# Lagrangian analysis of tracked anticyclonic structures in reanalysis data

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## Are air masses in summer anticyclones more likely to warm due to adiabatic processes during blocking (and diabatic processes during heat waves)?

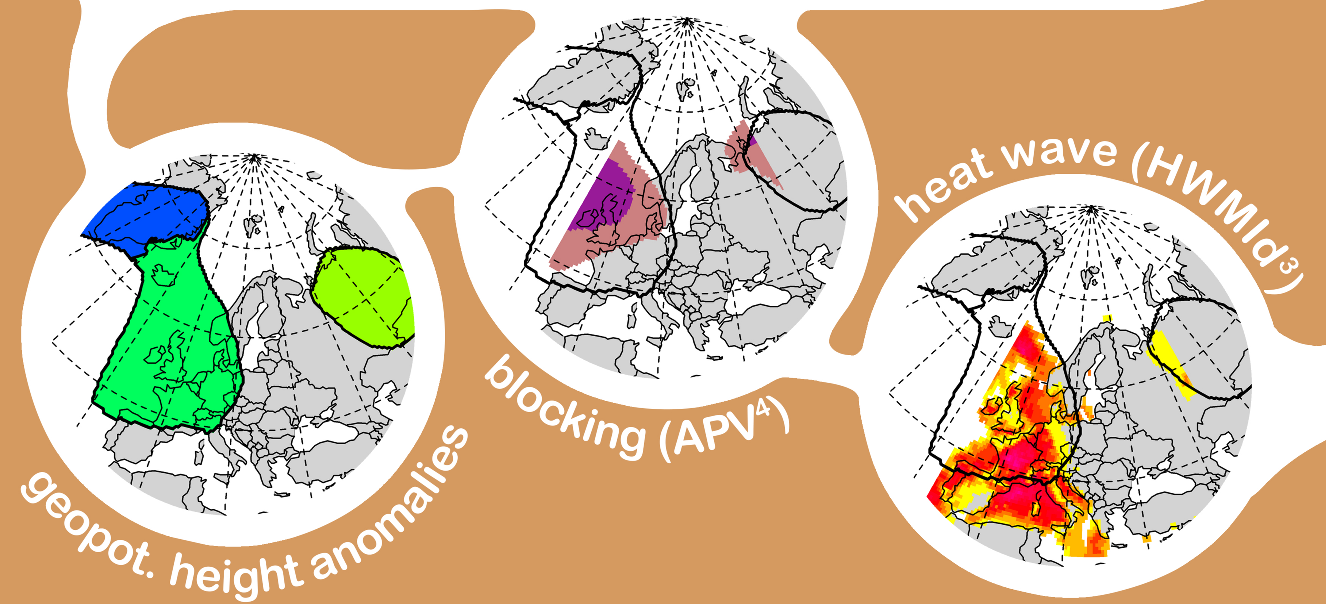
## Background

- known connection between blocking and surface temperature extremes[1]
- diabatic processes mainly responsible for heat extremes in summer during blocking regimes[2]

**Q: Why do some blocking anticyclones (AC) result in a heat wave and others don‘t?**

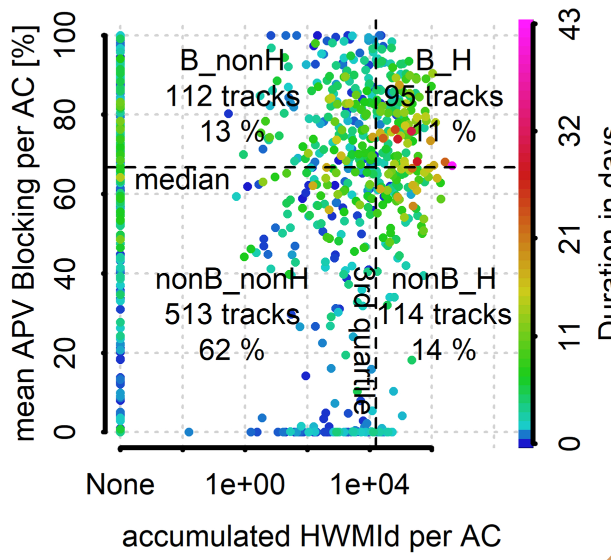
## Data & Preprocessing

- ERA5 case study
- summer (MJJAS) anticyclones over Europe
- four decades of data (1980 - 2019)
- AC: 500 hPa geopotential height anomalies
- tracking AC regions and overlapping heat wave[3] & blocking data[4] (fig. below)

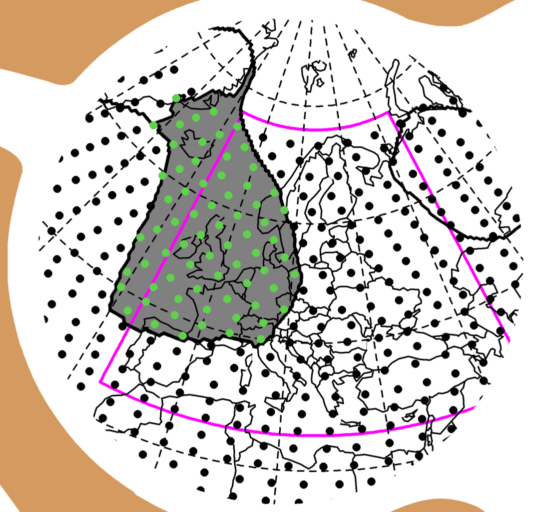



## Case definition

- 4 predefined cases for blocking (B) and heat wave (H) characteristics of ACs result from tracking
- e.g. „B_nonH“ is a blocking AC with no heat wave
- each point is a tracked AC
- one AC per case gets selected for further analysis




## Lagrangian analysis



- backwards trajectories[6] on fixed grid of start points (see **figure left**, black dots)
- near surface levels (ps -10/-30/-50 hPa)
- initiation triggered by presence of tracked AC (e.g. green dots)
- initiation only during growth phase of AC

- Temperature change decomposition for each time step t in a trajectory:

$$T_t = T_{adv,t} + \Delta T_{d,t} + \Delta T_{a,t} \approx T_{t-1} + \Delta T_{d,t} + \Delta T_{a,t}$$

- adiabatic*: $\Delta T_{t,a} = \frac{\kappa \overline{T_t}}{\overline{p_t}}(p_t - p_{t-1})$
- diabatic*: $\Delta T_{t,d} = (\frac{\overline{p_t}}{p_0})^{\kappa}(\Theta_t - \Theta_{t-1})$
- with $\overline{T_t} = \frac{T_t + T_{t-1}}{2}$ and $\overline{p_t} = \frac{p_t + p_{t-1}}{2}$

* from the thermodynamic energy equation[5]

## Conclusions

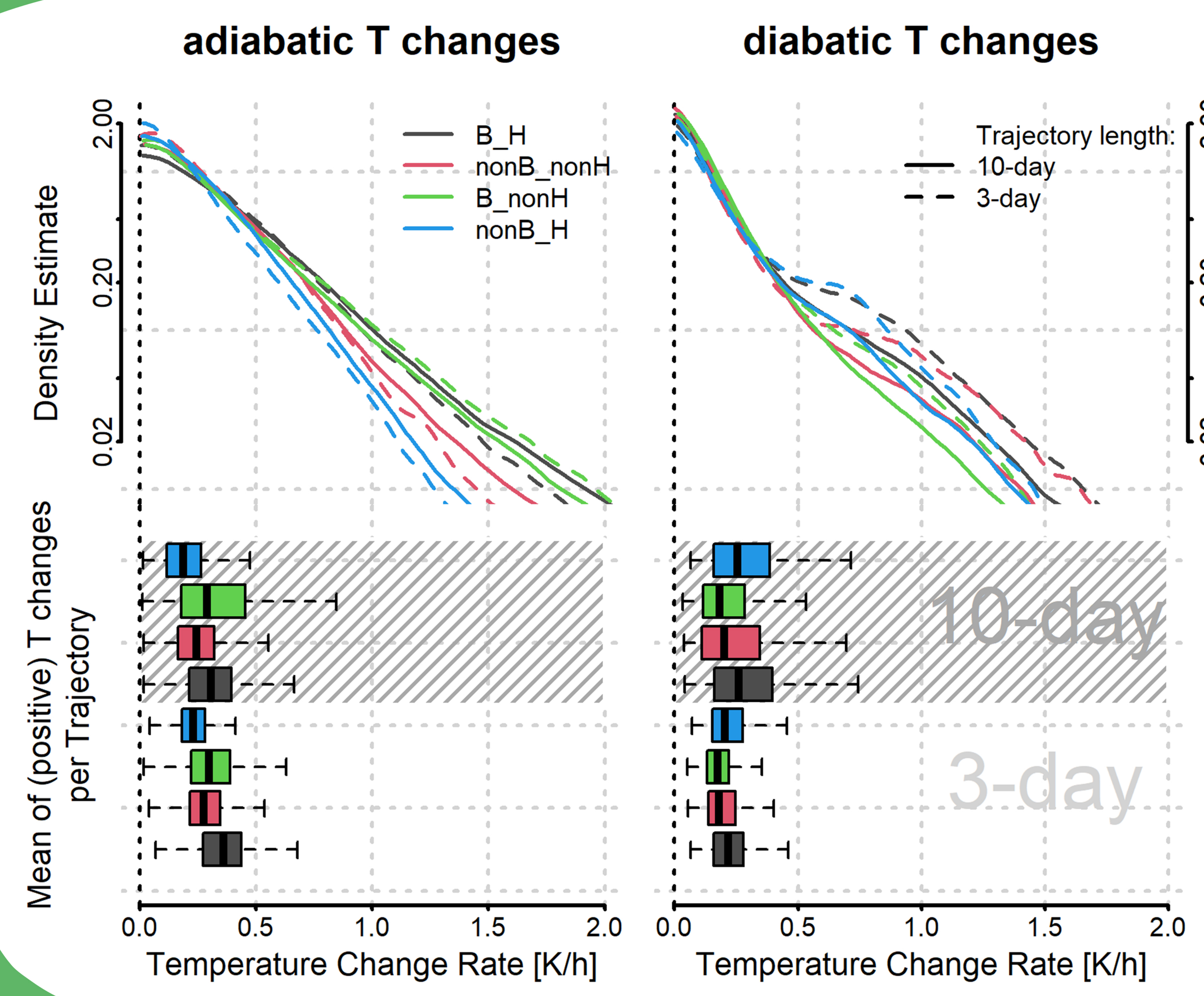



**Figure above:** Process attribution for temperature changes in trajectories, shown per case. Density of all T changes (upper plots) and mean of T changes per trajectory (boxplots), 3- & 10-day backwards trajectories

- higher adiabatic change rates during blocking ACs (left)
- higher diabatic change rates during heatwave related ACs (right)
- 10-day vs. 3-day trajectories show similar pattern in the diabatic T change distribution

## Outlook

- expand analysis on more ACs per case
- AC-relative perspective: Are there specific warming patterns with respect to thermodynamic processes?
- composite trajectory analysis in AC-relative perspective

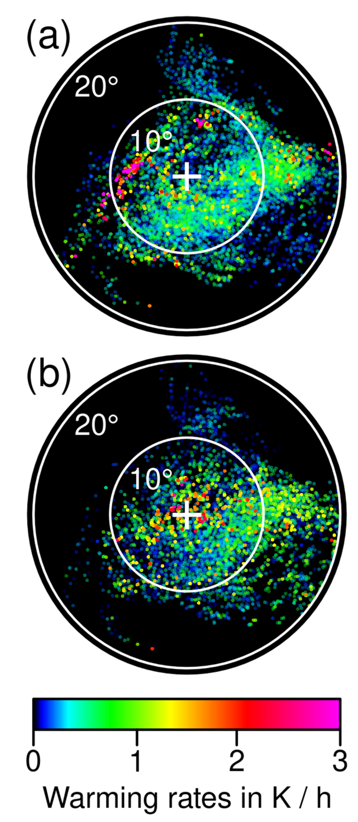



**Fig. right:** Relative adiabatic (a) and diabatic (b) warming rates in AC-relative perspective. Trajectory data for the B_H case anticyclone.

References:

[1] Pfahl, S., and H. Wernli (2012), Quantifying the relevance of atmospheric blocking for co-located temperature extremes in the Northern Hemisphere on (sub-)daily time scales, Geophys. Res. Lett., 39, L12807, doi:10.1029/2012GL052261

[2] Sousa, P.M., Trigo, R.M., Barriopedro, D. et al. (2018), European temperature responses to blocking and ridge regional patterns. Clim Dyn 50, 457–477. https://doi.org/10.1007/s00382-017-3620-2

[3] Russo, S., Sillmann, J., & Fischer, E. (2015), Top ten European heatwaves since 1950 and their occurrence in the coming decades. Environmental Research Letters, 10(12), 124003. https://doi.org/10.1088/1748-9326/10/12/124003

[4] Schwierz, C., M. Croci-Maspoli, and H. C. Davies (2004), Perspicacious indicators of atmospheric blocking, Geophys. Res. Lett., 31, L06125, doi:10.1029/2003GL019341

[5] Röthlisberger, M., Papritz, L. (2023), Quantifying the physical processes leading to atmospheric hot extremes at a global scale. Nat. Geosci. 16, 210–216. https://doi.org/10.1038/s41561-023-01126-1

[6] Sprenger, M. and Wernli, H. (2015): The LAGRANTO Lagrangian analysis tool - version 2.0, Geosci. Model Dev., 8, 2569–2586, doi:10.5194/gmd-8-2569-2015

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Abstract:

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