A Lagrangian analysis of upper-tropospheric anticyclones associated with heat waves in Europe

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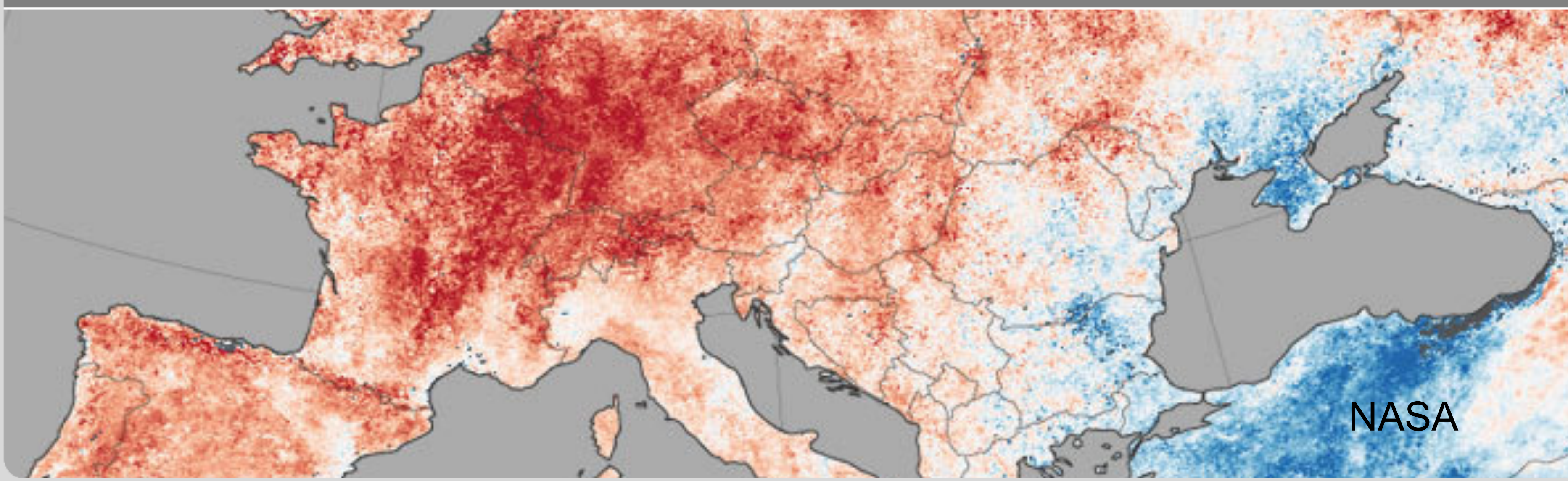


Introduction and main goals

- Heat waves impose large impacts especially on human health (e.g. Watts et al., 2018) and are often associated with persistent upper-tropospheric anticyclones (e.g. Sousa et al., 2018; Zschenderlein et al., 2019)

- Studies on atmospheric blocking emphasise relevance of upstream latent heat release for upper-level ridge building (Pfahl et al., 2015; Steinfeld & Pfahl, 2019)

  → but not yet studied for upper-tropospheric anticyclones in association with heat waves in Europe

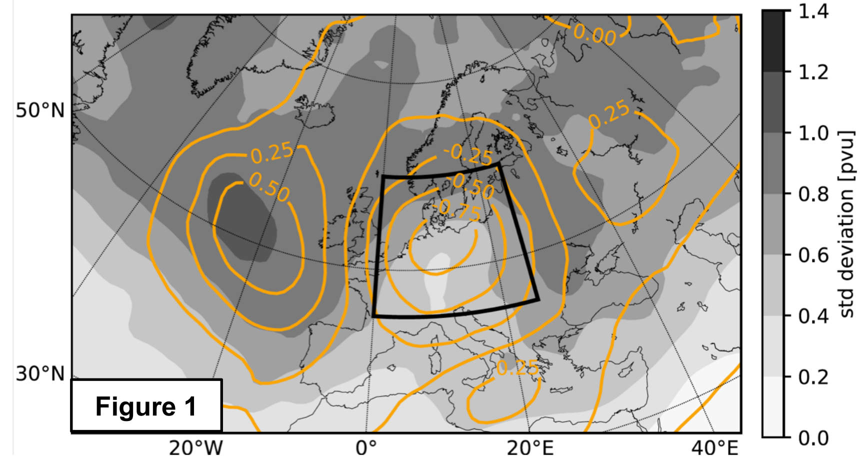
- <u>Goals:</u>
  - Analyse the role of diabatic heating in the formation and maintenance of upper-tropospheric anticyclones connected to surface heat waves
  - Focus in this presentation is on Central Europe (other regions in recent publication in Zschenderlein et al., 2020)

Data and Methods

Step 1: Identification of upper-tropospheric anticyclones

Figure 1: Composite of vertically averaged potential vorticity anomalies between 500 and 150 hPa for all heat waves (as identified in Zschenderlein et al. (2019)) in Central Europe. Contours denote mean values and grey shading the standard deviation.

→ All grid points with vertically averaged PV anomalies below -0.7 PVU in the black box during heat wave days in Central Europe are belonging to upper-tropospheric anticyclones.

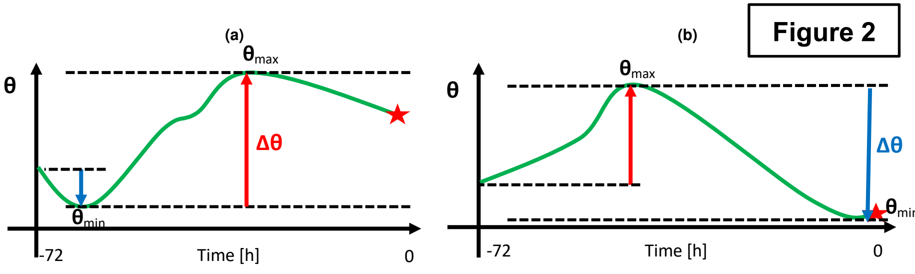


Step 2: Calculation of backward trajectories initialised in anticyclones

- For every heat wave day between 1979 and 2016
- In the troposphere between 500 and 150 hPa, every 50 hPa
- Started from an equidistant grid (Δx = 100 km)
- Driven by ERA-Interim (Dee et al., 2011), calculated with LAGRANTO (Sprenger et al., 2015)

Step 3: Separation of trajectories according to pot. temp. changes Δθ

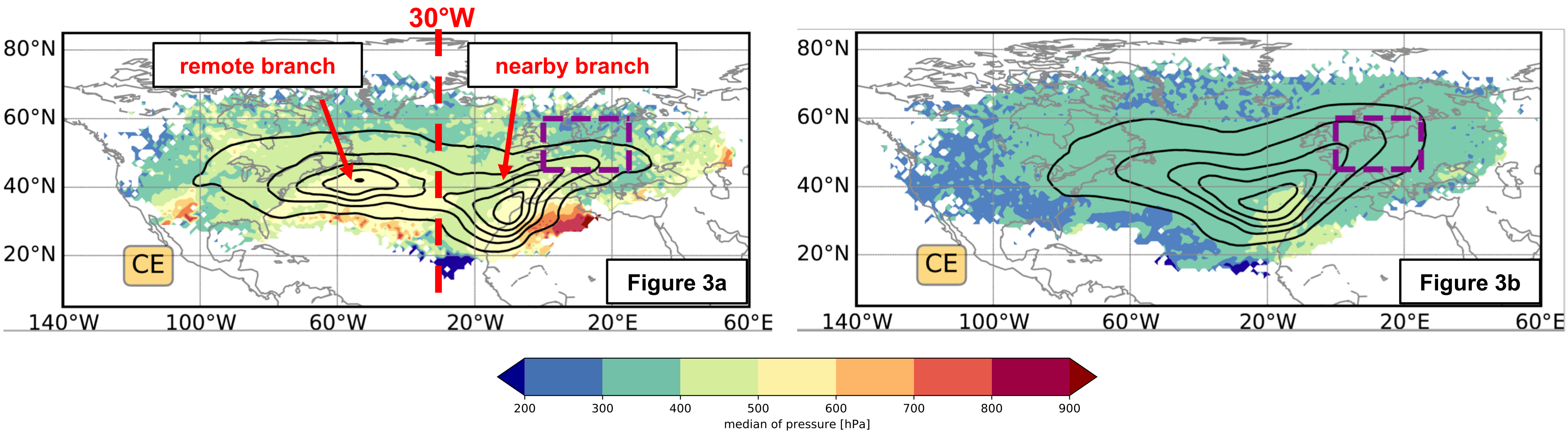
Figure 2



Heating branch (Δθ>0K) Cooling branch (Δθ≤0K)

Source regions of heating and cooling branches

Figure 3: Spatial distribution of diabatically heated (a) and cooled (b) trajectories 3d prior to arrival in the upper-tropospheric anticyclone over Central Europe. The colours indicate the median pressure of air parcels, and the contours display the air parcel density (starting from 1‰ per 10^5 km^2 in 2 ‰ increments). The dashed purple boxes represent the area in which upper-tropospheric anticyclones are associated with heat waves.



→ 29 (42) % of the air parcels reaching upper-tropospheric anticyclones over Central Europe (CE) are diabatically heated during the last three (seven) days

→ Two geographically separate origins of the heating branch (remote and nearby branch)

Locations of maximum diabatic heating

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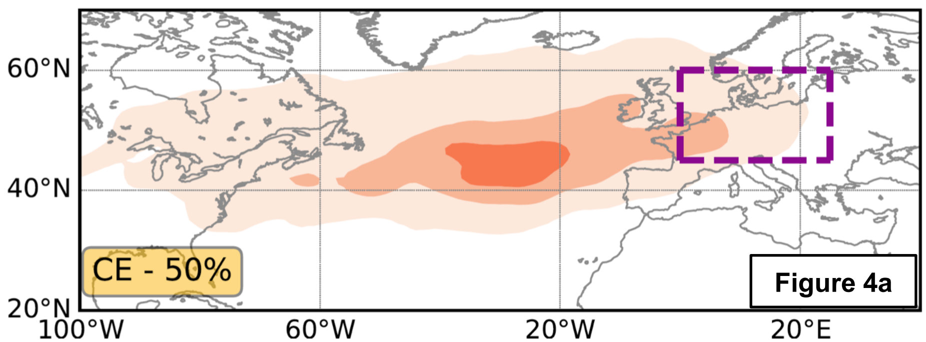
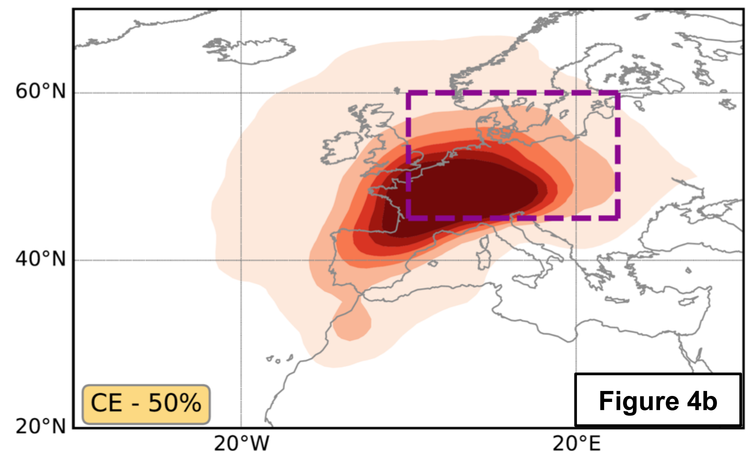
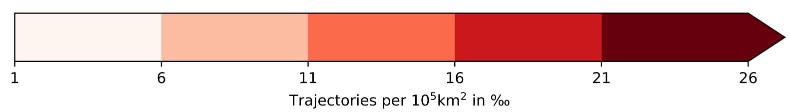
Figure 4: Geographic location of the maximum diabatic heating along trajectories for the remote (a) and nearby heating branch (b) during the last 3d prior to reaching upper-tropospheric anticyclones above Central Europe (CE).







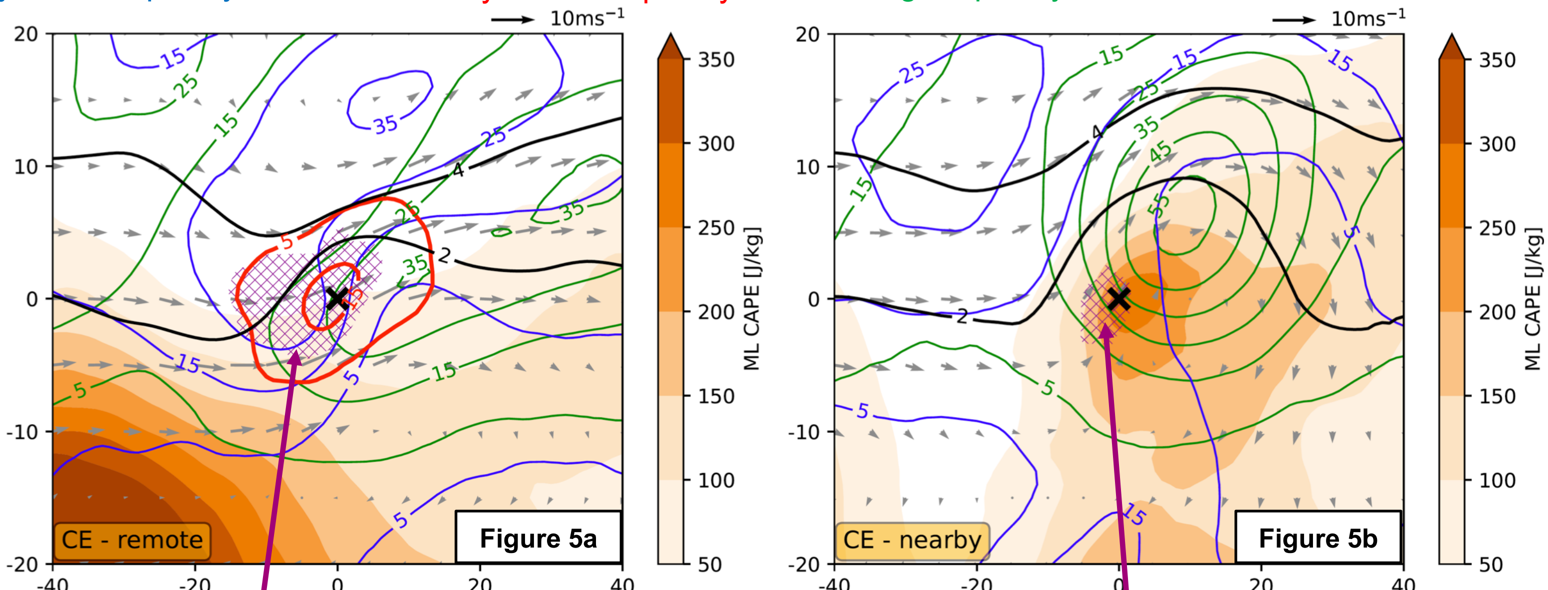
→ 50% of the heating branch belongs to the remote branch. They are heated predominantly in the central North Atlantic between 40° and 50°N (Fig. 4a).

→ The remaining 50% of the heating branch belongs to the nearby branch. They are heated predominantly closer to the heat wave area in a similar latitude band (Fig. 4b).

Synoptic causes of diabatic heating

Figure 5: Composite centred around the position of maximum diabatic heating for the remote (a) and nearby heating branch (b) reaching upper-tropospheric anticyclones above Central Europe.

Cyclone frequency — Warm conveyor belt frequency — Blocking frequency — Wind at 800 hPa — PV at 330K



Features (Cyclones, WCBs and Blocks) derived from Sprenger et al. (2017)

area where stratiform precipitation exceeds convective precipitation

area where, in contrast to Fig. 5a, convective precipitation exceeds stratiform precipitation

→ Latent heating in remote branch predominantly due to warm conveyor belts ahead of extratropical cyclones

→ Latent heating in nearby branch predominantly due to convection, as inferred from enhanced ML CAPE and convective precipitation

Diabatic heating during the life cycle of heat wave anticyclones

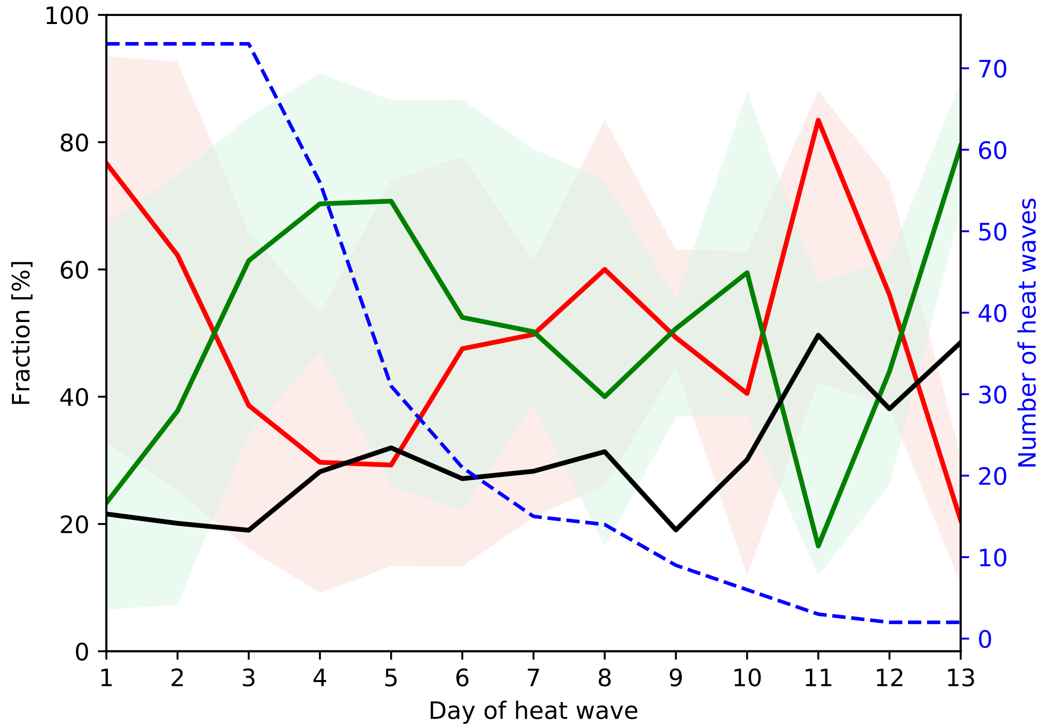


Figure 6: The red (green) line shows the median contribution of the remote (nearby) heating branch to the whole heating branch, and the shading represents the range between the 25th and 75th percentile. The median fraction of the heating branch relative to all trajectories is represented by the black line, and the number of heat waves is indicated by the blue dashed line.

- During onset (day 1), remote branch is of primary importance, during maintenance (day 3-5), nearby branch more important
- For longer-lasting events, both branches are relevant
- Results less robust after day 6 due to smaller amount of events

Conclusions

- 29 (42)% of air parcels experience latent heating during the last three (seven) days prior to reaching upper-tropospheric anticyclones
- This heating branch consists of two regions (Fig. 3a) with different synoptic conditions:
  - i. remote branch is heated above the North Atlantic (Fig. 4a) within extratropical cyclones (Fig. 5a)
  - ii. nearby branch is heated above western/ central Europe (Fig. 4b) within higher mixed layer convective available potential energy (Fig. 5b)
- Remote branch is relevant for the onset of the anticyclone, and therefore of the heat wave, whereas nearby branch is relevant for the maintenance of the anticyclone (Fig. 6)
- Other regions: Influence of diabatic heating stronger for heat wave-related anticyclones above western Russia and Scandinavia, reduced for southern Europe
- More information in: Zschenderlein et al. (2020), Weather and Climate Dynamics, https://doi.org/10.5194/wcd-1-191-2020