

Supplementary Materials

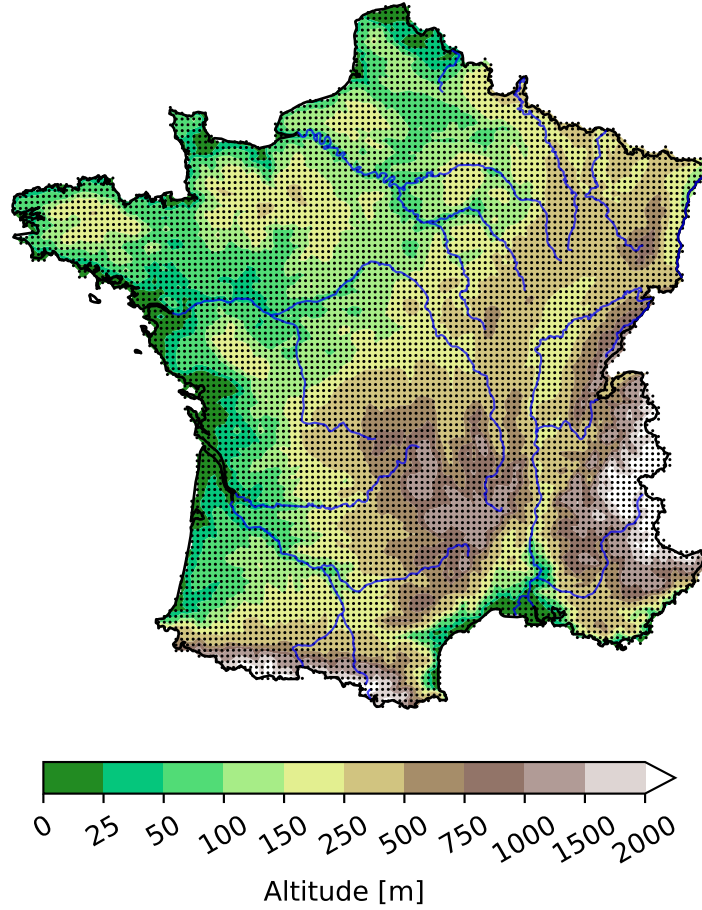


Fig. S1: Map of the studied area. Each data point is represented with a black dot on the map, shaping an $8\text{km} \times 8\text{km}$ grid. The main French rivers are drawn in blue, and the background colors represent the altitude of the points.

Table S1: Global Climate Models (GCM) used to build the ensemble of simulations and their associated letter used in this paper.

GCM name	Associated Letter
CNRM-CERFACS-CNRM-CM5	A
ICHEC-EC-EARTH	B
MOHC-HadGEM2-ES	C

GCM name	Associated Letter
IPSL-IPSL-CM5A-MR	D
MPI-M-MPI-ESM-LR	E
NCC-NorESM1-M	F

Table S2: Regional Climate Models (RCM) used to build the ensemble of simulations and their associated identifier used in this paper.

RCM name	Associated ID
CNRM-ALADIN63	0
CLMcom-CCLM4-8-17	1
DMI-HIRHAM5	2
MOHC-HadREM3-GA7-05	3
KNMI-RACMO22E	4
GERICS-REMO2015	5
IPSL-WRF381P	6

Table S3: Matrix of GCM-RCM combinations used in this study. GCMs are labeled from A to F and RCMs from 0 to 6. An '-' indicates that the specific combination is in the ensemble only under scenario RCP 8.5 while '+' indicates that the specific combination is in the ensemble for RCP 4.5 and RCP 8.5.

	A	B	C	D	E	F
0	+		-			
1			+		+	
2				-		+
3	-	-	-			
4		+				
5						+
6						-

Table S4: List of atmospheric variables used as input to the ORCHIDEE model.

Variable Name	Description
Tair	Near Surface Air Temperature at 2 m
Psurf	Surface Pressure

Variable Name	Description
Qair	Near Surface Specific Humidity at 2 m
Wind	Wind Speed at 10 m
Rainf	Rain Fall
Snowf	Snow Fall
LWdown	Downward Longwave Radiation
SWdown	Downward Shortwave Radiation

Table S5: Sign of the significant trends detected in the dataset for each characteristic and SDI. Trend test is done with a Mann-Kendall test with $\alpha = 0.05$. Dataset is based on drought events detected in all the simulations.

	Duration	Intensity	Surface Area
SPI-3	+	+	+
SPI-12	+	+	
SPEI-3	+	+	+
SPEI-12	+	+	+
SSWI-3	+	+	
SSWI-12		+	
SRI-3		+	
SRI-12		+	

Table S6: Sign of the significant trends detected in the dataset for each characteristic and SDI. Trend test is done with a Mann-Kendall test with $\alpha = 0.05$. Dataset is based on drought events detected in EAS and CAS simulations.

	EAS			CAS		
	Duration	Intensity	Surface Area	Duration	Intensity	Surface Area
SPI-3	+	+		+	+	+
SPI-12		+		+	+	
SPEI-3	+	+	+	+	+	+
SPEI-12	+	+	+	+	+	+
SSWI-3	+	+	+		+	
SSWI-12		+			+	
SRI-3		+			+	

	EAS			CAS		
	Duration	Intensity	Surface Area	Duration	Intensity	Surface Area
SRI-12		+			+	

Table S7: Sign of significant trends (Mann-Kendall test, $\alpha = 0.05$) detected in the physiological CO_2 sensitivity ensemble for each drought characteristic and standardized drought index. Trends are shown separately for CO_2 -disabled simulations (excluding physiological effects of CO_2 on vegetation) and CO_2 -enabled simulations (including these effects). CO_2 physiological effects only influence SSWI and SRI drought metrics, as these parameters exclusively affect land surface model behavior, not meteorological forcing.

Index	CO ₂ -enabled			CO ₂ -disabled		
	Duration	Intensity	Surface Area	Duration	Intensity	Surface Area
SSWI-3		+		+	+	+
SSWI-12		+		+	+	+
SRI-3		+			+	
SRI-12		+	-		+	

Table S8: As Table S6 but for all simulations under RCP 8.5 with events filtered with a minimum surface at each month of 5% of French territory.

	Duration	Intensity	Surface Area
SPI-3	+	+	+
SPI-12		+	
SPEI-3	+	+	+
SPEI-12	+	+	+
SSWI-3	+	+	
SSWI-12		+	
SRI-3		+	
SRI-12		+	-

Table S9: As Table S6 but for all simulations under RCP 8.5 with a local drought threshold of -1.28.

	Duration	Intensity	Surface Area
SPI-3	+	+	+
SPI-12	+	+	

	Duration	Intensity	Surface Area
SPEI-3	+	+	+
SPEI-12	+	+	+
SSWI-3		+	
SSWI-12	+	+	
SRI-3			
SRI-12		+	

Table S10: Number of drought events detected for each warming level and in the reanalysis. The numbers are given in number of events per simulation per 30 years.

SDI	Reanalysis	+1.5°C	+2°C	+3°C
SPI-3	25	23	23	27
SPI-12	11	10	9	12
SPEI-3	22	27	28	29
SPEI-12	11	11	10	8
SSWI-3	13	13	13	12
SSWI-12	6	6	6	7
SRI-3	16	13	14	16
SRI-12	7	7	7	8

Table S11: As Table S6 but for all simulations under RCP 4.5.

	Duration	Intensity	Surface Area
SPI-3	+	+	+
SPI-12		+	
SPEI-3	+	+	+
SPEI-12	+	+	
SSWI-3		+	
SSWI-12		+	
SRI-3		+	
SRI-12		+	

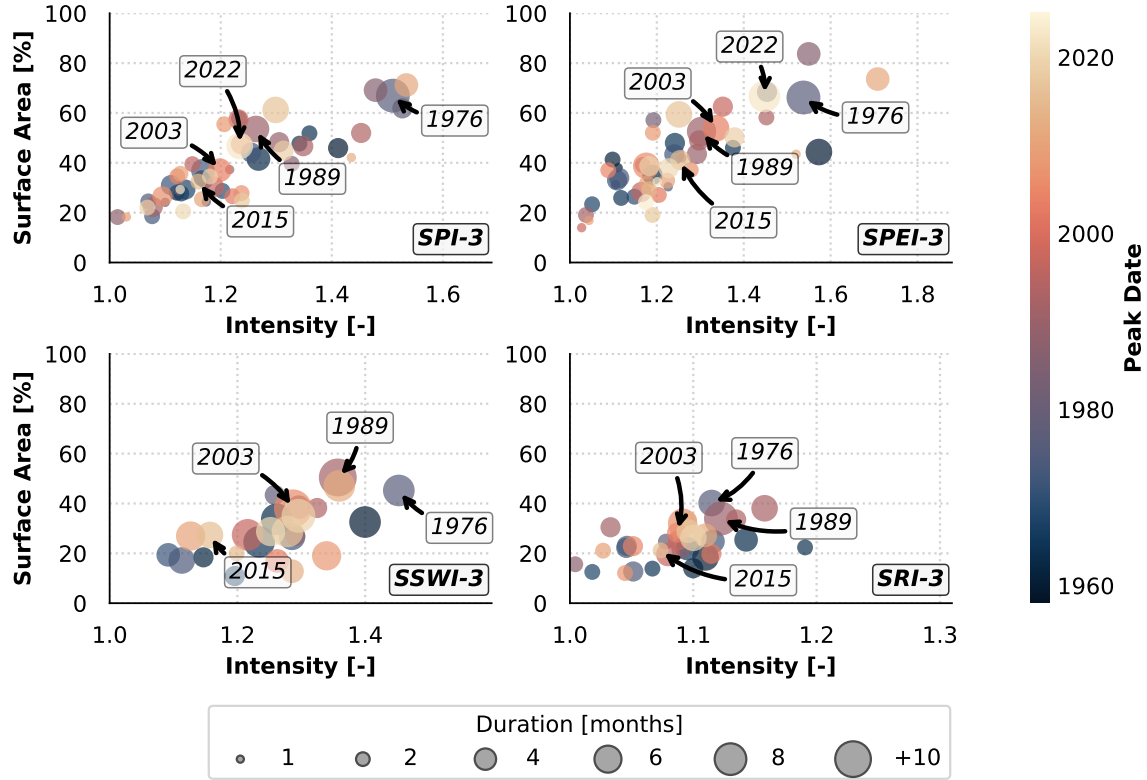


Fig. S2: Drought events' characteristics evolution for SPI-3, SPEI-3, SSWI-3, and SRI-3 for the reanalysis. Every SDI-3 is displayed in its own panel. A bubble represents a single drought event detected in the ensemble of simulations. The bubble is positioned according to the drought characteristics: surface area on the y-axis, intensity on the x-axis, and duration for the bubble size.

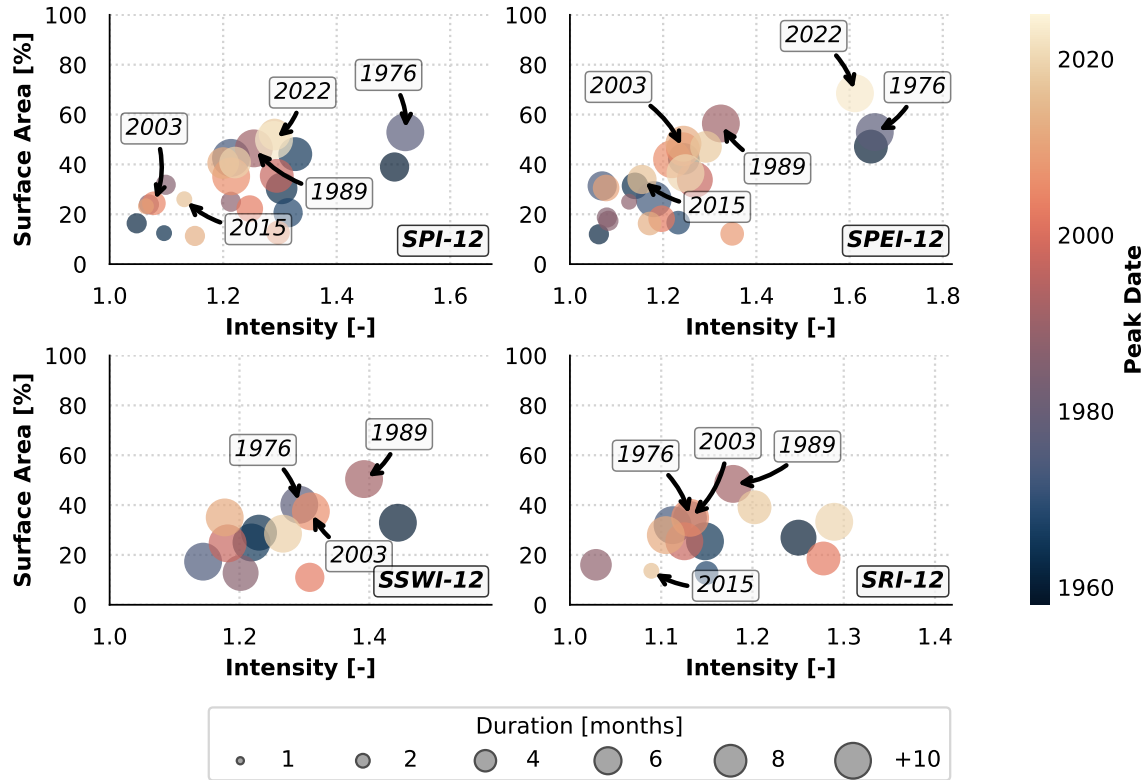


Fig. S3: As Figure S2 for SDI-12.

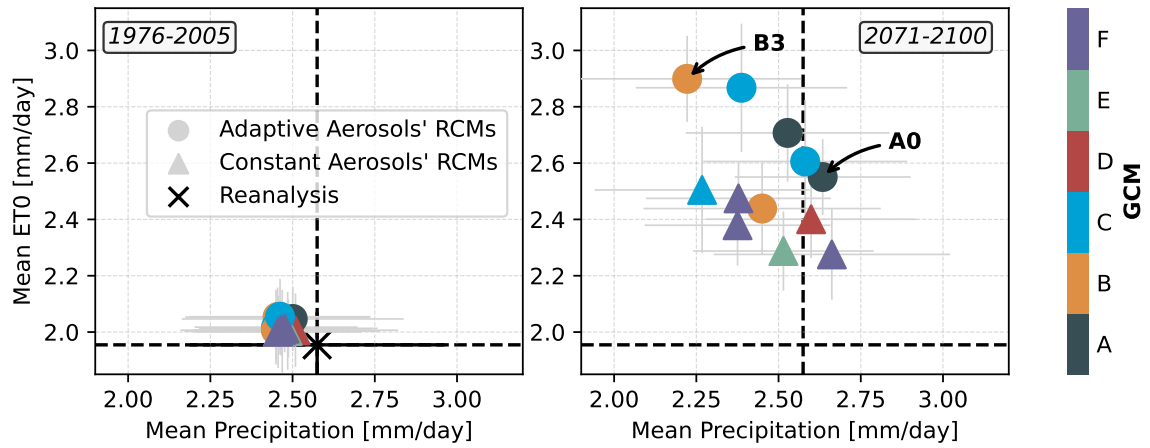


Fig. S4: Mean potential evapotranspiration (ET0) versus precipitation over France for the twelve climate simulations and the reanalysis. Colors represent different GCMs, while symbols distinguish aerosol treatments in the RCMs: circles for RCMs with evolving aerosol scenarios, triangles for RCMs with constant aerosol climatology. Arrows indicate the two storylines identified in the study. Left panel: historical period (1976-2005). Right panel: future period (2071-2100).

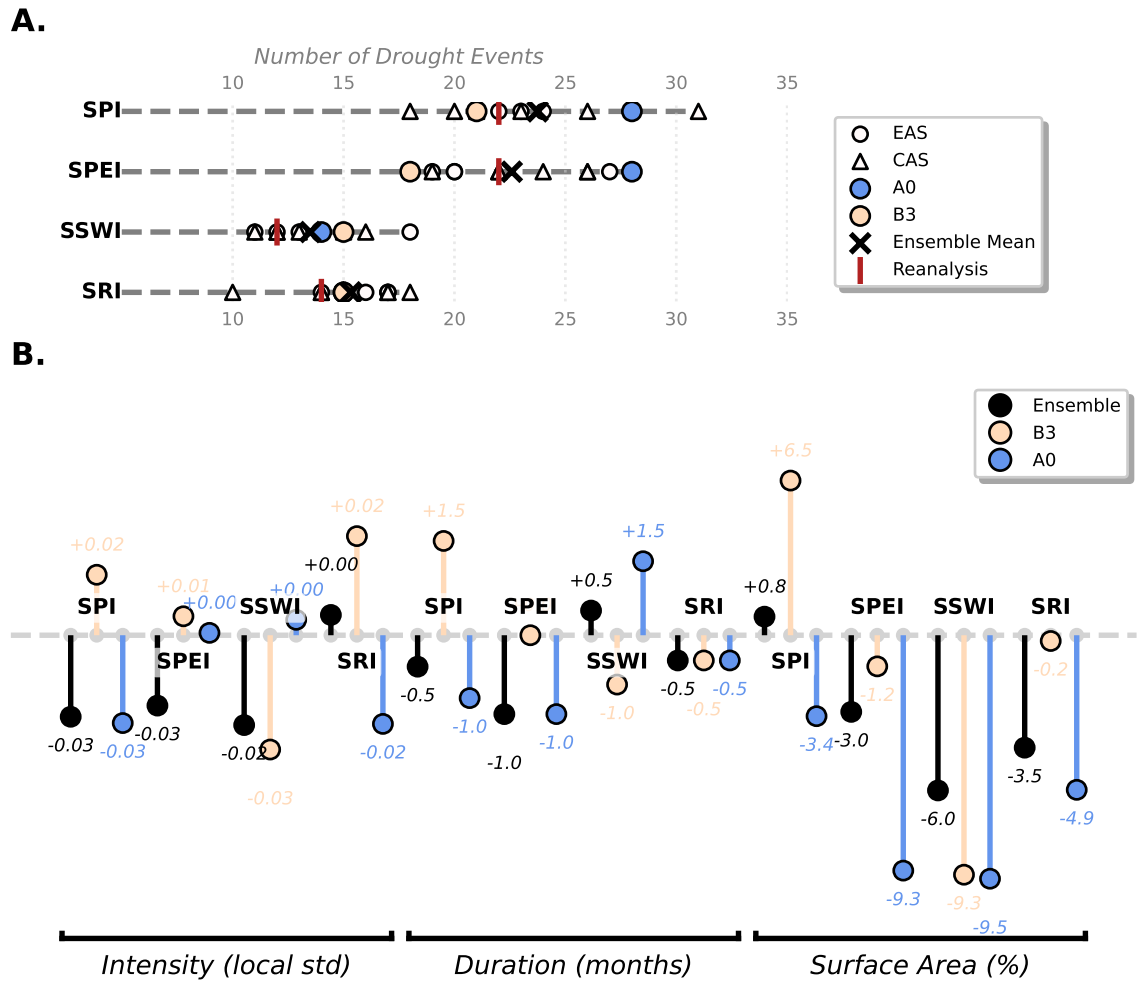


Fig. S5: As Figure 2 but for SDI-12

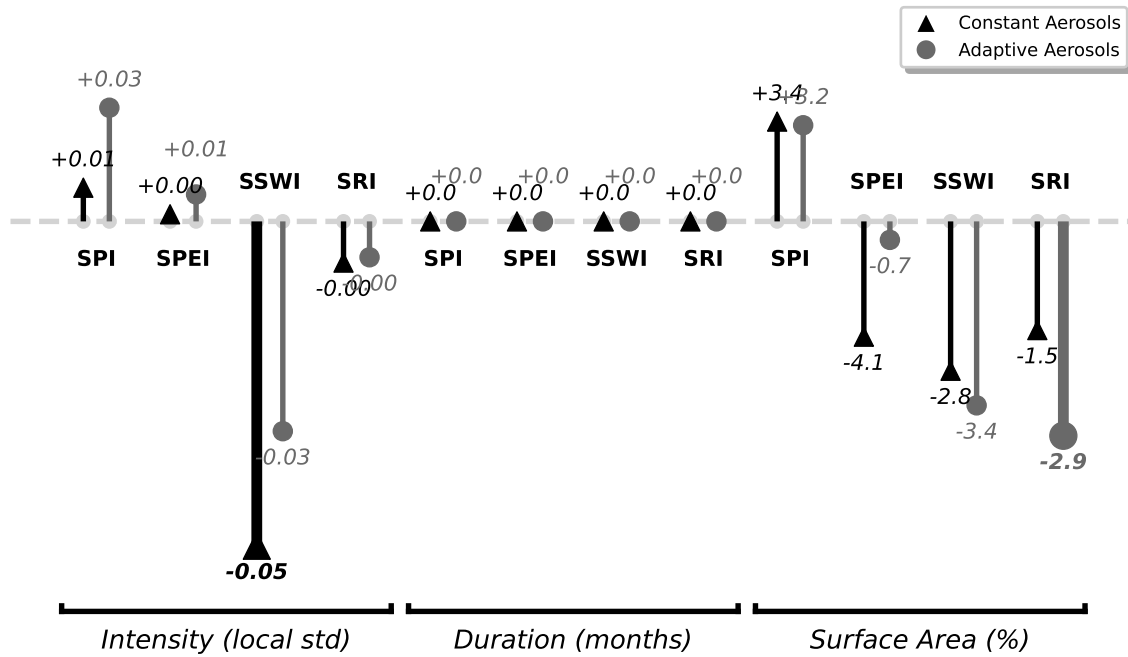


Fig. S6: Biases of the EAS and CAS simulations compared to the reanalysis in the production of drought events (SDI-3). It shows the median difference of each characteristic between the reanalysis and the ensemble of simulations (black), the A0 storyline (blue), and the B3 storyline (orange) for each SDI-3. A positive deviation indicates higher values in the simulations. The bold values are the ones with a significant statistical difference according to the Kolmogorov–Smirnov test ($\alpha = 0.05$).

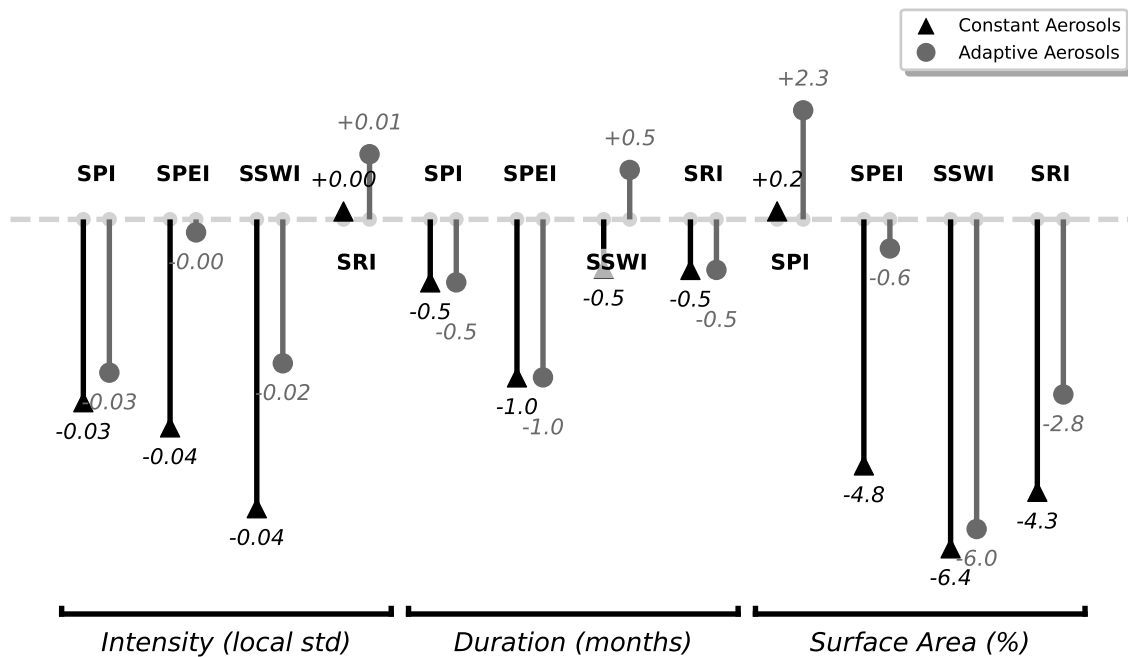


Fig. S7: As Figure S6 but for SDI-12

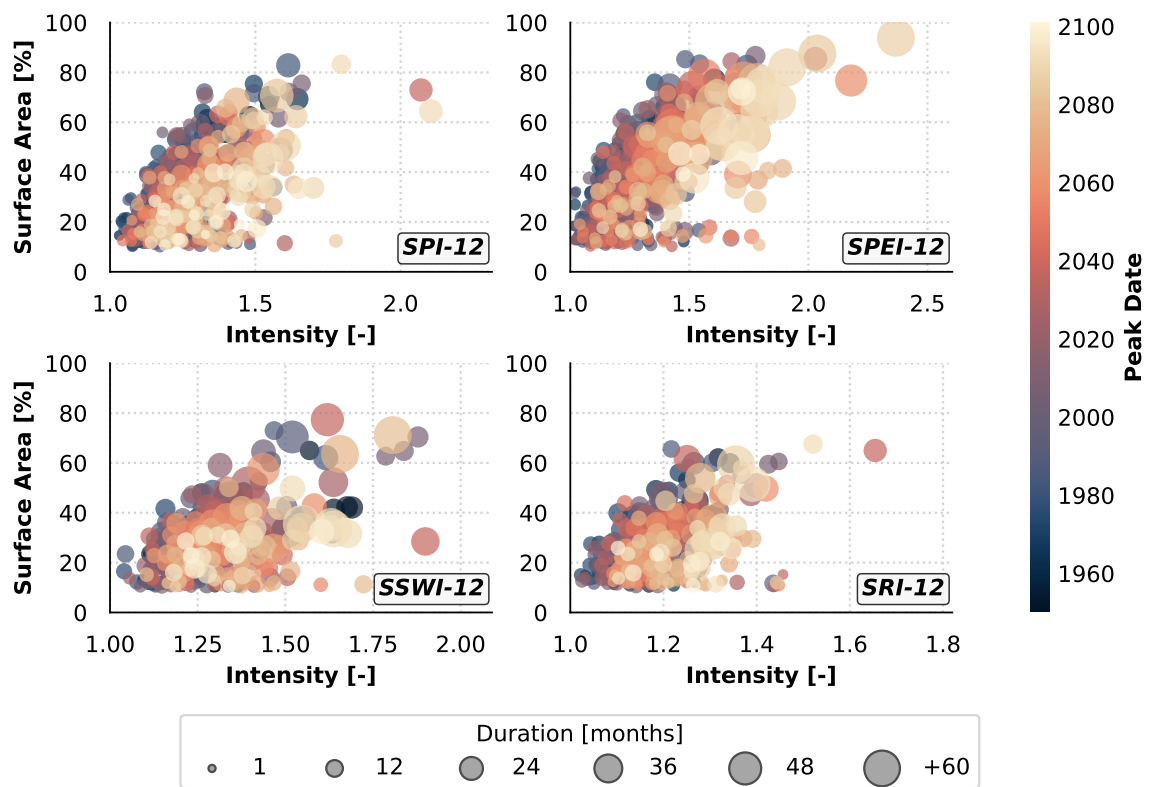


Fig. S8: As Figure 3 but for SDI-12.

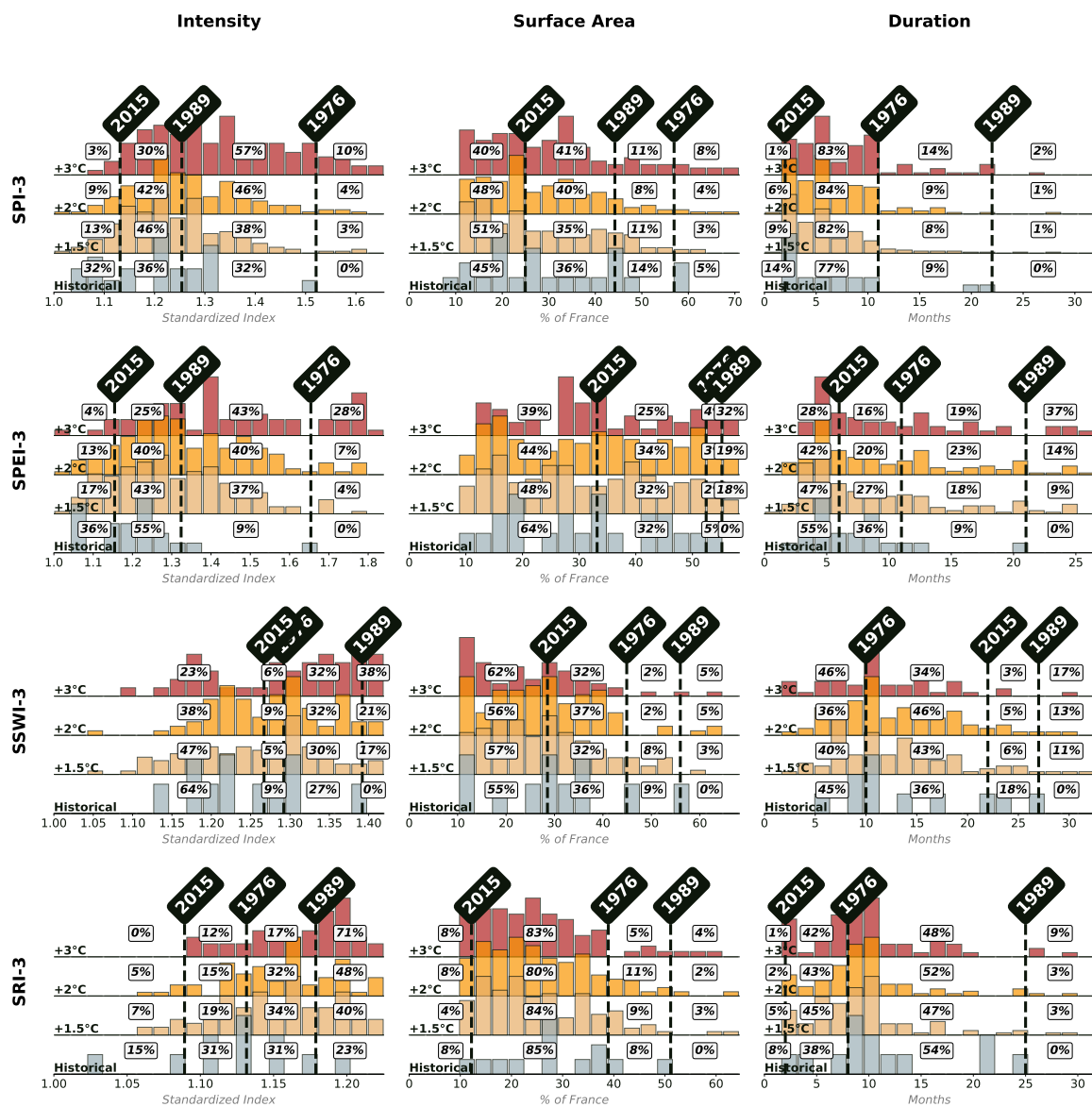


Fig. S9: As Figure 4 but for SDI-12.

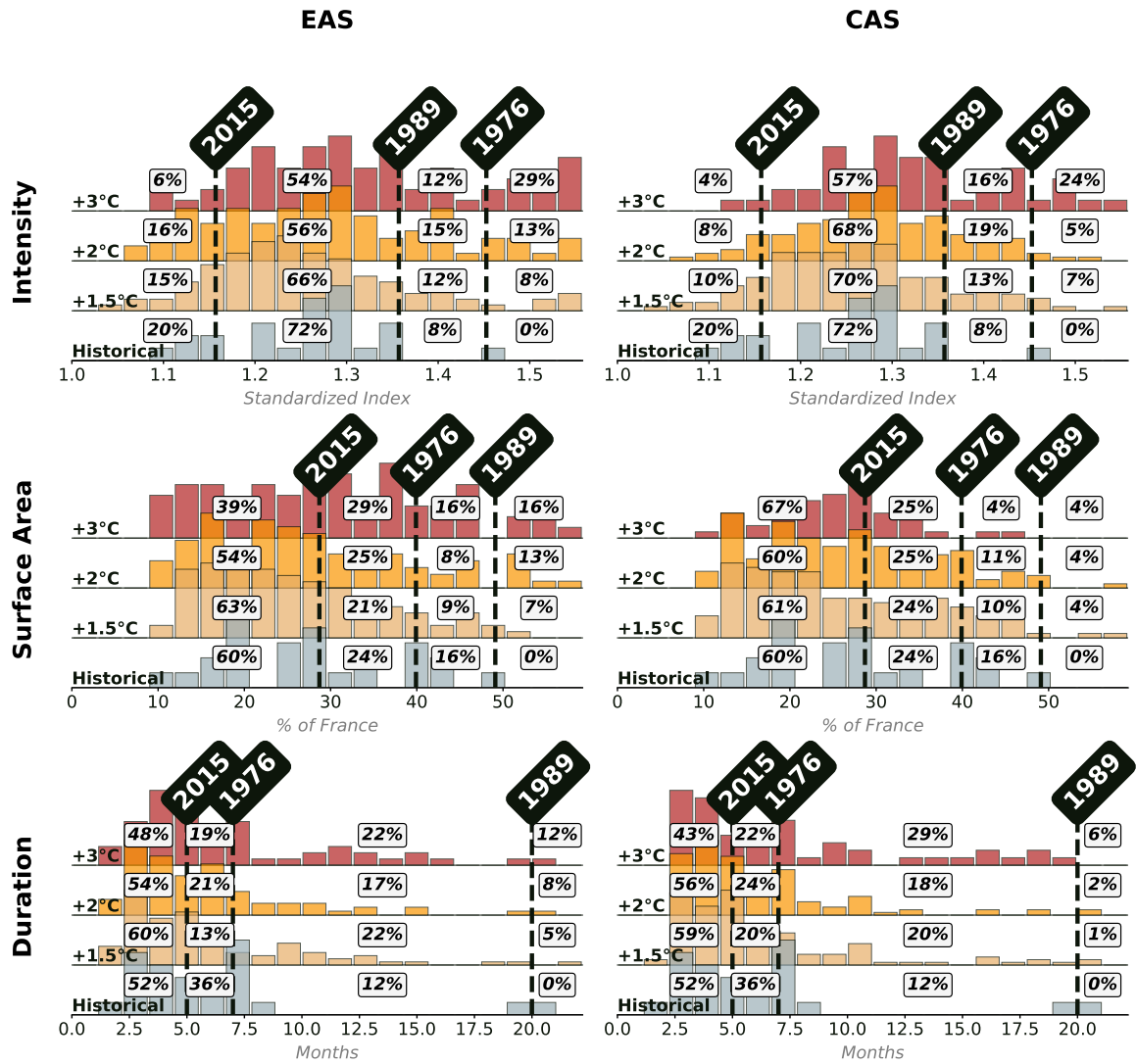


Fig. S11: As Figure S10 but for SSWI-3.

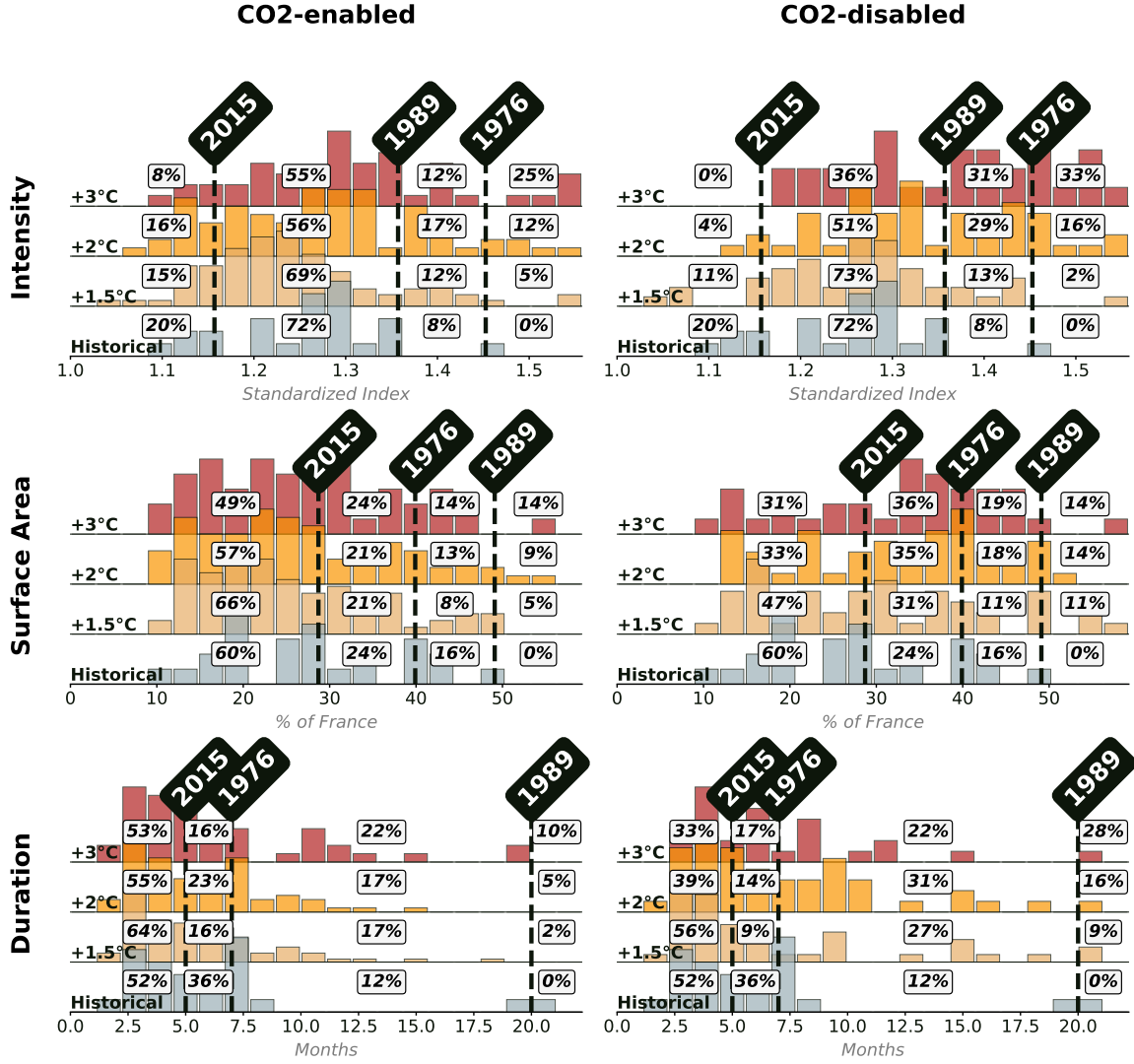


Fig. S12: Distribution of SSWI-3 drought characteristics (intensity, surface area, and duration) across different GWLs for CO₂-enabled and CO₂-disabled simulations. For better visualization, distributions may be truncated before their maximum values. Vertical dashed lines indicate three historical reference events (2015, 1989, and 1976). The percentage values shown on each distribution represent the proportion of drought events with characteristics falling within the range defined by these three reference events, displayed for the reanalysis period and the three GWLs (+1.5°C, +2°C, +3°C relative to preindustrial levels, corresponding to +2°C, +2.7°C, and +4°C RWLs, respectively). Intensity is expressed as standardized index values, surface area as percentage of French territory affected, and duration in months.

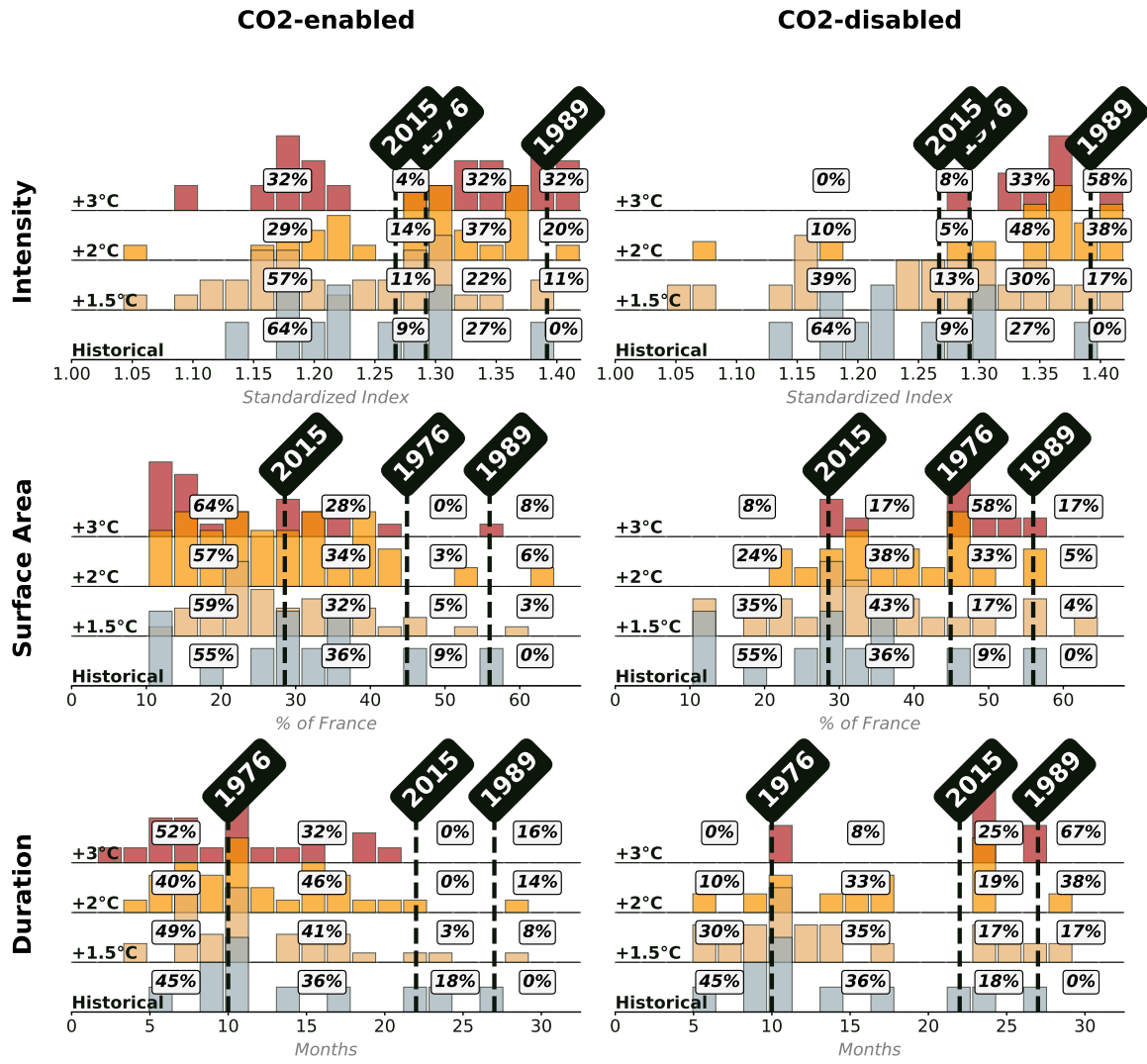


Fig. S13: As Figure S12 but for SSWI-12.

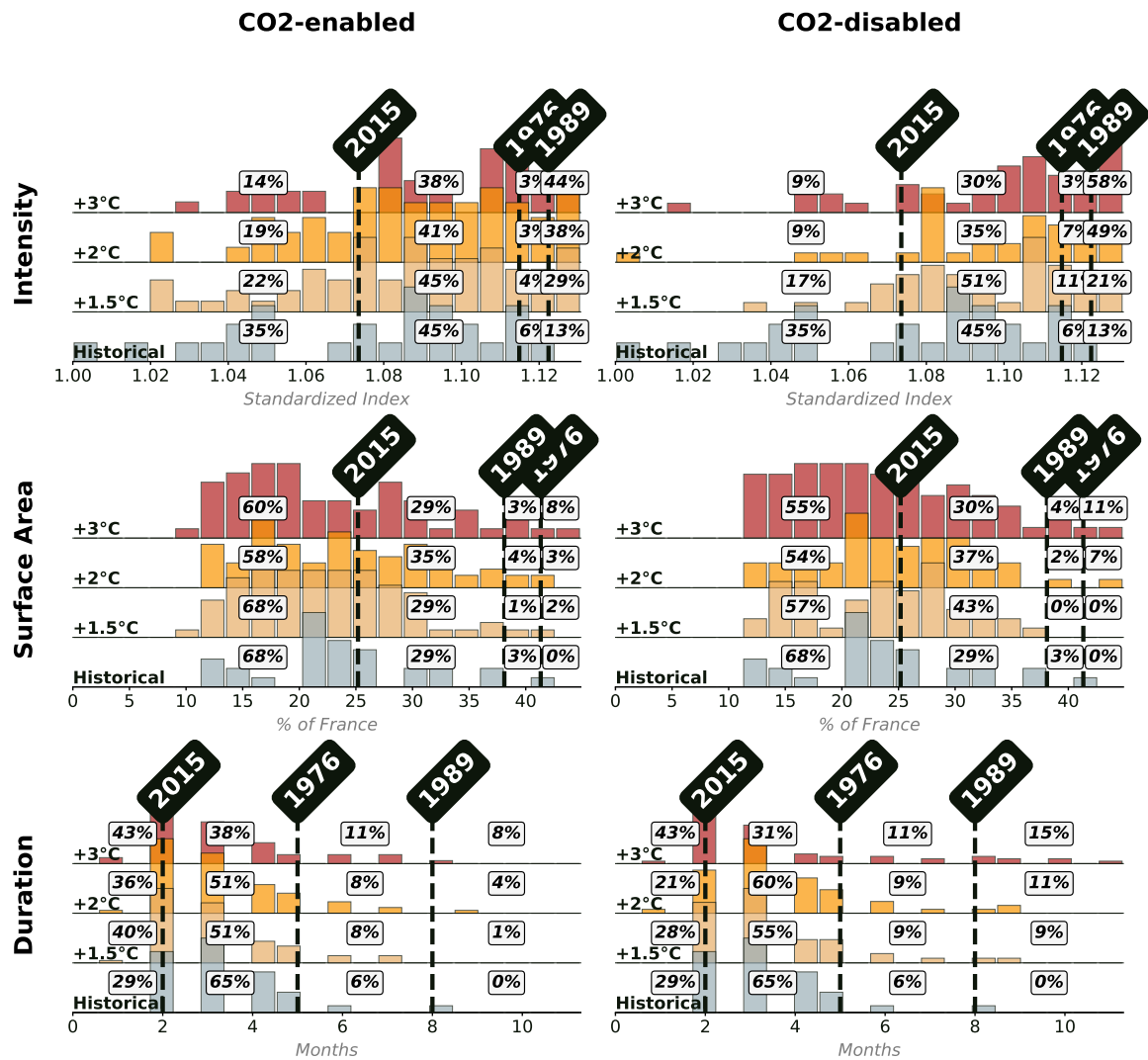


Fig. S14: As Figure S12 but for SRI-3.

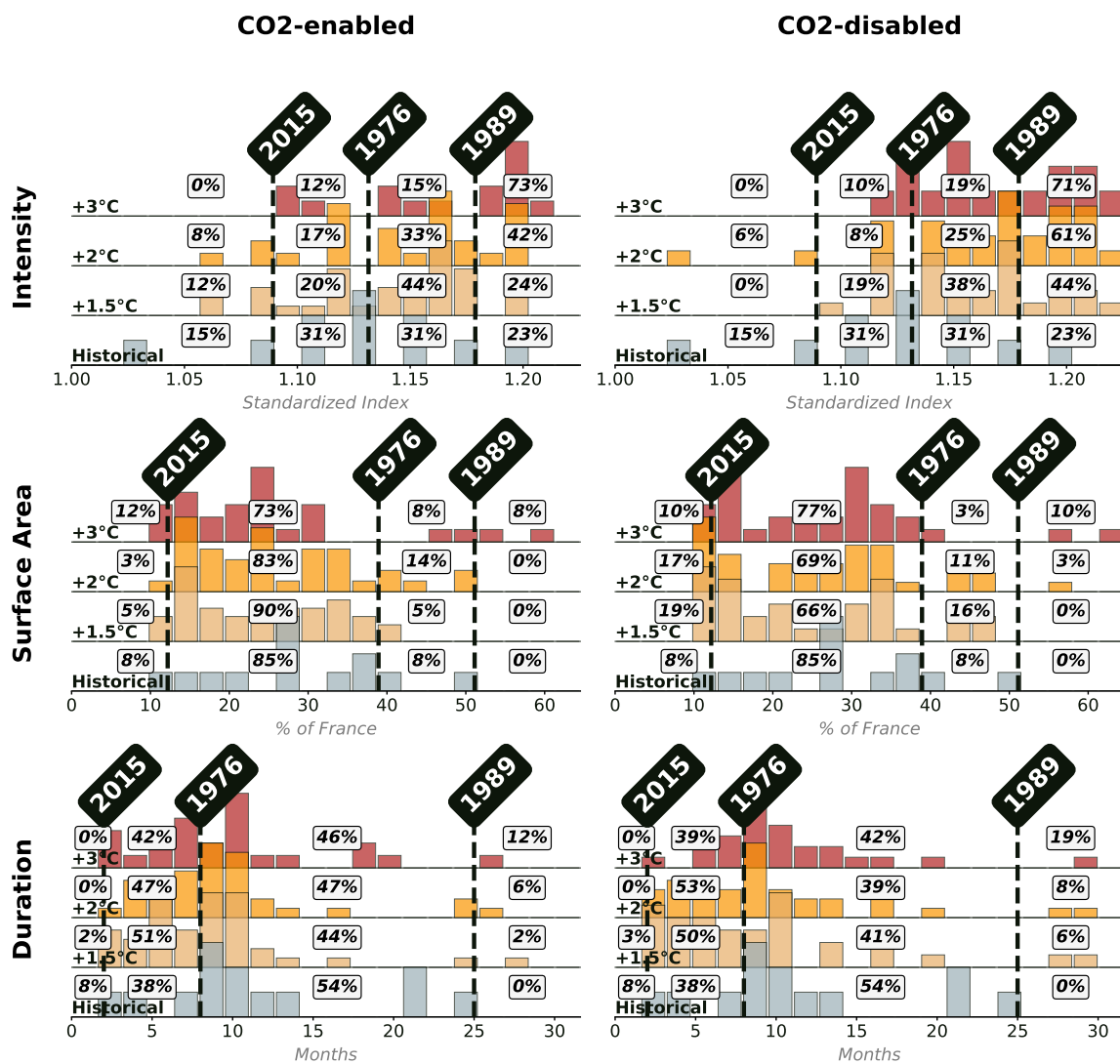


Fig. S15: As Figure S12 but for SRI-12.

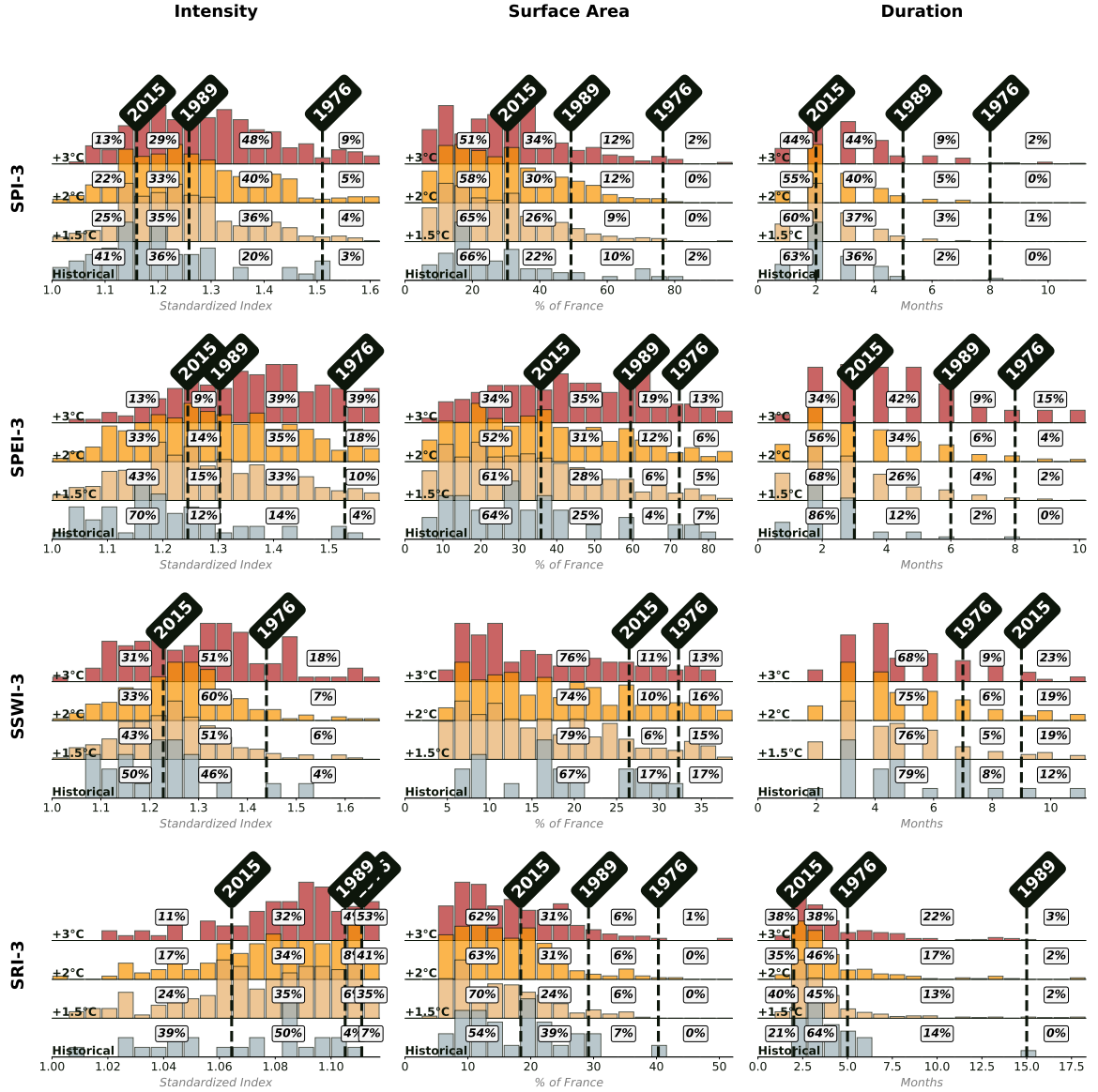


Fig. S16: As Figure 4 but for all simulations under RCP 8.5 with events filtered with a minimum surface at each month of 5% of French territory.

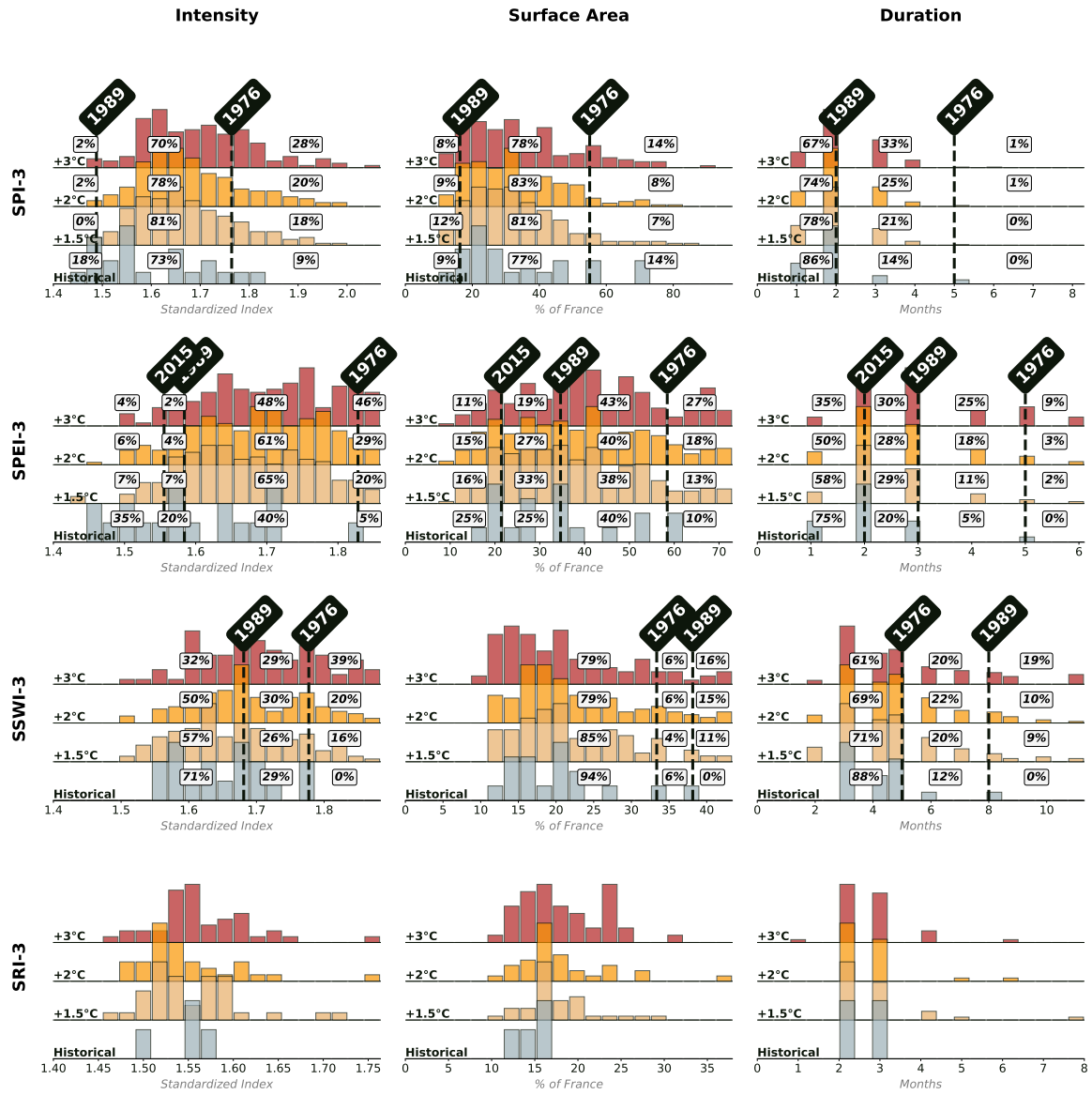


Fig. S17: As Figure 4 but for all simulations under RCP 8.5 with a local drought threshold of -1.28.

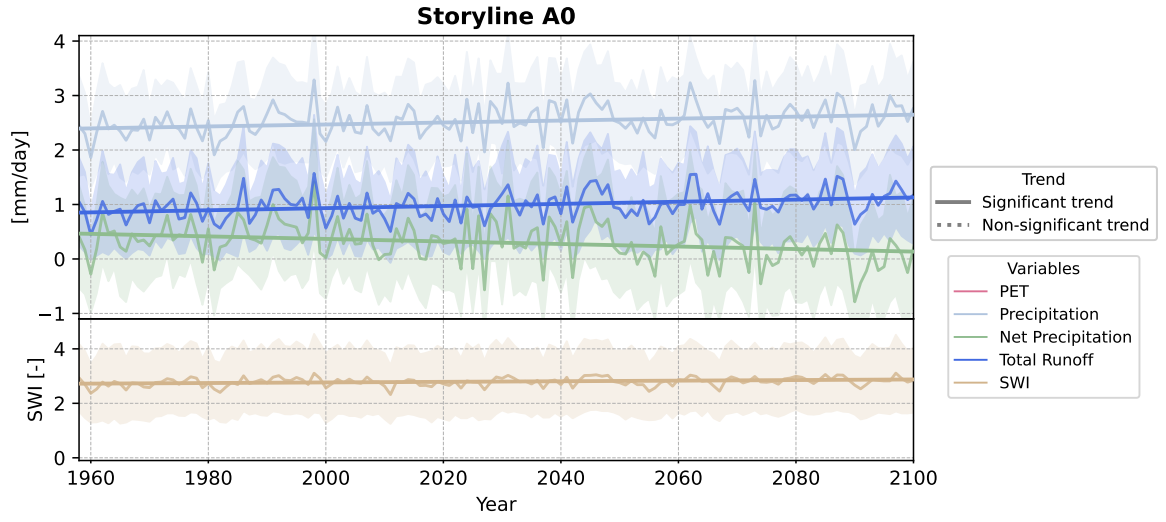


Fig. S18: Mean-state evolution for the A0 storyline. Yearly time series of precipitation, net precipitation ($P - PET$), total runoff, and SWI averaged over France. Thin lines show annual values, shaded areas indicate spatial variability, and bold lines show the estimated trend.

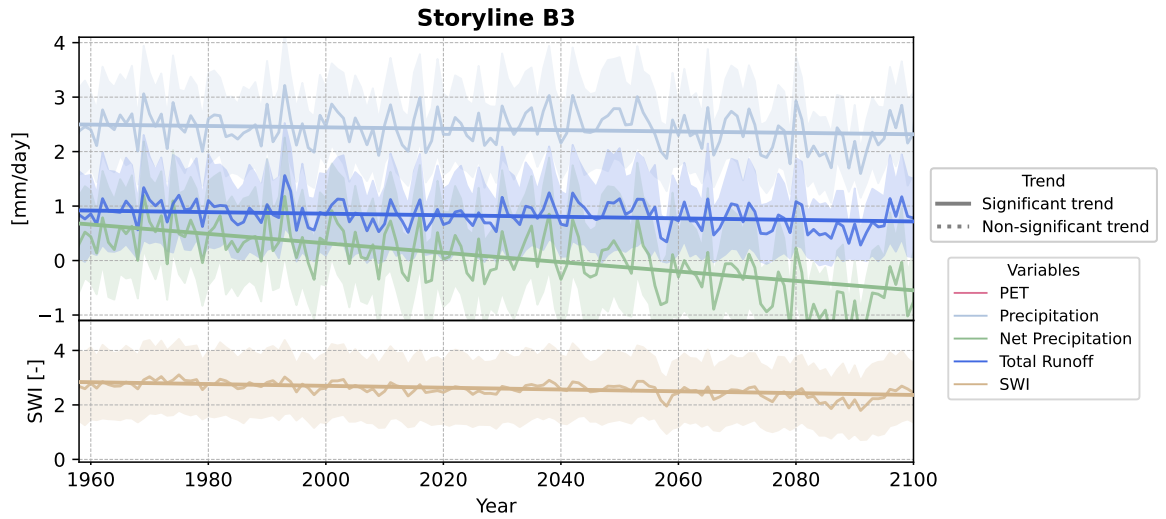


Fig. S19: Mean-state evolution for the B3 storyline. Same as Figure S18.