Exploring and Characterizing the Life Cycles of Tracked Anticyclones in the Northern Hemisphere

Michael Thomas, Stephan Pfahl; Freie Universität Berlin

FREIE UNIVERSITÄT BERLIN

BACKGROUND & KEY INFO

In this work we track **mid-tropospheric geopotential height anomalies** using a method similar to Prein et al. (2023) to explore the connection between **size, lifetime** and **heat wave intensity (H)** within the **life cylces of anticyclones (ACs).**

- **previous tracking of anticyclones in context of:** extreme precipitation[1], rossby-wave-breaking[2], global anticyclone or blocking climatology[3,4] or temperature response on the zonal velocity of tracked blocking systems[3]
- to date, **the connection between size, duration & surface extremes** in blocking systems has received little attention in research[6]

Key info: ERA5 reanalysis • 1980-2019 • 3-hourly • summer only (MJJAS) • NH

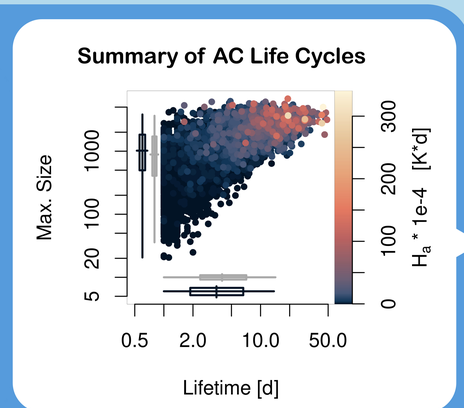


FIGURE 1 (TOP RIGHT): Summary of AC life cycles, where each point represents one AC. Size is the maximum AC area reached and H_a the spatio-temporally accumulated values of heat wave intensity during lifetime. Grey box plots show the filtered ACs.

Heat Wave Detection

- for each diurnal time step t (e.g. 06 UTC) at grid point i
- **heat wave intensity** H as the product of the local temperature anomaly $\hat{T}$ and anomaly duration d

$$\hat{T}_{i,t} = \left(T - T_{p90}\right)_{i,t}$$

$$d_{i,t} = \begin{cases} \hat{T}_{i,t} > 0 & \rightarrow \quad \hat{T}_{i,t-1} + 1 \\ \hat{T}_{i,t} \leq 0 & \rightarrow \quad 0 \end{cases}$$

$$H_{i,t} = \begin{cases} d_{i,t} \geq 3 & \rightarrow \quad d_{i,t} \cdot \hat{T}_{i,t} \\ d_{i,t} < 3 & \rightarrow \quad 0 \end{cases}$$

The resulting 3-hourly heat wave data is matched with the tracked AC regions.

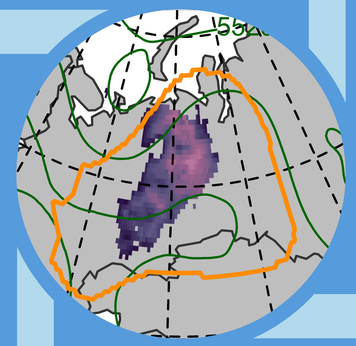


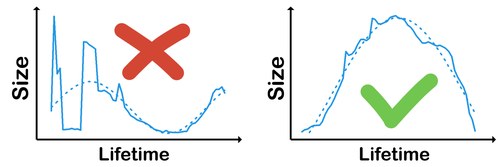
FIGURE 0 (LEFT): Example for a tracked AC (yellow line) over western Russia. The colored region marks an ongoing heat wave, green lines are 500 hPa isohypses.

DATA PREPARATION

FIGURE 2 (BELOW): Example for two life cycles with different merging & splitting behaviors, the left one is omitted, the right one selected.

Filtering Life Cycles

- total of 5905 life cycles, many complex histories of merging and splitting with other ACs



- filtering involves curve analysis and fitting of the AC size evolution (see above), we filter:

- **ACs with intense merging / splitting events**
- **ACs that emerged from splits, or end in merges**

The remaining dataset consists of 2000 complete and comparable life cycles.

CORRELATION ANALYSIS

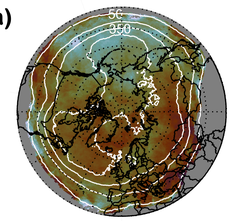
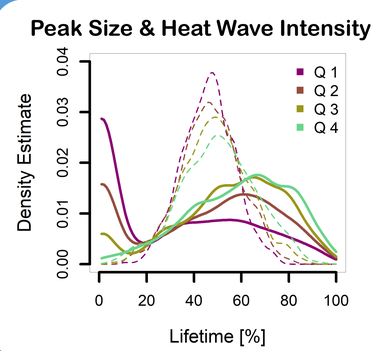


FIGURE 5 (LEFT): Spatial distribution of tracked and unfiltered ACs in absolute numbers (white isolines);
a) Pearson-correlation between log(size) and log(H) for a minimum of 30 tracked anticyclones present at a grid point;
b) same as a) but between log(lifetime) and log(H).

FIGURE 4 (BOTTOM): Distribution of peak-size (dashed lines) and -heat wave (solid lines) timing in life cycle. Depicted per quartile Q of lifetime.

LIFE CYCLE ANALYSIS



Comparison of H-distributions for different quartiles Q of lifetime

⟶ for true H-values from the AC tracking

⟶ for AC tracking with temporally randomized H-values as a test for significance

⟵ distributions relative to lifetime for peaks of size and heat wave intensity

⟵ lag between peaks of size and H

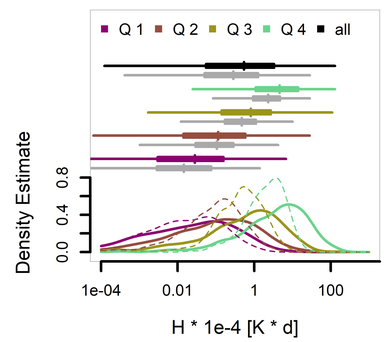


FIGURE 3 (RIGHT): Heatwave Intensity per quantile Q of lifetime. Distributions in dashed lines / grey boxplots show control data with randomized H values.

CONCLUSIONS & OUTLOOK

- **higher (lower) correlation between lifetime (size) and heat wave intensity, exception: Central Asia and the Greenland Sea**
- **lower correlation between size and heat wave intensity over the pacific ocean**, possibly due to dampening effects
- **long-lived anticyclones are more likely** to grow **larger in size** and more likely be connected with **intense heat waves**
- anticyclones reach their **peak in size most likely at mid-lifetime**
- **peak heat wave intensities** occur most likely **at start or around 2/3 of lifetime**, depending on the anticyclones lifetime

What next?

• include land-sea coverage and soil moisture in the tracking • include the role of the propagation speed in context of H • analyze the lag between H and AC size

This presentation participates in OSPP

EGU Outstanding Student & PhD candidate Presentation contest

Sharing is encouraged

References

[1] Prein, A. F., Mooney, P. A., & Done, J. M. (2023). The multi-scale interactions of atmospheric phenomenon in mean and extreme precipitation. Earth's Future, 11, e2023EF003534. https://doi.org/10.1029/2023EF003534
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[3] Pepler, A., Dowdy, A. & Hope, P. A global climatology of surface anticyclones, their variability, associated drivers and long-term trends. Clim Dyn 52, 5397–5412 (2019). https://doi.org/10.1007/s00382-018-4451-5
[4] Liu, P., Zhu, Y., Zhang, Q. et al. Climatology of tracked persistent maxima of 500-hPa geopotential height. Clim Dyn 51, 701–717 (2018). https://doi.org/10.1007/s00382-017-3950-0
[5] van Mourik, J., de Vries, H., and Baatsen, M.: On the movement of atmospheric blocking systems and the associated temperature responses, Weather Clim. Dynam., 6, 413–429, https://doi.org/10.5194/wcd-6-413-2025, 2025.
[6] Nabizadeh, E., Hassanzadeh, P., Yang, D., & Barnes, E. A. (2019). Size of the atmospheric blocking events: Scaling law and response to climate change. Geophysical Research Letters, 46, 13488–13499.

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Abstract