

Interactive comment on “Global warming makes weather in boreal summer more persistent” by Dim Coumou and Paolo De Luca

Anonymous Referee #1

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Global warming makes weather in boreal summer more persistent, by Coumou and De Luca

This study examines reanalysis and CMIP model simulations to determine the change in persistence of the summertime circulation over a large number of regions in the Northern Hemisphere. This is done using a persistence metric based on dynamical systems theory that the authors claim is more advanced than metrics used previously. The primary analysis in the main text is for Z500 and for that it is shown that there is a trend toward increased persistence over the historical record and also under the two SSP scenarios considered. I think this is an interesting approach and the conclusion that there is a robust trend in persistence would be interesting, if correct. However, I have a number of concerns that prevent me from recommending publication at this

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time. My two primary concerns are the large differences in trends between SLP and Z500. The authors claim in the text that they give similar conclusions, but they don't look similar at all to me (see my general comment (1)). This makes me concerned that the increasing trend is a peculiarity to the Z500 metric which might be heavily impacted by an overall warming trend. I'm not sure how the trend is dealt with, but at this point, I don't see why there should be such a big difference in the trends in persistence between Z500 and SLP if it really represents a measure of the persistence of circulation patterns. My second major concern (general comment 2) is about the inference that readers will take away related to the increase in extremes when it seems like the trends in increased persistence could arise through less variability overall. I recommend that these two major points, along with my other minor suggestions below, be considered before publication. I have given an overall recommendation of "major revisions", but really I would have liked to have given something between major revisions and reject e.g., reject but encourage resubmission. I think my two major concerns may be enough to prevent the manuscript from being published, but I also think it's possible that the authors could adjust the analysis or make clarifications to alleviate these concerns, after which point it should be published.

General comments:

(1) The comparison with SLP. It is stated at l203 that the analysis was repeated using SLP and similar significant trends for the mid-latitudes were found (with reference to Fig S4). This seems like a major over-statement to me. For many of the cases where the models show a significant trend for Z500, there is no trend in SLP (ALA, CAS, CGI, EAS, NA). For some where there is still a significant trends in SLP, the magnitudes are massively different e.g., in MID-LAT, the increase in persistence for Z500 is about 0.4 days whereas for SLP it is about 0.05 days. Is there a reason the change in persistence in units of days should be so different between these two fields? Presumably it is the same weather systems that are responsible for the Z500 and SLP anomalies so why wouldn't they show the same change in persistence? Overall, the SLP results in Fig

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S4 make me very sceptical of the conclusions of this paper and I recommend that the differences between Z500 and SLP be investigated further before this paper is considered for publication.

(2) Throughout the paper, readers will infer that this increase in persistence will be associated with increased extremes e.g., the fact that the abstract begins talking about devastating impacts of summer extremes and the last sentence of the abstract mentions the societal risk associated with the increase in persistence found. However, I'm not certain that this has to be the conclusion. Couldn't it also be that persistence has increased and degrees of freedom has decreased because there is just less variability? So that extreme events themselves may actually have reduced because there's less variability and the atmosphere is more likely to stay in a "normal" state for longer. Indeed, the authors state at l177-178 that the too small local dimensionality in models might be due to their underestimation of variability such that they are more likely to persist. So, the connection between showing this increase in persistence and there being an increase in extremes is unclear to me. I suggest this be clarified or the wording that links this to extremes be toned down and the fact that this increased persistence could be due to reduced variability be acknowledged. The authors show the change in persistence of the most extremely persistent events, but I don't think that demonstrates that things are becoming more extreme. It seems this needs to be accompanied by some metric of variance. Indeed, we know from some of the papers cited in the text like Chang et al (2016) that summer extra-tropical cyclone activity is expected to decrease.

(3) I think the description of the methodology could be enhanced to make it accessible to readers who are not experts in dynamical systems theory (readers like myself). For example, I'm left at a bit of a loss as to how θ and σ are determined. Are they the parameters that give the best fit to the Generalized Pareto Distribution in equation (2)? If so, how well is the cumulative distribution function of the recurrences actually represented by this Generalized Pareto Distribution? Is it a given that it will be? Or is

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this something that should be tested before it is used?

(4) I recommend discussing a bit more the scaling of the change in persistence with warming. It surprises me that the change in persistence under SSP585 in Figure 4 is about the same order of magnitude as the change over the historical record, when I think the greenhouse gas forced temperature changes by 2081-2100 will be much larger than the trend that has occurred over the 1979-2019 period.

I11: I find the statement that "Global warming weakens the hemispheric-wide circulation in boreal summer" to be too much of a generalization. I think this needs to be more specific because it is not true that the circulation weakens everywhere in boreal summer. For example, the westerlies in the upper troposphere are expected to strengthen under greenhouse gas forcing (Grise and Polvani 2014, 10.1002/2014GL061638, their Fig 1) and the westerlies on the northward side of the Atlantic jet maximum are also expected to strengthen in the lower troposphere (Simpson et al 2014, <https://doi.org/10.1175/JAS-D-13-0325.1> their Fig 7e).

I28-30: It might be worth clarifying what timescale of record breaking heat has increased 5-fold. I believe it is monthly?

I40: Similar to my comment at I11, I recommend being more specific about where this statement is referring to as there are some regions where a strengthening of the westerlies in the summertime is robust.

Figure 2 (and other figures): suggest being clear in the caption that this is for Z500. It's stated throughout the data section that the persistence metric is calculated for Z500 and SLP and, while it is stated that SLP is used as a sensitivity test, I think this could be easily missed.

I229: I think that this is perhaps an over-statement given the way that Figure S6 looks. It should perhaps be mentioned that the r^2 of this regression is 0.074 and 0.157 for SSP126 and SSP585, respectively. Furthermore, I'm sceptical that the uncertainty

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range on the regression coefficients has been calculated correctly. It doesn't look right to me, given the spread in the points. Please clarify how this has been done.

I282: I think it could be worth mentioning that there is more than just greenhouse gas forcing in these simulations. In particular, aerosols are evolving too. Perhaps it could be changed to something like "attributable to external forcing, most likely greenhouse gas forcing".

Typo's/wording:

I34: degree symbol should be superscripted. I105: "is the more" → "is more" I154: "composed by" → "composed of" I252: I'm not sure if it's actually "formally" that is intended here, as opposed to "formerly"?

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