons – snow-rich (a, c) and snow-poor (b, d). Boxplots represent the variation among catchments, with the 25th and 75th percentiles represented by each box, the median as a thick line and the whiskers showing the maximum and minimum values. Boxes are grouped and colored according to the temperature (T) and precipitation (P) perturbations.

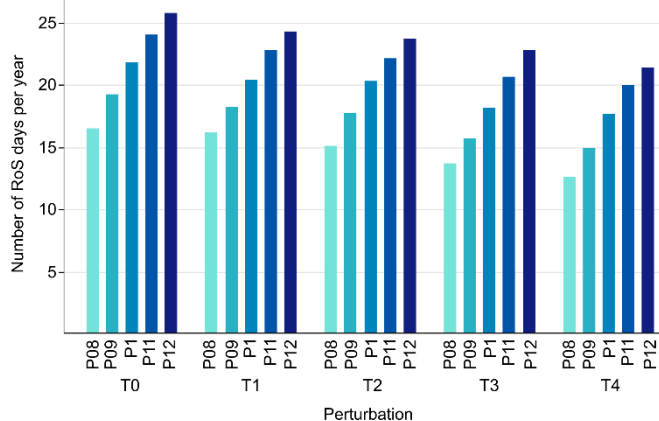
(a) RoS count in RoS-rich catchment (Cerna Desna, CZ-304)



(b) RoS count in RoS-poor catchment (Opavice, CZ-513)



(c) RoS count in high-elevated catchment (Ova da Cluozza, CH-207)



(d) RoS count in low-elevated catchment (Ergolz, CH-107)

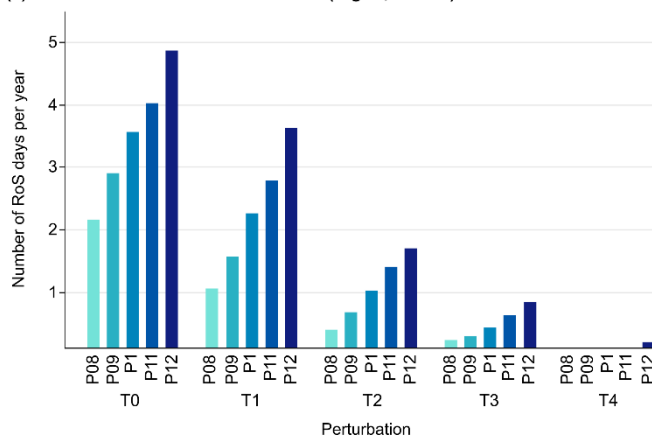


Figure S3: Number of RoS days per year for all perturbations in selected catchments with contrasting characteristics. Columns are grouped and colored according to the temperature (T) and precipitation (P) perturbations. Please note the different ranges of the y-axis in the individual panels.