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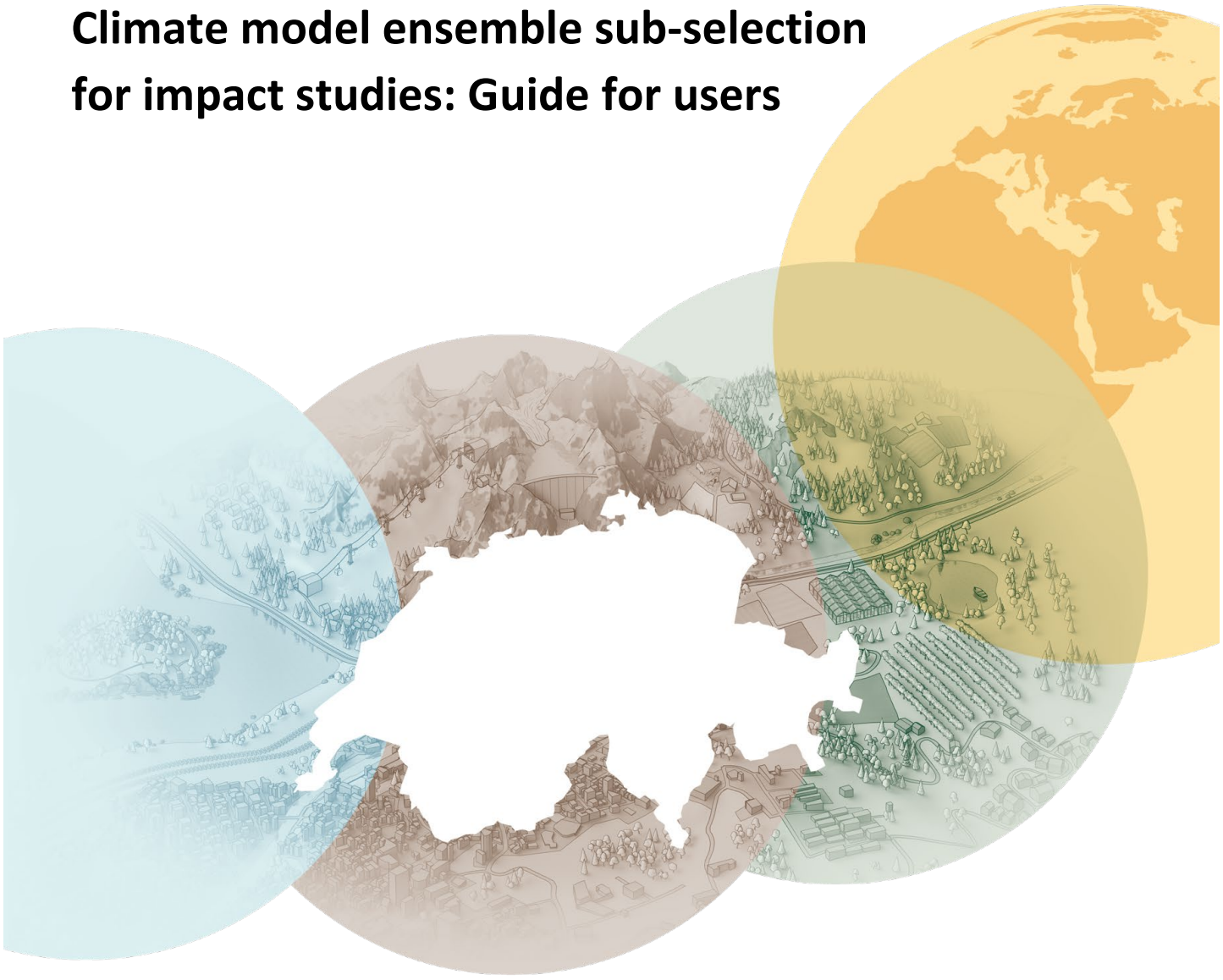
Climate CH2025

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



Climate CH2025

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Climate CH2025

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

Version 1.0, 30.03.2026

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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 (e.g. impact modellers). 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 to best represent model uncertainty. To support users in defining a meaningful sub-selection of individual ensemble members, if really required, Sikorska-Senoner et al. (2024) have developed a novel selection procedure for a variety of common use cases in impact studies tied to the key messages of the CH2018 Climate Scenarios for Switzerland such as heat, 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 or yearly mean temperature. Based on the strength of their **c**limate **c**hange **s**ignal (CCS), the procedure generates a ranking of all ensemble members. From this ranking, three members that represent the best estimate, the upper, and the lower limit of the original model ensemble are selected and recommended to the users (figure 1).

The originally developed ensemble sub-selection has now been updated for the recently released Swiss *Climate* CH2025 Scenarios (MeteoSwiss and ETH Zurich, 2025a). While this summary provides only a condensed description of the updated methodology with example results specific for *Climate* CH2025, the full description of the methodology, developed based on CH2018, can be found in Sikorska-Senoner et al. (2024).

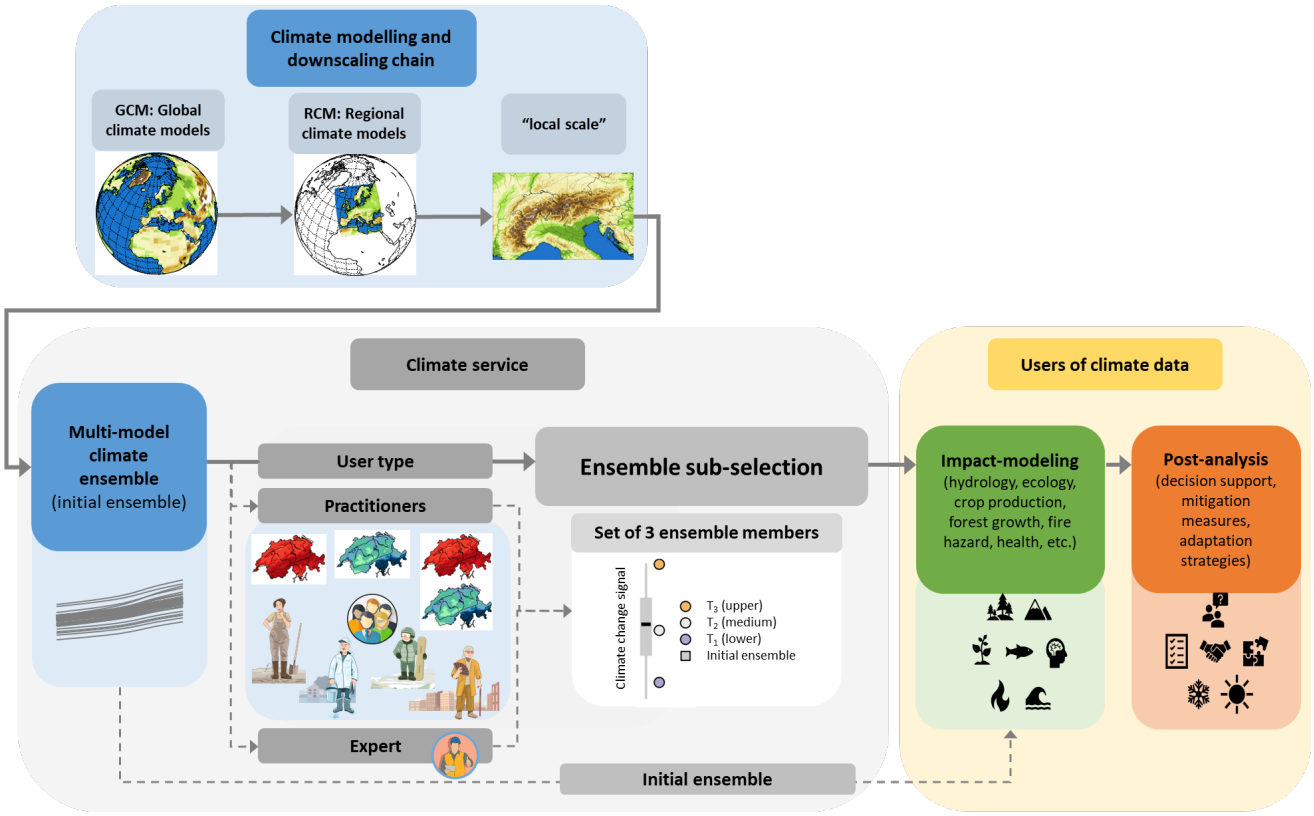

Figure 1 General concept of the sub-selection method, adapted from Sikorska-Senoner et al. (2024).

2. Data and Methods

Swiss *Climate* CH2025 Scenarios

The original sub-selection method has been developed and tested for the Swiss Climate Scenarios CH2018 (CH2018, 2018) using three Representative Concentration Pathways (RCPs): RCP 2.6, RCP 4.5 and RCP 8.5. The current version of the ensemble sub-selection builds upon the previous one but has been updated for the Swiss Scenarios *Climate* CH2025 (MeteoSwiss and ETH Zurich, 2025a). Therefore, it follows the concept of Global Warming Levels (GWLs), and the selection of climate models is performed based on GWLs rather than RCPs. The sub-selection is applied individually to each given GWL and is performed on the DAILY-GRIDDED dataset of *Climate* CH2025, i.e. on bias-adjusted and downscaled daily 1 km grids for Switzerland (MeteoSwiss and ETH Zurich, 2025a, Herrmann et al. 2026). These data are available for 26 GCM-RCM pairs (simulations of a specific regional climate model driven by a specific global climate model) for GWLs 1.5, 2.0 and 2.5 and for 24 GCM-RCM pairs in the case of GWL 3.0 (see Table 1 in the Appendix B, see also MeteoSwiss and ETH Zurich, 2025a for more details on GCM-RCM pairs). Further GWLs may be added in the future.

Ensemble sub-selection overview

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) for the entire available set of simulations for a given GWL and with respect to the reference period 1991-2020. The selection is performed in such 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 GWL 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. For these indices, all *M* simulations within a given GWL were ranked according to the strength of their CCS from *1* (strongest CCS) to *M* (weakest CCS). Based on their ranks, the members are assigned to three tercile groups: upper, middle and lower tercile. 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, which are recommended to the users as the lower, medium and upper model estimate for the respective use case and the respective GWL. These three selected ensemble members should represent the median (50th percentile), the strongest (95th percentile) and the weakest (5th percentile) CCS. Therefore, this sub-selection should, to a certain extent, represent the spread of the complete climate model ensemble. In principle, the full ensemble should be used; if this is not possible, the sub-selection can be used instead. 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: 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, to best define climate indices based on the individual user's needs.

Regions

The subselection is available for the entrire Switzerland and for five major bio-geographical regions of Switzerland: Jura, Swiss Plateau, Pre-Alps, Alps, South Alps (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.

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

As demonstrated by applications to two different editions of the Swiss climate scenarios (CH2018 and *Climate* CH2025), using two different concepts (RCPs and GWLs), the sub-selection method is highly flexible. It can be transferred directly to other climate model ensembles, for example in other countries or regions, or for different climate simulations.

5. Integration in Product Browser

The sub-selection is available via the MeteoSwiss Website in the application *ProductBrowser* as *CH2025: Ensemble sub-selection* (Figure 3). Users of the climate scenario data can currently choose pre-selected climate models for four Global Warming Levels (GWL1.5, GWL2.0, GWL2.5, and GWL3.0), seven different application cases (temperature, precipitation, temperature & precipitation, drought, heat wave, heavy precipitation, and snow-scarce winter) and from several regions of interest. In addition, there are two half-year variants (summer and winter half year) available for two cases: precipitation and heavy precipitation.

Product types

The selection is built in the form of five different products integrated into *CH2025: Ensemble sub-selection*, which are (see Appendix A for examples):

1. *CH2025: Ensemble sub-selection (climate change signal according to Global Warming Level)*, which shows the climate change signal for all indices per case and region (Figure A1 in Appendix A).
2. *CH2025: 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 (Figure A2 in Appendix A).

3. *CH2025: Ensemble sub-selection (climate models selected by case)*, which shows the finally selected simulations per application case for all regions (Figure A3 in Appendix A).
4. *CH2025: Ensemble sub-selection (climate models selected by region)*, which shows the finally selected simulations by region and for all application cases (Figure A4 in Appendix A).
5. *CH2025: Ensemble sub-selection (boxplot)*, which shows the climate change signals of the climate indices specific for a given application case for the three selected models in comparison to the original climate model ensemble. These plots are displayed per case and region (Figure A5 in Appendix A).

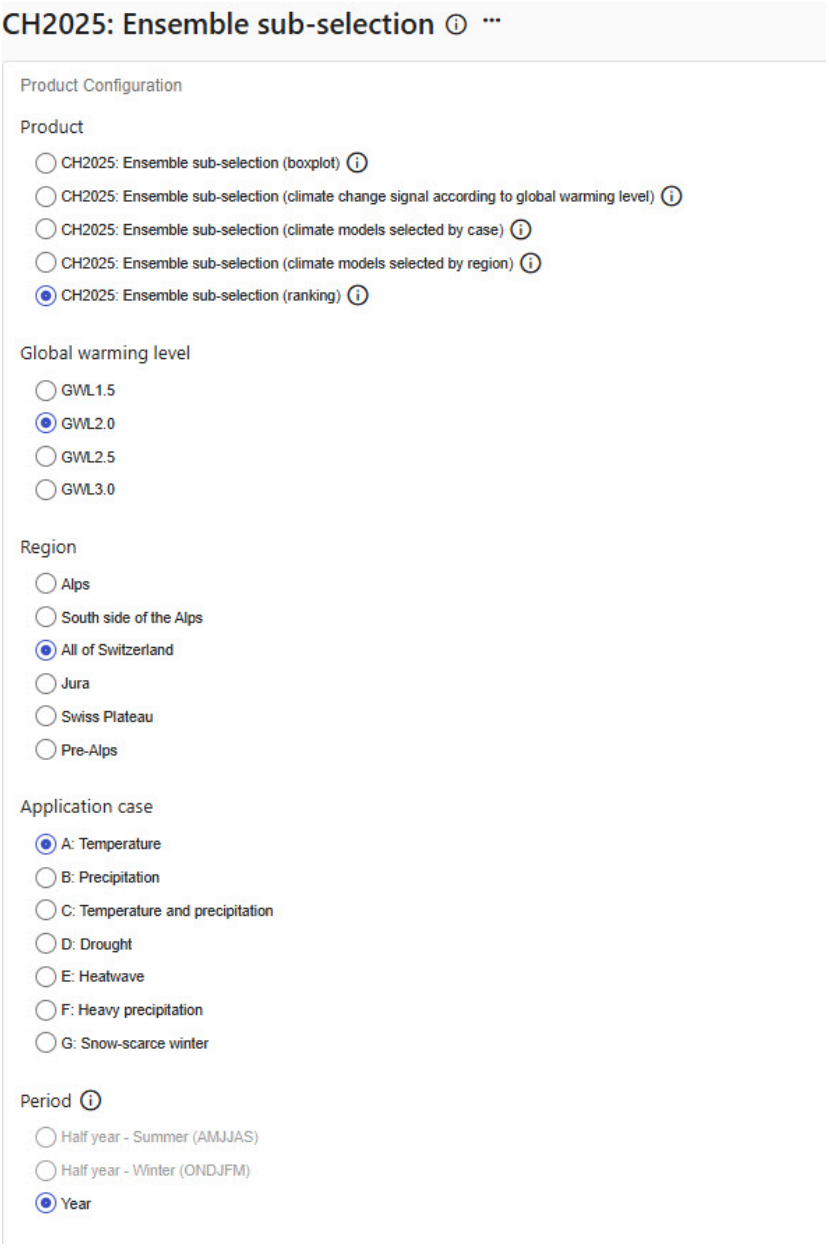

Figure 3 Product Configuration of the CH2025: Ensemble sub-selection in the Product Browser.

Underlying data

The DAILY-GRIDDED dataset CH2025 (MeteoSwiss and ETH Zurich, 2025b) is freely available as a part of the Open Government Data at: https://opendatadocs.meteoswiss.ch/de/c-climate-data

All CH2025 datasets are published under the CC BY 4.0 license that includes the right to share (copy and redistribute in any medium or format) and adapt (remix, transform, and build upon for any purpose, even commercially) the data under the condition that proper reference to CH2025 is given (see https://www.meteoswiss.admin.ch/climate/climate-change/swiss-climate-scenarios/reports-data-and-graphs-of-climate-change-scenarios/climate-ch2025-datasets.html).

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Appendix

Appendix A: Example products available in Product Browser

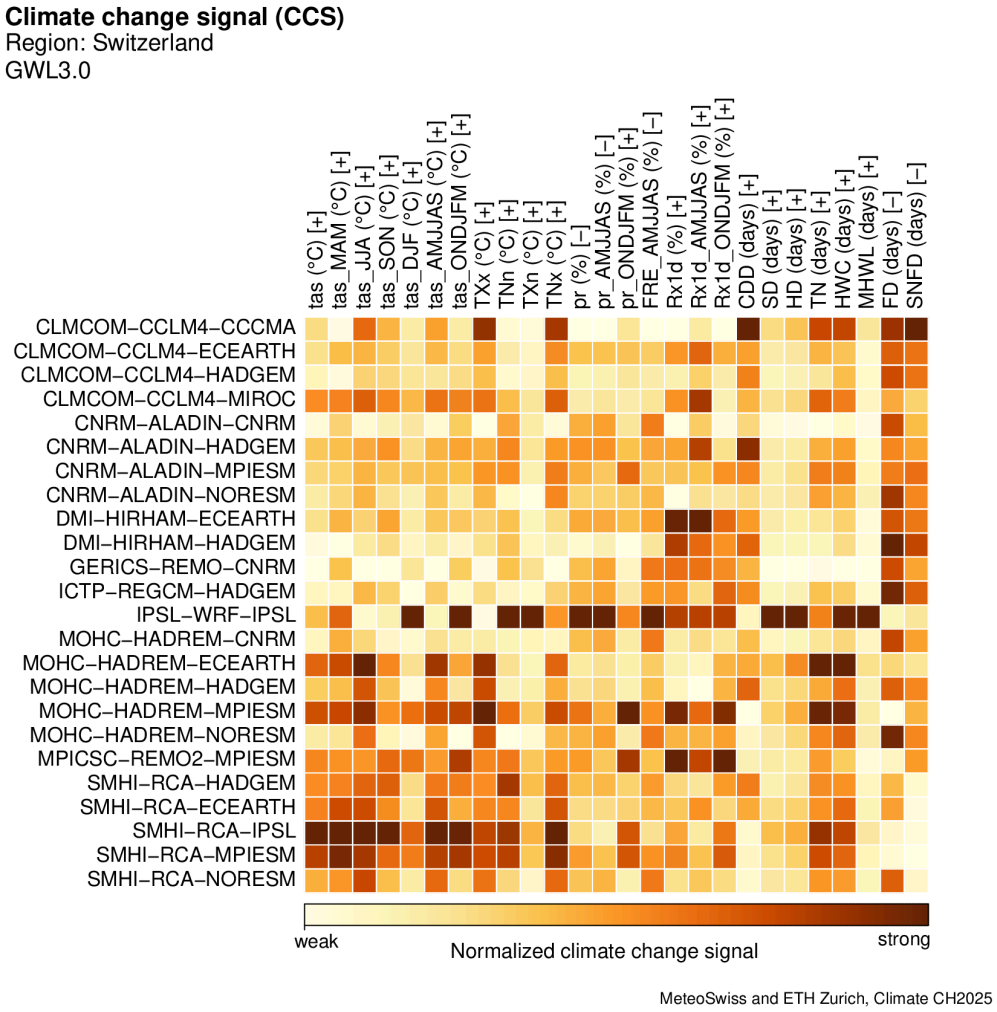


Figure A1 Normalized CCS for climate indices, GWL3.0, region: CH. [Product name: "CH2025: Ensemble sub-selection (climate change signal according to Global Warming Level)".

Ranking of climate models
Region: Switzerland
Application case: A, Temperature
GWL3.0

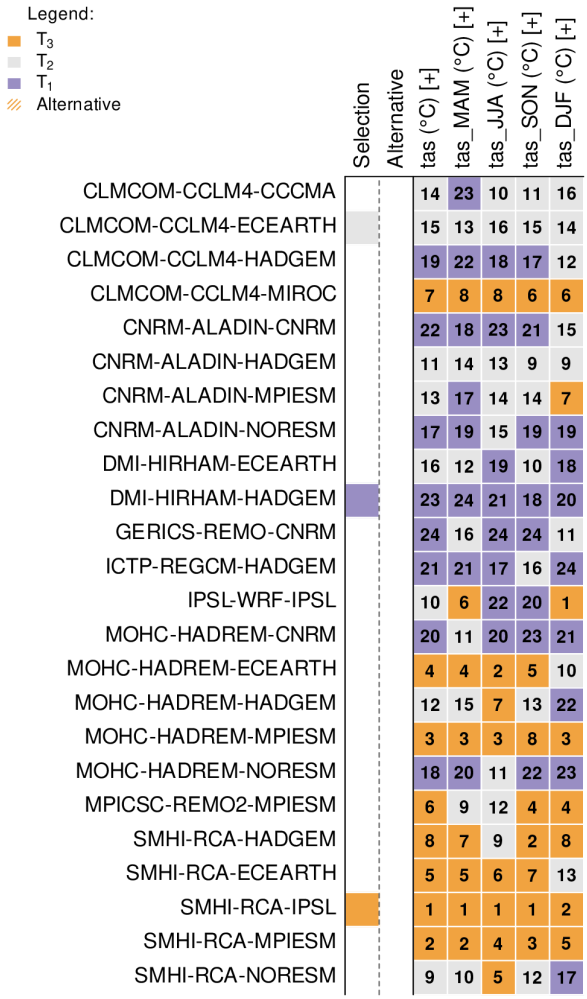


Figure A2 Climate model ranking according to their CCS strength for individual indices, Region CH, case: Temperature (A), GWL3.0. [Product name: "CH2025: Ensemble sub-selection (ranking)".]

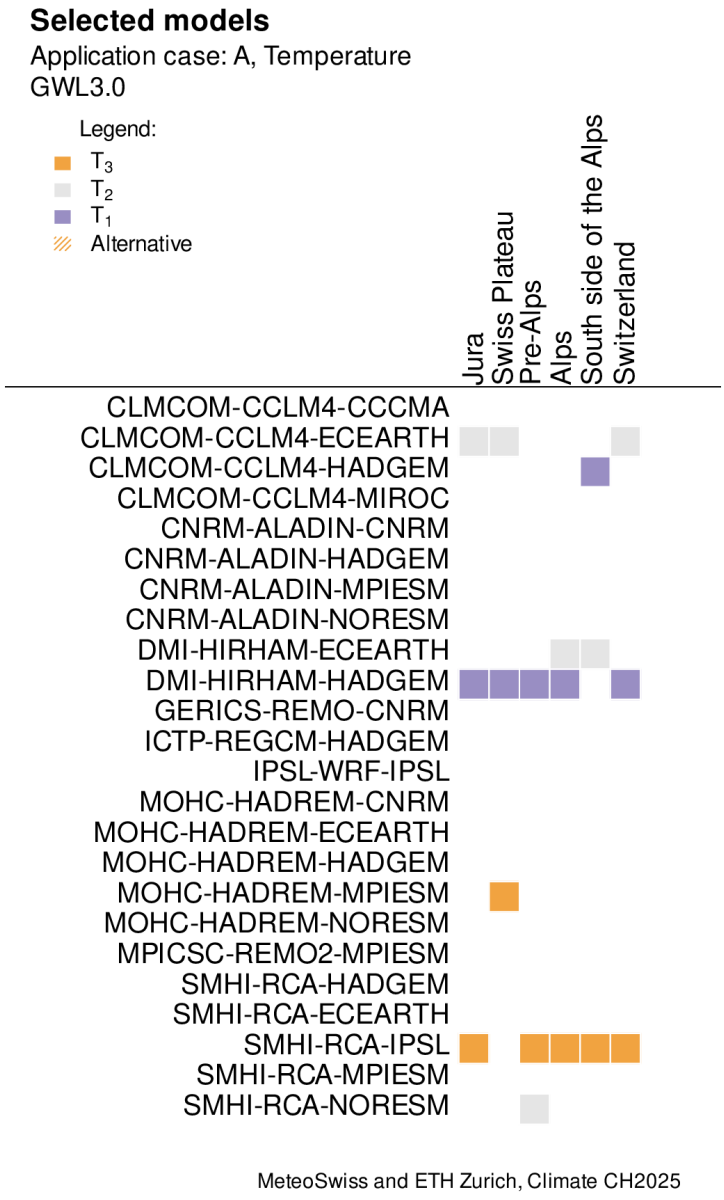


Figure A3 Selected climate models in various regions, case: Temperature (A), GWL3.0. [Product name: "CH2025: Ensemble sub-selection (climate models selected by case)".]

Figure A4 Selected climate models in various cases, region CH, GWL3.0. [Product name: "CH2025: Ensemble sub-selection (climate models selected by region)".]

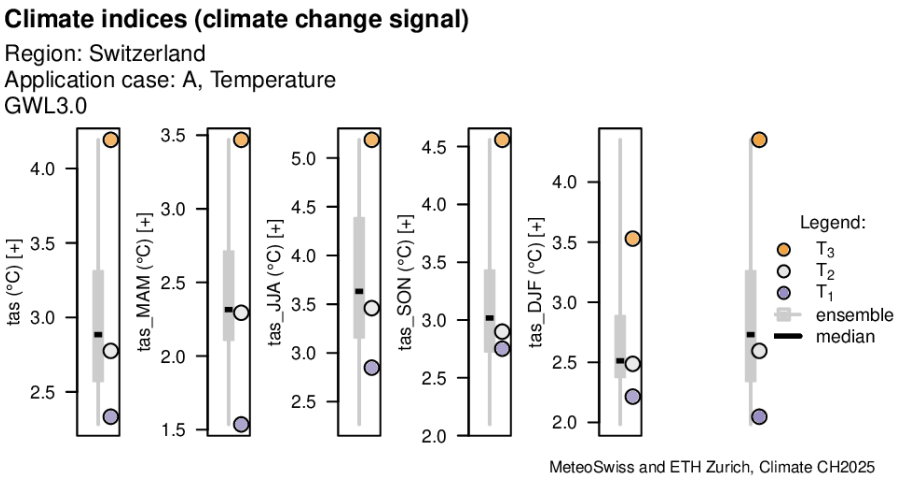


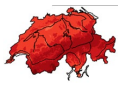
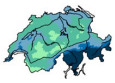
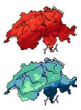
Figure A5 Climate indices for selected models (colored points) vs. all models (boxplots), region: CH, GWL3.0, case: temperature (A). [Product name: "CH2025: Ensemble sub-selection (boxplot)".]

Appendix B: Supporting tables

Table 1 The initial ensemble CH2025 of climate models for three Global Warming Levels.

No.	RCM-GCM pair	*GWL1.5*	*GWL2.0*	*GWL2.5*	*GWL3.0*
1	CLMCOM-CCLM4-CCCMA	X	X	X	X
2	CLMCOM-CCLM4-ECEARTH	X	X	X	X
3	CLMCOM-CCLM4-HADGEM	X	X	X	X
4	CLMCOM-CCLM4-MIROC	X	X	X	X
5	CLMCOM-CCLM4-MPIESM	X	X	X	-
6	CNRM-ALADIN-CNRM	X	X	X	X
7	CNRM-ALADIN-HADGEM	X	X	X	X
8	CNRM-ALADIN-MPIESM	X	X	X	X
9	CNRM-ALADIN-NORESM	X	X	X	X
10	DMI-HIRHAM-ECEARTH	X	X	X	X
11	DMI-HIRHAM-HADGEM	X	X	X	X
12	GERICS-REMO-CNRM	X	X	X	X
13	ICTP-REGCM-HADGEM	X	X	X	X
14	IPSL-WRF-IPSL	X	X	X	X
15	MOHC-HADREM-CNRM	X	X	X	X
16	MOHC-HADREM-ECEARTH	X	X	X	X
17	MOHC-HADREM-HADGEM	X	X	X	X
18	MOHC-HADREM-MPIESM	X	X	X	X
19	MOHC-HADREM-NORESM	X	X	X	X
20	MPICSC-REMO1-MPIESM	X	X	X	-
21	MPICSC-REMO2-MPIESM	X	X	X	X
22	SMHI-RCA-HADGEM	X	X	X	X
23	SMHI-RCA-ECEARTH	X	X	X	X
24	SMHI-RCA-IPSL	X	X	X	X
25	SMHI-RCA-MPIESM	X	X	X	X
26	SMHI-RCA-NORESM	X	X	X	X
No. of members (M) in the ensemble:		**26**	**26**	**26**	**24**

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** [+]	**SNFD** [-] 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 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
Snowfall days	***SNFD***	days	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 heatwave 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 one day	relative

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