Nonlocal soil moisture effects during European heatwaves

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Study overview

Background

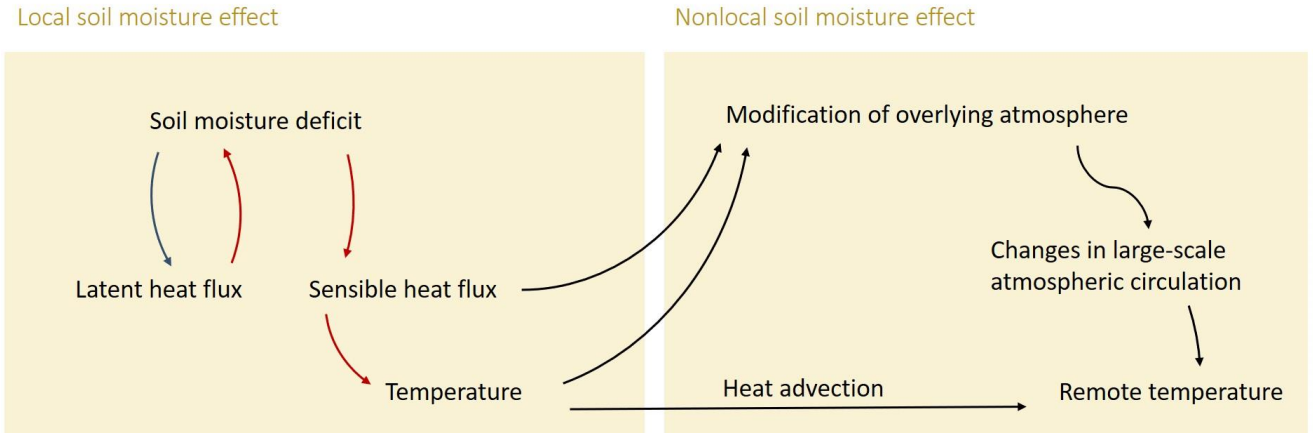
- Nonlocal soil moisture effect on temperature (Miralles et al., 2018)

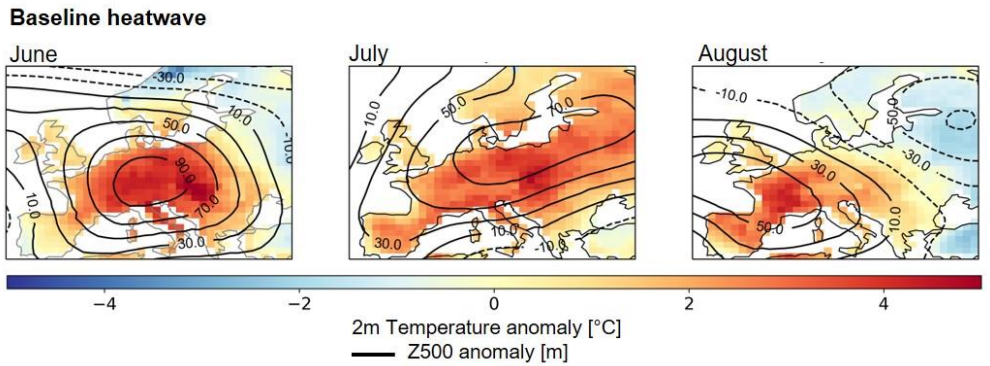
Research goal

- What amplifies a persistent European heatwave?

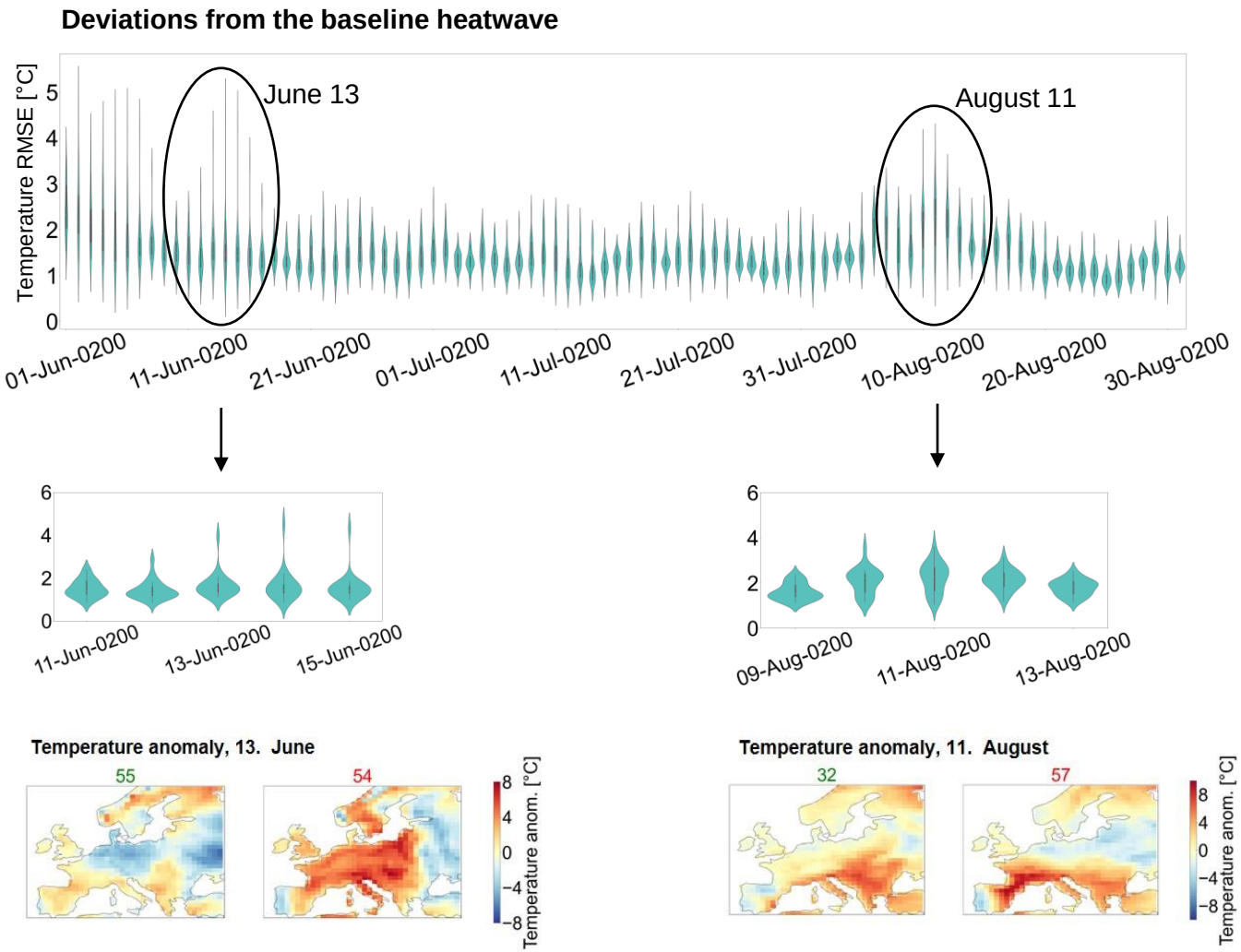
Data and Methods

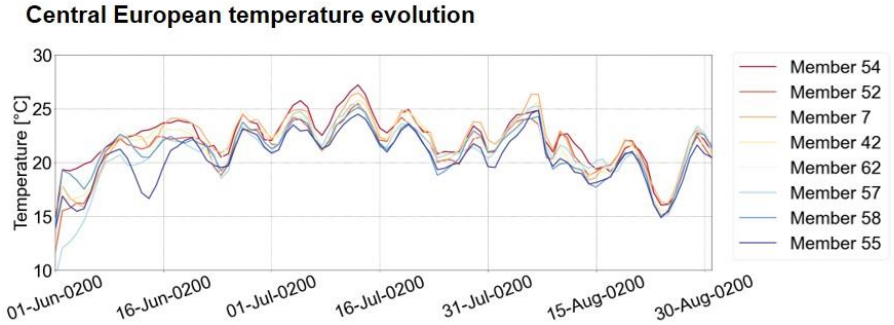
- **Dataset:** Described in Merrifield et al. (2019)
- **Heatwave:** Persistent European heatwave occurring in a CESM1 preindustrial control run
- **Ensemble:** 22 ensemble members with different land surface conditions and atmosphere nudged towards the heatwave.
  Only upper atmosphere constrained (above 322hPa) → Atmosphere can be modified by the land surface.





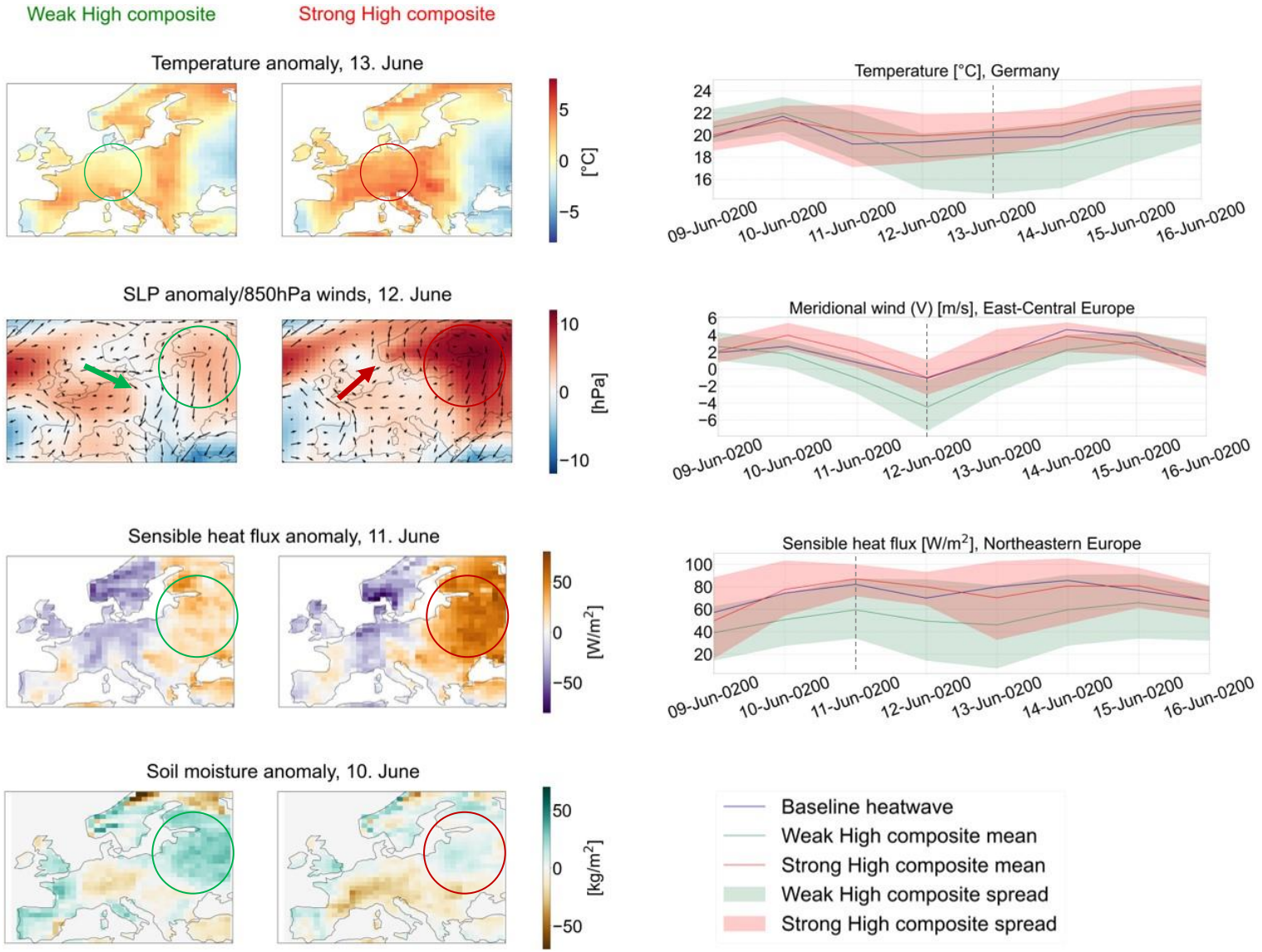
Deviations from the baseline heatwave





- Top left: Temperature [°C] root mean squared error (RMSE) between the ensemble members and the baseline heatwave at each grid point averaged over Europe.
- Heatwave initiation phase (June 13) and heatwave decay phase (August 11) stand out.
- Storylines: How and why do the ensemble members evolve differently during these two periods?

Case study: Heatwave initiation phase

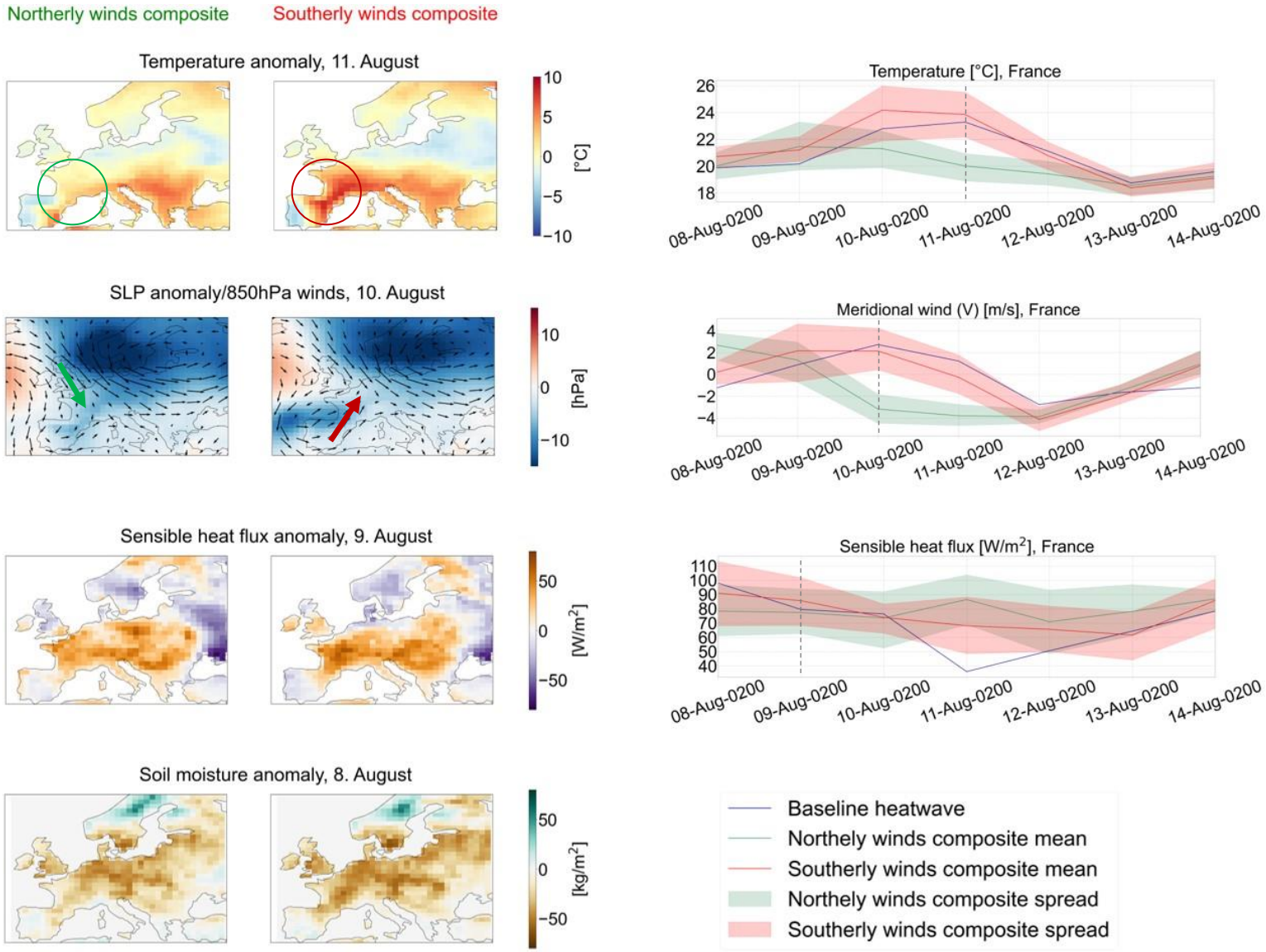


Two composites

- **Weak High composite:** Mean of 4 ensemble members characterized by a weak high pressure system over Northeastern Europe.
- **Strong High composite:** Mean of 4 ensemble members characterized by a strong high pressure system over Northeastern Europe.

Temperature ↓	Temperature ↑
Northwesterly winds	Southwesterly winds
SLP ↓	SLP ↑
Sensible heat flux ↓	Sensible heat flux ↑
Wetter soils	Drier soils

Case study: Heatwave decay phase



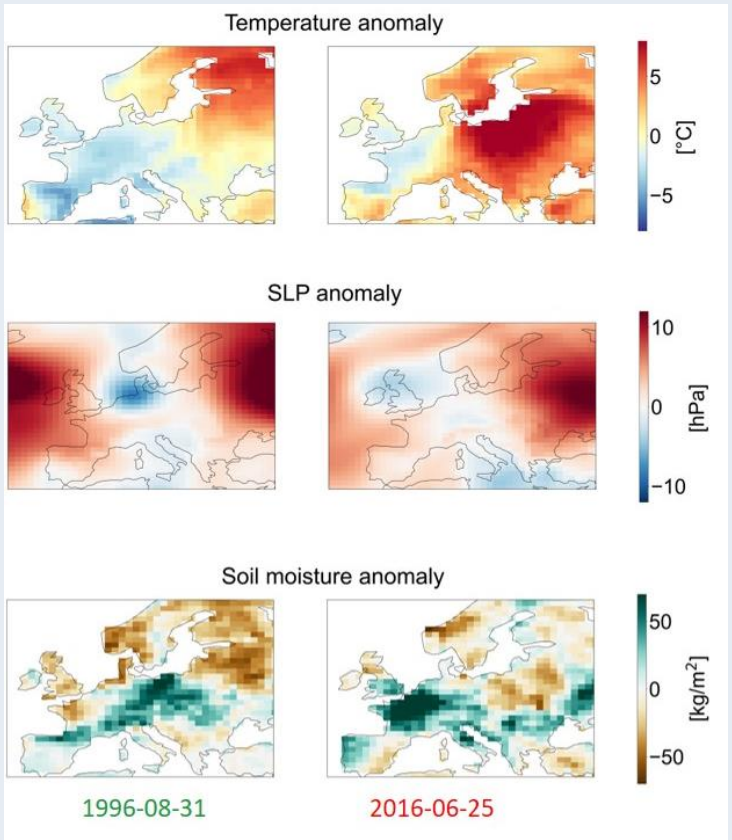
Two composites

- **Northerly winds composite:** Mean of 4 ensemble members characterized by northerly winds over France.
- **Southerly winds composite:** Mean of 4 ensemble members characterized by southerly winds over France associated with a cyclone off the coast of France.

Temperature ↓	Temperature ↑
Northerly winds	Southerly winds
SLP ↑	SLP ↓
Sensible heat flux ↓	Sensible heat flux ↑
Wetter soils	Drier soils

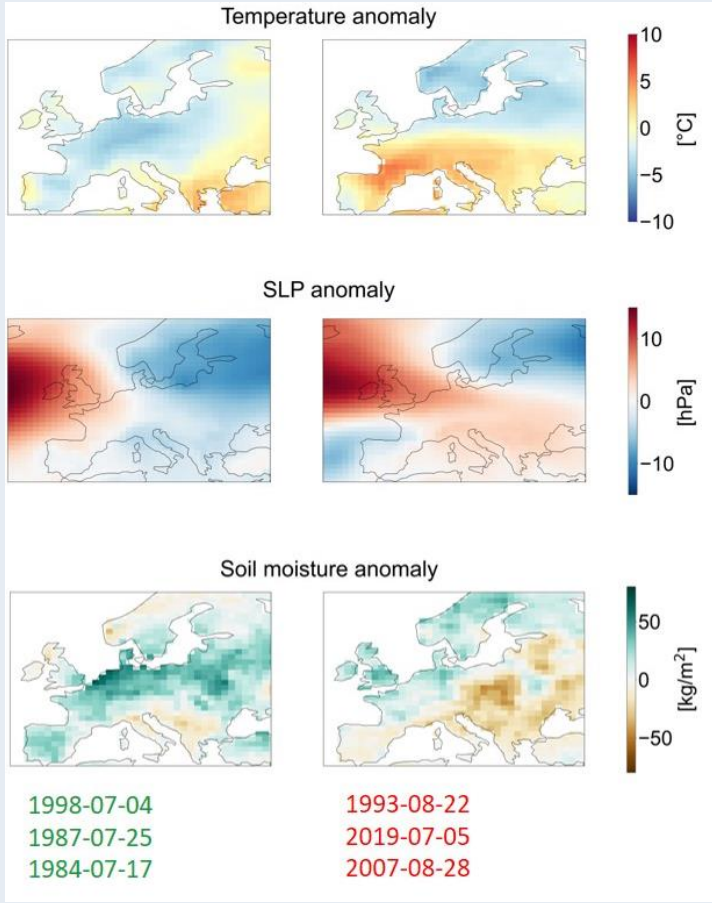
Similar patterns in observations

Heatwave initiation case study: Similar situations



ERA5-Land observational data

Heawave decay case study: Similar situations



ERA5-Land observational data

- Similar atmospheric situations in ERA5-Land as in the model
- Consistent relationship between temperature and pressure visible
- Land surface influence difficult to establish without the constrained circulation ensemble

Data: Muñoz Sabater (2019)

Key findings

- Land surface «anchoring» effect on the high pressure system
- Amplification/damping of low pressure system bringing southerly winds
- Consistent analogues in observations

References

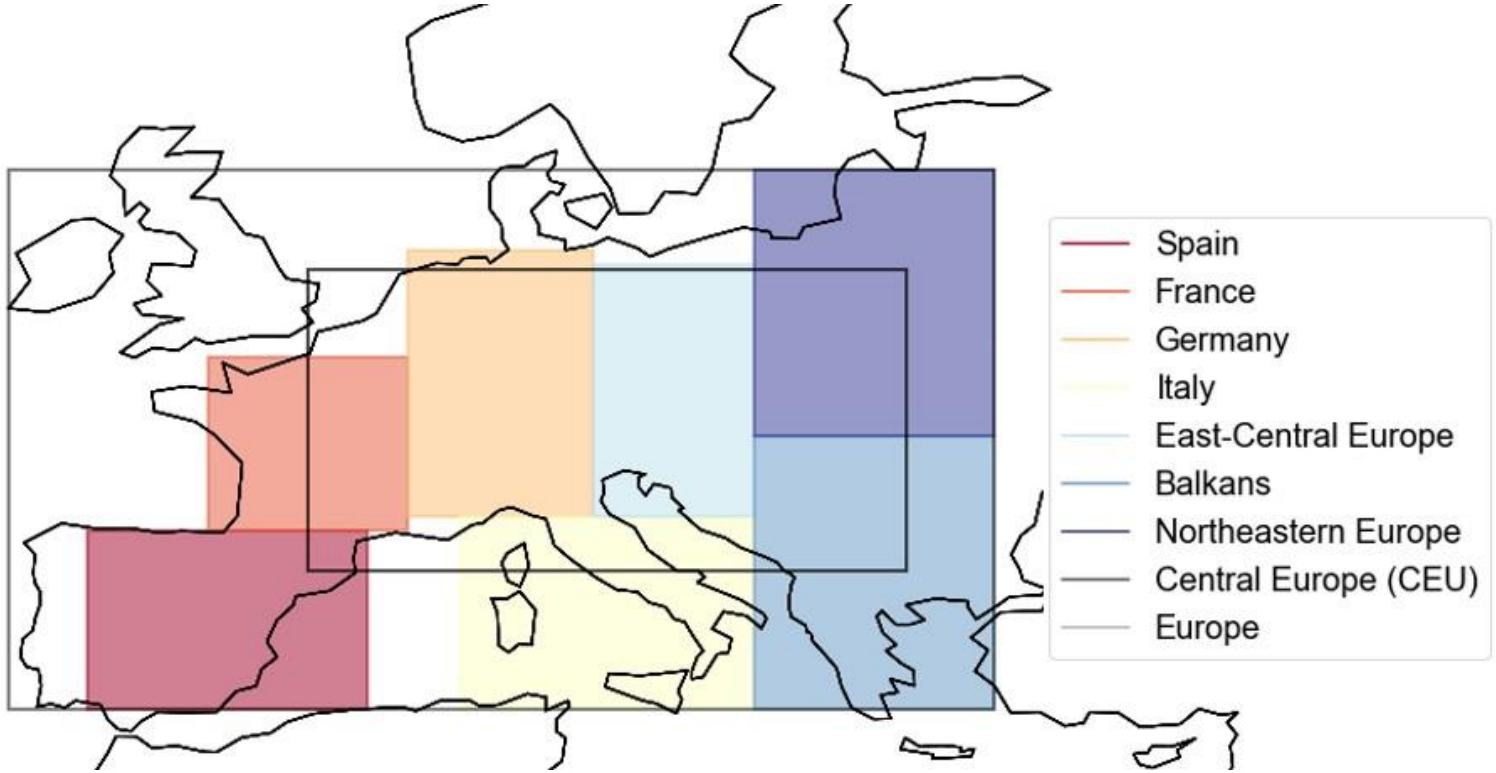
Merrifield, A. L., Simpson, I. R., McKinnon, K. A., Sippel, S., Xie, S.-P., & Deser, C. (2019). Local and nonlocal land surface influence in european heatwave initial condition ensembles. *Geophysical Research Letters*, 46, 14082–14092. https://doi.org/10.1029/2019GL083945

Miralles, D., Gentine, P., Seneviratne, S., Teuling, A. (2018). Land-atmospheric feedbacks during droughts and heatwaves: state of the science and current challenges. Annals of the New York Academy of Sciences. 1436. https://doi.org/10.1111/nyas.13912

Muñoz Sabater, J., (2019): ERA5-Land hourly data from 1981 to present. Copernicus Climate Change Service (C3S) Climate Data Store (CDS). (Accessed on 25.04.2021). https://doi.org/10.24381/cds.e2161bac

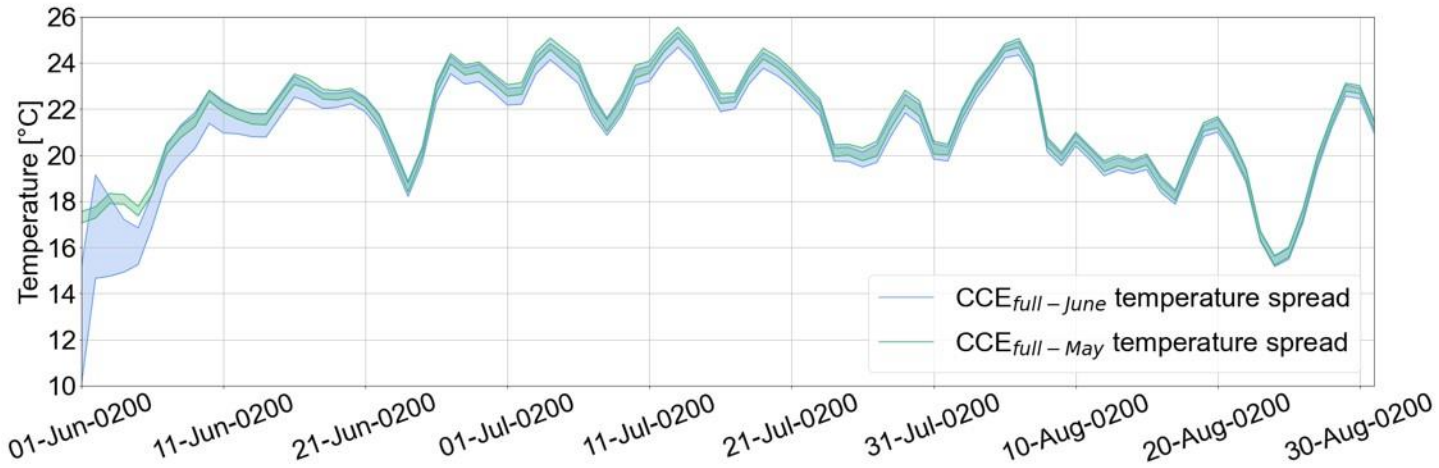
Supplementary Slides

Regions

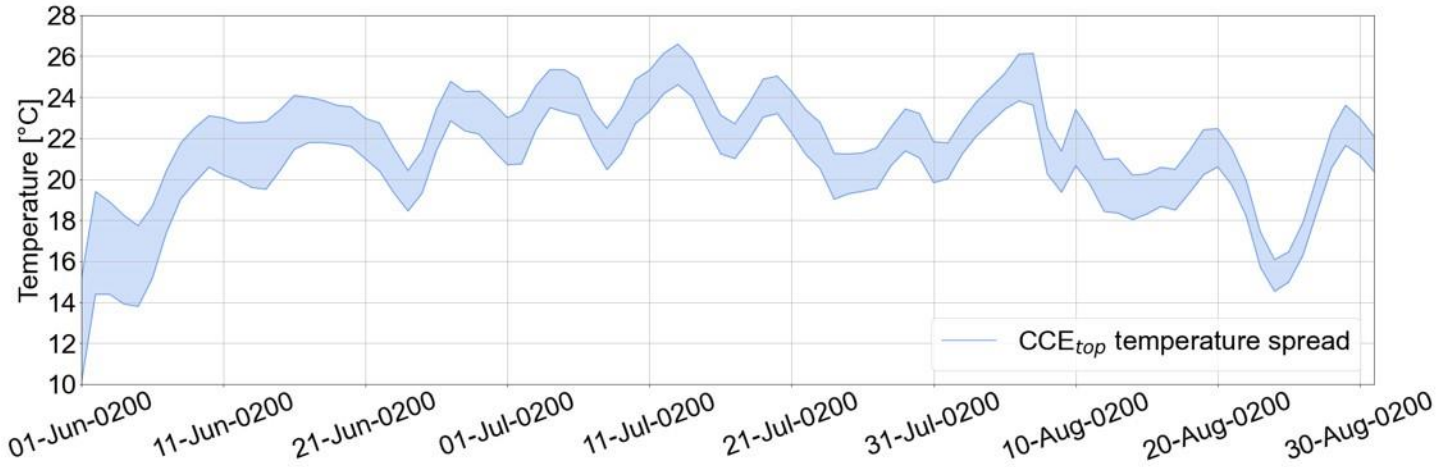

Spain
France
Germany
Italy
East-Central Europe
Balkans
Northeastern Europe
Central Europe (CEU)
Europe

Nudging time

(a) Temperature spread (std) across CCE_{full} ensemble members with nuding starting in May or in June



(b) Temperature spread (std) across CCE_{top} ensemble members with nuding starting in June



CCE: Constrained Circulation Ensemble.

CCE_{top}: Nudging only of top atmosphere (above 322hPa).

CCE_{full}: Nudging of the full atmosphere (above 998hPa).

(a) Central European (CEU) average temperature ensemble spread, obtained by calculating the standard deviation (std) of temperature across ensemble members in the $CCE_{full\text{-}May}$ ensemble with nudging starting on May 1 (green) and the $CCE_{full\text{-}June}$ ensemble with nudging starting on June 1 (blue). (b) CEU average temperature ensemble spread in the CCE_{top} with nudging starting on June 1 (blue).