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Supplementary Materials for

Direct and seasonal legacy effects of the 2018 heat wave and drought on European ecosystem productivity

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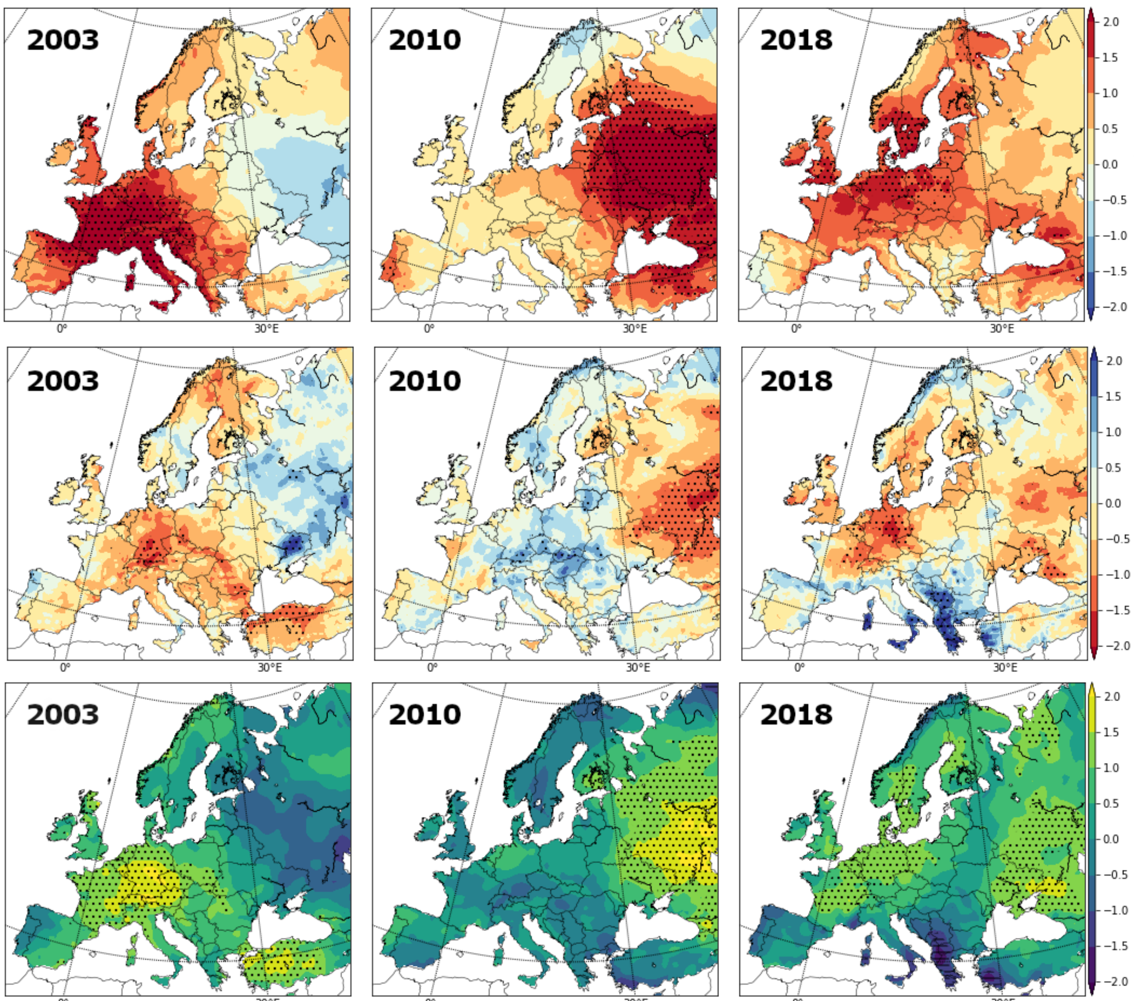
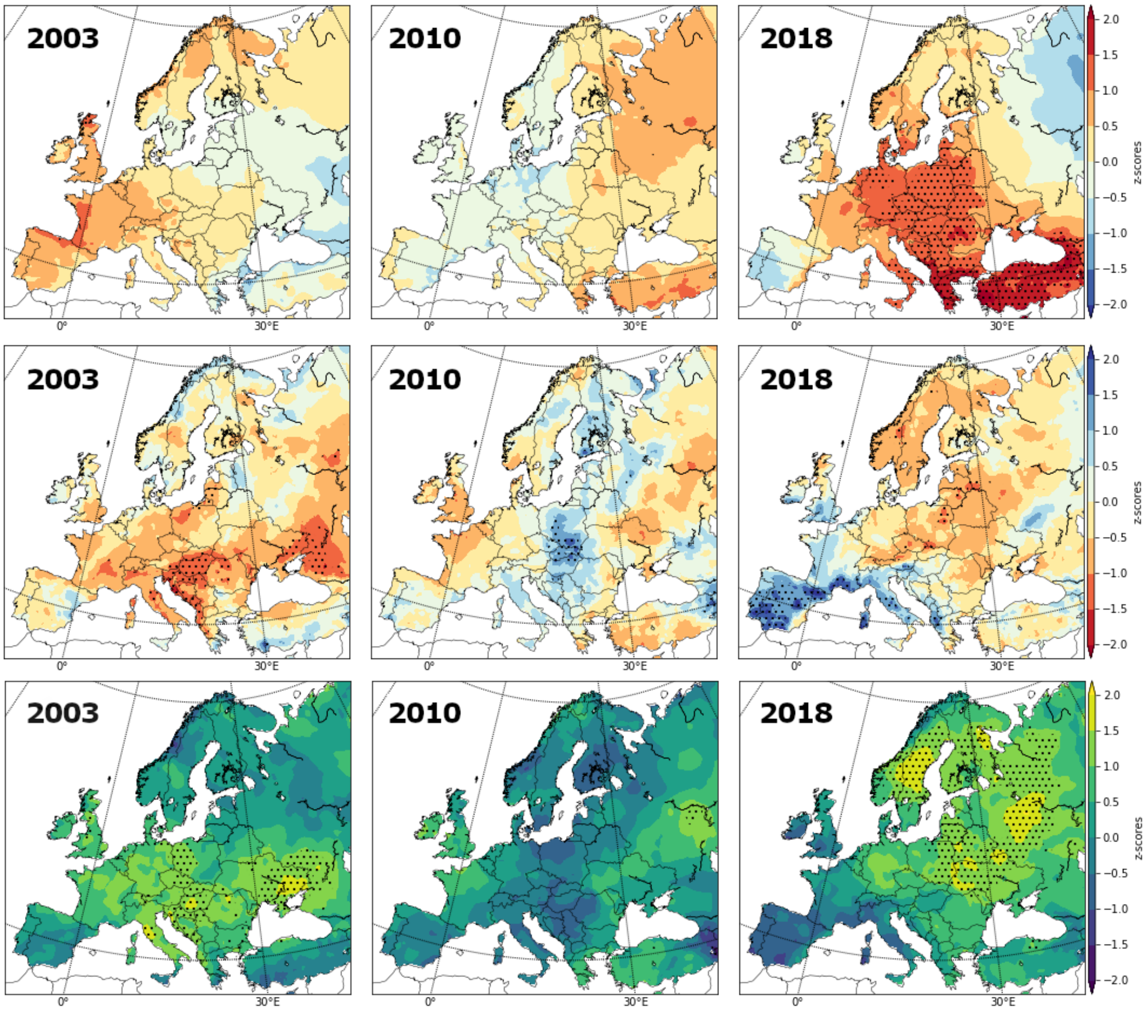
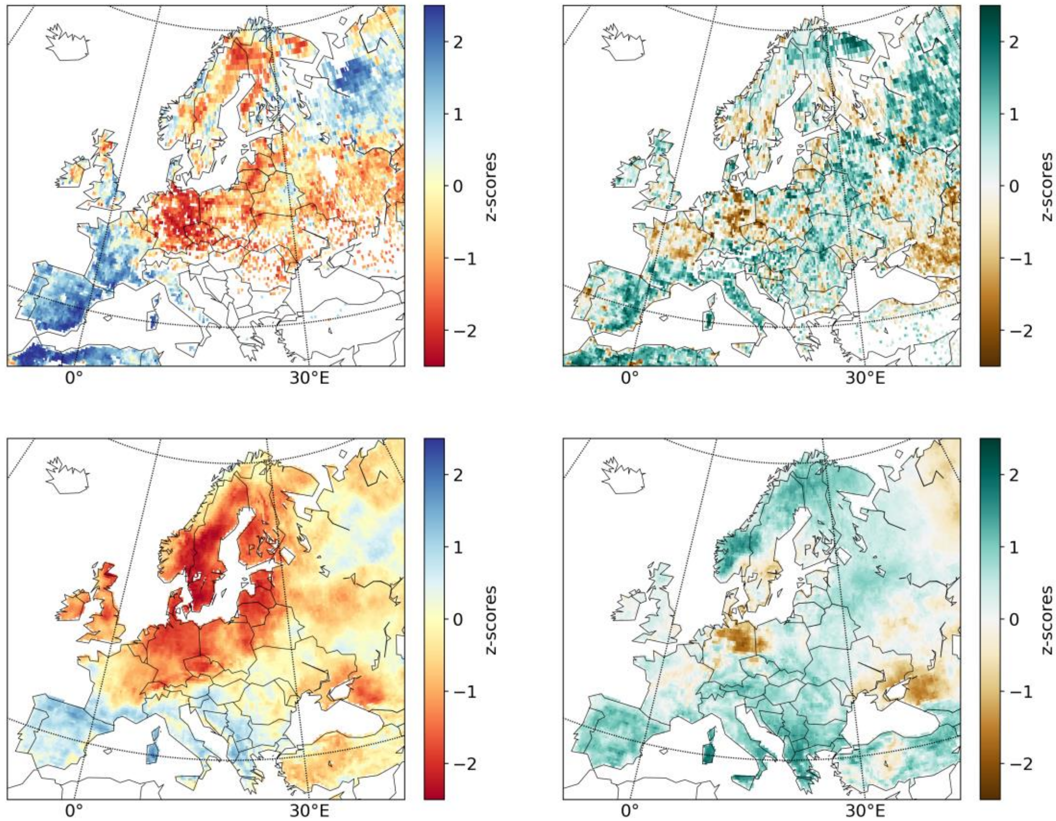
Supplementary Materials



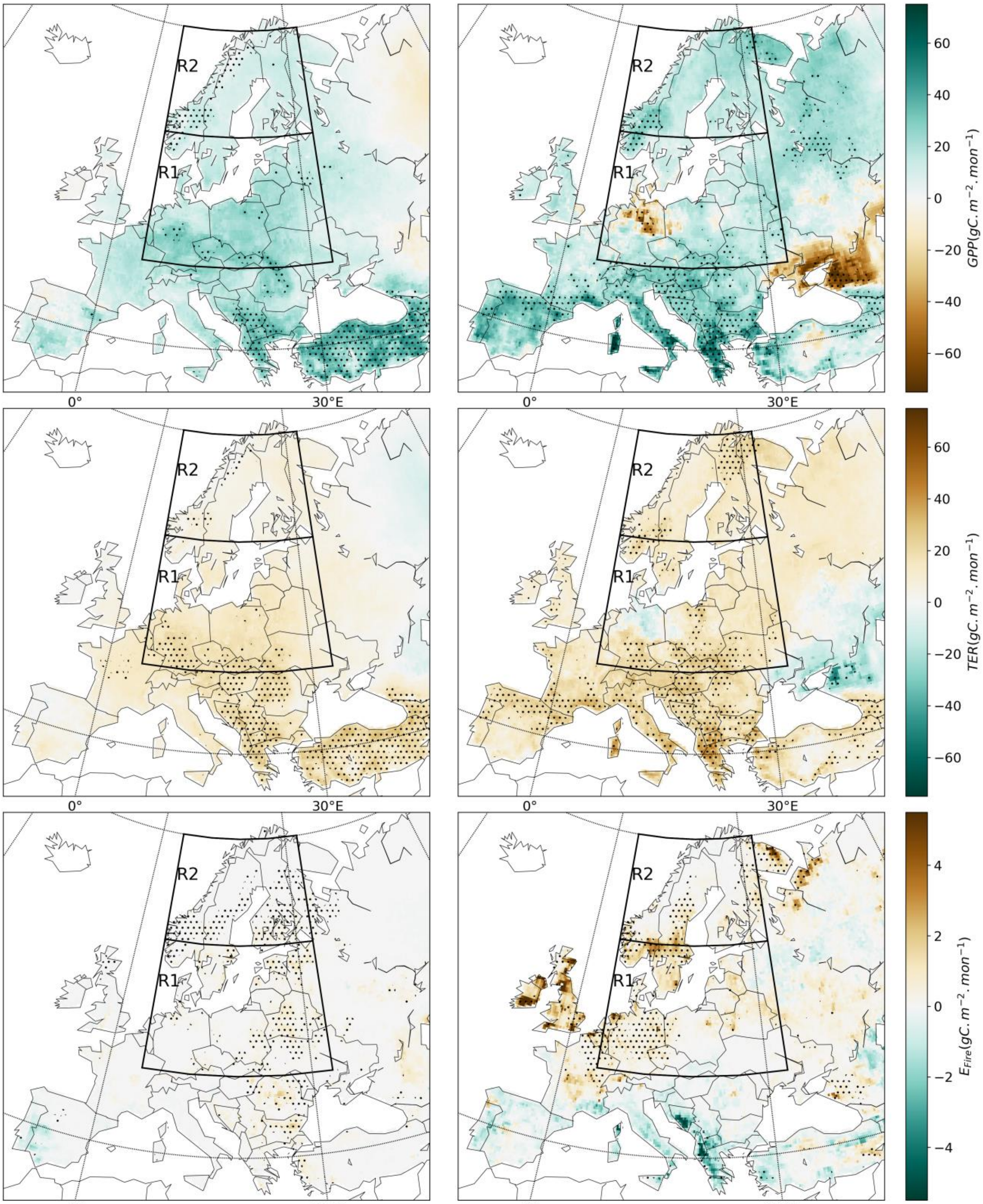
Supplementary Figure 1. Standardized mean temperature (top), precipitation (center) and incoming surface shortwave radiation (bottom) anomalies in summer (JJA) 2003, 2010 and 2018. The stippling indicates extremely high (rank highest) or extremely low (rank lowest) anomalies over the period 1979-2018.



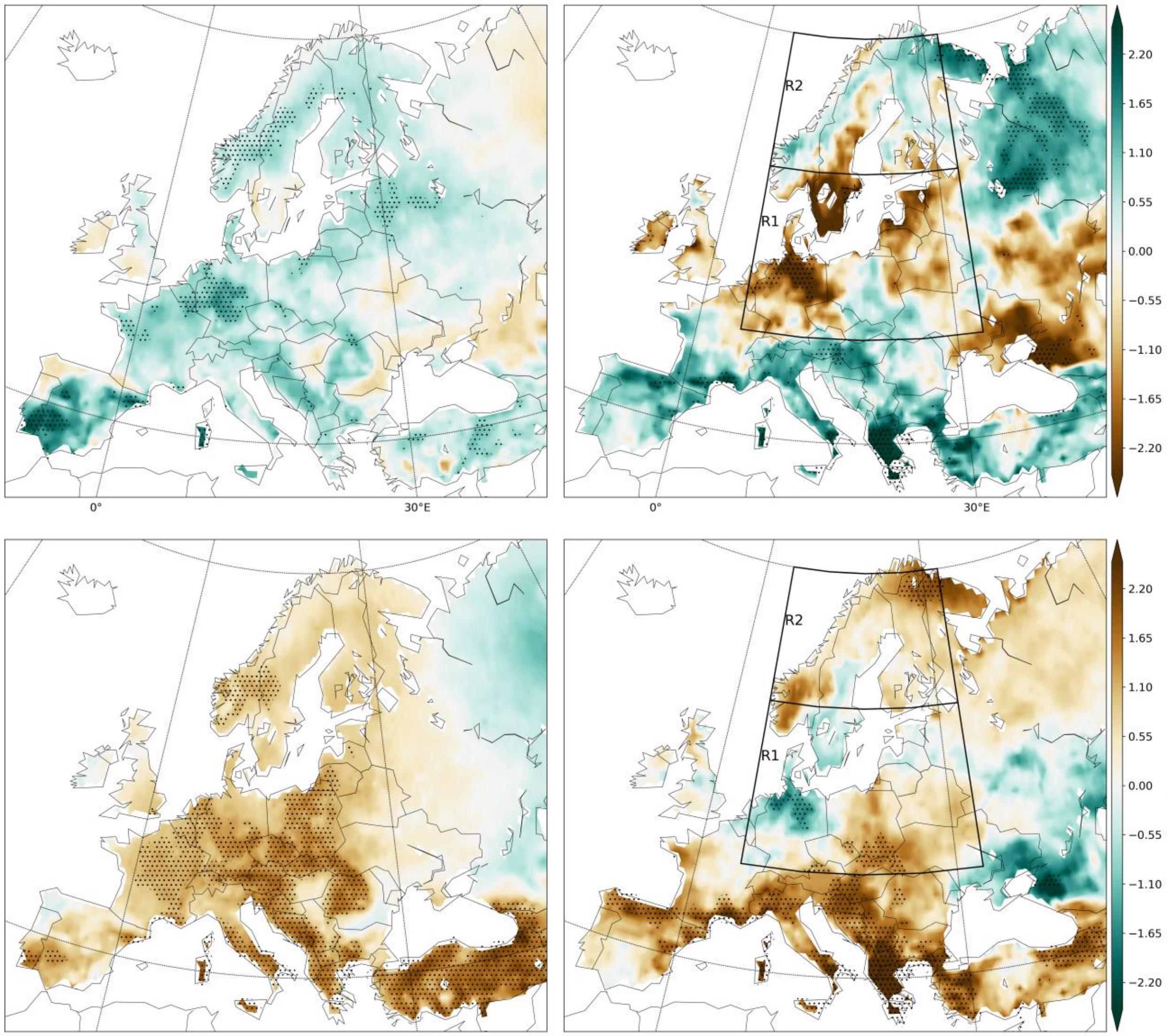
Supplementary Figure 2. Standardized mean temperature (top), precipitation (center) and incoming surface shortwave radiation (bottom) anomalies in spring (MAM) 2003, 2010 and 2018. The stippling indicates extremely high (rank highest) or extremely low (rank lowest) anomalies over the period 1979-2018.



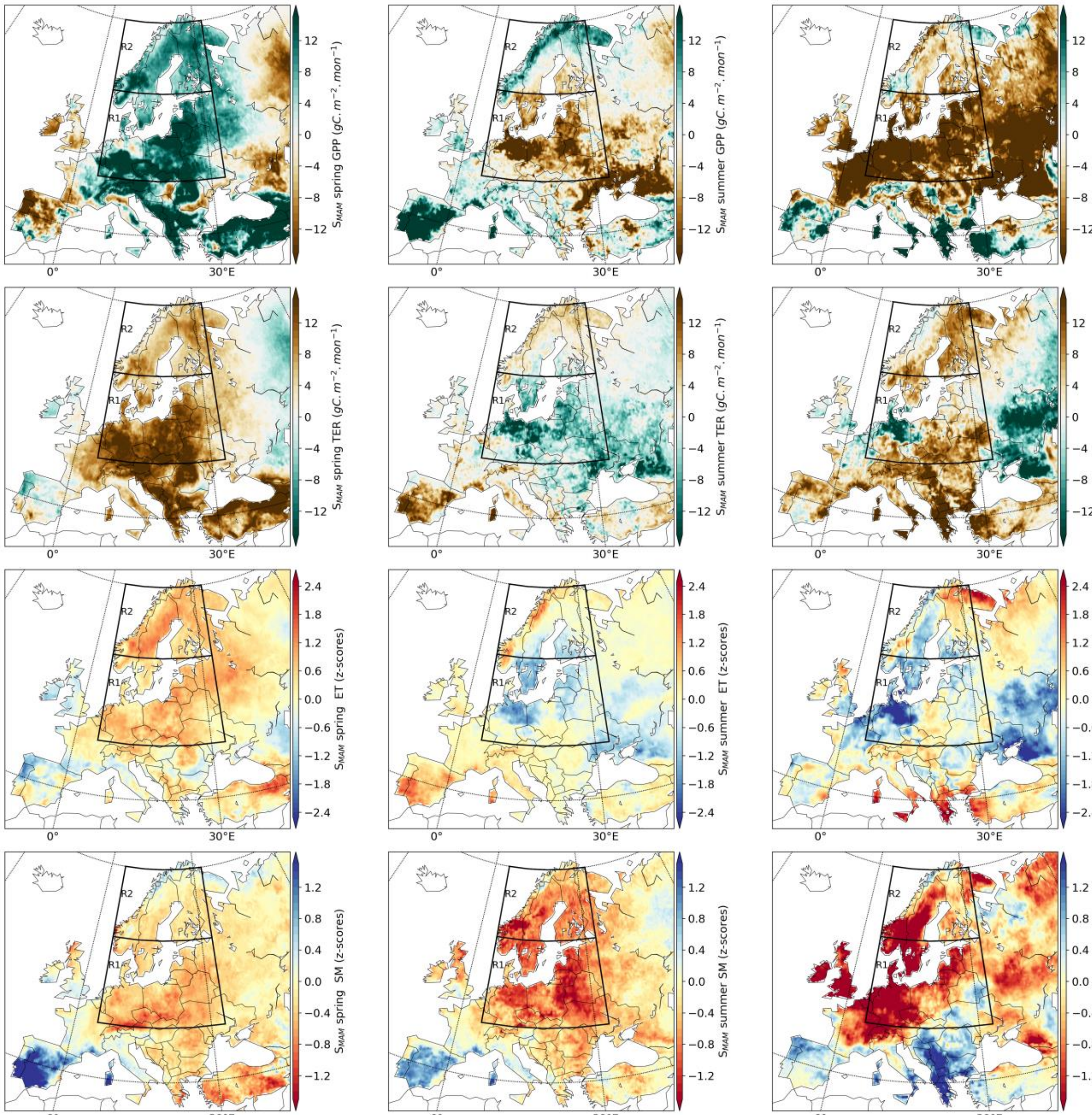
Supplementary Figure 3. Anomalies in the annual changes of spring and summer anomalies in soil-moisture (top left) and aboveground biomass C-stocks (AGB, top right) derived from L-band vegetation optical depth (VOD) from SMOS as in (23–25). The anomalies are calculated as z-scores, relative to the period covered by SMOS (2010-2018). The anomalies in SMOS data are compared with multi-model ensemble mean (MMEM) anomalies for soil-moisture (bottom left) and the L-VOD changes compared to aboveground components of NBP (i.e. excluding soil respiration) (bottom right).



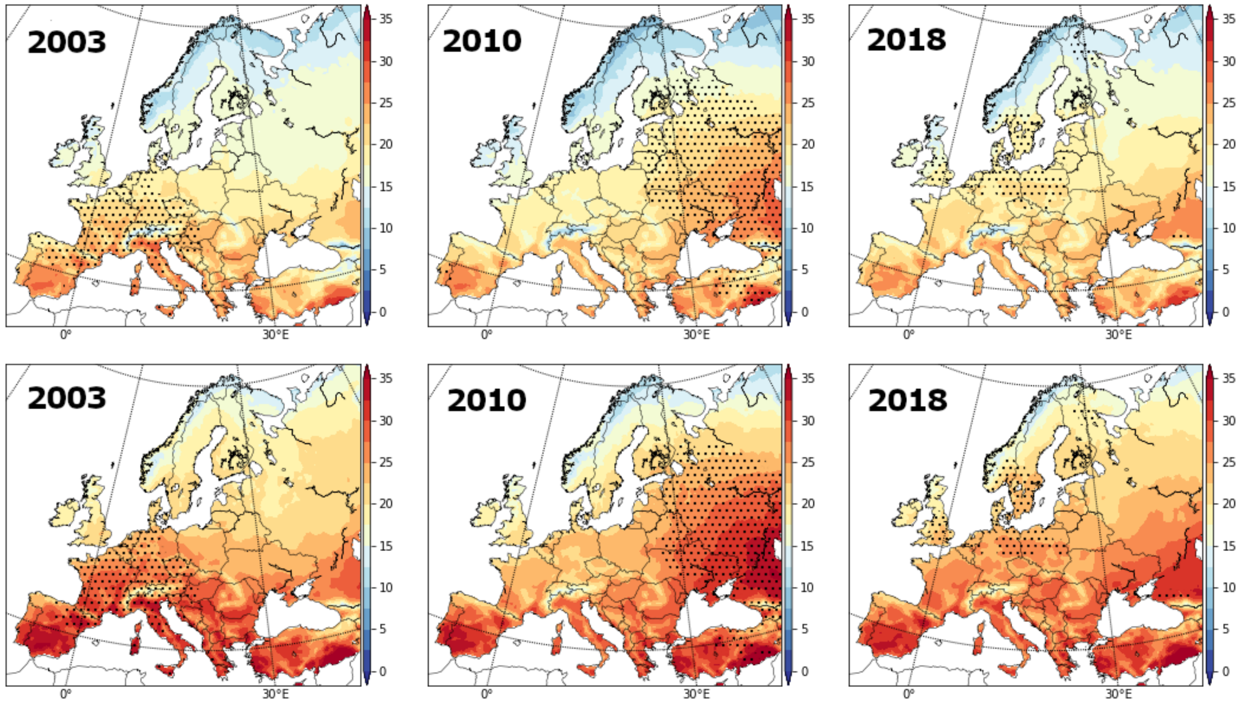
Supplementary Figure 4. MMEM Anomalies for GPP (top), TER (center) and emissions from fires (bottom) in spring (left) and summer (right) of 2018. Note the different scales in the color bars. From the 11 models, only a sub-set of six DGVMs simulated fire emissions (ISBA-CTRIP, DLEM, JSBACH, LPJ-GUESS, LPX-Bern, ORCHIDEE-MICT).



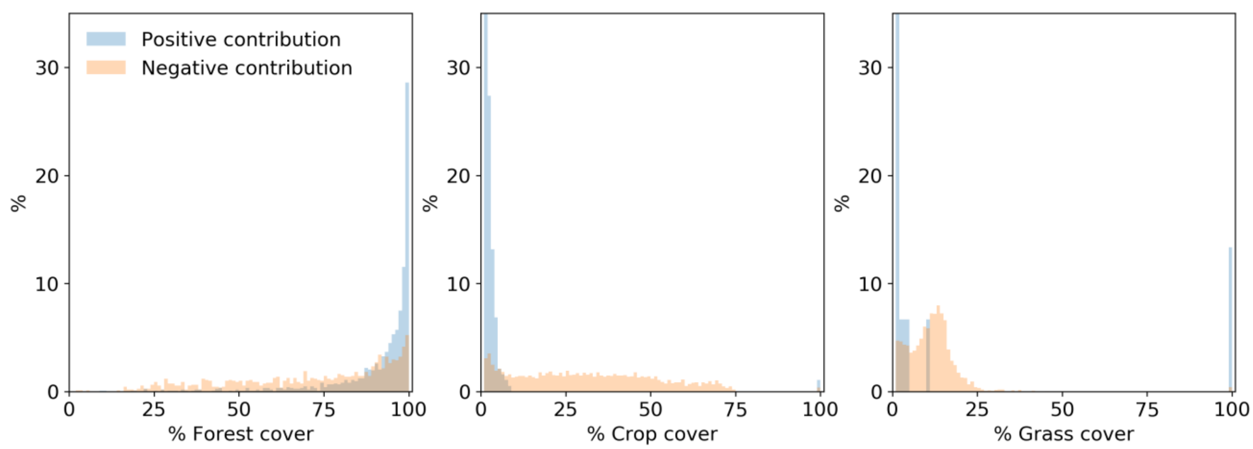
Supplementary Figure 5. GPP (top) and TER (bottom) anomalies (z-scores) in spring (left) and summer (right) 2018, estimated as the ensemble mean of the FLUXCOM data-driven product.



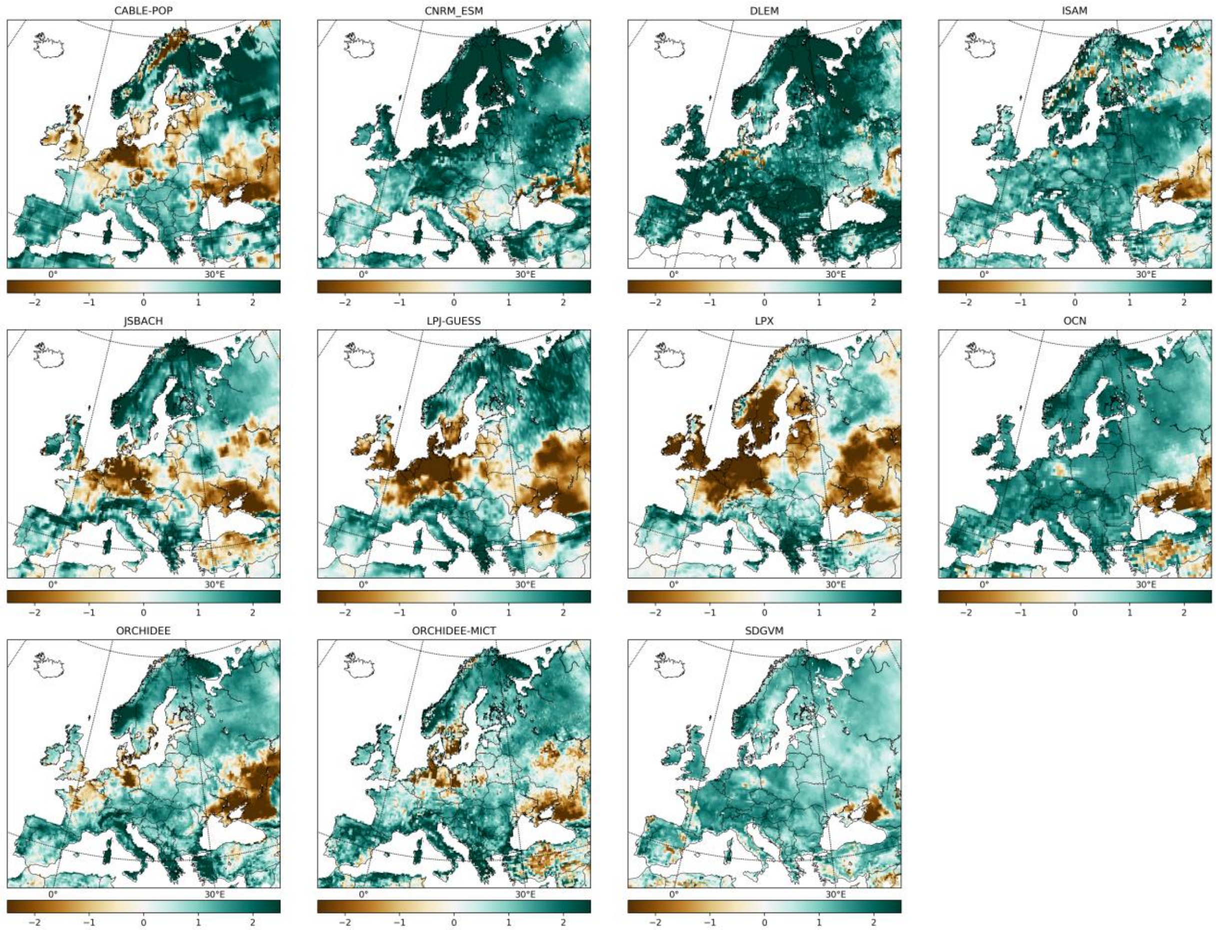
Supplementary Figure 6. Anomalies in GPP (1st row), TER (2nd row), evapotranspiration (ET, 3rd row) and soil-moisture (SM, 4th row) during spring (left panel) and summer (central and right panels), estimated by S_{MAM} (left and central panels) and S_{JJA} (right panel). The left and right panels show the individual impact of spring and summer climate, respectively, while the central vertical panel shows the legacy effect of spring climate to summer GPP, TER and soil-moisture.



Supplementary Figure 7. Absolute daily mean (top) and daily maximum (bottom) temperature values during summers of 2003, 2010 and 2018. The stippling indicates extremely high (rank highest) or extremely low (rank lowest) anomalies over the period 1979-2018.



Supplementary Figure 8. Land-cover composition of the regions where positive (blue) and negative (orange) contribution of spring to summer anomalies in NBP, according to Fig. 3D.



Supplementary Figure 9. Summer 2018 GPP anomalies from the individual DGVMs (in z-score units), to be compared with the corresponding anomalies from FLUXCOM Supplementary Figure 5 (top right panel).

Supplementary Table 1. Summary of the model simulations performed for this study. The difference between S_{Ref} and S_{MAM} gives, for spring, the direct impacts of the spring climate anomalies (temperature, precipitation, incoming shortwave and longwave radiation, wind speed, sea level pressure and specific humidity) on soil-moisture and ecosystem C-fluxes. Because we continue the simulation S_{MAM} until the end of 2018 with the same climate forcing as S_{Ref}, the differences in the simulated C-fluxes can only be due to legacy effects on SM from the spring climate anomalies and from the response of ecosystems to those anomalies. The difference between S_{Ref} and S_{JJA} for the summer months allows estimating the SM and C-flux anomalies due to the summer climate anomalies only. The null hypothesis is that there is no effect, i.e. the difference should be zero.

Simulation	CO_2	Climate	LUC	Purpose
Control	Fixed (1979)	Randomize 1979-1998	Fixed (2010) LUH2v2h	Evaluate steady-state
S_{Ref}	Time-varying 1979-2018	Time-varying 1979- Dec 2018	Fixed (2010) LUH2v2h	Compare with observations
S_{MAM}	Time-varying 1979-2018	1979 - March 2018 (S_{Ref}) March-May 2018 (spring climatology) July-Dec 2018 (S_{Ref})	Fixed (2010) LUH2v2h	Spring direct and legacy effects (S_{Ref} – S_{MAM})
S_{JJA}	Time-varying 1979-2018	1979 - Jun 2018 (S_{Ref}) June-Aug 2018 (summer climatology) July-Dec 2018 (S_{Ref})	Fixed (2010) LUH2v2h	Summer direct and legacy effects (S_{Ref} - S_{JJA})