

Supplementary Information

Major Intensification of Fire Weather across Southern Europe in Recent Decades

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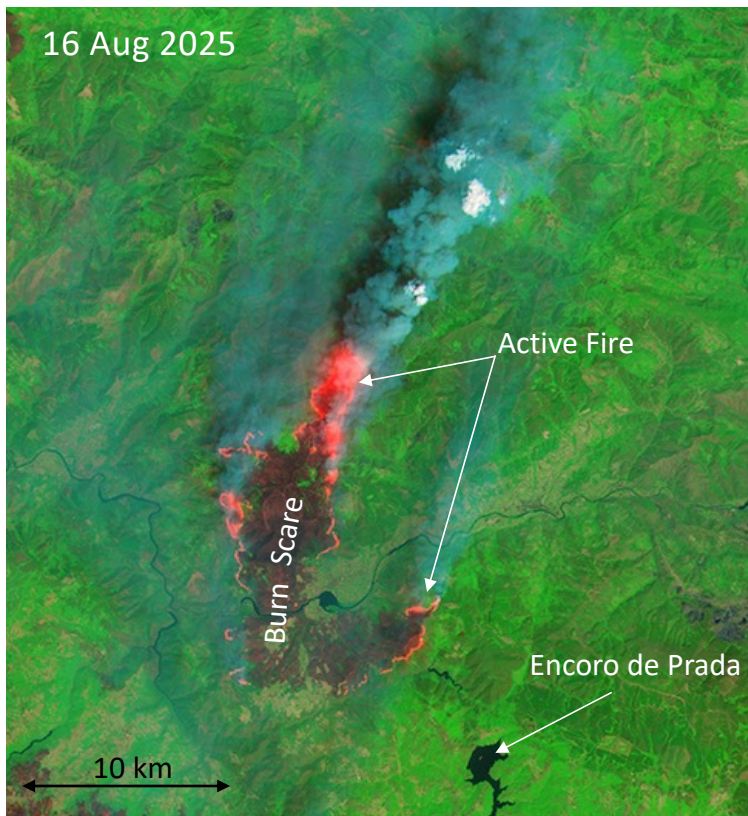


Fig. S1

False-color image using Sentinel-2's shortwave-infrared channel, highlighting the Larouco fire on 16 August 2025 (42.3°N, 7.2°W). This fire burned more than 40,000 ha, becoming the largest ever recorded in Galicia, northwestern Spain. Image source: [https://www.esa.int/Applications/Observing the Earth/Iberian wildfires seen from space](https://www.esa.int/Applications/Observing_the_Earth/Iberian_wildfires_seen_from_space)

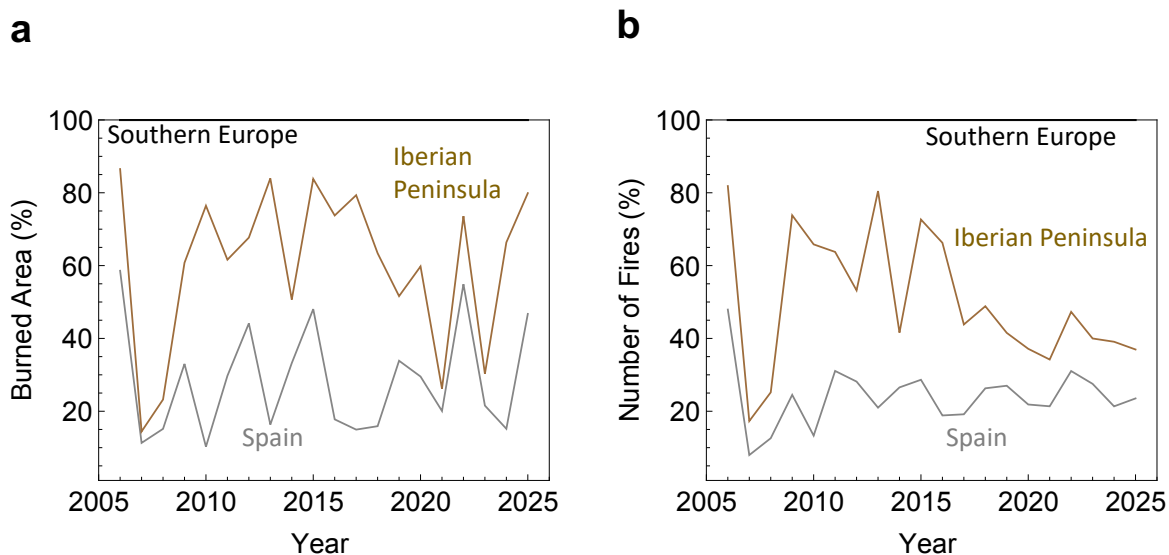


Fig. S2

Spain and Portugal (i.e., the Iberian Peninsula) account for a major share of the satellite-derived estimates of

a) the burned area, and

b) the number of fires

in Southern Europe.

Fire metrics in this figure comes from European Forest Fire Information System (EFFIS), <https://forest-fire.emergency.copernicus.eu/apps/effis.statistics/estimates>

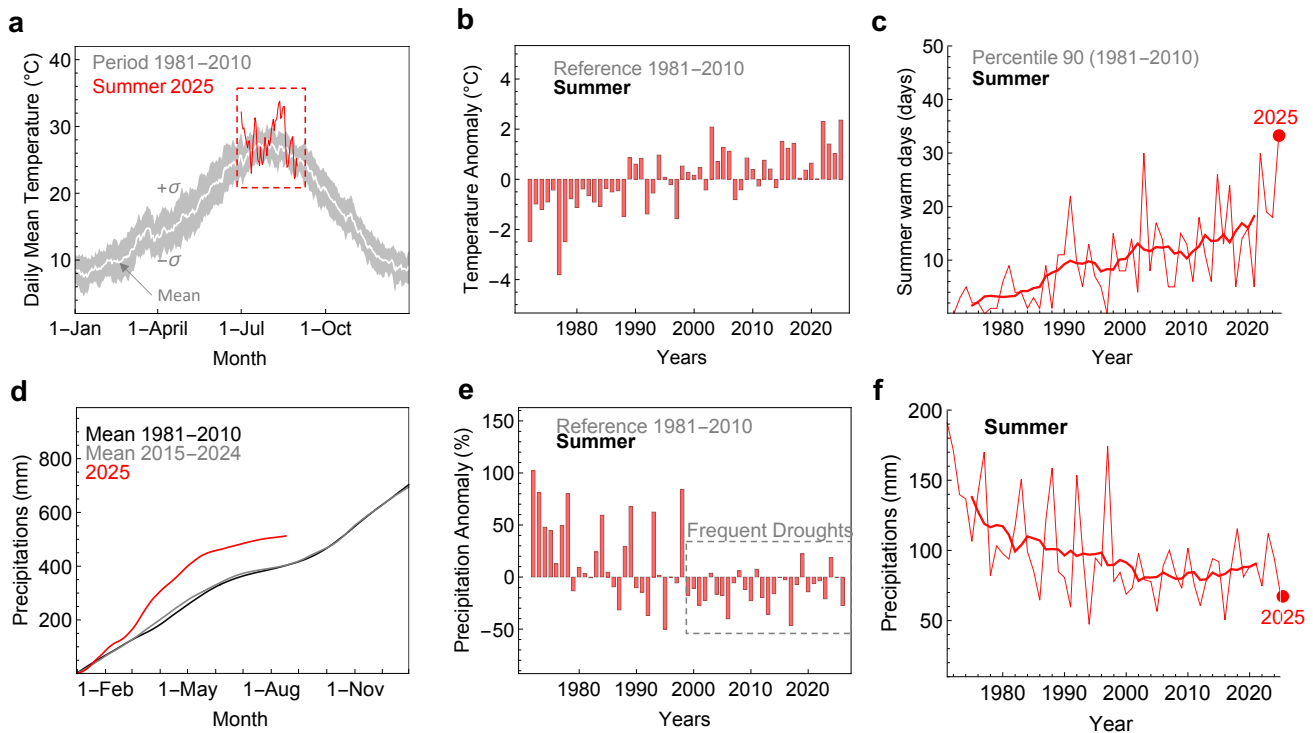


Fig. S3

a) Daily temperature averaged over the Iberian Peninsula. For each day of the year (DOY), we constructed datasets using daily data from 1981–2010. The mean (white line) and standard deviation (gray shading) of these datasets are shown. Daily mean values for Summer (JJA) 2025 are also plotted (red line).

b) Summer temperature anomalies over the Iberian Peninsula, relative to the 1981–2010 mean.

c) Summer “warm” days across the Iberian Peninsula. A day is classified as warm if its daily temperature exceeds the 90th percentile of the corresponding daily climatology, derived from the 1981–2010 baseline period. The bold line represents the 9-year centered moving average.

d) Accumulated precipitation across the Iberian Peninsula, averaged over two periods: 1981–2010 (black line) and 2015–2024 (gray line). The cumulative precipitation from January 1 to August 31 is also shown (red line). The unusually wet spring of 2025 promoted vegetation growth, which likely intensified fuel loads and worsened the subsequent fire season.

e) Summer precipitation anomalies over the Iberian Peninsula, relative to the 1981–2010 mean.

f) Evolution of summer precipitation over the Iberian Peninsula.

Temperature and precipitation data come from ERA5 reanalysis available at <https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5>.

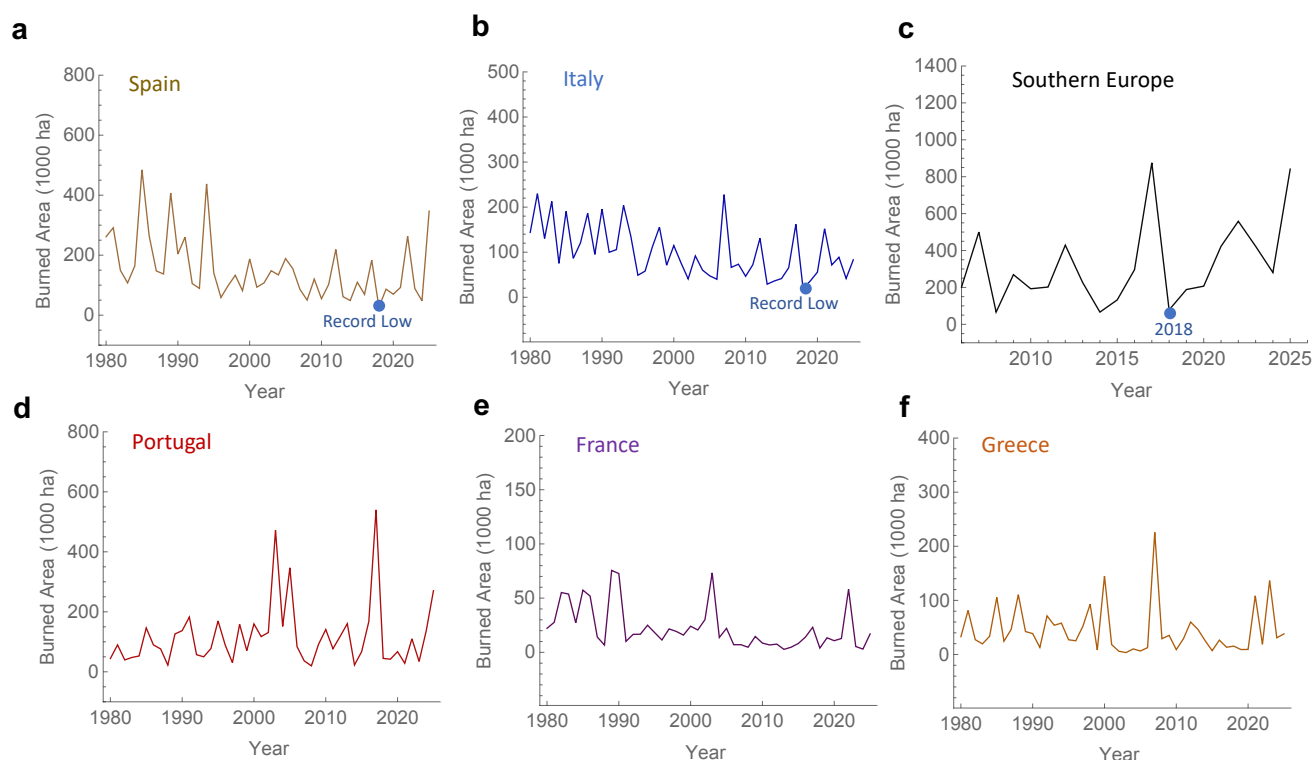


Fig. S4

Area annually burned in

- a) Spain,
- b) Italy,
- c) Southern Europe,
- d) Portugal,
- e) France, and
- f) Greece.

The burned area in Southern Europe (c) was calculated by summing the satellite-derived burned-area estimates for Spain, Portugal, France, Italy, and Greece provided by the European Forest Fire Information System (EFFIS), available at <https://forest-fire.emergency.copernicus.eu/apps/effis.statistics/estimates>. In the case of individual countries, data comes from the corresponding national agencies.

Fire metrics in Spain comes from the Ministry for the Ecological Transition and the Demographic Challenge (MITECO): <https://www.miteco.gob.es/es/biodiversidad/temas/incendios-forestales/estadisticas-avances.html>

Fire metrics in Portugal comes from the Integrated Management System for Rural Fires (Sistema de Gestão Integrada de Fogos Rurais) (SGIFR): <https://www.sgifr.gov.pt/estatisticas-incendios-rurais>

Fire metrics in Greece comes from the Greek Fire Service: <https://www.fireservice.gr/el/synoladedomonon> and from <https://postfire.es/estadisticas.php>

Fire metrics in France comes from the L'Observatoire des forêts françaises: <https://observatoire.foret.gouv.fr/themes/l-historique-des-feux-de-foret-en-france-metropolitaine>

Fire metrics in Italy comes from the Piattaforma Nazionale Adattamento Cambiamenti Climatici: <https://climadat.isprambiente.it/dati-e-indicatori/indicatori-di-impatto-dei-cambiamenti-climatici/incendi-boschivi/>

In Spain, the year with the largest burned area was 1985 with nearly half a million ha followed by 1994 with nearly 438,000 ha. Since 1980, the burned area has surpassed the 300,000 ha level only 4 times, in 1985, 1989, 1994, and 2025.

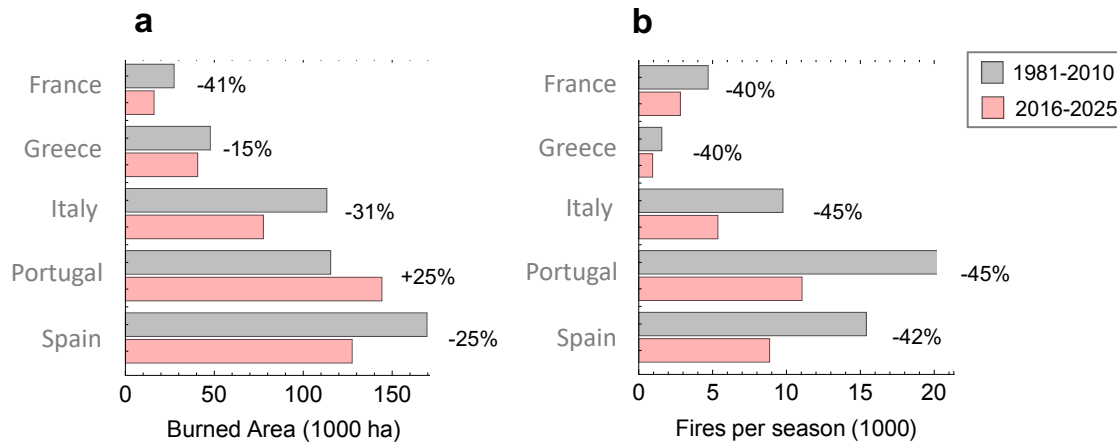


Fig. S5

Change from 1981–2010 to 2016–2025 in

- a) the annual burned area, and
- b) the annual number of fires.

Fire metrics in Spain comes from the Ministry for the Ecological Transition and the Demographic Challenge (MITECO): <https://www.miteco.gob.es/es/biodiversidad/temas/incendios-forestales/estadisticas-avances.html>

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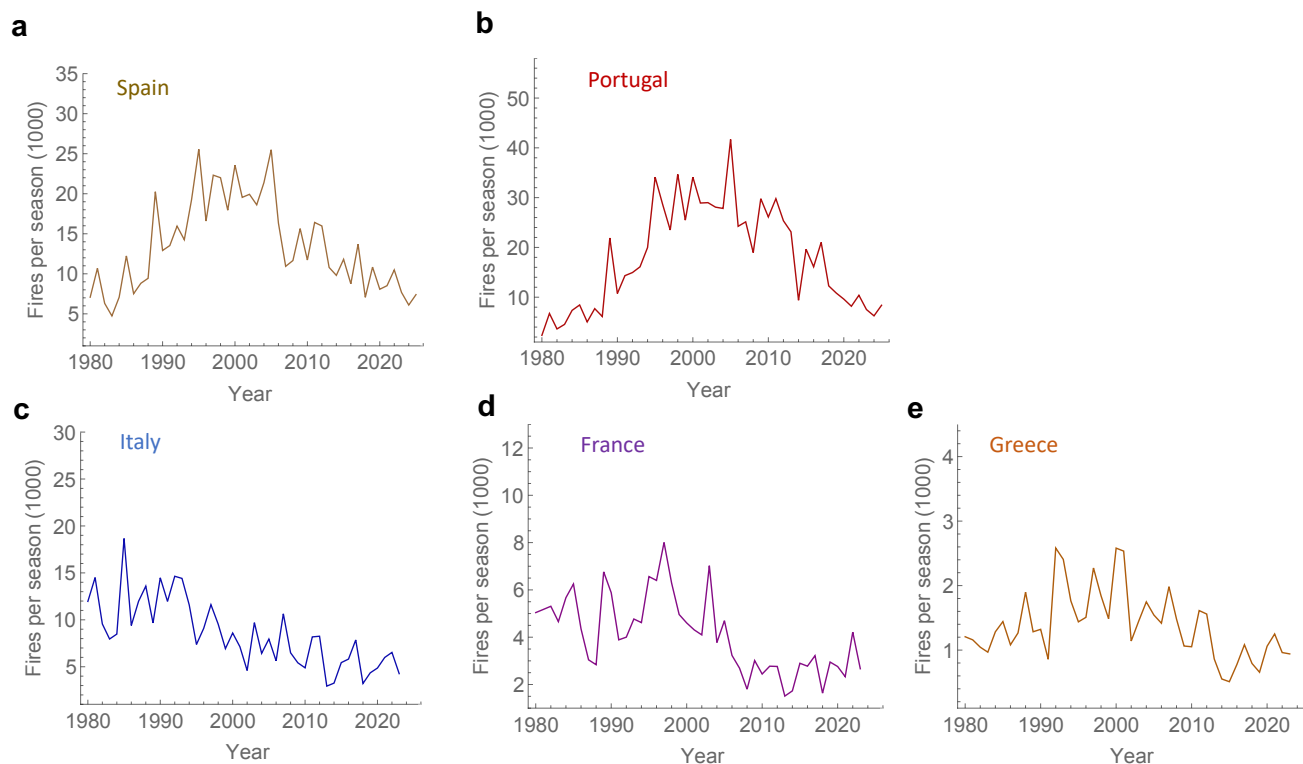


Fig. S6

Annual number of fires in

- a) Spain,
- b) Portugal,
- c) Italy,
- d) France, and
- e) Greece.

Fire metrics in Spain comes from the Ministry for the Ecological Transition and the Demographic Challenge (MITECO): <https://www.miteco.gob.es/es/biodiversidad/temas/incendios-forestales/estadisticas-avances.html>

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Fire metrics in Italy comes from the Piattaforma Nazionale Adattamento Cambiamenti Climatici: <https://climadat.isprambiente.it/dati-e-indicatori/indicatori-di-impatto-dei-cambiamenti-climatici/incendi-boschivi/>

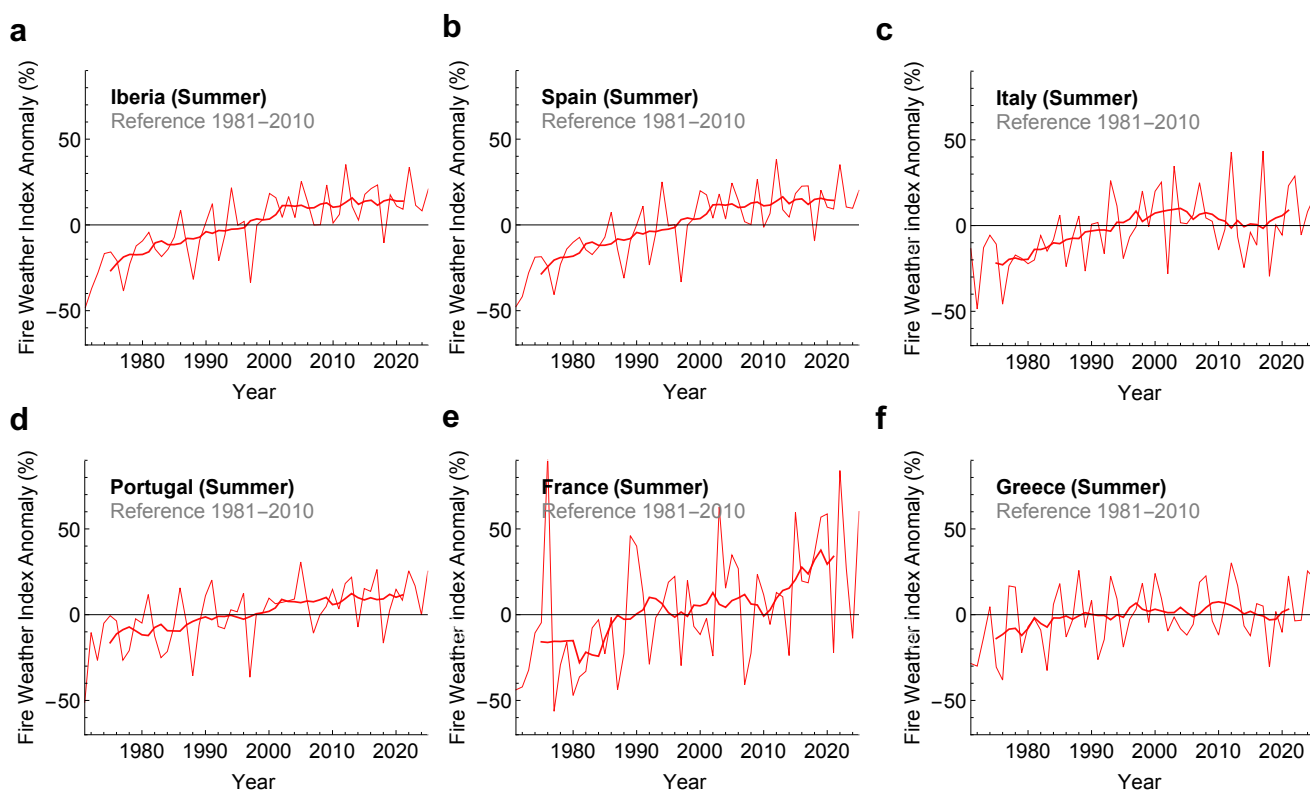


Fig. S7

Summer (JJA) Fire Weather Index (FWI), relative to the 1981–2010 mean, across the:

- a) Iberian Peninsula,
- b) Spain,
- c) Italy,
- d) Portugal,
- e) France, and
- f) Greece.

FWI data come from the ERA5 dataset produced by the European Centre for Medium-Range Weather Forecasts (ECMWF).

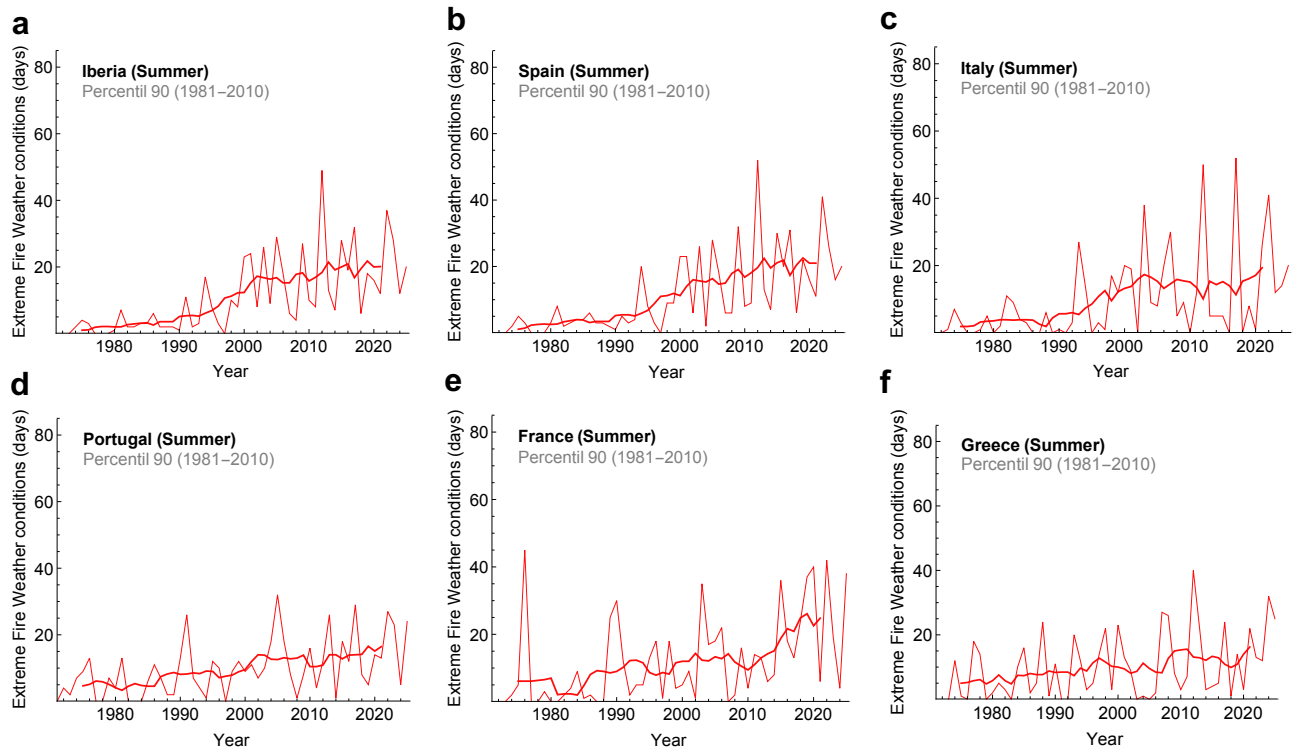


Fig. S8

Number of summer flammable days across the:

- a) Iberian Peninsula,
- b) Spain,
- c) Italy,
- d) Portugal,
- e) France, and
- f) Greece.

A day is classified as *flammable* if its Fire Weather Index (FWI) exceeds the 90th percentile of the daily baseline climatology. The climatology is based on daily temperature, and daily FWI over the 1981–2010 reference period (see Methods). Daily FWI data come from the ERA5 dataset produced by the European Centre for Medium-Range Weather Forecasts (ECMWF).

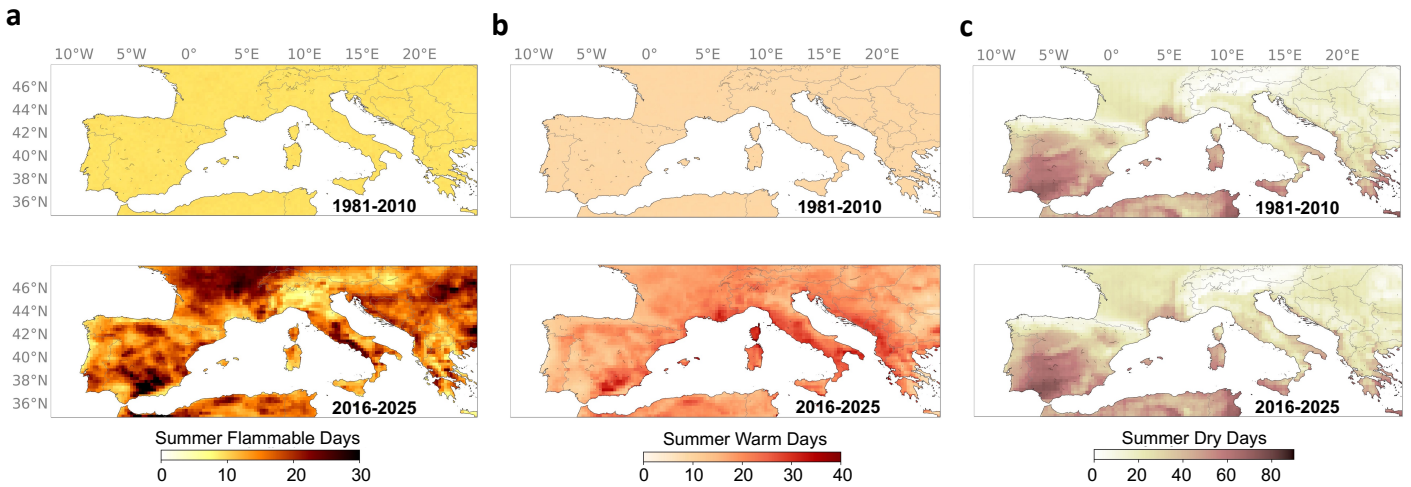


Fig. S9

a) Annual number of summer flammable days, averaged for 1981–2000 (upper panel) and 2016–2025 (lower panel).

b) Annual number of summer warm days, averaged for 1981–2000 (upper panel) and 2016–2025 (lower panel).

c) Annual number of summer dry days, averaged for 1981–2000 (upper panel) and 2016–2025 (lower panel).

A day is classified as *warm* or *flammable* if its mean temperature or Fire Weather Index (FWI), respectively, exceeds the 90th percentile of the daily baseline climatology. A day is considered as *dry* if no precipitation occurs. The climatology is based on daily temperature, and daily FWI over the 1981–2010 reference period (see Methods). Daily FWI, temperature, and precipitation are from the ERA5 dataset produced by the European Centre for Medium-Range Weather Forecasts (ECMWF). Plots were generated using Python’s Matplotlib library.

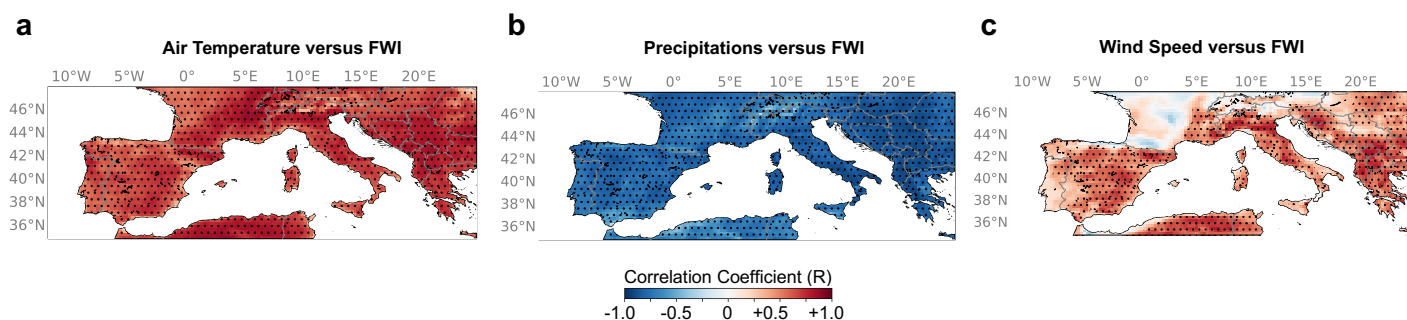


Fig. S10

Pearson correlation between the summer (JJA) Fire Weather Index (FWI) and

- a) the JJA air temperatures,
- b) the JJA precipitations, and
- c) JJA surface wind speed.

All time series were linearly detrended prior to the correlation analysis, and temporal autocorrelation was accounted for using effective sample sizes derived from the lag-1 autocorrelation of the paired time series. Stippling indicates correlations that are statistically significant at the 0.05 significance level.

Data over the period 1982-2025 were used. FWI data come from the ERA5 reanalysis. SST anomalies in the Niño Region come from NOAA's CPC available at <https://www.cpc.ncep.noaa.gov/data/indices/wksst8110.for>. Plots were generated using Python's Matplotlib library, version 3.4.3, <https://matplotlib.org/3.4.3/contents.html>.

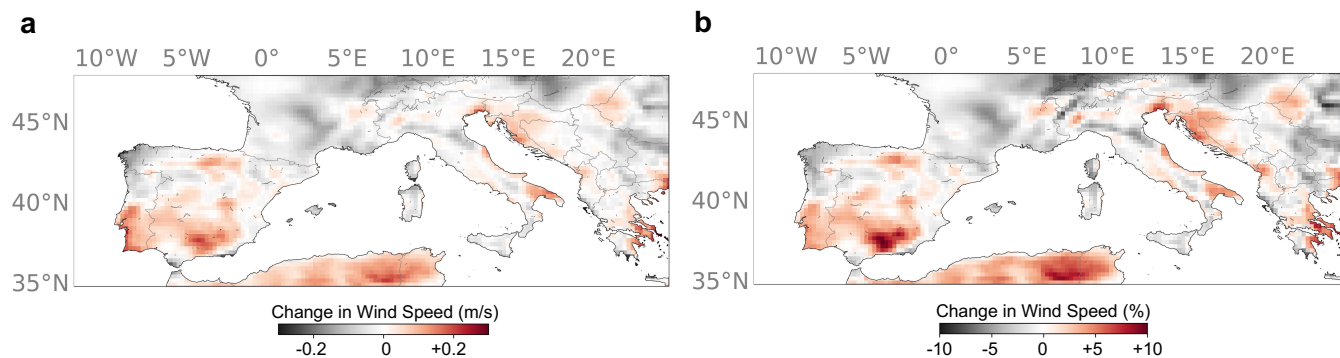


Fig. S11

Change in surface wind speed from 1981–2010 to 2016–2025, shown in m/s (a) and in percent (b).

Data are from the ERA5 reanalysis. Plots were generated using Python's Matplotlib library (version 3.4.3), available at <https://matplotlib.org/3.4.3/contents.html>.

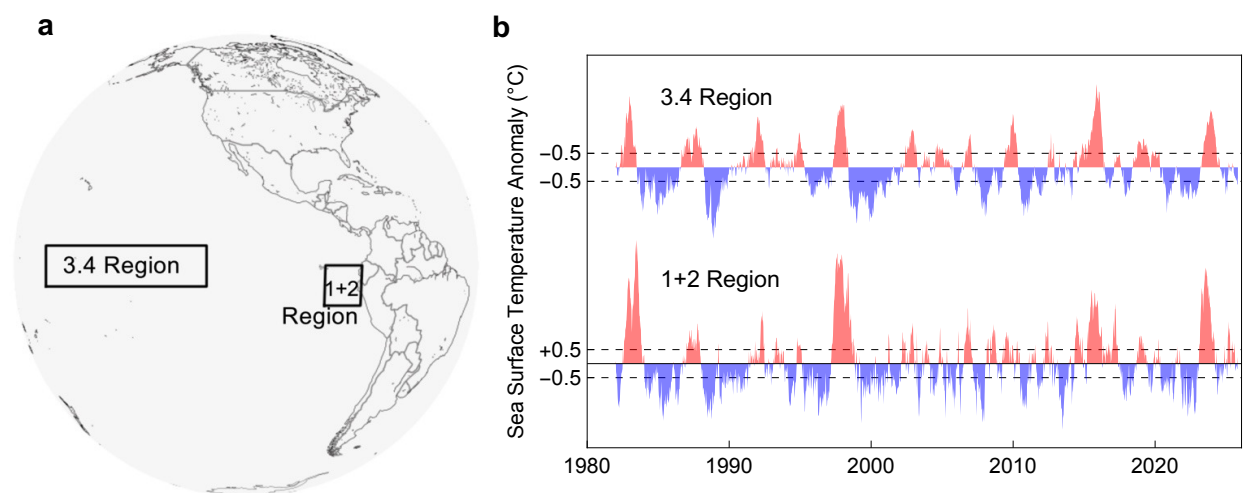


Fig. S12

a) Two of the main Niño regions monitored by NOAA's CPC: the Niño 1+2 Region (0–10°S, 90°W–80°W) and the Niño 3.4 Region (5°N–5°S, 170°W–120°W).

b) Weekly anomalies of the sea surface temperature (SST) in the Niño 3.4 Region (upper panel) and in the Niño 1+2 Region (lower panel).

El Niño/La Niña events are classified according to SST anomalies exceeding the ± 0.5 °C threshold in the Niño 3.4 Region. Since 1998 we have seen two triple-dip La Niña's that spanned the years 1998–2001 and 2020–2023. Other La Niña events were recorded in 2005–2006, 2007–2009, 2010–2012, and 2016–2018.

SST anomalies in the Niño Regions come from NOAA's CPC and are available at <https://www.cpc.ncep.noaa.gov/data/indices/wksst8110.for>.

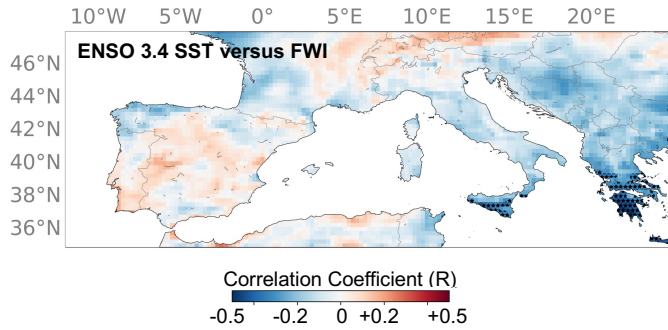


Fig. S13

Pearson correlation between the summer (JJA) Fire Weather Index (FWI) and the JJA sea surface temperature (SST) anomalies in the Niño 3.4 region.

All time series were linearly detrended prior to the correlation analysis, and temporal autocorrelation was accounted for using effective sample sizes derived from the lag-1 autocorrelation of the paired time series. Stippling indicates correlations that are statistically significant at the 0.05 significance level. Fig. S14c shows a version of this correlation with the statistical significance corrected for multiple testing using the Benjamini–Hochberg false discovery rate (FDR).

Data over the period 1982–2025 were used. FWI data come from the ERA5 reanalysis. SST anomalies in the Niño Region come from NOAA’s CPC available at <https://www.cpc.ncep.noaa.gov/data/indices/wksst8110.for>. Plots were generated using Python’s Matplotlib library, version 3.4.3, <https://matplotlib.org/3.4.3/contents.html>.

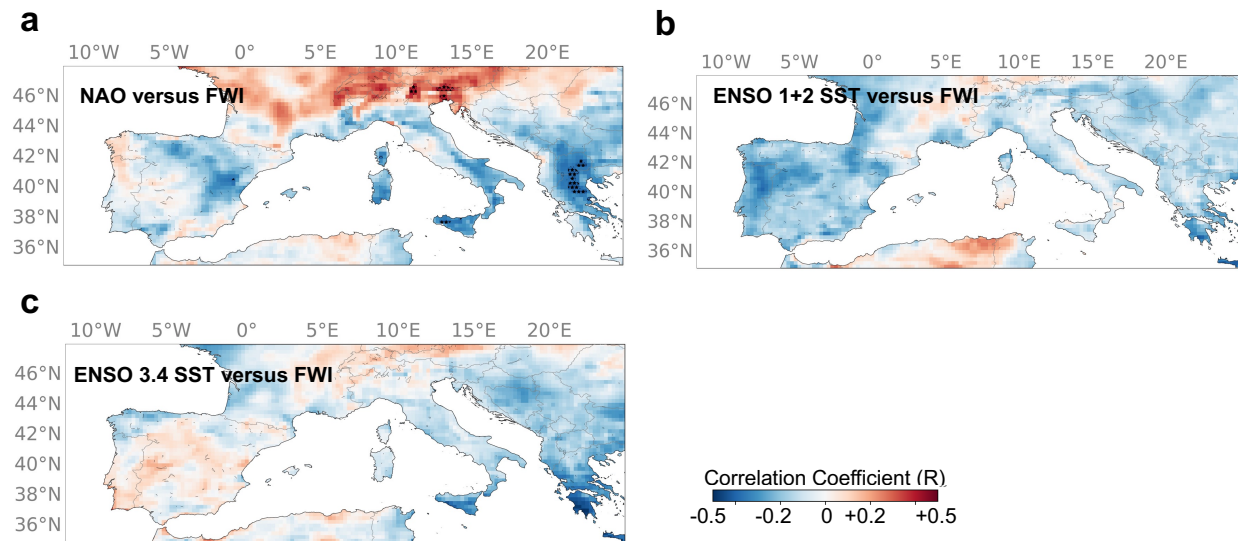


Fig. S14

Pearson correlation between the summer (JJA) Fire Weather Index (FWI) and the

a) JJA NAO index;

b) JJA sea surface temperature (SST) anomalies in the Niño 1+2 region (in the eastern tropical Pacific);

c) JJA sea surface temperature (SST) anomalies in the Niño 3.4 region

All time series were linearly detrended prior to the correlation analysis, and temporal autocorrelation was accounted for using effective sample sizes derived from the lag-1 autocorrelation of the paired time series. In addition to these adjustments, statistical significance was corrected for multiple testing using the Benjamini–Hochberg false discovery rate (FDR) procedure at the 0.05 significance level. Stippling indicates statistically significant correlations.

Data over the period 1982–2025 were used. FWI data come from the ERA5 reanalysis. The NAO index values come from NOAA’s Climate Prediction Center (CPC) available at <https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao.shtml> while SST anomalies in the Niño Regions come from NOAA’s CPC available at <https://www.cpc.ncep.noaa.gov/data/indices/wksst8110.for>. Plots were generated using Python’s Matplotlib library (version 3.4.3), available at <https://matplotlib.org/3.4.3/contents.html>.