Supplement of Hydrol. Earth Syst. Sci., 29, 2321–2337, 2025
https://doi.org/10.5194/hess-29-2321-2025-supplement

Hydrology and Earth System Sciences
Open Access

Supplement of

Analysis of past and future droughts causing clay shrinkage in France

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Supplement 1 – Selection of a single ISBA patch

To select a single ISBA patch for this study, we use the method developed by Barthelemy et al. (2023). The concept is to compute a yearly drought magnitude index (YDMI), from soil moisture simulations.

A unitless Soil Wetness Index (SWI) is derived from ISBA simulations that include an interactive vegetation leaf area index (LAI). In this configuration of ISBA, LAI is not prescribed but updated daily from modeled leaf biomass, taking into account mass-based leaf nitrogen concentration (Calvet and Soussana, 2001). Phenology is driven by photosynthesis. Since modeled photosynthesis depends on soil moisture, leaf temperature, solar radiation, and air humidity, all environmental conditions can affect the simulated LAI. The interactive LAI has the advantage of incorporating vegetation feedback in response to soil drought.

For each grid cell of the ISBA model, SWI results from the rescaling of volumetric soil moisture (W_{G}, in $m^3\ m^{-3}$) between field capacity (W_{fc}) and wilting point (W_{wilt}) volumetric soil moisture values derived from texture-dependent pedotransfer functions:

$$\mathrm{SWI} = (W_{\mathrm{G}} - W_{\mathrm{wilt}})/(W_{\mathrm{fc}} - W_{\mathrm{wilt}}).$$

The magnitude is the sum of the daily SWI deficit values (equivalent to an integral) below a given SWI threshold. The latter corresponds to a certain percentile of the empirical SWI distribution calculated over a given ISBA grid point. Following Barthelemy et al. (2023), the SWI of a deep model soil layer (layer 8, from 0.8 to 1.0 m) is used, and the averaged magnitudes are computed with thresholds corresponding to the 1st to 5th percentiles.

The YDMI is confronted with a sample of insurance claims data by performing a Kendall rank correlation, which yields a Kendall tau metric. We apply this method with the same sample of insurance data to ISBA simulations that separate patch and layer, and drought magnitude characteristics (threshold value defining drought periods). Figure S1 shows that the highest Kendall tau is obtained for the deciduous broadleaf trees patch (patch number 4). Therefore, the SWI of this patch is used to determine the YDMI.

References:

Barthelemy, S., Bonan, B., Calvet, J.-C., Grandjean, G., Moncoulon, D., Kapsambelis, D., and Bernardie, S.: A new approach for drought index adjustment to clay-shrinkage-induced subsidence over France: advantages of the interactive leaf area index, Nat. Hazards Earth Syst. Sci., 24, 999–1016, https://doi.org/10.5194/nhess-24-999-2024, 2024.

Calvet, J.-C. and Soussana, J.-F.: Modelling CO_2-enrichment effects using an interactive vegetation SVAT scheme, Agric. For. Meteorol., 108, 129–152, https://doi.org/10.1016/S0168-1923(01)00235-0, 2001.

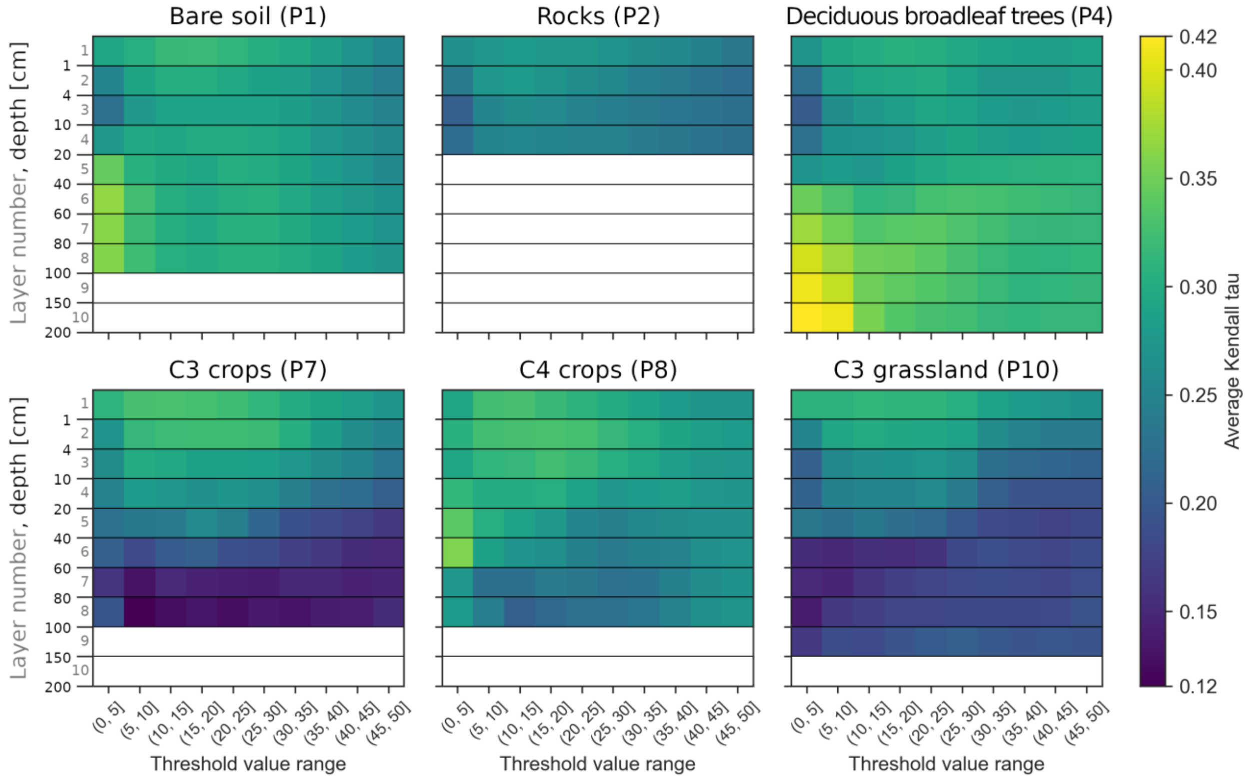

Figure S1 – Results of the Kendall rank correlation between drought magnitude and insurance claims, separating model patches, soil layers and magnitude threshold values (method developed by Barthélemy et al. (2023)). In this study, YDMI corresponds to deciduous broadleaf trees (patch number 4), soil layer 8 (80-100 cm), and average (0,5] magnitude percentiles.

Supplement 2 – Historical vs. projected simulations

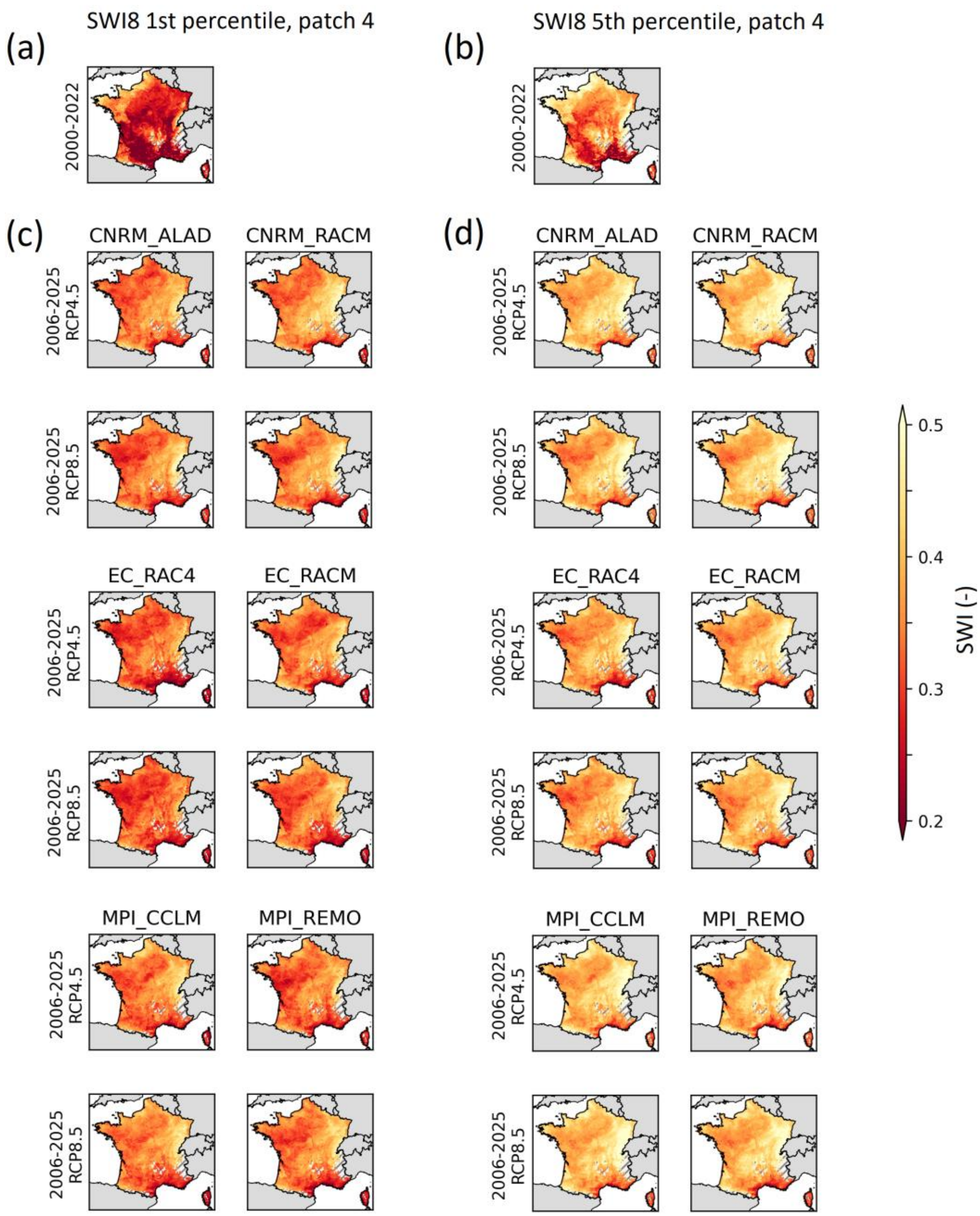

Figure S2 – Drought threshold values for (a,b) historical, and (c,d) projected simulations: (a,c) 1st percentile, (b,d) 5th percentile, for deciduous broadleaf trees (patch number 4), soil layer 8 (80-100 cm).

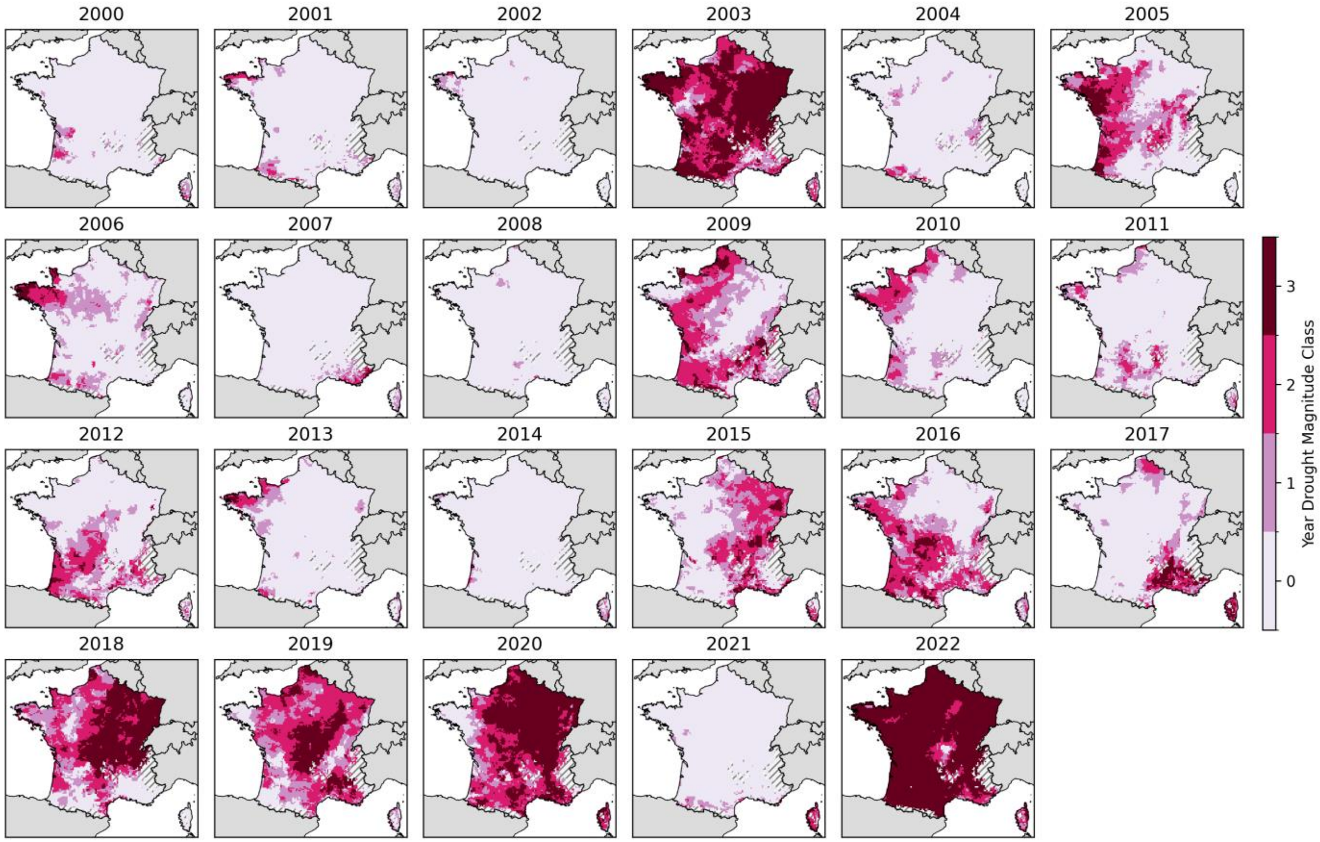

Figure S3 – Year drought magnitudes in classes for years 2000 to 2022, computed over France in each grid point from the ISBA historical simulation. Areas with gray hatching correspond to filtered mountain areas (average altitude > 1100 meters).

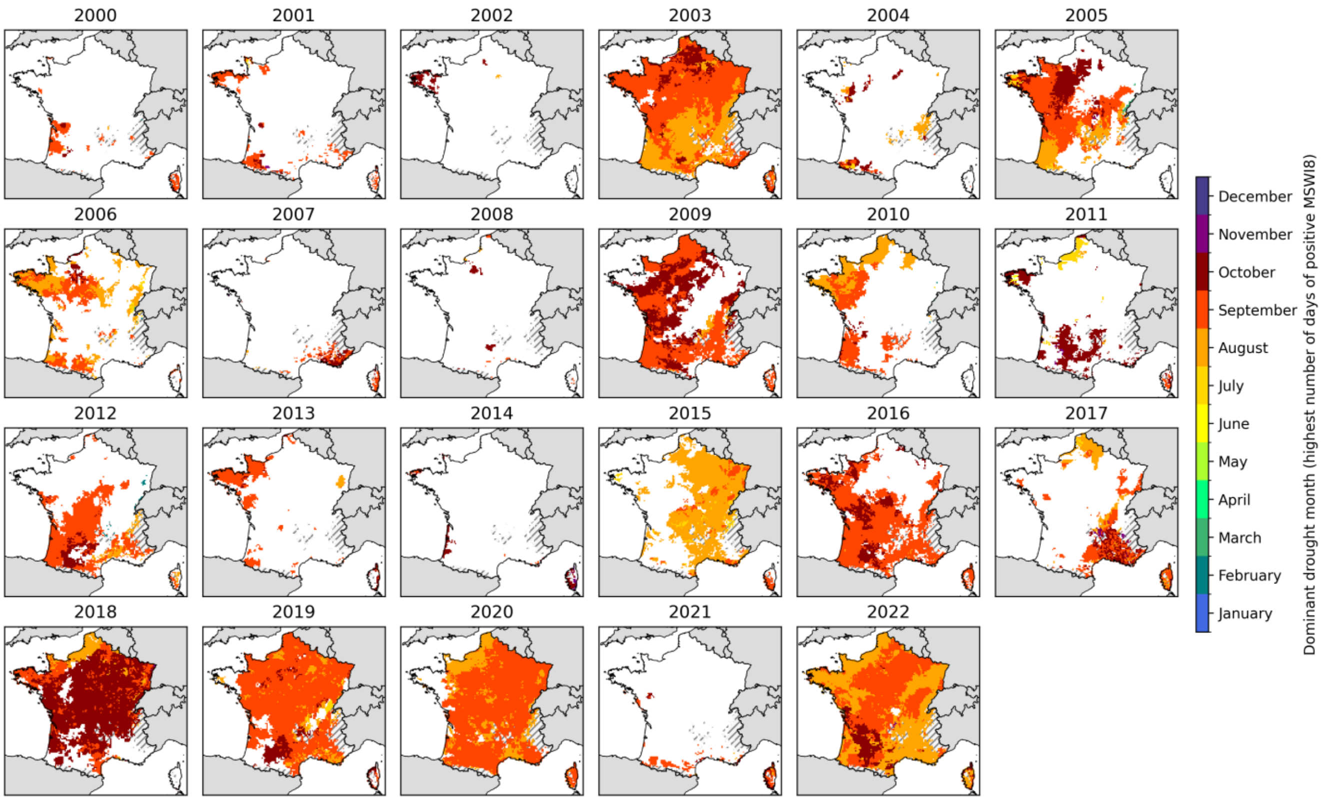

Figure S4 – Dominant drought month (highest number of days with positive magnitude) for years 2000 to 2022, computed over France in each grid point from the ISBA historical simulation. Areas with gray hatching correspond to filtered mountain areas (average altitude > 1100 meters).

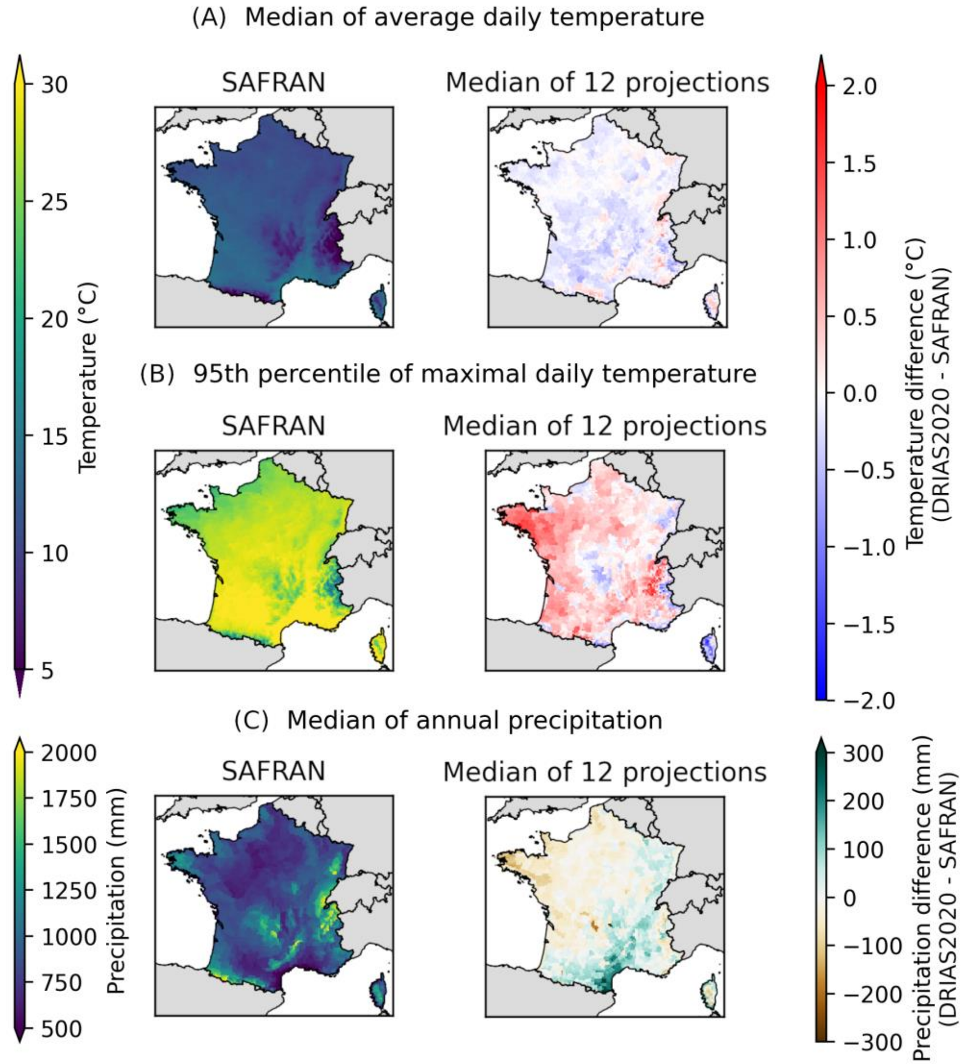

Figure S5 – Climate forcing of (left) SAFRAN and (right) projected minus historical differences over their common period 2006-2022. The median of the 12 projected simulations is used. (a) Median of average daily temperature, (b) 95th percentile of maximum daily temperature and (c) median of annual precipitation.

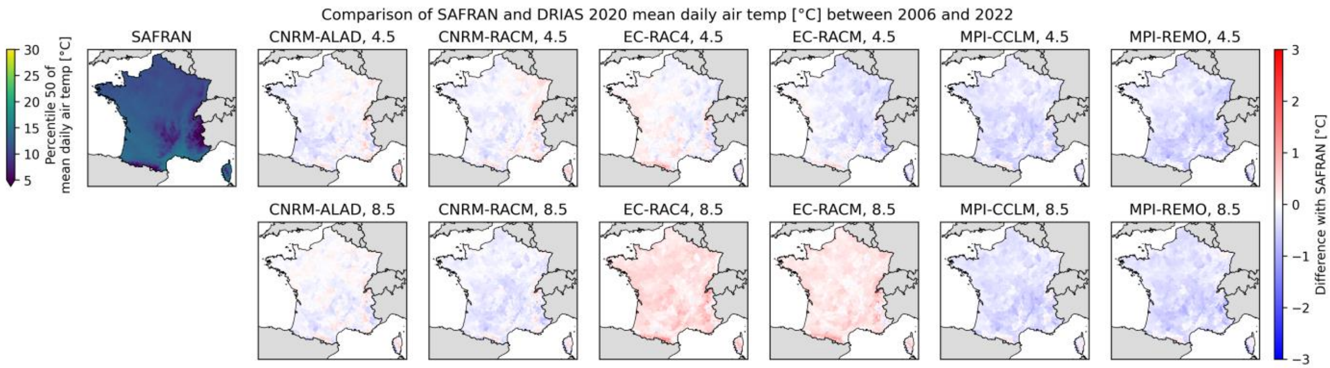

Figure S6 – Comparison of the median of the average daily air temperature of SAFRAN and of the 12 projected simulations over their common period 2006-2022.

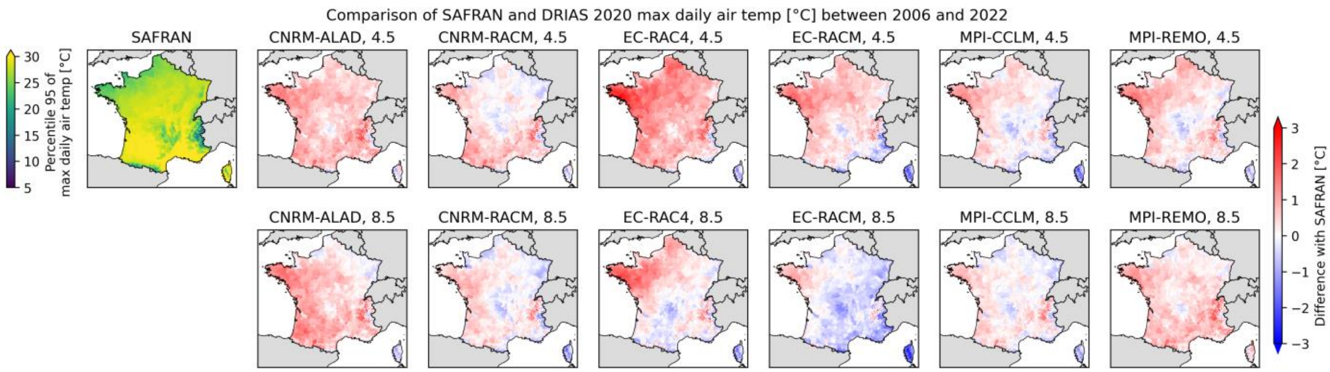

Figure S7 – Comparison of the 95th percentile of the maximum daily air temperature of SAFRAN and of the 12 projected simulations over their common period 2006-2022.

The dispersion of temperature and precipitation changes for the DRIAS-2020 ensemble for the summer season are shown below, for RCP 4.5 and 8.5. These are available at https://www.drias-climat.fr/document/20200914_DRIAS-ScenarioRCP4.5_support_selection_modeles_v3.pdf and https://www.drias-climat.fr/document/20201214_DRIAS-ScenarioRCP8.5_support_selection_modeles_v3.pdf

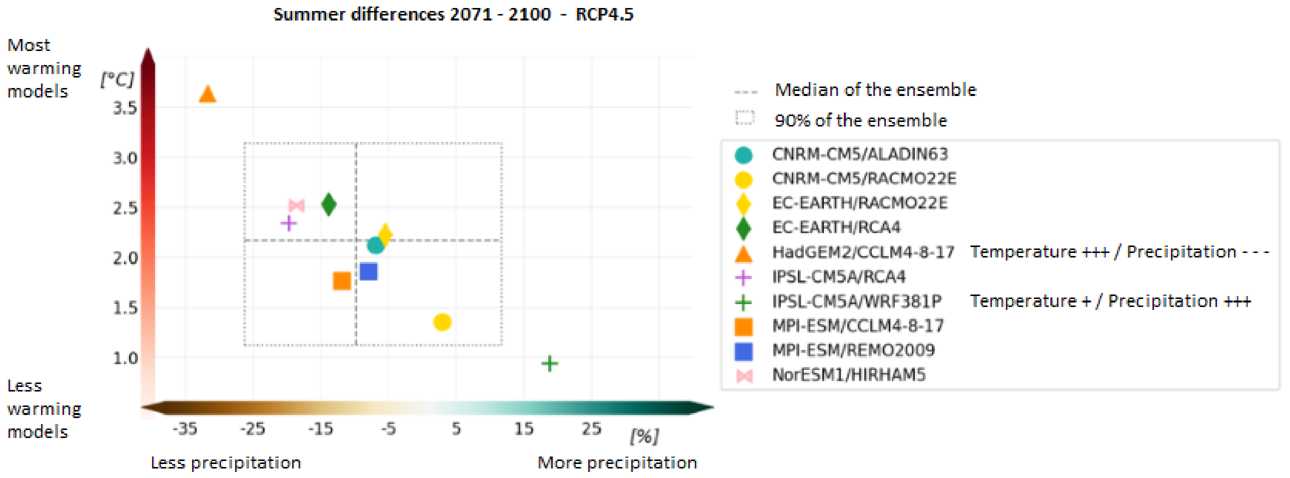

Figure S8 – Dispersion of the DRIAS-2020 ensemble in summertime temperature and precipitation changes over metropolitan France in 2071-2100 for RCP 4.5 (adapted from DRIAS 2020).

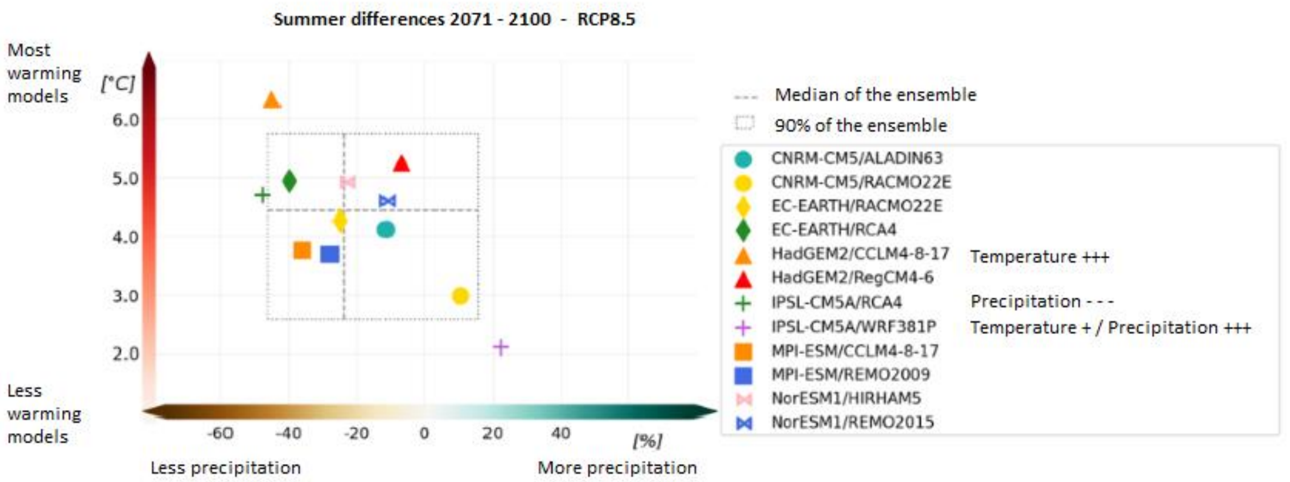

Figure S9 – As in Fig. S8, except for RCP8.5.