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Impacts of extreme summers on European ecosystems: a comparative analysis of 2003, 2010 and 2018

A. Bastos[1*+], Z. Fu[2], P. Ciais[2], P. Friedlingstein[3], S. Sitch[4], J. Pongratz[1,5], U. Weber[6], M. Reichstein[6], P. Anthoni[7], A. Arneth[7], V. Haverd[8], A. Jain[9], E. Joetzjer[10], J. Knauer[8], S. Lienert[11], T. Loughran[1], P.C. McGuire[12], W. Obermeier[1], R. S. Padrón[13], H. Shi[14], H. Tian[14], N. Viovy[2], S. Zaehle[6]

1. Ludwig Maximilians Universität, Dept. of Geography, Luisenstr. 37, 80333 Munich, Germany
2. Laboratoire des Sciences du Climat et de l'Environnement (LSCE), CEA-CNRS-UVSQ, UMR8212, 91191 Gif-sur-Yvette, France
3. College of Engineering, Mathematics and Physical Sciences, University of Exeter, Exeter EX4 4QF, UK
4. College of Life and Environmental Sciences, University of Exeter, Exeter EX4 4RJ, UK
5. Max Planck Institute for Meteorology, 20146 Hamburg, Germany
6. Max Planck Institute for Biogeochemistry, 07745 Jena, Germany
7. Karlsruhe Institute of Technology, Institute of Meteorology and Climate Research / Atmospheric Environmental Research, 82467 Garmisch-Partenkirchen, Germany
8. CSIRO Oceans and Atmosphere, Canberra, 2601, Australia
9. Department of Atmospheric Sciences, University of Illinois, Urbana, IL 61801, USA
10. Laboratoire Evolution et Diversite Biologique UMR 5174, CNRS Universite Paul Sabatier, Toulouse, France
11. Climate and Environmental Physics, Physics Institute and Oeschger Centre for climate Change Research, University of Bern, Bern CH-3012, Switzerland
12. Department of Meteorology, University of Reading, Earley Gate RG66BB Reading, United Kingdom
13. Institute for Atmospheric and Climate Science, Department of Environmental Systems Science, ETH Zürich, Zürich, Switzerland
14. International Center for Climate and Global Change Research, School of Forestry and Wildlife Sciences, Auburn University, 602 Duncan Drive, Auburn, AL 36849, USA

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*Author for correspondence (abastos@bgc-jena.mpg.de)
+ now at *Max Planck Institute for Biogeochemistry, 07745 Jena, Germany*

Supplementary material

*Author for correspondence (ana.bastos@lmu.de).
†Present address: Department, Institution, Address, City, Code, Country

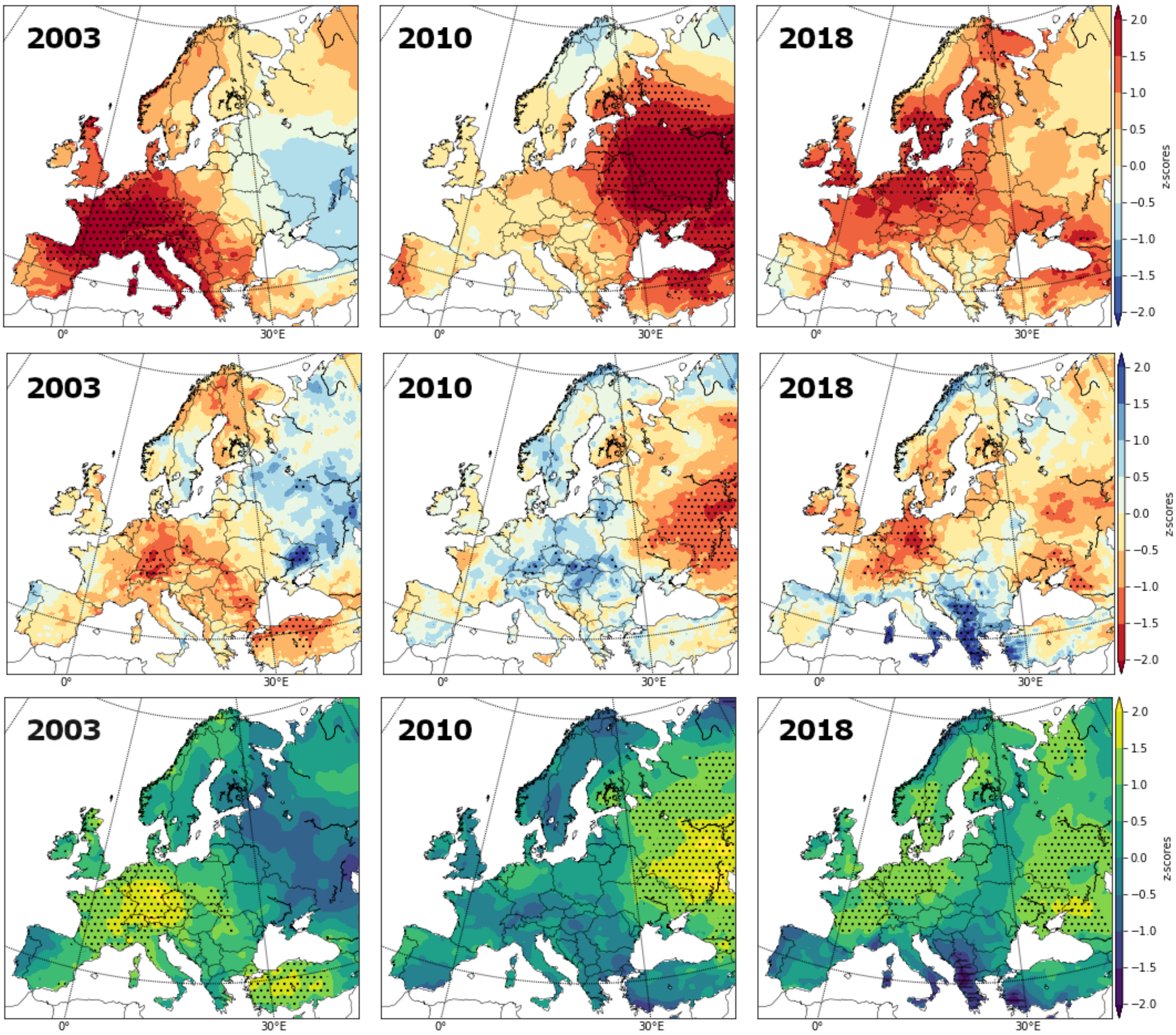

Figure S1. Standardized mean temperature (top), precipitation (center) and incoming surface shortwave radiation (bottom) anomalies in summer (June-August) 2003, 2010 and 2018. The stippling indicates extremely high (rank highest) or extremely low (rank lowest) anomalies over the period 1979-2018.

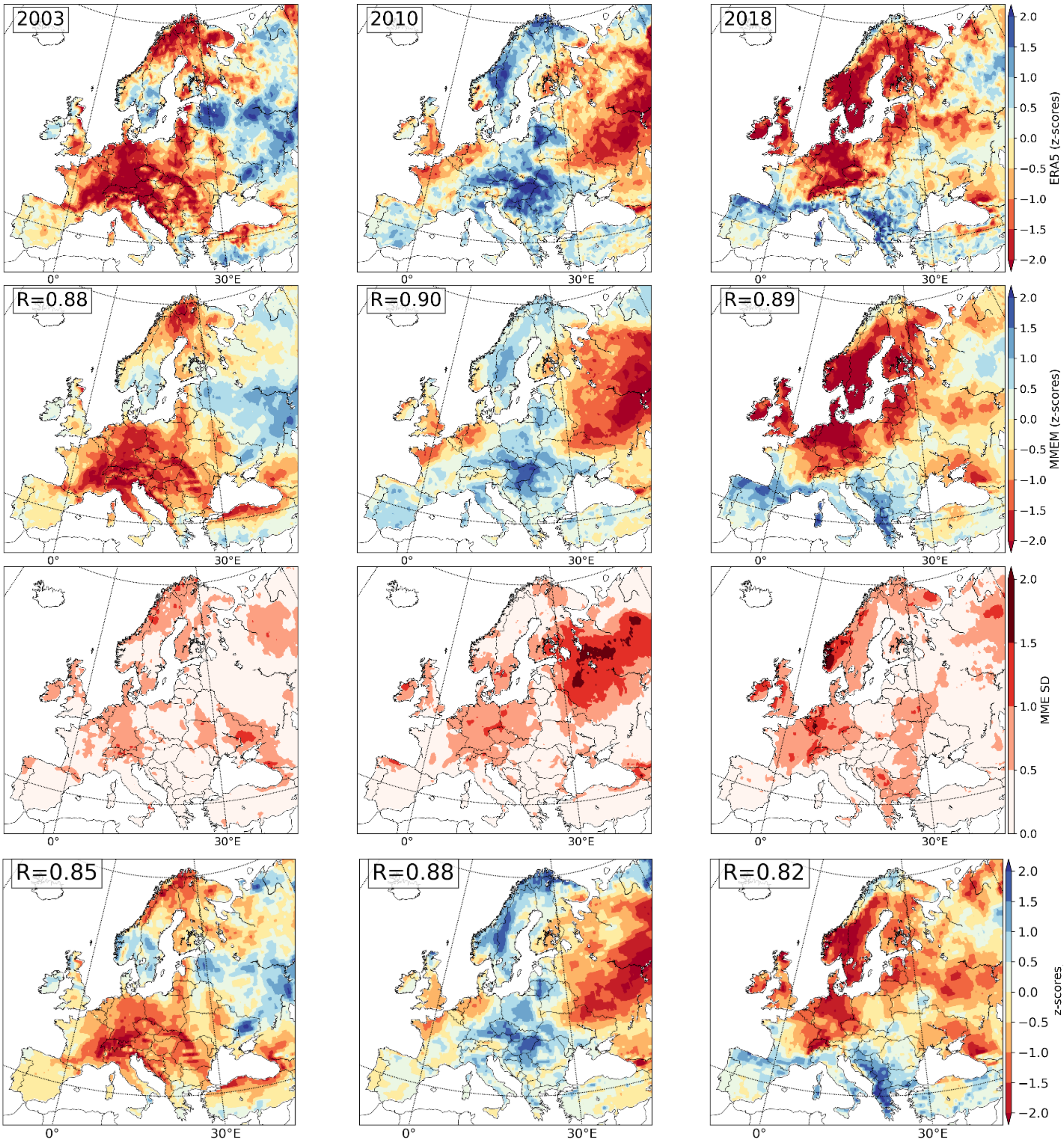

Figure S2. Soil-moisture (SM) anomalies in summers of 2003, 2010 and 2018 (left to right) from ERA5 (top row) and from the 11DGVM multi-model ensemble mean (second row). The multi-model 1σ range is shown in the third row. The bottom row shows results for FLUXCOM Water Availability Index. In ERA5 soil-moisture is evaluated at a depth of 0-289cm, while in DGVMs soil-depth is variable. Therefore, results are presented as standardized anomalies, rather than absolute values, and the long-term trend is removed.

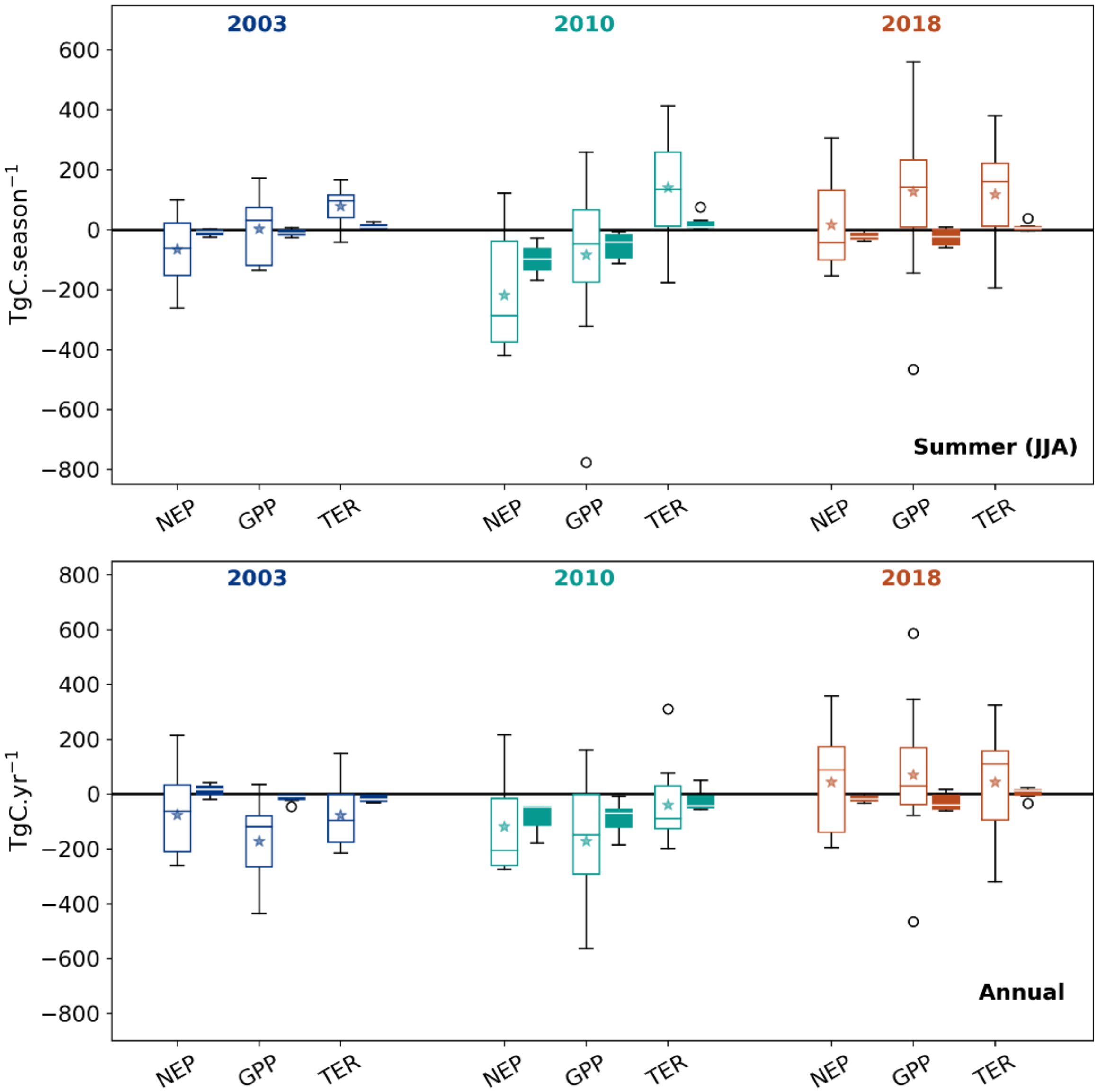

Figure S3. As in Figure 1, but for absolute detrended summer and annual NEP_{anom}, GPP_{anom} and TER_{anom}.

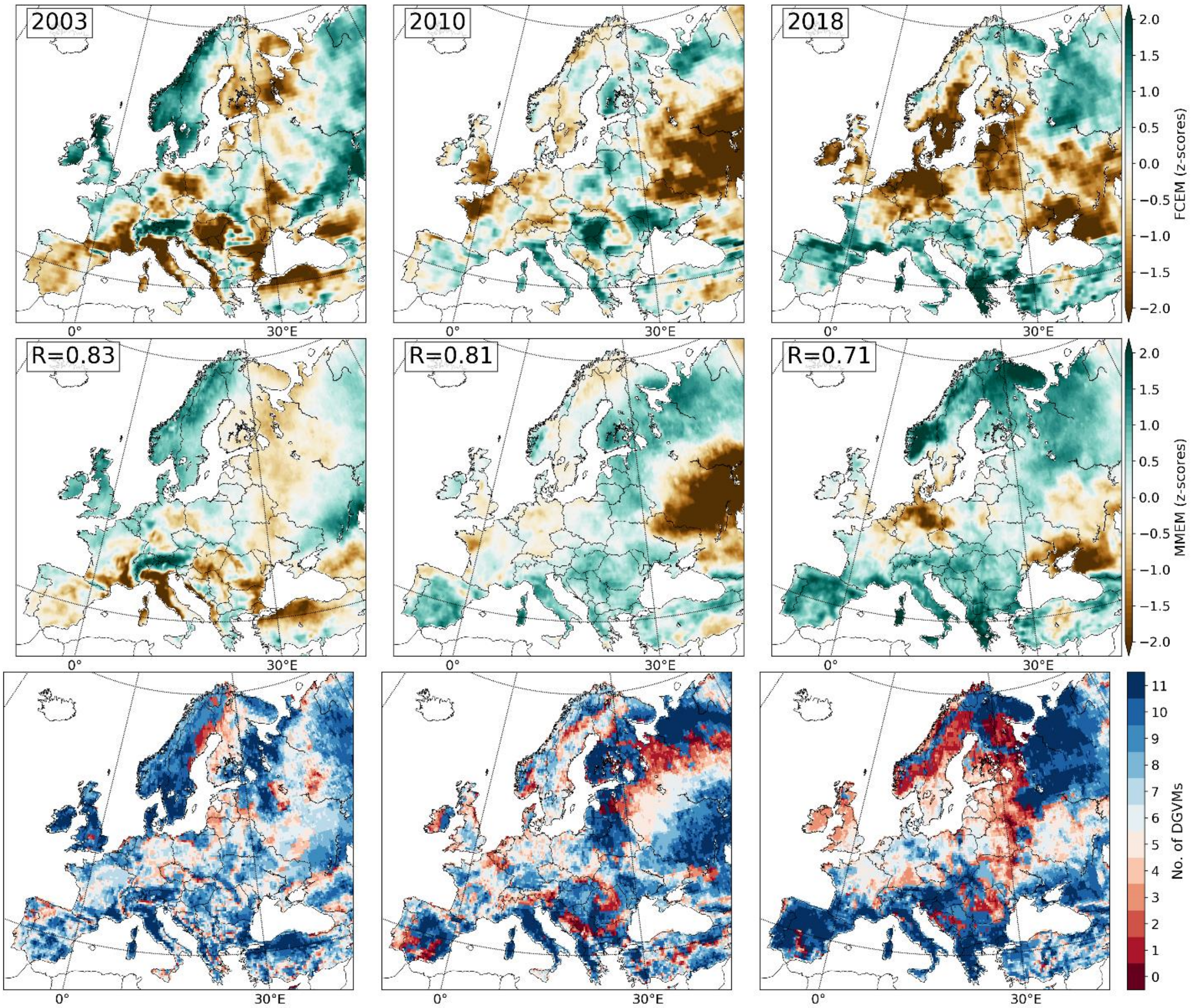

Figure S4. Gross primary productivity anomalies (GPP_{anom}) in summers of 2003, 2010 and 2018 from FLUXCOM 6-member ensemble mean (FCEM, top row) and from the 11 DGVM multi-model ensemble mean (central row), divided by the 40-yr standard deviation in each pixel. The number of DGVMs agreeing on the sign of GPP_{anom} with the FLUXCOM ensemble mean are shown in the bottom row. The FLUXCOM ensemble strongly underestimates the absolute variance of GPP, as pointed out by Jung et al. (2019) which is masked by the z-score transformation shown here. Therefore, results are presented as standardized anomalies, rather than absolute values.

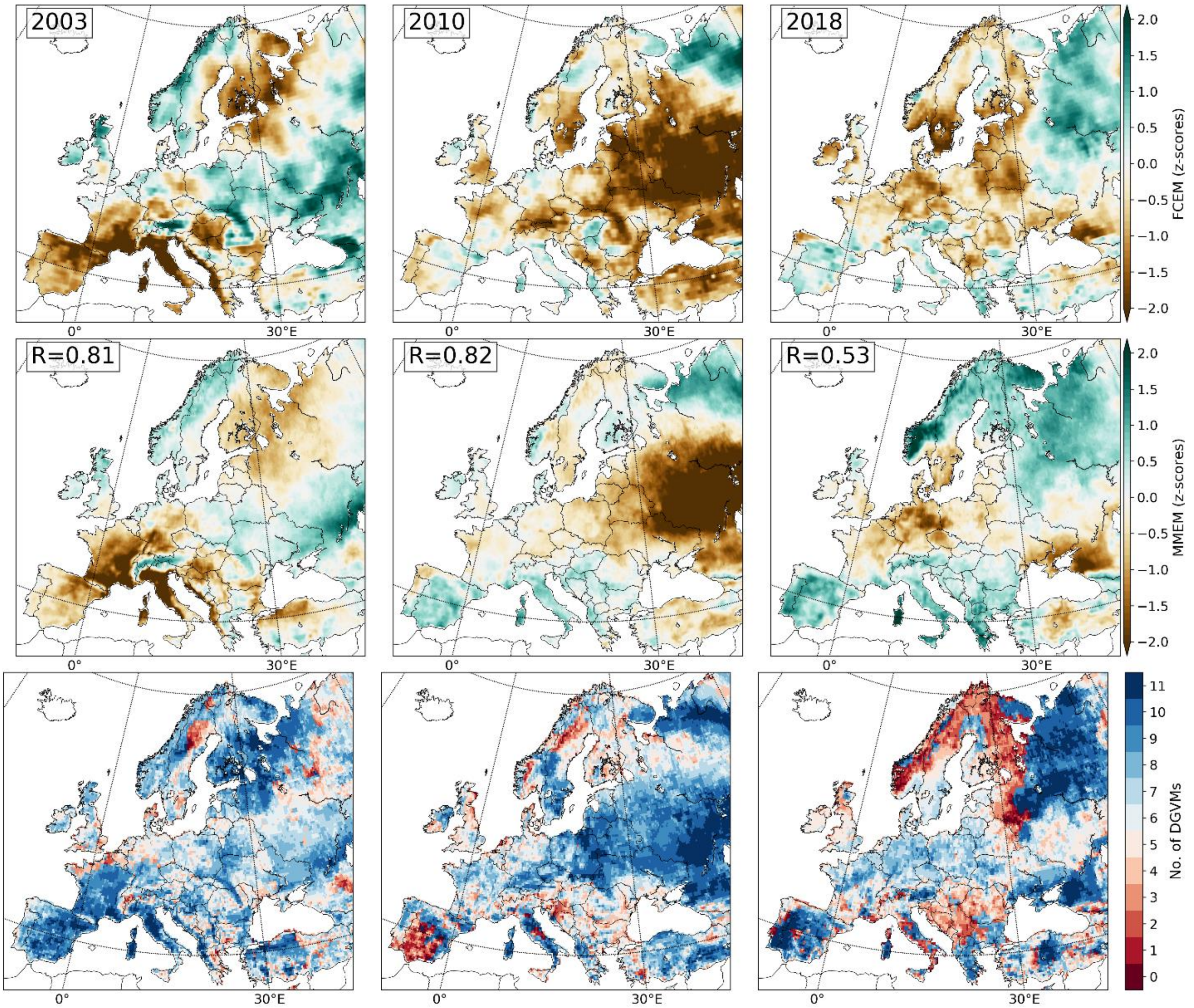

Figure S5. Net ecosystem productivity (NEP_{anom}) anomalies in summers of 2003, 2010 and 2018 from FLUXCOM 3-member ensemble mean (FCEM, top row) and from the 11 DGVM multi-model ensemble mean (central row). The number of DGVMs agreeing on the sign of NEP_{anom} with the FLUXCOM ensemble mean are shown in the bottom row. As in Figure S4, results are presented as standardized anomalies, rather than absolute values.

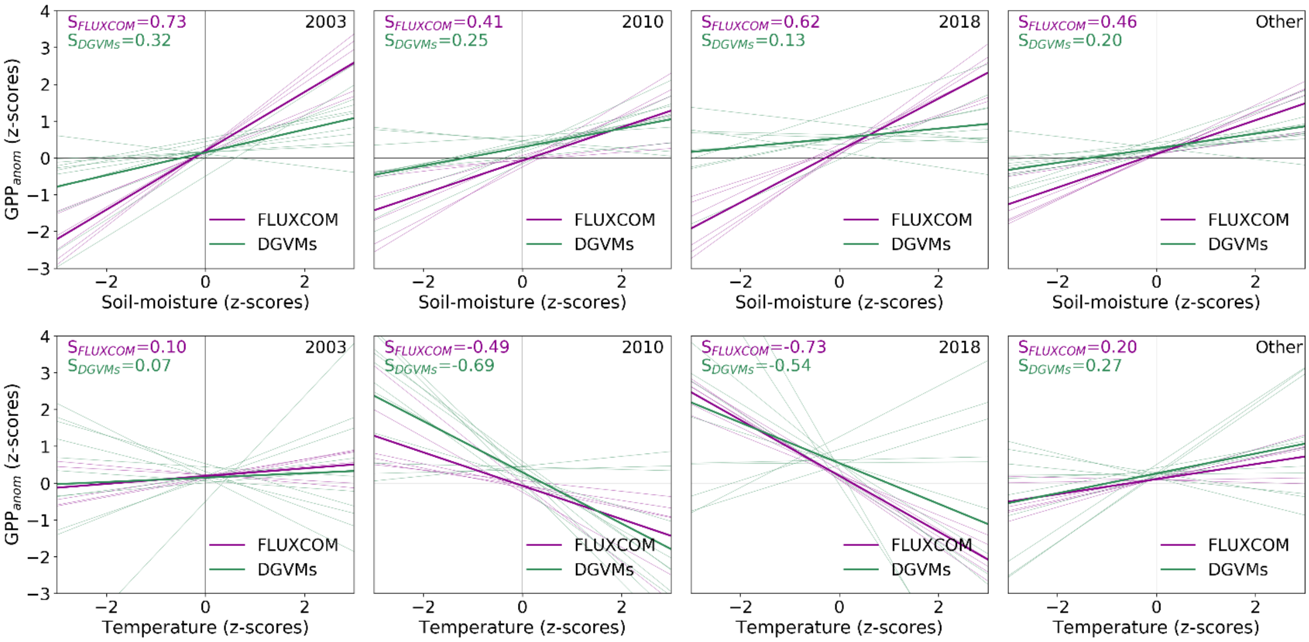

Figure S6. Summer anomalies in GPP in response to extreme summers in Europe. Anomalies in GPP versus SM (top) and temperature (bottom) anomalies during 2003, 2010 and 2018 summers from six ensemble members of the FLUXCOM data-driven product (magenta lines) and from the set of 11 DGVMS (green lines). The sensitivities of GPP to SM for the extreme summers are compared to other years in the 2000s (excluding 2015, also a dry summer).

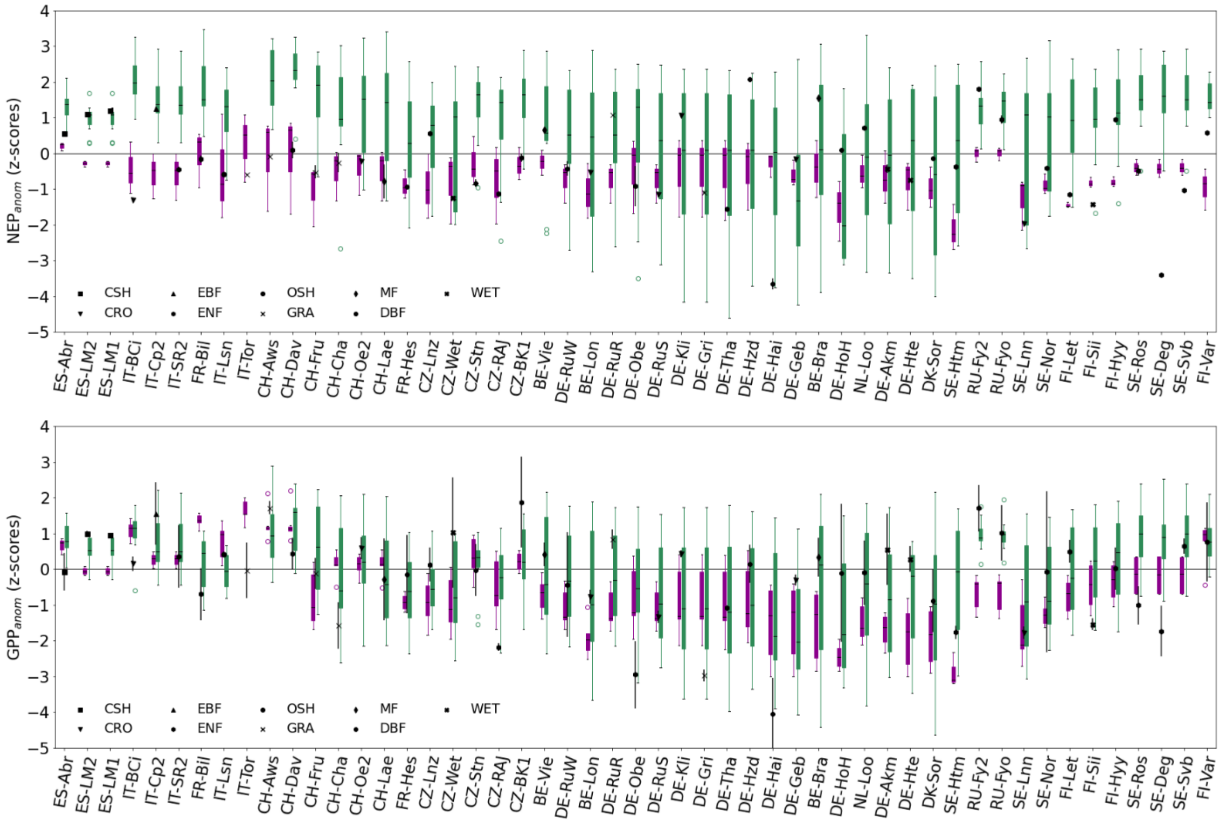

Figure S7. Comparison of NEP and GPP anomalies for the 52 eddy-covariance measurement sites from the ICOS (2020) compilation (black markers), FLUXCOM (magenta boxplots) and DGVMs (green boxplots). The anomaly calculation and standardization of all three datasets is based on the period covered by each site. The error bars in the EC data correspond to the range of anomalies estimated by different methods. The sites are ordered from left to right by increasing latitude. The markers indicate different vegetation types: evergreen broadleaf forests (EBF), evergreen needleleaf forests (ENF), deciduous broadleaf forests (DBF), mixed forests (MF), closed and open shrublands (CSH and OSH, respectively), wetlands (WET), croplands (CRO) and grasslands (GRA). Finally, it should be noted that not all sites were used in the training of the FLUXCOM dataset.

Part of the disagreements can be explained by the coarse resolution of the datasets and the fact that the fluxes from EC sites correspond to a single ecosystem type, while the pixels of both FLUXCOM and DGVMs are mixed. This is evident, for example, for DE-Kli, DE-Gri and DE-Tha, which are located very close to each other but correspond to different vegetation types and show large differences in NEP and GPP anomalies. Because these three sites correspond to one pixel of FLUXCOM and DGVMs, their estimates correspond roughly to the average anomaly of the three sites. For an accurate comparison, outputs of NBP and GPP per vegetation type would be needed, but there are not available.