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# Comment on esd-2022-50

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Community comment on "The link between European warm-temperature extremes and atmospheric persistence" by Emma Holmberg et al., Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2022-50-CC1, 2022

This manuscript investigates the link between summer and winter warm spells in Europe and the persistence of the associated atmospheric circulation. The authors rely on metrics inspired by dynamical systems theory to show that while in winter, warm spells do tend to be generally related to persistent large-scale circulation favouring warm advection, in summer, they are not necessarily associated with persistent flow configurations.

This manuscript is overall well-written, and the methods and results are clear to follow. However, I have some strong reservations regarding the results and their physical interpretation, which I detail below.

**Main comments**

My main issue with this manuscript is that you start from an incorrect assumption, which is that "European" summer heatwaves are related to persistent blocking. The use of the word "Europe" here is misleading – it is by now well-known that summer heatwaves across Europe are driven by different processes, and are not systematically associated with blocking. Specifically, one must distinguish between Northwestern Europe/Scandinavia/Western Russia on the one hand and Southwestern/Southern Europe on the other hand. In the first group of regions, summertime heatwaves are known to be strongly related to blocking, with adiabatic warming and clear-sky radiative warming playing an important role. In the second group, blocking is not particularly relevant; instead, summer heatwaves are linked to persistent subtropical ridges (e.g., Carril et al. 2008 https://doi.org/10.1007/s00382-007-0274-5, Stefanon et al. 2012 https://doi.org/10.1088/1748-9326/7/1/014023, Sousa et al. 2018 https://doi.org/10.1007/s00382-017-3620-2). Blocking, for instance, was not relevant for the 2003 European heatwave (e.g., García-Herrera et al. https://doi.org/10.1080/10643380802238137). Admittedly, there is still some debate as to where the boundary between a block and a persistent ridge is, but "blocking" is generally not deemed to be an appropriate term for most persistent ridges below 45°N in summer. I am therefore quite uncomfortable with you writing at various points that your results go against the "conventional" view on European heatwaves.

Second, it seems that, when calculating analogues and persistence indices, you use the whole record (i.e., including both winter and summer days). Is that so? This might be a problem, because there is no a priori reason why the same flow pattern should have the same persistence in winter than it does in summer (you discuss for instance the role of land-atmosphere feedbacks and how they can affect the persistence of the circulation). One might argue that circulation analogues for a summer day would be more likely to be found in summer itself than in winter, but there is no guarantee that this is the case. Based on the results alone, it is also impossible to judge the quality of the selected analogues.

One thing that bothers me in your results and that may be related to this winter/summer issue is the lack of a strong persistence signal for so much of the area during summer heatwaves. Summer heatwaves are almost mechanically associated with strong anomalous ridges above the warm region (since the warm air column expands). There is a strong one-to-one relationship between the circulation and surface conditions. Even when the heatwave is influenced by surface conditions (dry soils, for instance), one would nevertheless expect a strong and persistent anomalous ridge to develop. So I wonder if the lack of persistence that you find is related to the fact that you include winter data to calculate persistence indices. Your summer results are for instance quite different from those of Hoffmann et al. (2021) https://doi.org/10.1038/s41598-021-01808-z who actually find that hot summer spells in the Mediterranean and Southern Europe are linked to very persistent atmospheric flow, while over Scandinavia, it is the opposite. Can this be reconciled with your approach?

One other possible reason for the discrepancy with Hoffmann et al. might also be that your method characterises the "average" persistence of a given flow pattern, which might occur sometimes in conjunction with warm spells (in which cases it could be very persistent) and sometimes not. So while atmospheric circulation would still be very persistent (in the traditionally accepted sense of the term) during warm spells, with your index you might not find a very strong persistence anomaly.

Third, following on this last comment, I wonder to what extent your persistence metric is able to systematically capture atmospheric circulation persistence. The metric is based on a fixed domain, which means that:

(a) It characterises persistence for this whole domain, which is not necessarily relevant for all grid point within this domain (at the edges, for instance)

(b) It only focuses on large-scale circulation, not small-scale.

(c) The analogue selection may be biased by the fact that SLP variance is quite uneven across the domain.

In particular, to illustrate why points (a) and (b) may be problematic, we can look at the case of the British Isles in winter. You find that warm spells there are associated with weaker-than-average persistence. But the warm advection from which these warm spells result is still persistent. It may not be related to a persistent large-scale circulation pattern over the European continent, but still related to locally very persistent conditions, or to persistent large-scale conditions over the North Atlantic ocean to the west.

Your figure 6 is also a good illustration of the problem raised in (b). Even though theta is large for the June 2016 heatwave, the ridge over Germany seems very persistent. This suggests that your results may be sensitive to the choice of region (and potentially distance metric). For instance, what happens if you let the region on which you calculate theta vary to be always centred on the grid point or region under analysis?

**Minor comments**

ll. 43-44 You may also cite Röthlisberger and Martius (2019) https://doi.org/10.1029/2019GL083745

ll. 75-77 I don’t know if this is such a “discrepancy”. As you mention later in the paper, a blocking system can be very persistent from a Lagrangian perspective, without being necessarily persistent from a Eulerian perspective. For continental blocking there is also a strong difference between winter and summer. In summer, positive feedbacks act to make blocking more persistent than in winter. Hochman et al. (2021) for instance analyse summer and winter together, but for Scandinavian/Northern European blocking, I am not sure this is relevant.

ll. 130-131 Which package exactly?

l. 163 It is difficult to conclude without looking at the other terms of the temperature budget. Meridional temperature gradients are much weaker in summer than in winter, as are the rescaled temperature anomalies (smaller daily variance in summer than in winter).

l. 165 Over topography, the adiabatic term would likely be as much if not more important. For an air parcel traveling downwards by 1000 meters, the advection component would be of the order of 5-7°C, and the diabatic component around 8°C (assuming an initial pressure of 900 hPa and temperature of 0°C). At such small scales and over complex orography, SLP is also not ideal to estimate surface temperature advection.

ll. 171-172 “The one exception is Russia, although we observe warm air in the Black Sea and Baltic Sea regions during warm spells in the Russian region. Anomalies over land are comparatively weak” Unclear what this means and refers to.

ll. 202-203 But your analysis should exclude blocking onset and decay days (when surface temperature are not maximized)

ll. 225-226 “We suggest that, for heatwaves predominantly driven by radiative or local effects, it is not a necessary requirement to have highly persistent large-scale atmospheric configurations” I am not sure I follow you here. Over Scandinavia, for instance, summer heatwaves are linked to very persistent conditions (your Figure 2b) but also strong radiative warming (clear-sky forcing below the block; Figure 5e).

+ the DOI is missing from a handful of references.