The role of moisture source and temperature anomalies in the 2022 European Drought

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Introduction

Europe experienced an exceptional drought in 2022, resulting:

- In widespread agricultural losses (Baruth et al., 2022; Toreti et al., 2022; Faranda et al., 2023),
- reductions in hydropower and wind energy, increased solar potential (Toreti et al., 2022),
- disruptions to river transport and ecosystems, severe water shortages, forest fires,
- substantial anomalies in carbon emissions (Toreti et al., 2022; Faranda et al., 2023).

While previous studies have elucidated the large-scale circulation and climate change influence, ***the specific role of anomalous moisture and temperature sources in shaping the drought's evolution remains unclear.***

Previous analyses have investigated the event's drivers and its links to anthropogenic climate change:

- Showing that it produced the largest terrestrial water storage deficit since 2002 across Central–Southern Europe, with human-induced warming amplifying drought intensity by more than 30%.
- The drought was primarily driven by a persistent anticyclonic anomaly, together with other large-scale atmospheric circulation features: a blocking over western Europe.

Objective: *To quantify the anomalous sources of atmospheric moisture uptake and temperature during the 2022 European drought.*

Data and Methodology

Data:

- ERA5 data (1994–2023, 0.5°)
- Forced FLEXPART model simulations with ERA5 (1994–2023, 0.5°).
- ERALand data at 0.1° (15°W–32°E, 30°N–62°N) were used to calculate 6-month Standardized Precipitation Evapotranspiration Index with reference period 1965–2022.

Methodology:

- The drought-affected area in Europe was defined using regions with SPEI6 ≤ –1.28 (Fig. 2a).
- To estimate moisture sources and sinks, a Lagrangian methodology of Stohl and James (2005) was applied.
- To identify sources of temperature anomalies, we applied the Lagrangian framework by Papritz and Röthlisberger (2023).

Results and Discussion

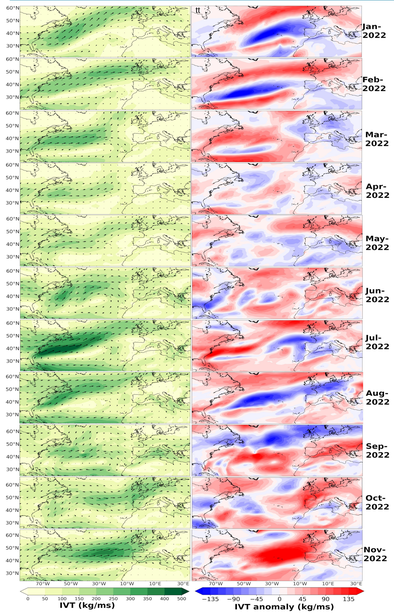

Fig. 1 The vertically integrated water vapour transport (IVT) and its monthly anomaly for the North Atlantic region and Europe | The figure presents the IVT (kg m^{-1} s^{-1}) module (coloured filled, first column) and direction (arrows) and its monthly anomaly (kg m^{-1} s^{-1}, second column) from January to November 2022 (top to bottom). The analysis covers the period from 1994 to 2023.

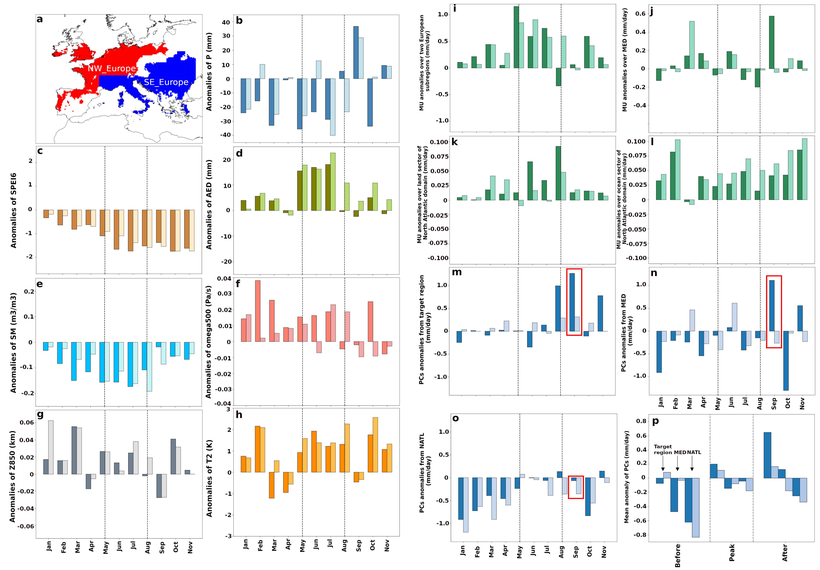

Fig. 2 Two European subregions, hydro-climatic monthly anomalies, moisture uptake (MU) and precipitation contributions (PCs) associated with the 2022 European drought | Monthly averaged anomalies of key hydro-climatic variables, calculated relative to the 1994–2023 climatology using ERA5 reanalysis data. The red rectangle indicates the month considered the drought-breaking month, September 2023. Colour intensity indicates each region: higher intensity for SE_Europe and lower intensity for NW_Europe. The framed area indicates the drought peak period (May–August 2022).

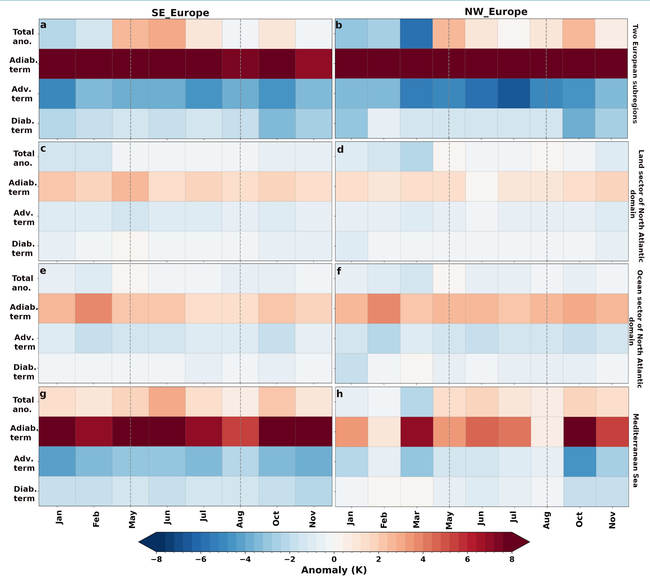

Fig. 3 Monthly series of temperature anomaly sources during the 2022 European drought | Heat maps show monthly anomalies of total temperature, and of the adiabatic, diabatic and advective components from January to November 2022. Left and right panels display anomalies for the SE Europe and NW_Europe subregions, respectively. The framed period highlights the peak drought months (May–August 2022). Anomalies are computed relative to the 1994-2023 climatology.

Summary and Conclusions

- The 2022 European mega-drought was driven not by moisture scarcity but by persistent atmospheric stability that suppressed rainfall formation.
- A long-lasting anticyclonic regime blocked convection, diverted Atlantic and Mediterranean moisture, and induced adiabatic warming, deepening regional dryness.
- The drought was maintained by subsidence, warming-enhanced soil drying, and weak oceanic moisture contributions.
- Its abrupt end showed the system's high sensitivity: a shift toward unstable synoptic conditions rapidly reactivated regional moisture sources, underscoring that large-scale dynamics—not just moisture availability—will shape future European drought severity.

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