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Predicting extreme sub-hourly precipitation intensification based on temperature shifts

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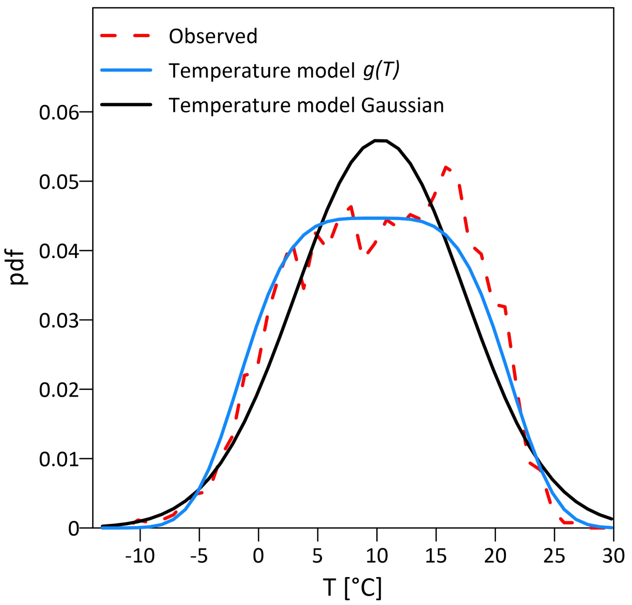

Figure S1. Empirical probability density of the average temperatures observed during the 24 hours preceding the 10-minute peak precipitation intensities (dashed red) and the estimated Generalized Gaussian temperature model $g(T)$ (solid blue) – as in Fig. 2b. A black line represents the estimated Normal (Gaussian) temperature model.

Table S1. Location of the climate stations used in the case study. Coordinates are in Swiss projections (LV95).

Name	Lon [m]	Lat [m]	Elevation [m]
Aadorf	2710518	1259824	539
Adelboden	2609372	1148939	1321
Aigle	2560404	1130713	381
Altdorf	2690181	1193564	438
Chasseral	2570845	1220158	1594
Lugano	2717874	1095883	273
Piz Corvatsch	2783156	1143524	3294
Säntis	2744188	1234920	2501

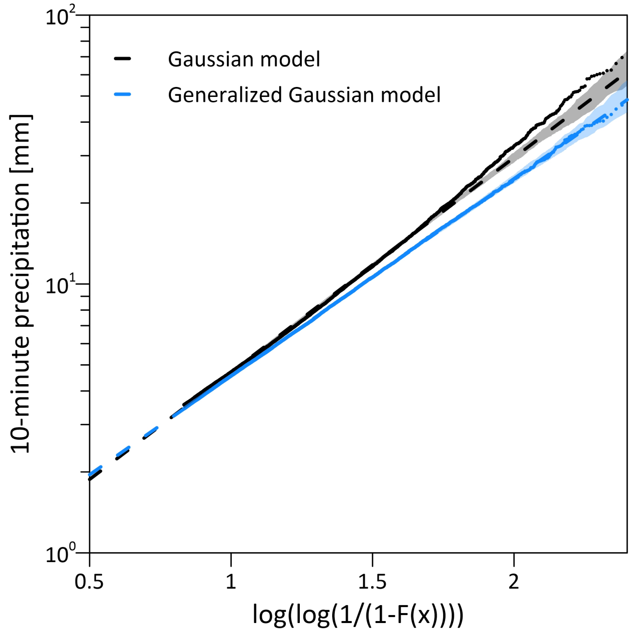

Figure S2. Example of empirical parent distributions of the event magnitude $F(x)$ emerging from the combination of the Weibull model $W(x;T)$ in Fig. 2a with two temperature models, namely the Generalized Gaussian temperature model $g(T)$ (blue line here and in Fig. S1) and the Gaussian temperature model (black line here and in Fig. S1), which has a heavier right tail. The shaded areas show the 5-95th sampling confidence intervals from Weibull tails fitted to the models; the black dots are not likely samples from a Weibull tail. The samples shown here consist of $2 \cdot 10^5$ points.

Table S2. Projections of changes in mean temperature μ [$^\circ$C], the standard deviation of temperature σ, and the occurrence of annual precipitation events n from 10 climate models obtained from the official CH2018 climate change projections of Switzerland. The projections are for the end of the century (2080-2099) in comparison with the reference period of 1981-2020, for the RCP8.5 emission scenario.

Climate model	Aadorf			Adelboden			Aigle			Altdorf			Chasseral			Lugano			Piz			Säntis		
	$\mu+$	$\sigma\cdot$	$n\cdot$	$\mu+$	$\sigma\cdot$	$n\cdot$	$\mu+$	$\sigma\cdot$	$n\cdot$	$\mu+$	$\sigma\cdot$	$n\cdot$	$\mu+$	$\sigma\cdot$	$n\cdot$	$\mu+$	$\sigma\cdot$	$n\cdot$	$\mu+$	$\sigma\cdot$	$n\cdot$	$\mu+$	$\sigma\cdot$	$n\cdot$
SMHI-RCA_MPIESM	2.8	0.99	0.96	4.4	1.29	1.03	2.9	1.07	0.97	4.1	1.20	1.03	3.1	1.04	0.95	2.6	1.06	1.00	4.2	1.37	1.03	3.5	0.99	0.96
SMHI-RCA_IPSL	3.2	1.01	0.93	5.5	1.39	0.96	3.2	1.15	0.89	5.3	1.32	0.99	3.5	1.06	0.89	2.9	1.06	0.94	5.5	1.47	0.96	3.8	1.03	0.92
SMHI-RCA_HADGEM	3.7	1.01	0.94	6.4	1.41	0.98	4.1	1.13	0.92	5.5	1.32	1.03	4.2	1.08	0.90	3.8	1.05	0.93	6.5	1.56	1.01	4.1	1.08	0.94
SMHI-RCA_ECEARTH	3.6	1.01	0.93	5.0	1.31	0.98	3.7	1.15	0.90	4.8	1.28	0.99	4.1	1.07	0.91	3.4	1.06	0.92	4.7	1.34	0.98	4.1	1.06	0.96
MPICSC-REMO2_MPIESM	2.0	0.97	1.01	3.0	1.07	0.96	1.6	1.03	1.03	2.5	1.07	0.98	2.6	1.05	1.00	2.2	1.04	0.96	3.2	1.12	0.95	2.5	1.02	1.02
MPICSC-REMO1_MPIESM	2.1	0.91	1.00	2.7	1.03	0.97	1.7	0.99	1.03	2.4	1.02	0.99	2.5	0.97	0.98	2.3	1.00	0.98	3.0	1.09	0.95	2.3	0.96	1.00
DMI-HIRHAM_ECEARTH	2.7	1.04	0.97	2.8	1.07	0.96	2.3	1.07	0.96	2.8	1.13	0.99	2.8	1.08	0.96	3.0	1.10	1.01	2.8	1.07	0.95	3.0	1.06	0.97
CLMCOM-CCLM4_MPIESM	2.2	0.94	0.93	2.5	1.01	0.93	1.8	0.99	0.92	2.1	1.02	0.93	2.3	0.98	0.90	1.5	1.02	0.89	2.6	1.00	0.92	2.6	0.98	0.92
CLMCOM-CCLM4_HADGEM	3.0	1.00	0.84	3.1	1.01	0.82	2.4	0.99	0.78	2.5	1.04	0.81	3.8	1.11	0.83	2.4	1.03	0.74	3.7	1.04	0.85	3.5	1.09	0.82
CLMCOM-CCLM4_ECEARTH	2.7	0.96	0.91	3.2	1.02	0.89	2.3	1.00	0.86	2.6	1.03	0.90	2.9	1.02	0.86	2.1	1.04	0.81	3.3	1.03	0.90	3.1	1.01	0.91

Table S3. Detail information of the CH2018 climate models presented in Table S2. The header indicates the model chains by general circulation model (GCM), initial condition (init), and the nested regional climate model (RCM).

GCM	init	RCM	Model name in Table S2
ICHEC-EC-EARTH	r3i1p1	DMI-HIRHAM5	DMI-HIRHAM_ECEARTH
	r12i1p1	CLMcom-CCLM4-8-17	CLMCOM-CCLM4_ECEARTH
		SMHI-RCA4	SMHI-RCA_ECEARTH
MOHC-HadGEM2-ES	r1i1p1	CLMcom-CCLM4-8-17	CLMCOM-CCLM4_HADGEM
		SMHI-RCA4	SMHI-RCA_HADGEM
MPI-M-MPI-ESM-LR	r1i1p1	CLMcom-CCLM4-8-17	CLMCOM-CCLM4_MPIESM
		MPI-CSC-REM2009	MPICSC-REMO1_MPIESM
		SMHI-RCA4	SMHI-RCA_MPIESM
	r2i1p1	MPI-CSC-REM2009	MPICSC-REMO2_MPIESM
IPSL-IPSL-CM5A-MR	r1i1p1	SMHI-RCA4	SMHI-RCA_IPSL

Table S4. Model parameters for the eight stations.

Name	λ_0	α	κ_0	b
Aadorf	0.313	0.111	0.865	0
Adelboden	0.073	0.222	0.516	0.026
Aigle	0.207	0.122	1.043	0
Altdorf	0.106	0.144	0.931	0
Chasseral	0.455	0.127	0.742	0.019
Lugano	0.855	0.084	1.113	0
Piz	0.942	0.109	1.143	0.032
Säntis	1.143	0.135	0.915	0.034

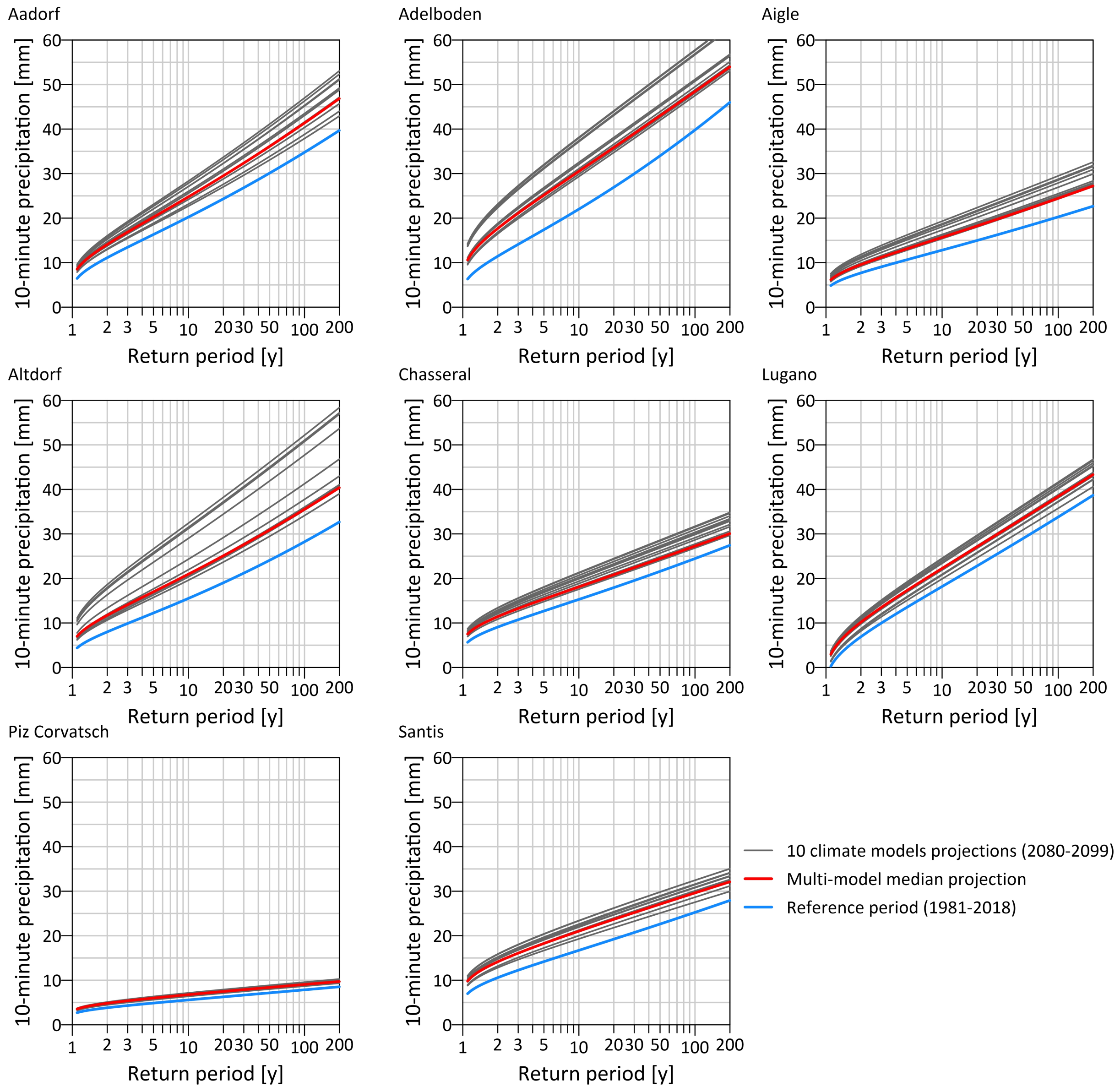

Figure S3. As Fig. 9 but for all 8 climate stations.