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Changes in drought features at the European level over the last 120 years

Monica Ionita and Viorica Nagavciuc

Correspondence to: Monica Ionita (monica.ionita@awi.de)

Supplement

To analyze if there are significant changes in the SPEI12, SPI12, scPDSI (Figure1 and Figure S2), PP, TT and PET (Figure S3) and the drought area (Figures 3 - 5) we have used the rank-based non-parametric Mann-Kendall (M-K) test and Spearman's Rho (Mann, 1945; Kendall, 1948), which are less sensitive to outliers than parametric statistics. To avoid the influence of serial persistence on M-K test results, the modified M-K (MMK) trend test was used, using the computation algorithm discussed by Hamed and Rao (1998).

Table S1. Linear trends of the drought area for different drought types (moderate, severe and extreme) for SPEI12, SPI12 and scPDSI for the three analyzed regions: MED, CEU and NEU.

	SPEI12			**SPI12**			**scPDSI**		
	Moderate[i)]	Severe[ii)]	Extreme[iii)]	Moderate[i)]	Severe[ii)]	Extreme[iii)]	Moderate[i)]	Severe[ii)]	Extreme[iii)]
MED	↑*	↑*	↑*	↑	↑	↑	↑*	↑*	↑*
CEU	↑*	↑*	↑*	↓	↓	↓	↑*	↑*	↑*
NEU	↓*	↓*	↓	↓*	↓*	↓*	↓*	↓*	↓*

↑* - indicates a significant positive trend (99% significance level);
↑ - indicates a positive, but not significant trend;
↓*- indicates a significant negative trend (99% significance level);
↓ - indicates a negative, but not significant trend;

i) moderate drought (SPI/SPEI values between -1 and -1.5 and scPDSI values between -2 and -3);
ii) severe drought (SPI/SPEI values between -1.5 and -2 and scPDSI values between -3 and -4);
iii) extreme drought (SPI/SPEI values less than -2 and scPDSI values smaller than -4).

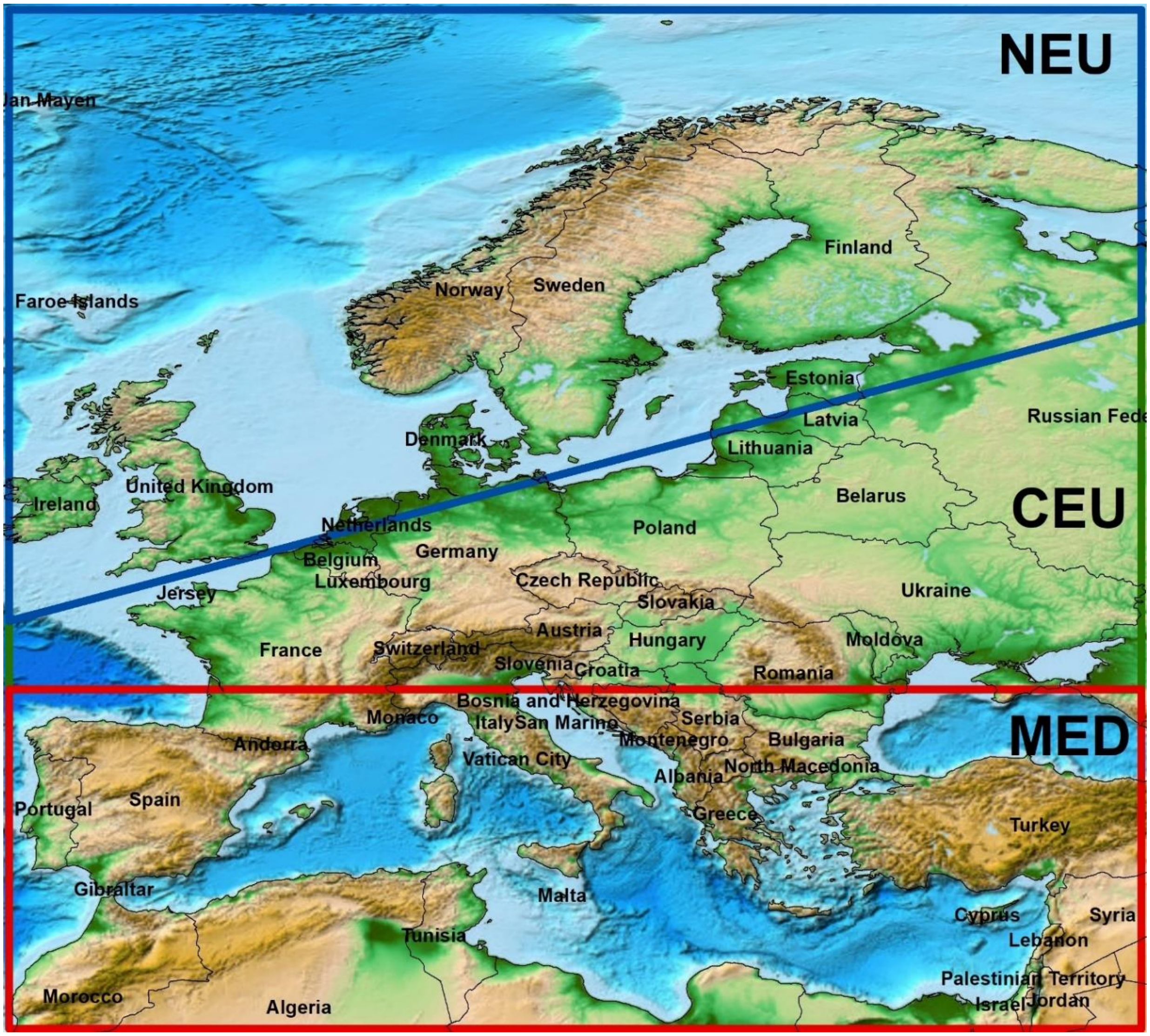


Figure S1. Spatial delimitation of the macro regions analyzed in this study: South Europe/ Mediterranean region (MED); Central Europe (CEU) and North Europe (NEU). Data source for the digital elevation model: (NOAA, 2009).

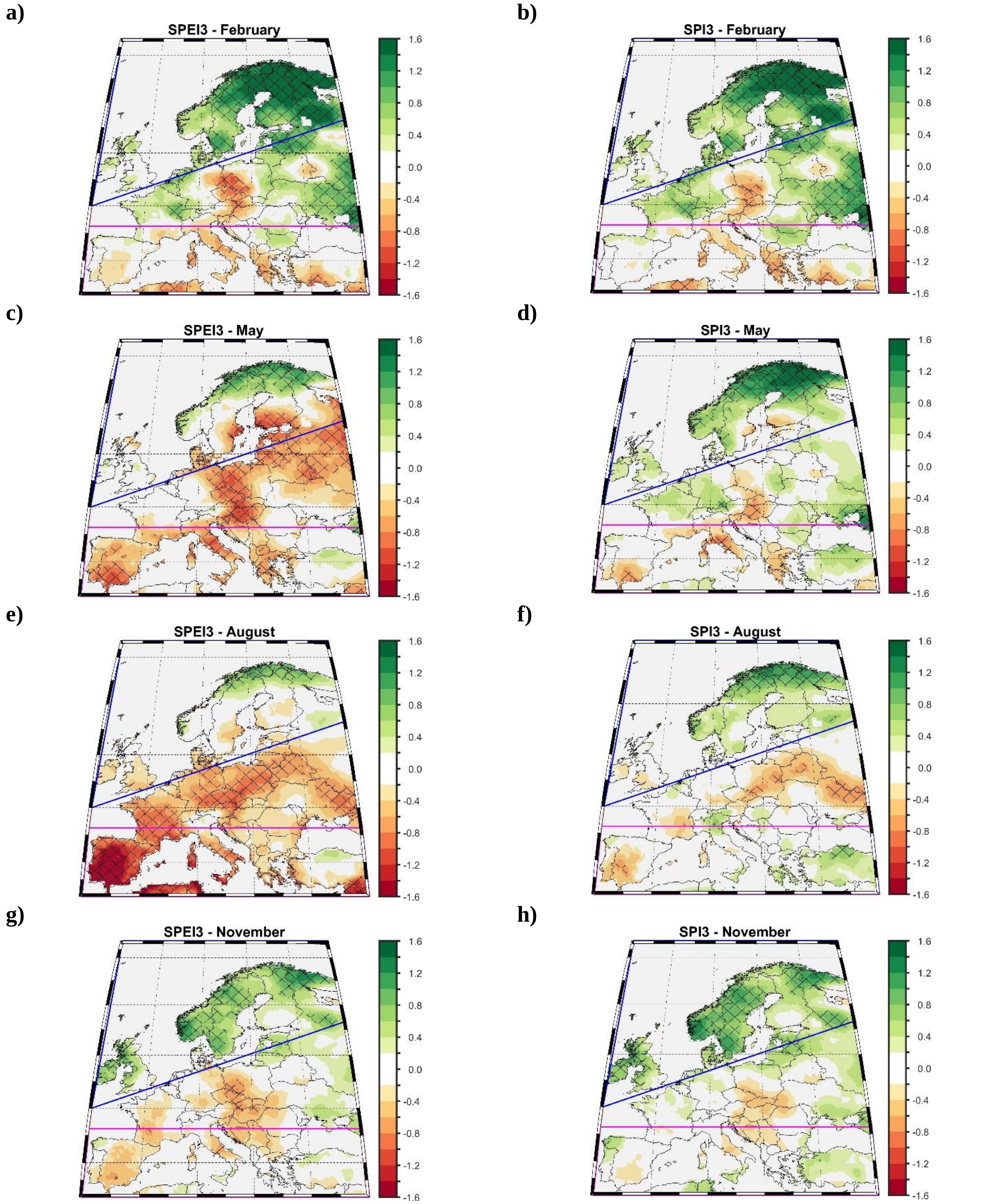


Figure S2. a) Linear trend of February SPEI3; b) as in a) but for SPI3; c) linear trend of May SPEI3; d) as in c) but for SPI3; e) linear trend of August SPEI3; f) as in e) but for SPI3; g) linear trend of SPEI3 November and h) as in g) but for SPI3. Stipples indicate statistically significant trends. Analyzed period 1902 – 2019. Units: z-scores/ 118 years.

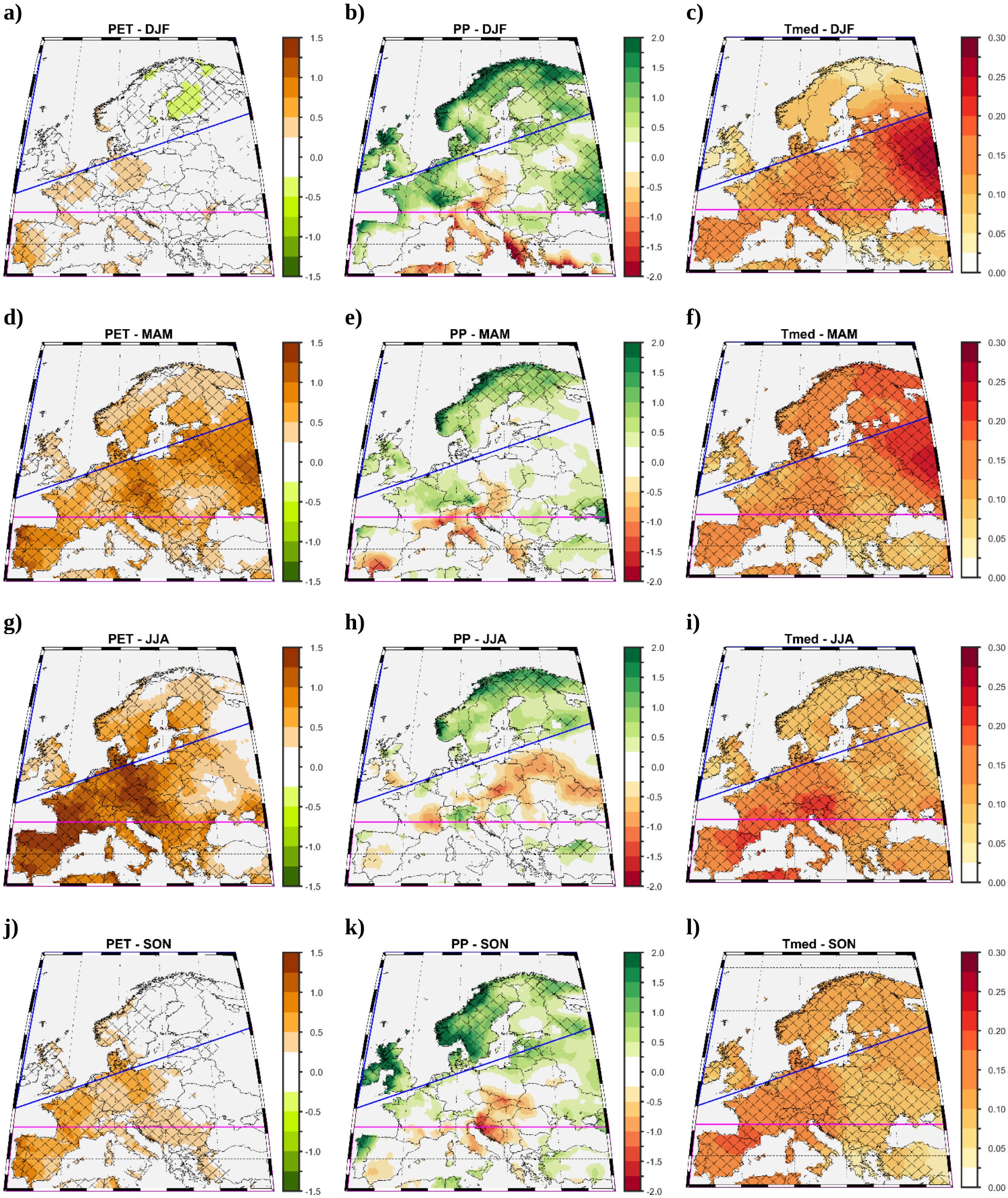


Figure S3. a) Linear trend of winter (DJF) potential evapotranspiration (PET); b) as in a) but for the winter (DJF) precipitation (PP); c) as in a) but for the winter (DJF) mean air temperature (TT); d) as in a) but for spring (MAM); e) as in b) but for spring (MAM); f) as in c) but for spring (MAM); g) as in a) but for summer (JJA); h) as in b) but for summer (JJA); i) as in c) but for summer (JJA); j) as in a) but for autumn (SON); k) as in b) but for autumn (SON) and l) as in c) but for autumn (SON). Stipples indicate statistically significant trends. Analyzed period 1902 – 2019. Units: PET (mm/decade), PP (mm/decade) and TT (°C/decade).

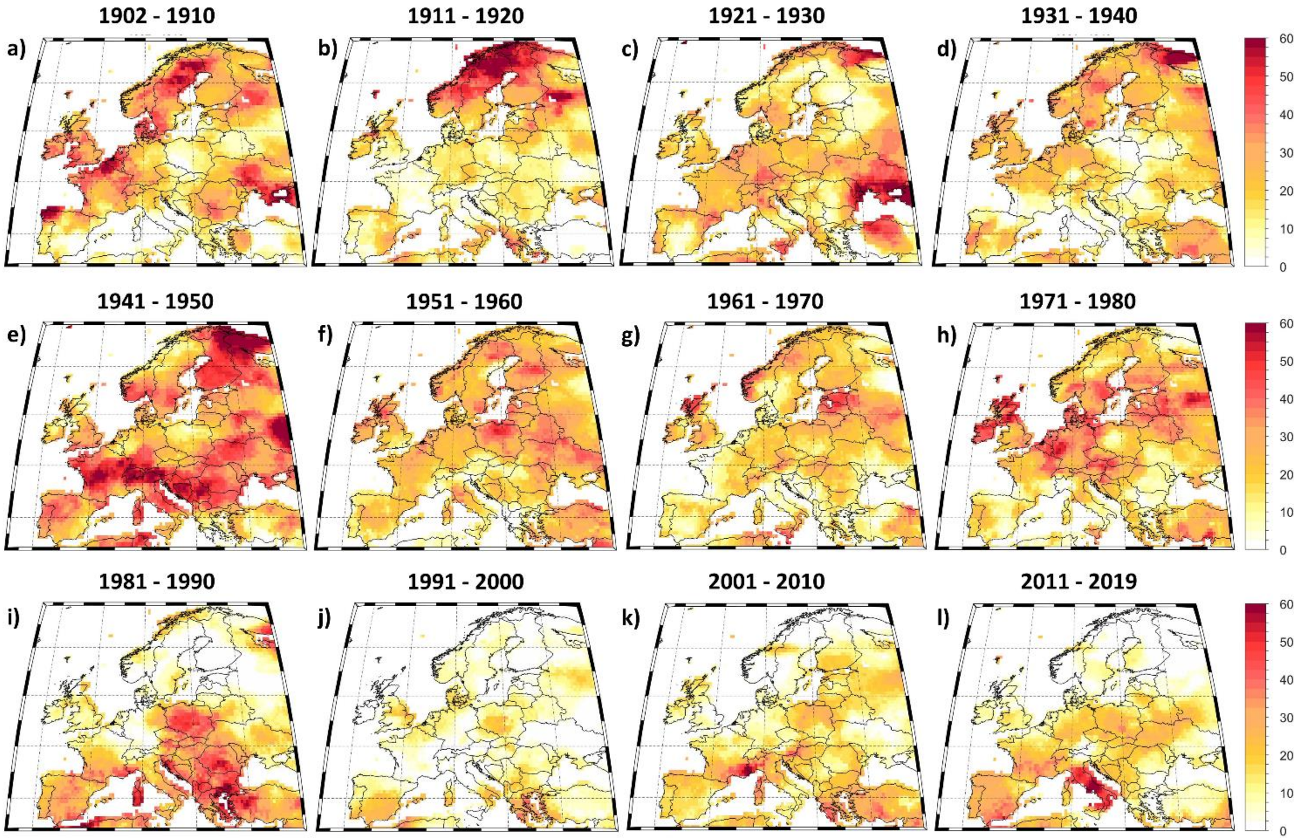


***Figure S4*.** Decadal frequency of drought duration for **moderate drought** (SPI12 between -1.0 and -1.5): a) 1902 – 1901; b) 1911 – 1920; c) 1921 – 1930; d) 1931 – 1940; e) 1941 – 1950; f) 1951 – 1960; g) 1961 – 1970; h) 1971 – 1980; i) 1981 – 1990; j) 1991 – 2000; k) 2001 – 2010 and l) 2011 – 2019. Units: number of months/period.

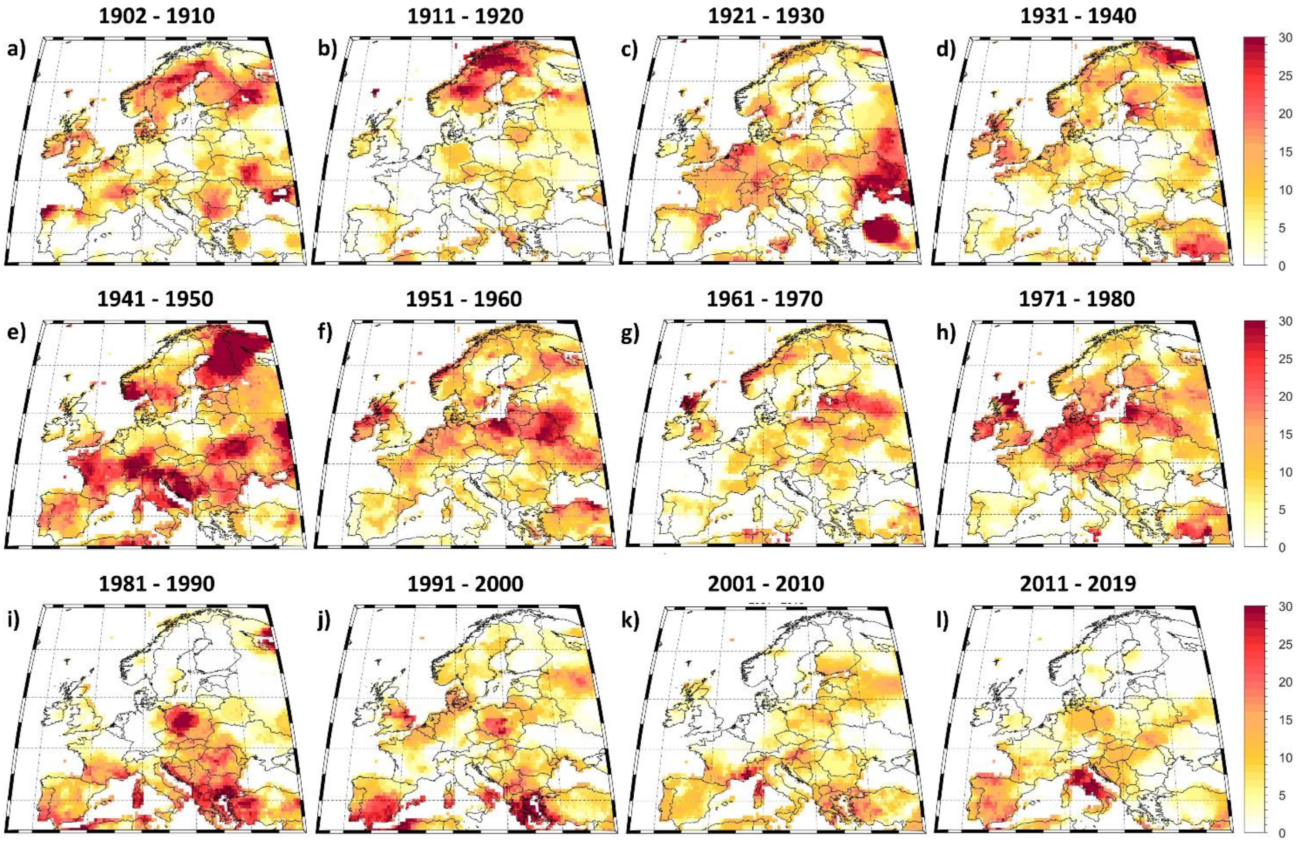


Figure S5. Decadal frequency of drought duration for **severe drought** (SPI12 between **-**1.51 and **-**2): a) 1902 – 1901; b) 1911 – 1920; c) 1921 – 1930; d) 1931 – 1940; e) 1941 – 1950; f) 1951 – 1960; g) 1961 – 1970; h) 1971 – 1980; i) 1981 – 1990; j) 1991 – 2000; k) 2001 – 2010 and l) 2011 – 2019. Units: number of months/period.

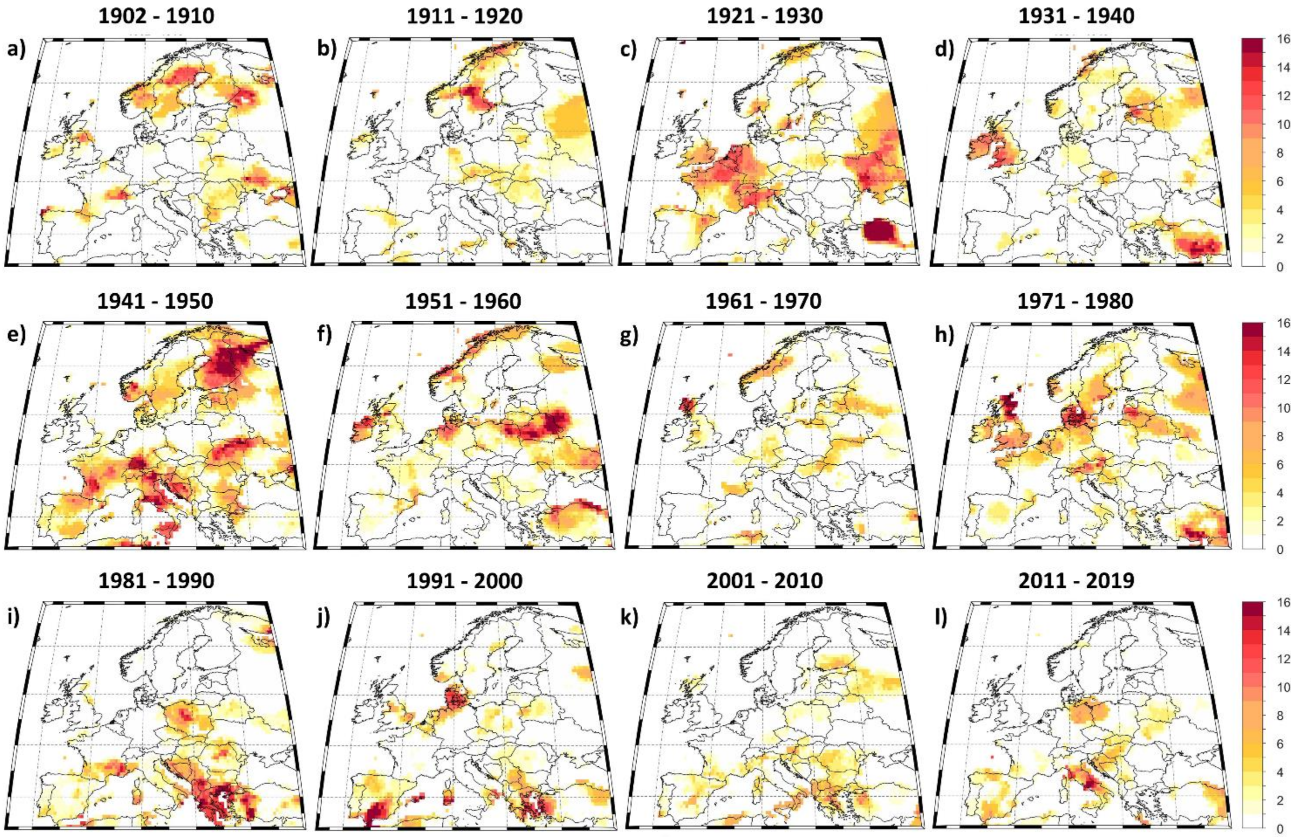


Figure S6. Decadal frequency of drought duration for **extreme drought** (SPI12<-2): a) 1902 – 1901; b) 1911 – 1920; c) 1921 – 1930; d) 1931 – 1940; e) 1941 – 1950; f) 1951 – 1960; g) 1961 – 1970; h) 1971 – 1980; i) 1981 – 1990; j) 1991 – 2000; k) 2001 – 2010 and l) 2011 – 2019. Units: number of months/period.

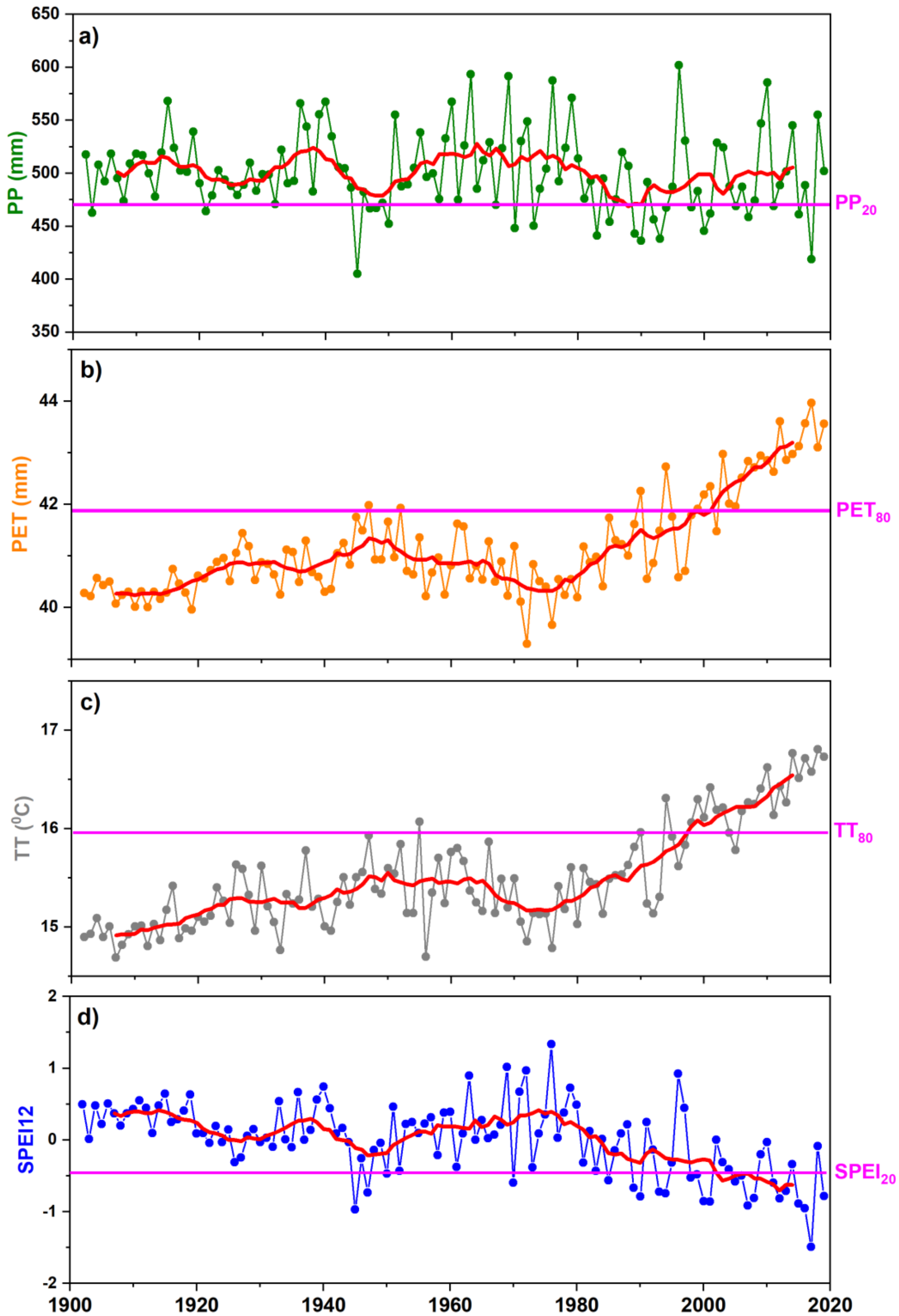


Figure S7. a) Time series of the annual precipitation (PP) averaged over MED; b) as in a) but for the potential evapotranspiration (PET); c) as in a) but for mean air temperature (TT) and d) as in a) but for SPEI12. The red line in a) – d) indicates the 21 years running mean.

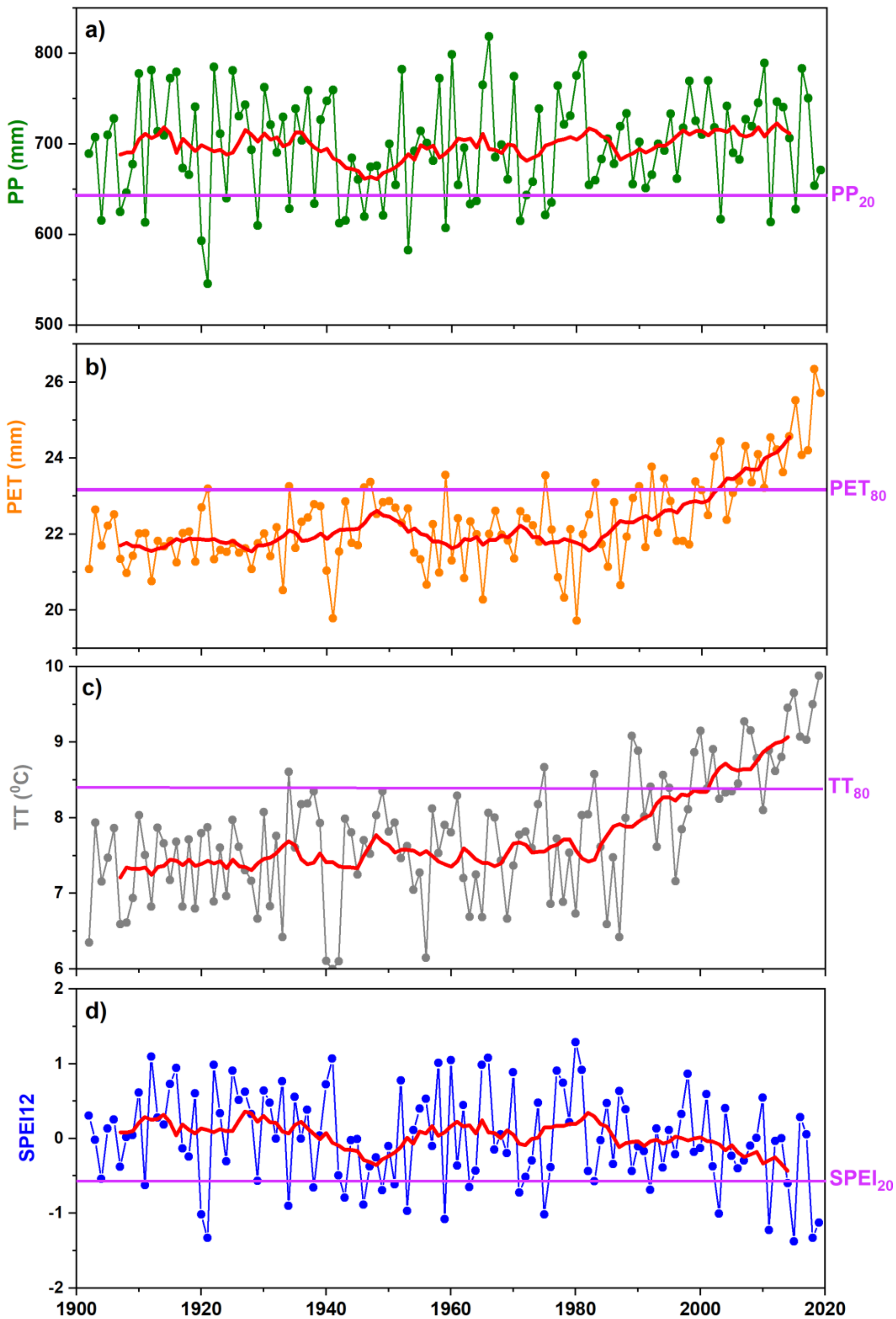


Figure S8. a) Time series of the annual precipitation (PP) averaged over CEU; b) as in a) but for the potential evapotranspiration (PET); c) as in a) but for mean air temperature (TT) and d) as in a) but for SPEI12. The red line in a) – d) indicates the 21 years running mean.

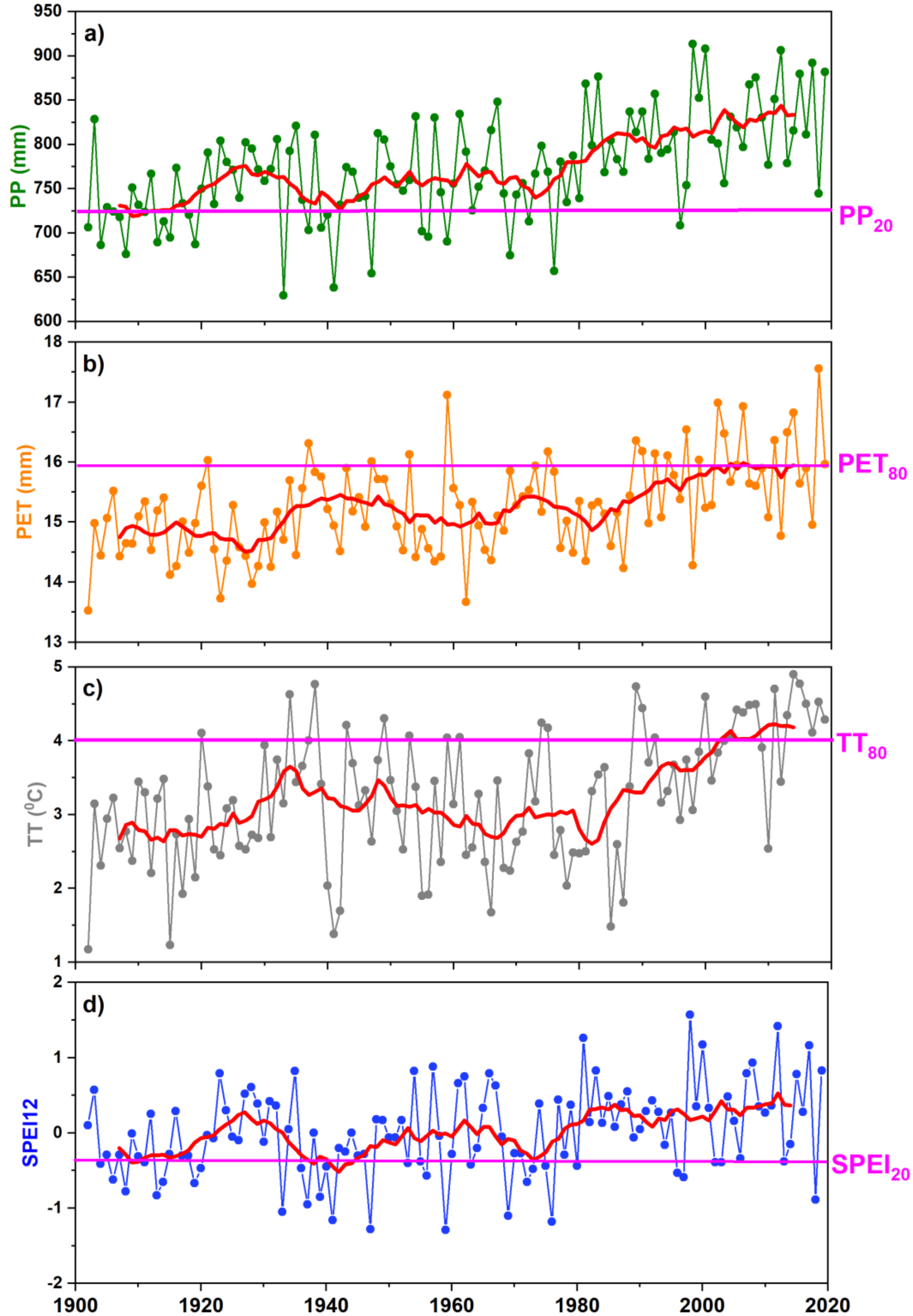
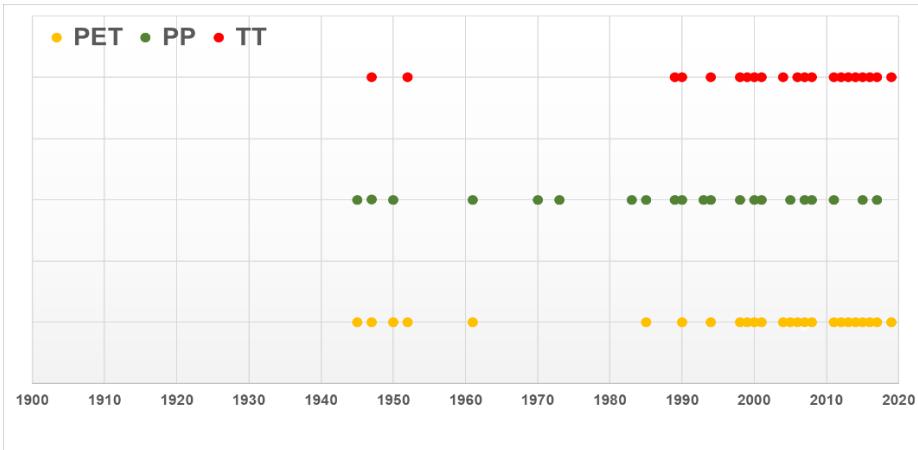
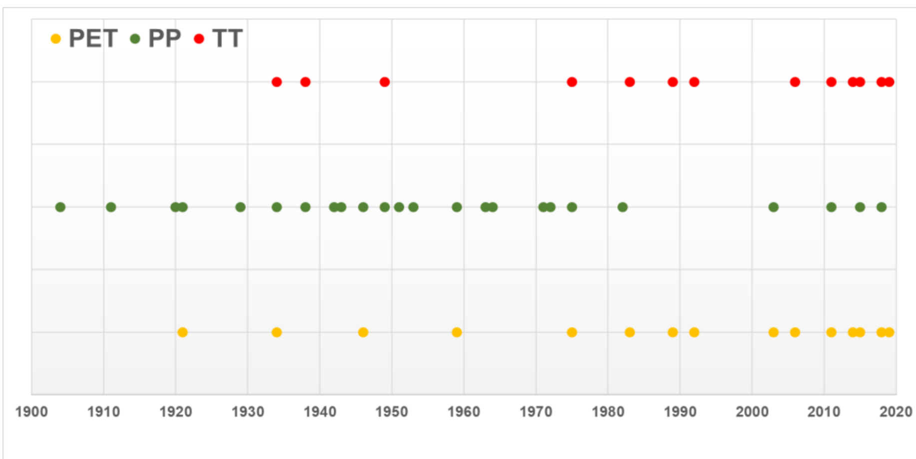


Figure S9. a) Time series of the annual precipitation (PP) averaged over MED; b) as in a) but for the potential evapotranspiration (PET); c) as in a) but for mean air temperature (TT) and d) as in a) but for SPEI12. The red line in a) – d) indicates the 21 years running mean.

a)



b)



c)

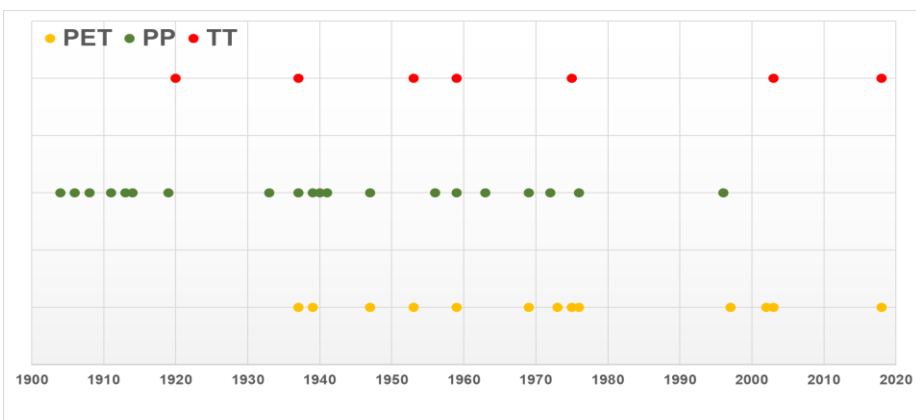
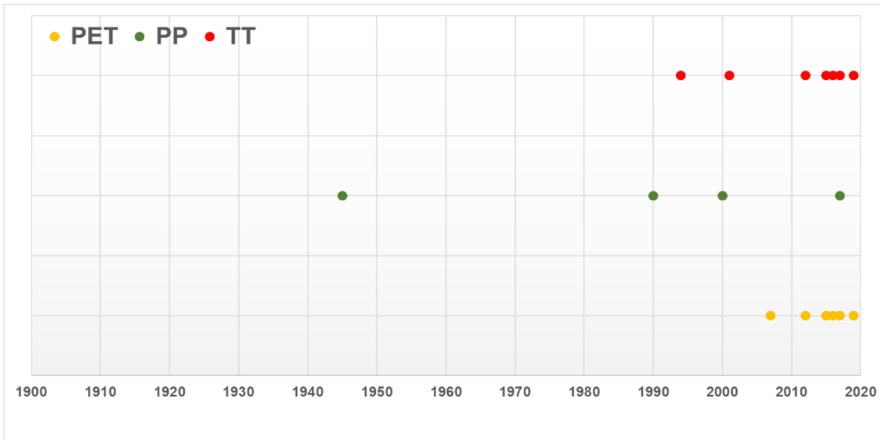
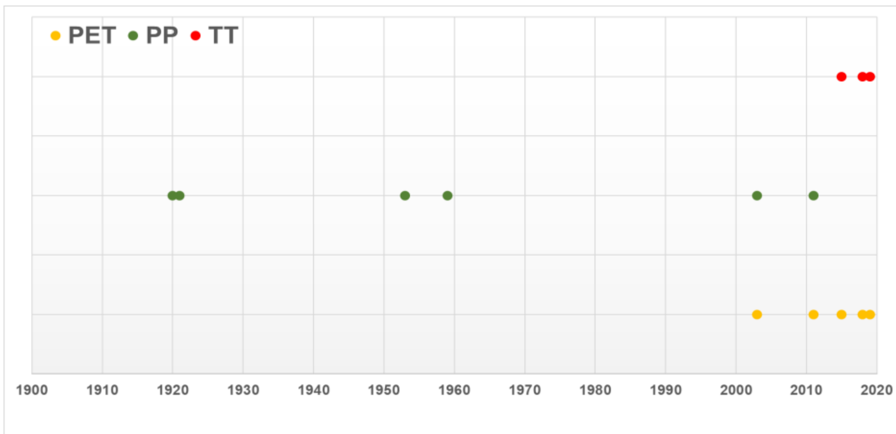


Figure S10. a) Occurrence of warm and dry events ($TT_{75}/SPEI12_{25}$ – red dots), low precipitation and dry events ($PP_{25}/SPEI12_{25}$ – green dots) and enhanced evaporation and dry events ($PET_{75}/SPEI12_{25}$ – yellow dots) for MED area; b) as in a) but for CEU and c) as in a) but for NEU. $TT_{75}/SPEI12_{25}$ indicates that we took into account the common years when the temperature was higher than the 75th percentile and SPEI12 was smaller that the 25th percentile. $PP_{25}/SPEI12_{25}$ indicates that we took into account the common years when the precipitation was smaller than the 25th percentile and SPEI12 was smaller that the 25th percentile. $PET_{75}/SPEI12_{25}$ indicates that we took into account the common years when the potential evapotranspiration was higher than the 75th percentile and SPEI12 was smaller that the 25th percentile.

a)



b)



c)

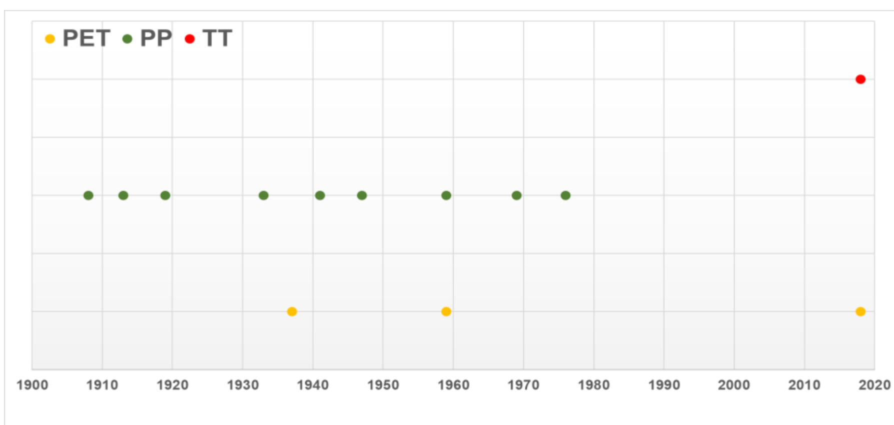


Figure S11. a) Occurrence of warm and dry events ($TT_{90}/SPEI12_{10}$ – red dots), low precipitation and dry events ($PP_{10}/SPEI12_{10}$ – green dots) and enhanced evaporation and dry events ($PET_{90}/SPEI12_{10}$ – yellow dots) for MED area; b) as in a) but for CEU and c) as in a) but for NEU. $TT_{90}/SPEI12_{10}$ indicates that we took into account the common years when the temperature was higher than the 90th percentile and SPEI12 was smaller that the 10th percentile. $PP_{10}/SPEI12_{10}$ indicates that we took into account the common years when the precipitation was smaller than the 10th percentile and SPEI12 was smaller that the 10th percentile. $PET_{90}/SPEI12_{10}$ indicates that we took into account the common years when the potential evapotranspiration was higher than the 90th percentile and SPEI12 was smaller that the 10th percentile.

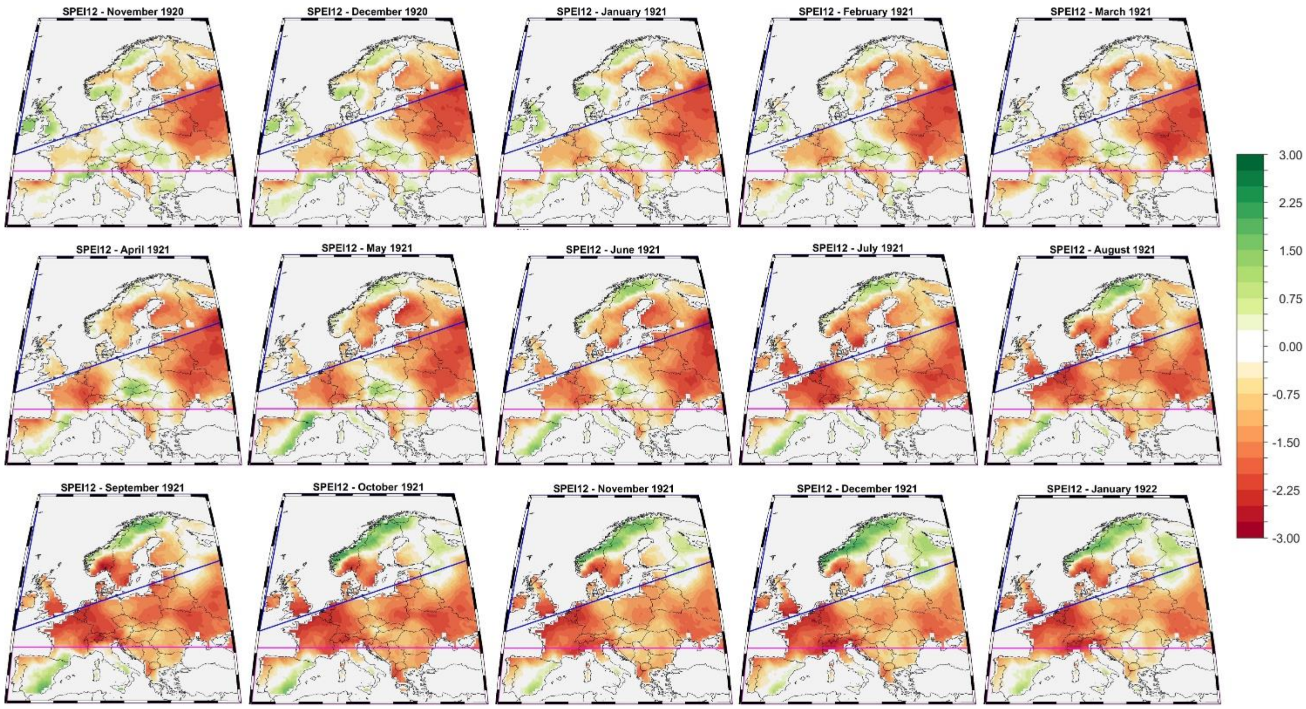


Figure S12. Spatial evolution of the SPEI12 between November 1920 until January 1922.

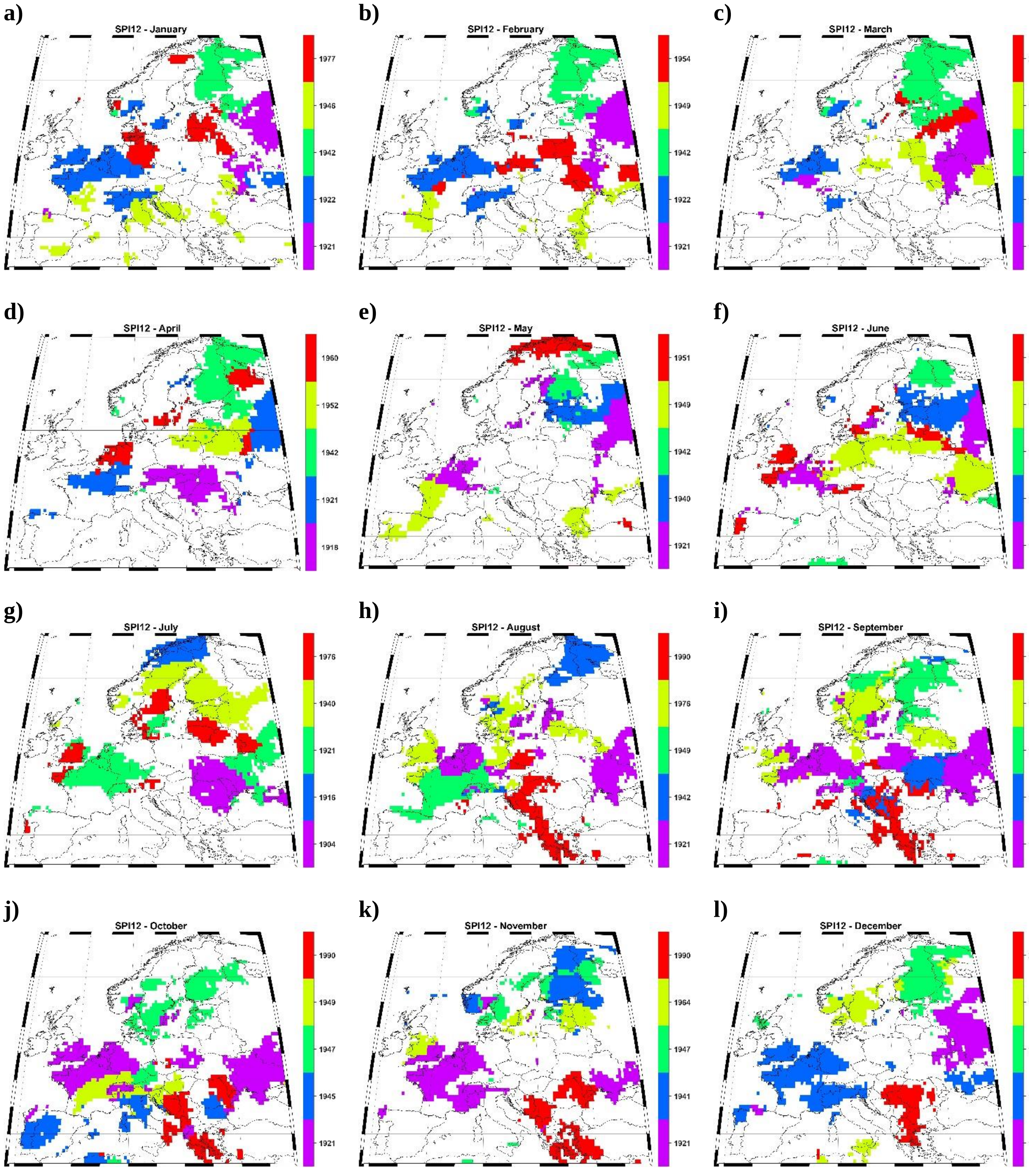


Figure S13. The spatial extent and the year of record of the driest years, based on the monthly SPI12, over Europe. Analyzed period: 1902–2019.

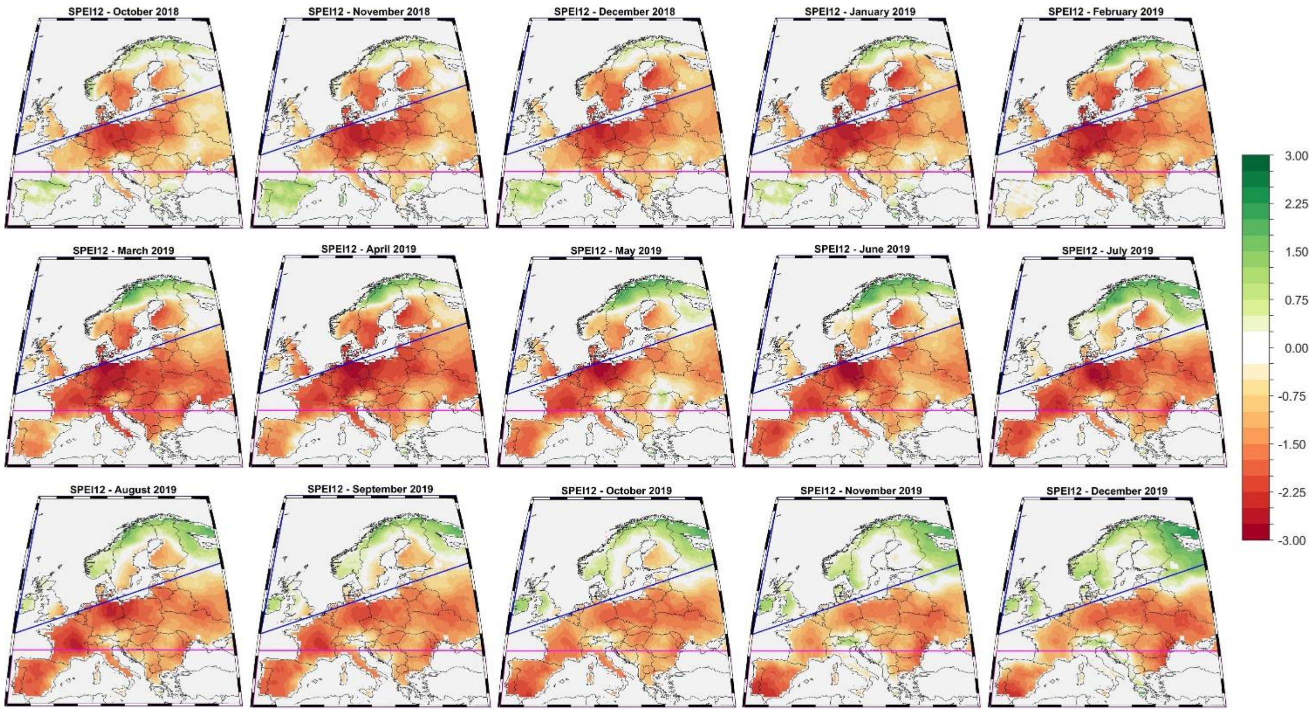


Figure S14. Spatial evolution of the SPEI12 between October 2018 until December 2019.

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