Second review of paper

The link between European warm temperature extremes and atmospheric persistence

by Emma Holmberg et al.

submitted to *Earth System Dynamics*

I thank the authors for the thoughtful and thorough revision of their paper. Many of my initial concerns have been addressed: (a) the introduction to/description of the persistence measure θ is much clearer (the authors' response to my first review also helped me greatly in that regard). (b) The study gained substance by including the analyses of Z500 persistence (I find in particular the new Fig. 2 very interesting). (c) The temperature advection analysis is now also somewhat clearer, even though I still don't find it entirely convincing (see comments 7–11 below).

Nevertheless, I believe that this paper now meets the quality standards of ESD and I therefore recommend this paper for publication after minor revision. Note that I still have a considerable number of minor comments remaining, which, however, almost exclusively pertain to the presentation of the material and ideas, rather than the content itself. I list those comments below and invite the authors to address them when producing their final version of this manuscript.

Minor comments

1. Abstract: I find several sentences too vague for meaningfully conveying the key results of this study to a first-time reader. Hereafter, I point to several very specific wordings that I have difficulties to fully and clearly understand what they mean. Moreover, I provide suggestions for how they could be written more clearly. I certainly do not expect that you adopt (all of) them exactly but please reword these sentences to increase their clarity.
    a. Line 5: "… no clear persistence signal in the …" -> " … no statistically significant persistence anomaly in the …".
    b. Lines 6–7: "…, while the surface signal is very weak." -> "…, while there are no significant persistence anomalies of the surface circulation pattern."
    c. Line 7: "… suggesting that other radiative and dynamical processes, as well as local effects," -> Please specify what these processes and effects could be! Do you mean maybe "… suggesting that sensible heating or adiabatic warming …"?
2. L54–55: I agree with this statement for temperature anomalies built up by diabatic heating or adiabatic warming, but not for temperature anomalies built up by advection. Very strong temperature advection often occurs in association with fronts and these are themselves clearly not persistent circulation patterns and they can surely also occur within short-lived large-scale circulation patterns. Therefore, please reword or delete this statement.
3. L62–63: The study of Miralles et al., (2014) goes in that direction. They showed that persistent anticyclonic conditions are needed to facilitate the accumulation of exceptional

heat during recent mega heat waves. Consider whether or not that reference is appropriate here.

4. L130: I find the symbol $T_{potential}$ for potential temperature rather confusing. Firstly, in all other symbols you use the subscript to indicate the level (e.g., "surf", or "500"). Secondly, the standard symbol for potential temperature is θ, which, unfortunately, is already taken by your measure of persistence. Please nevertheless try to come up with a less confusing notation. Also, I find it strange to read the words "potential temperature advection" as part of a numbered equation. Please give this quantity its own symbol or introduce the quantity in an in-text equation, e.g., "The surface potential temperature advection, $-\boldsymbol{v}_{surf} \times \nabla T_{surf}^{potential}$, where …"
5. L142–143: Please specify in which figures you have applied the FDR test.
6. L178–180: I only see a "canonical blocked configuration" in panels (g) and (j), panels (h) and (i) just show zonally oriented wave train/dipole patterns.
7. Figure 4: Please adjust the spacing of the color scale so that not only the temperature advection from onshore/offshore flows is highlighted.
8. Figures 4 & 5: Perhaps specify in the methods section how exactly you computed the gradients (centered differences?). The noisiness of the resulting advection fields can quite strongly depend on the way how gradients are computed.
9. Line 214: "potential temperature advection" or "temperature advection"?
10. Line 215: I don't think the term "dominant" is justified here, because you have not stated over "what" exactly, advection should dominate and because you have not yet quantified the importance of these other factors. Use "significant" instead, wherever the results are indeed statistically significant?
11. L226: You allude here to a "strong advective signal", but I just can't quite see such a "strong" positive signal in Fig. 4a–f, except over coastal seas. This is somehow puzzling, as we are looking at data from winter, during which the oceans are surely warmer than the land. So how could a positive temperature advection occur over coastal seas? Also, over the land-regions in your boxes the positive values are modest at best. Therefore I'd highly appreciate if (a) you could explain why the largest positive temperature advection values are found over coastal seas (and not coastal land regions) and (b) where exactly you see this "strong advective signal".
12. L249–251: I couldn't quite follow here. I agree that during "blocking onset" I would indeed expect low persistence of the large-scale flow by your metric. However, I would also not expect any relevant heat waves during that phase in the life-cycle of blocks. Rather I'd expect heat waves when blocks attain their maximum intensity or even slightly later. For that later phase, however, I'd indeed expect a rather persistent (upper-level) large-scale flow.
13. L279–281: What do you mean here exactly with "new dynamical behaviors"? To me this reads like "new synoptic flow configurations will lead to heat waves", but this would clearly not be substantiated by your results.
14. L290–291: Please be more specific about what "other mechanisms" could be.

15. L299: delete “likely”, as descending motion will undoubtably lead to adiabatic warming.
16. Figure 8: Units are wrong in the color bar labels (Pa instead of hPa?).
17. Figure A11: Please increase the range of the color scale to avoid saturation in most parts of these plots. Also, the units in the color bar title do not match the units in the caption.
18. Figure A12: Please increase the range of the color scale to avoid saturation.

References

Miralles, D. G., Teuling, A. J., Van Heerwaarden, C. C., and De Arellano, J. V. G.: Mega-heatwave temperatures due to combined soil desiccation and atmospheric heat accumulation, Nat. Geosci., 7, 345–349, https://doi.org/10.1038/ngeo2141, 2014.