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CH2018 - Climate Scenarios for Switzerland

Climate model ensemble sub-selection for impact studies: Guide for users

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1. Rationale

Climate projections are subject to multiple uncertainties, one of them being climate model uncertainty: Depending on the chosen climate model and its specific setup, simulation results will differ even when following common simulation protocols. Therefore, instead of using single model estimates, climate projections are commonly communicated as multi model ensembles. The number of available realisations (ensemble members) tends to increase with advances in computing resources and often exceeds the current computing capabilities of many users of climate data. In the absence of expertise or guidelines, users often choose climate models at random.

In general, users are recommended to use the full model ensemble in order to best represent model uncertainty. To give users a hand for the meaningful sub-selection of individual ensemble members if really required, Sikorska-Senoner et al. (2024) have recently developed a novel selection procedure for a variety of common use cases tied to the CH2018 Climate Scenarios for Switzerland, such as heat waves, heavy precipitation, or snow-scarce winters. The method relies on climate indices, which are aggregated climate characteristics such as the annual number of hot days. Based on the strength of their climate change signal (CCS), the procedure generates a ranking of all ensemble members. From this ranking, three members that represent the best estimate and the upper and lower limits of the original model ensemble are selected and recommended to the users such as impact modellers (figure 1).

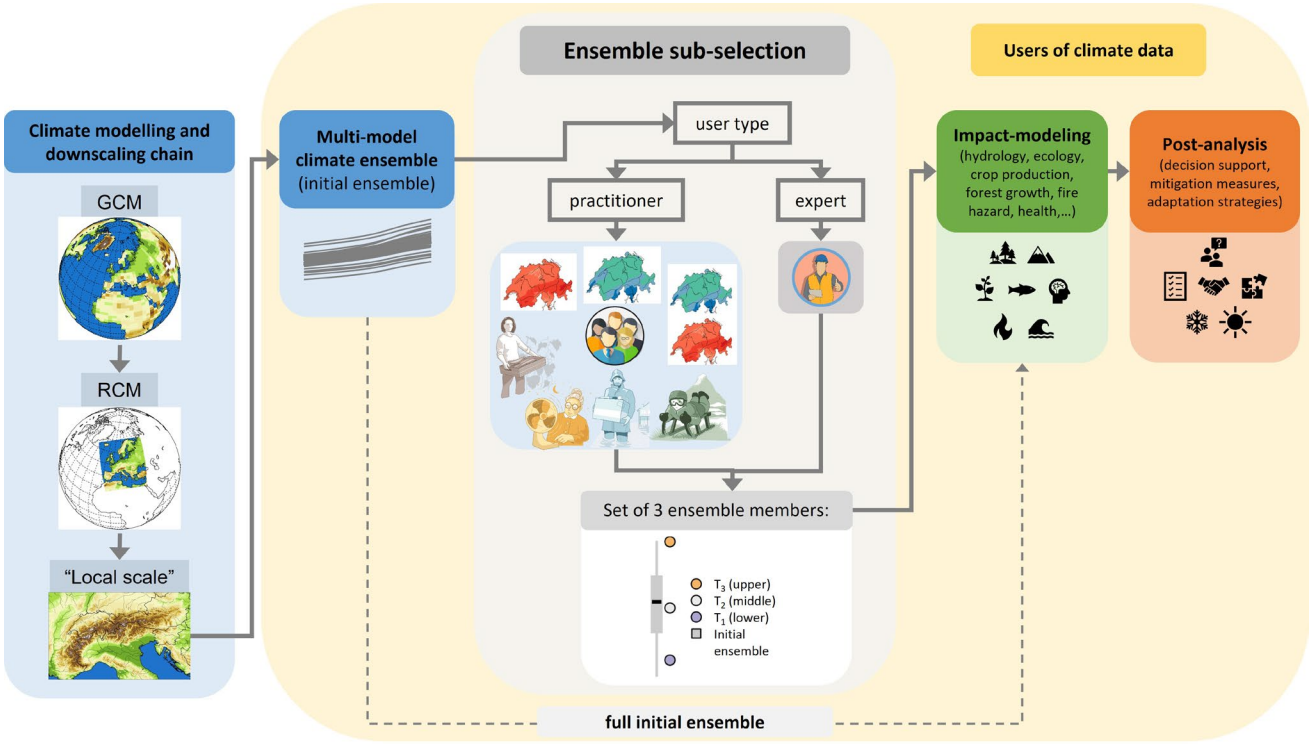

Figure 1 General concept of the sub-selection method, source: Sikorska-Senoner et al. (2024).

While this summary provides only a condensed description of the methodology with example results, the full description of the methodology can be found in Sikorska-Senoner, et al. (2024).

2. Data and Methods

Swiss Climate Scenarios

The sub-selection method has been developed and tested for the Swiss Climate Scenarios (current version: CH2018 (CH2018, 2018, DAILY-GRIDDED product)). It covers three Representative Concentration Pathways (RCPs): RCP 2.6, RCP 4.5 and RCP 8.5. For these RCPs, there are 12 (RCP 2.6), 25 (RCP 4.5) and 31 (RCP 8.5) individual model simulations available with an original spatial resolution of the raw RCM data of either 12.5 km (°0.11) or 50 km (°0.44). These individual simulations were quantile-mapped, resulting in bias-adjusted and downscaled daily series of several meteorological variables for the period 1981 to 2099 (see Table 1 in Appendix B and Feigenwinter et al. (2018) and Rajczak et al. (2016) for details).

Spatial aggregation

The method has been developed and tested firstly for Switzerland, and secondly for the five major Swiss bio-geographical sub-regions that reflect the main climatological features of Switzerland (Fischer et al., 2022) (Figure 2).

Figure 2 Five major bio-geographical regions of Switzerland (NCCS, 2024): 1) Jura; 2) Swiss Plateau; 3) Pre-Alps; 4) Alps; 5) South Alps.

Method summary

The sub-selection method is based on the ranking of the climate change signals (CCS) calculated for a set of climate indices (table 3 in Appendix B). The selection is performed in a way that the sub-ensemble best represents the spread of the initial climate model ensemble, assuming equality of the simulations, following the recommendations of Masson and Knutti (2011).

In detail, the method selects three members for each emission scenario (RCP) and a predefined set of application cases, representing the main climate impact drivers, such as heat-stress, drought or flood-risk. Currently, seven different cases have been defined (see sect. 3: Application cases). For each case, a set of key climate indices has been defined to best represent its climate impact drivers. Based on the value of the CCS for these indices, all M simulations within each RCP were ranked by the strength of their CCS from 1 (strongest CCS) to M (weakest CCS).

The ranks assigned serve for dividing members into three tercile groups: upper, middle and lower. Note that empirical quantiles are employed. Next, for each tercile group, one model (member) is selected that best meets the selection criteria. The result is a set of three members, labelled as T_1, T_2, and T_3, that are recommended to the users as lower, medium and upper model estimate, respectively. More details can be found in Sikorska-Senoner et al. (2024).

3. Application cases

Currently available cases

Seven application cases are currently available to the users, covering the most frequent uses of climate data in Switzerland. These are: temperature, precipitation, temperature & precipitation, drought, heatwave, heavy precipitation, and snow-scarce winter (table 2 in Appendix B). When in doubt about which application case to choose, we recommend using the overarching case (A: temperature), which is based on five temperature indices calculated on an annual and seasonal basis.

Expert case and further applications

The expert case is currently only available *on request* via *klimaszenarien@meteoswiss.ch*. It requires a personal exchange between users and service providers at MeteoSwiss, in order to best define climate indices based on the individual user's needs.

User feedback will be systematically collected with a view to include further cases into directly downloadable products as new cases are identified that are frequently requested by users. Feedback from users is therefore very welcome and can be sent directly to the following email address *klimaszenarien@meteoswiss.ch*.

4. Outlook and next generation

The developed method is directly transferable to other climate model ensembles (e.g., in other countries or regions, or with different climate simulations). The sub-selection will also be repeated for the next upcoming generation of the Swiss Climate Scenarios, to be released at the end of 2025 ("Klima CH2025" project).

5. Integration in Product Browser (PB)

The selection is available at the MeteoSwiss Website in the application *ProductBrowser* as *CH2018: Ensemble sub-selection.* Users of the climate scenarios data can currently choose from three emission scenarios (RCP2.6, RCP4.5 and RCP8.5), seven different application cases: temperature, precipitation, temperature & precipitation, drought, heat wave, heavy precipitation, and snow-scarce winter, and from several regions of interest (Switzerland, Jura, Swiss Plateau, Pre-Alps, Alps, South Alps).

Product types

The selection is built in the form of five different products integrated into *CH2018: Ensemble sub-selection*, which are (see Appendix A for examples):

1. *CH2018: Ensemble sub-selection (ranking)*, which shows the ranking of the available simulations for the selected application case according to the strength of the climate change signal calculated for the case-specific subset of climate indices;
2. *CH2018: Ensemble sub-selection (climate models selected by case)*, which shows the finally selected simulations per application case for all regions;
3. *CH2018: Ensemble sub-selection (climate models selected by region)*, which shows the finally selected simulations by region and for all application cases;
4. *CH2018: Ensemble sub-selection (climate change signal according to emission scenario)*, which shows the climate change signal for all indices per case and region;
5. *CH2018: Ensemble sub-selection (boxplot)*, which shows the climate change signal for all indices and simulations by emission scenario.

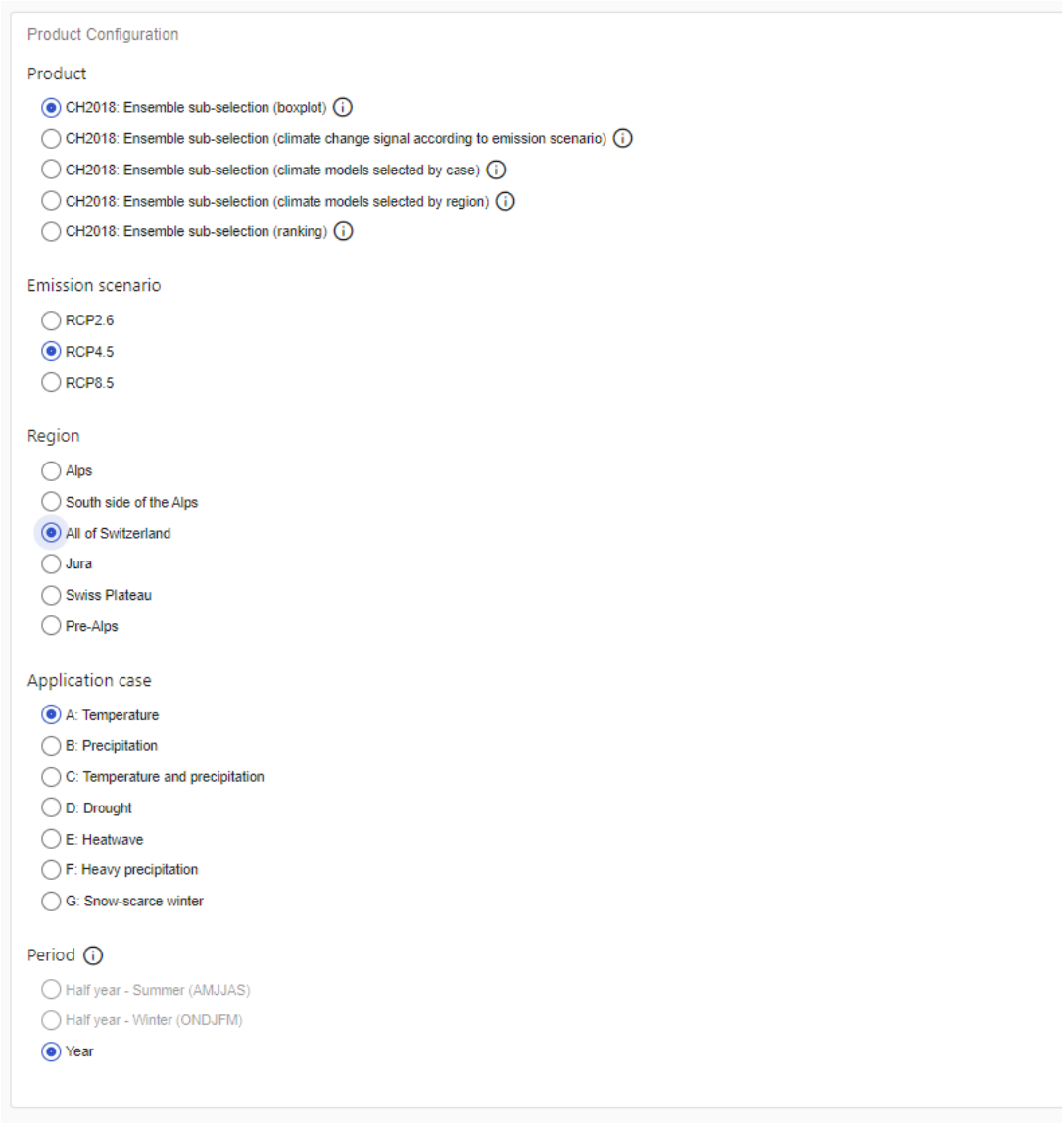

Figure 3 Product Configuration of the CH2018: Ensemble sub-selection in the Product Browser.

Product files

For the above-mentioned products, pre-calculated informative figures or tables can be visualised and downloaded directly from the ProductBrowser at: https://www.nccs.admin.ch/nccs/en/home/climate-change-and-impacts/swiss-climate-change-scenarios/ch2018-webatlas.html

Licence

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Appendix

Appendix A: Example products available in PB

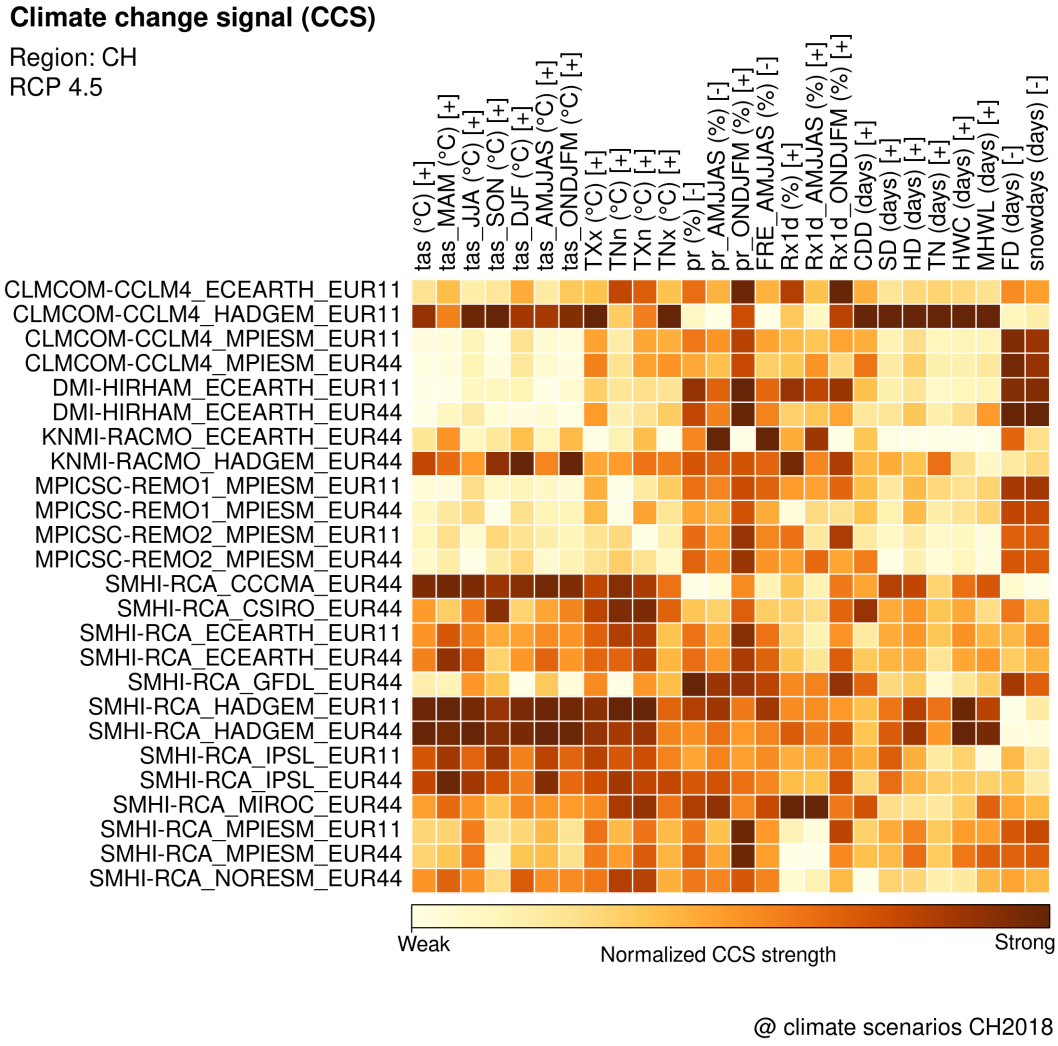


Figure 4 Normalized CCS for climate indices, RCP 8.5, region: CH. [Product name: "CH2018: Ensemble sub-selection (climate change signal according to emission scenario)".

Model ranks
Region: CH
Case: A: Temperature
RCP 4.5

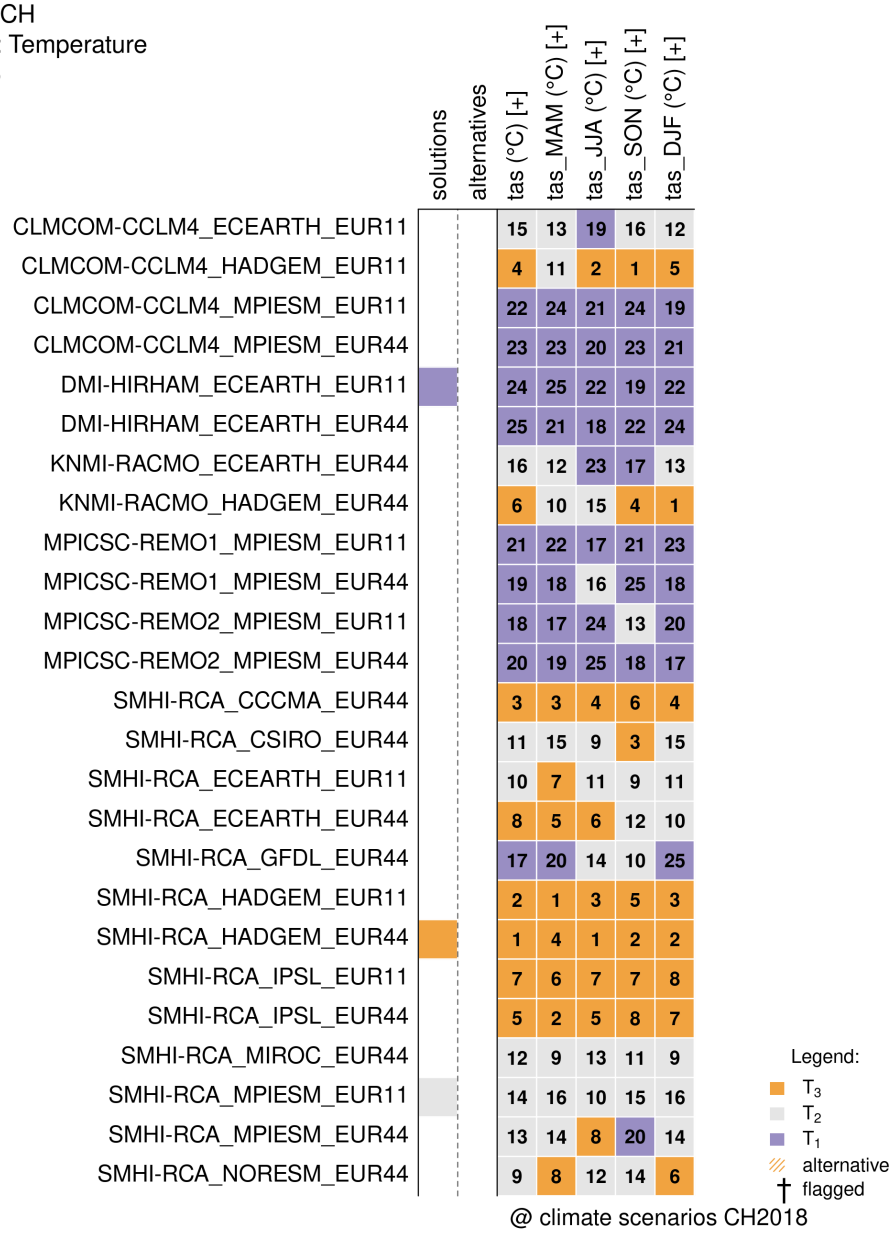


Figure 5 Climate model ranking according to their CCS strength for individual indices, Region CH, case: Temperature (A), RCP 8.5. [Product name: "CH2018: Ensemble sub-selection (ranking)".]

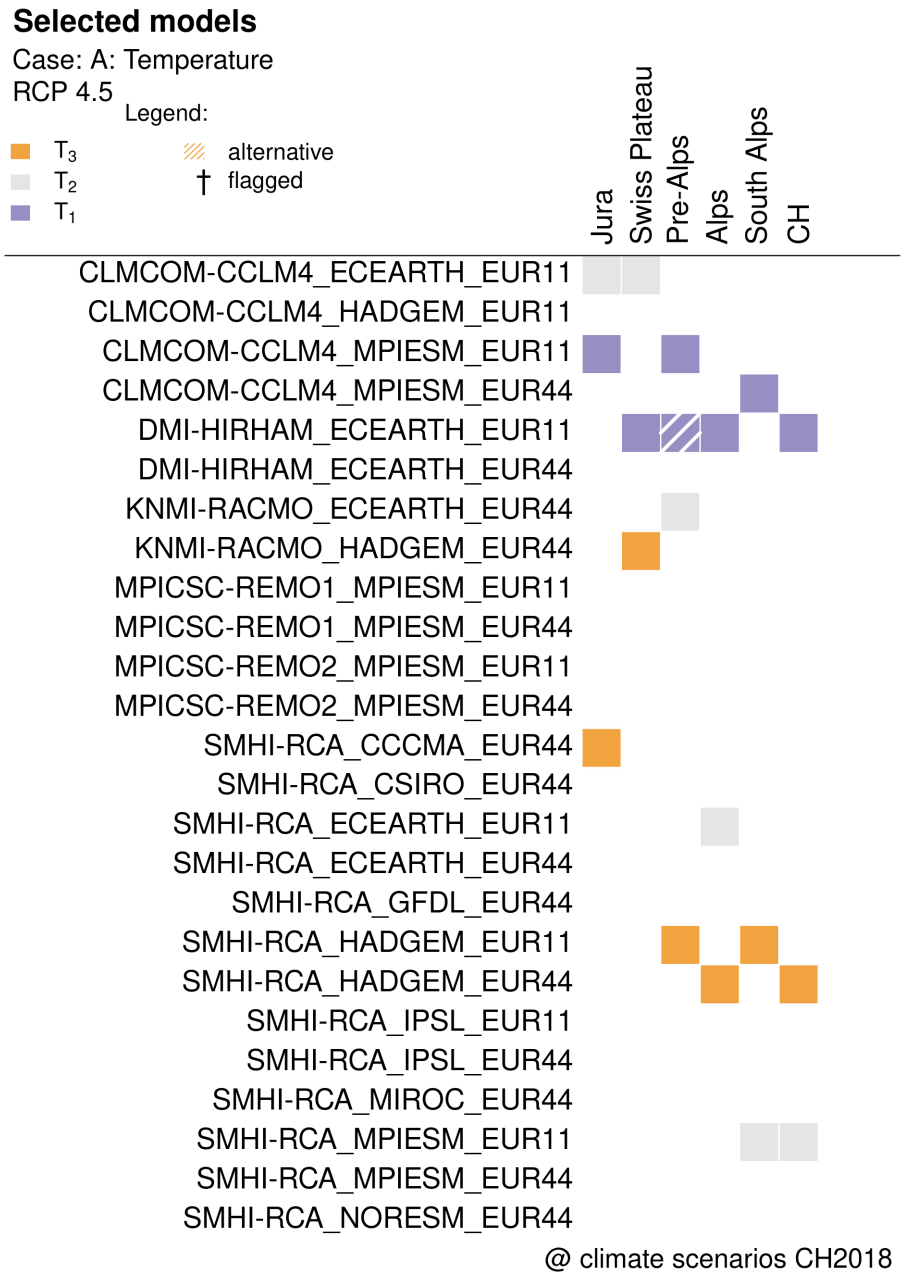


Figure 6 Selected climate models in various regions, case: Temperature (A), RCP 8.5. [Product name: "CH2018: Ensemble sub-selection (climate models selected by case)".]

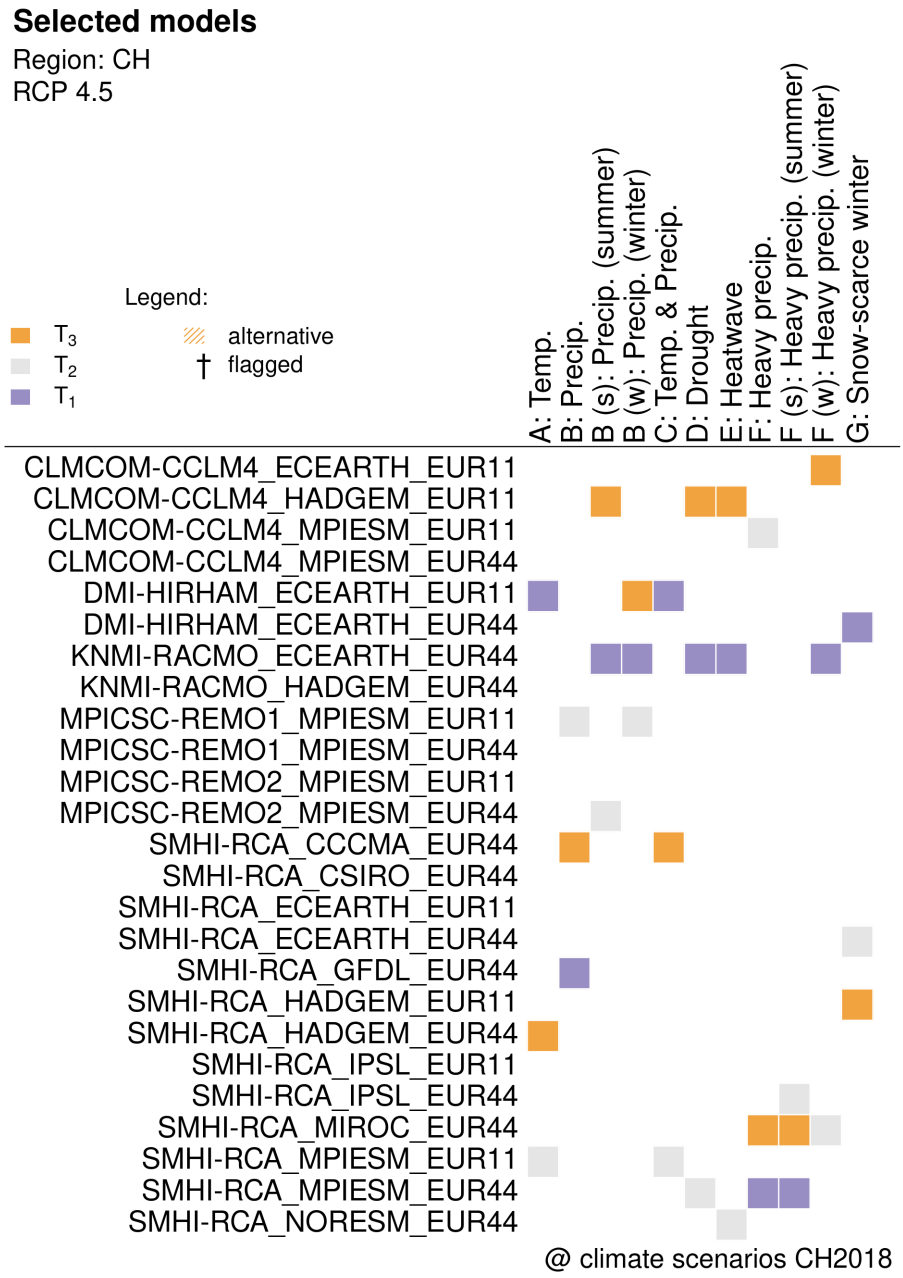


Figure 7 Selected climate models in various cases, region CH, RCP 8.5. [Product name: "CH2018: Ensemble sub-selection (climate models selected by region)".]

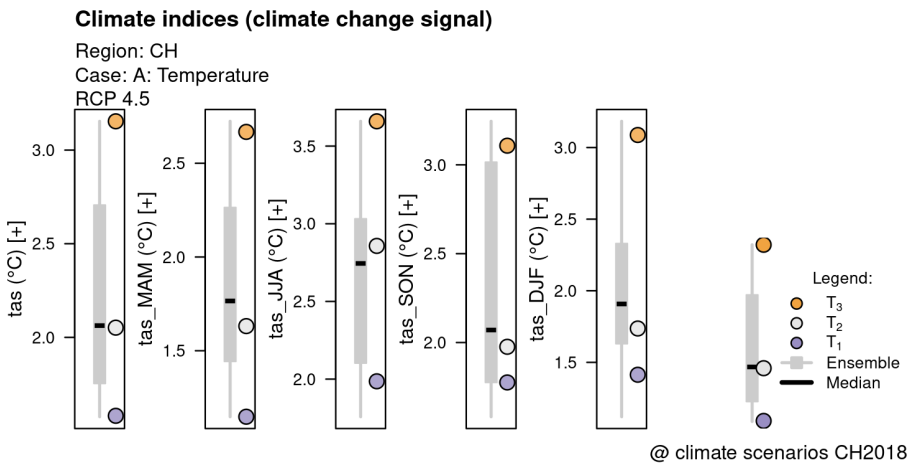


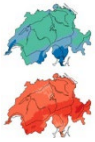
Figure 8 Climate indices for selected models (colored points) vs. all models (boxplots), region: CH, RCP 8.5, case: temperature (A). [Product name: "CH2018: Ensemble sub-selection (boxplot)".]

Appendix B: Supporting tables

Table 1 The initial ensemble CH2018 and its individual members.

No.	CH2018 Simulation Name	*RCP 2.6*		*RCP 4.5*		*RCP 8.5*	
		0.11°	*0.44°*	*0.11°*	*0.44°*	*0.11°*	*0.44°*
1	CLMCOM-CCLM4_ECEARTH			X		X	
2	CLMCOM-CCLM4_HADGEM			X		X	X
3	CLMCOM-CCLM4_MPIESM			X	X	X	X
4	CLMCOM-CCLM5_ECEARTH						X
5	CLMCOM-CCLM5_MIROC						X
6	CLMCOM-CCLM5_MPIESM						X
7	CLMCOM-CCLM5_HADGEM						X
8	DMI-HIRHAM_ECEARTH	X		X	X	X	X
9	ICTP-REGCM_HADGEM						X
10	KNMI-RACMO_ECEARTH				X		X
11	KNMI-RACMO_HADGEM		X		X		X
12	MPICSC-REMO1_MPIESM	X	X	X	X	X	X
13	MPICSC-REMO2_MPIESM	X	X	X	X	X	X
14	SMHI-RCA_ECEARTH	X	X	X	X	X	X
15	SMHI-RCA_IPSL			X	X	X	X
16	SMHI-RCA_HADGEM		X	X	X	X	X
17	SMHI-RCA_MPIESM		X	X	X	X	X
18	SMHI-RCA_CCCMA				X		X
19	SMHI-RCA_CSIRO				X		X
20	SMHI-RCA_MIROC		X		X		X
21	SMHI-RCA_NORESM		X		X		X
22	SMHI-RCA_GFDL				X		X
No. of members (M) in the ensemble:			**12**		**25**		**31**

Table 2 Application cases and the corresponding climate indices (see table 3 for their significance) with the desired CCS direction [+/-], where [+] means that the maximum and [-] the minimum CCS is ranked at the top. The climate indices are sorted for each case in the descending order of their importance with the most important indices marked in bold font*.

User-type	**Practitioner**							***Expert***
Case	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
	Temp. 	*Precip.* 	*Temp. & precip.* 	*Droughts* 	*Heat-waves* 	*Heavy precip.* 	*Snow-scarce winter* 	*Expert* 
Variant		year summer winter				year summer winter		
Focus period	year	year summer winter	year	summer	summer	year summer winter	winter	end-user specific
Climate indices & CCS	**tas** [+] tas_{JJA} [+] tas_{DJF} [+] tas_{MAM} [+] tas_{SON} [+]	<u>year:</u> **pr** [-]	**tas** [+] **pr** [-]	**pr_{AMJJAS}** [-] CDD [+] FRE_{AMJJAS} [-] tas_{AMJJAS} [+]	**tas_{JJA}** [+] HD [+] TN [+] SD [+] HWC [+] MHWL [+] TXx [+] TNx[+]	<u>year:</u> **Rx1d** [+]	**snowdays** [-] tas_{ONDJFM} [+] FD [-] TNn [+] TXn[+] pr_{ONDJFM} [-]	end-user specific [+/-]
		<u>summer:</u> **pr_{AMJJAS}** [-]				<u>summer:</u> **$Rx1d_{AMJJAS}$** [+]		
		<u>winter:</u> **pr_{ONDJFM}** [-]				<u>winter:</u> **$Rx1d_{ONDJFM}$** [+]		

Periods: MAM (March, April, May), JJA (June, July, August), SON (September, October, November), DJF (December, January, February). Summer half-year - AMJJAS (April-September), winter half-year - ONDJFM (October-November).
** The end-use specific selection of climate indices for the case H should always be done following the indices importance.*

Table 3 List and significance of the climate indices for ensemble sub-selection and the corresponding methodology to calculate spatial averages in order to derive climate change signals (CCS).

Variable name	Abbreviation	Unit	Significance	CCS
Temperature	***tas***	°C	Daily mean 2m temperature	absolute
Precipitation	***pr***	mm/day	Daily precipitation sum	relative
Hot days	***HD***	-	No. of days per year with the daily maximum temperature >30°C	absolute
Summer days	***SD***	-	No. of days per year with the daily maximum temperature >25°C	absolute
Tropical nights	***TN***	-	No. of days per year with the daily minimum temperature >20°C	absolute
Frost days	***FD***	-	No. of days per year with the daily minimum temperature <0°C	absolute
Snow days	***snowdays***	-	No. of days per year with tas<2°C and pr>1 mm	absolute
Heat wave counter	***HWC***	-	No. of events with five or more consecutive days with the daily maximum temperature >30°C	absolute
Mean maximum heat wave length	***MHWL***	days	Length of the longest consecutive period with the daily maximum temperature >30°C	absolute
Consecutive dry days	***CDD***	days*	Maximum No. of consecutive dry days (pr<1 mm) per period (season, year)	absolute
Hottest day of the year	***TXx***	°C	Yearly maximum of the daily maximum temperature	absolute
Coldest night of the year	***TNn***	°C	Yearly minimum of the daily minimum temperature	absolute
Coldest day of the year	***TXn***	°C	Yearly minimum of the daily maximum temperature	absolute
Hottest night of the year	***TNx***	°C	Yearly maximum of the daily minimum temperature	absolute
Wet-day frequency	***FRE***	-	No. of days per year with tas≥1 mm/day	absolute
Wet-day intensity	***INT***	mm/day	Mean precipitation on wet days with tas≥1 mm/day	relative
Maximum 1-day precipitation	***Rx1d***	mm	Maximum precipitation over 1 day	relative

**Calculated after Frich et al. (2002) and Alexander et al. (2006).*