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Interactive comment on "Diverging hydrological drought traits over Europe with global warming" *by* Carmelo Cammalleri et al.

Anonymous Referee #2

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This study examines the projected change in hydrologic drought severity, duration, and frequency due to climate change across Europe. It employs a unique GWL perspective to merge projections and represents a significant effort to combine climate, land cover, and population projections with hydrologic modeling to estimate drought exposure.

Overall the work is of a high quality; however, I have a number of reservations, as described below. The majority of these issues are clarifications of the methodology, which are needed to fully assess the findings. It is also important to clarify the interpretation of some results. I therefore recommend a significant revision.

Major issues:

M1. Is it possible to provide the range of years the ensemble members reach the GWLs

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for context? It would help to confirm that the present conditions have not surpassed 1.5K and provide some context to how fare off +1.5K is from the present. If this is not possible, at least provide delta K for the reference period.

M2. Related to A1, you are incorporating changes in population, land cover, and water abstraction with time through 2050. But, because the endpoints are tied to GWL, rather than a year, each member of your ensemble will have slightly different values for these model inputs. Are you accounting for this? Can you provide a relative estimate of the water abstraction changes? This would help provide sensitivity/scale for this portion of the model.

M3. Changes in snowmelt patterns and seasonality have a potential impact on future hydrologic changes at higher elevations and latitudes. You mention this on Line 372. Does your model incorporate a snow accumulation/melt module?

M4. Please provide more clarification as to how the return periods are being derived. More detail is needed than the reference to Cammalleri et al (2017) paper. It appears you are using a peak-over-threshold/partial duration series approach. I am most familiar with using the generalized pareto distribution for return periods in this context. It appears like you are using the Pareto Type II. Please explain this choice. Also, be aware that in the context of a partial duration series, your statement on line 163 "the probability that one event is topped in any one year" is slightly less accurate than for an annual maximum series.

M5. Please provide the methodology for calculating the change in drought duration shown in Figure 2. Does days/year represent a summation of all drought days during the reference period? I believe this is the correct interpretation. My confusion is because the Severity (D) analysis focuses on the severity of an individual event, whereas this Duration analysis focuses on a cumulative metric.

Also, as part of this, please revise your interpretation in Section 3.1.2. If you are summing up the days under drought conditions, then you cannot say that "droughts

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will last longer", as you do in Line 252. I interpret longer droughts as the individual drought events lasting longer, but this metric could increase due to more frequent, but similar duration droughts. Without knowing the number of unique droughts, you cannot make this statement, only that the total time spent in drought will increase.

M6. There is no significance testing for any of these claims. It is difficult to determine whether these trends are a significant signal or noise. The consistent regional patterns suggest a true trend. But, I would strongly recommend significance testing to quantify how much agreement there is among ensemble models (Fig 1) or how significant these changes are regionally (Fig 2/3).

M7. Line 426 - This interpretation, which depends on your assumption on Line 184, assumes independence among sites, which is not true. Regions enter drought at the same time, so it is not fair to say that 10% of the region will be exposed to a 10 year drought in any given year. More likely, a majority of the Mediterranean (or at least the eastern/western portions) will enter drought at the same time.

Associated with this is the interpretation of Figure 4/5. Is this based on the 10-year drought only or all droughts?

M8. Please provide a data availability statement. This is required by HESS and is not included in the version I had access to.

Minor issues:

- You are defining your GWLs relative to a pre-industrial baseline. Please provide the years for this baseline. Is it the 1881–1910 baseline used in Donnelly et al. (2017)?

- Line 160 - If you are using Maximum Likelihood to fit the Lomax distribution, this is not an "empirical" cumulative distribution, but rather an estimate of the population's cumulative distribution.

- Figure 1 - This figure caption and legend do not indicate that this is showing the change in the 10-year drought.

- Line 196 - Please indicate where these macro regions were derived from.

- Line 241 - I suggest you use "climate change-induced" here. Much of this trend is likely driven by changes in precipitation, rather than warming specifically. Similarly, on Line 423.

- Figure 3 - What is this x-axis? Is it standard normal deviates spacing? There isn't quite enough tick marks to know for sure. Can you please explain this in the caption?

- Figure 3 - Please add some type of reference point to this figure to highlight the 10 year drought event, as defined by the reference period. In its current format, there is not even a label fo the 10 year event. At a minimum, add this label, preferably add a vertical line so the reader can compare with the plotted distributions.

- Line 345 - You may also consider adding the following references, which provide additional support for this regional pattern of meteorological drought. They both attempt to parse the affect of precipitation trends from temperature/evapotranspiration trends.

DubrovskÃ¡, M., Hayes, M., Duce, P., Trnka, M., Svoboda, M., & Zara, P. (2013). Multi-GCM projections of future drought and climate variability indicators for the Mediterranean region. Regional Environmental Change, 14(5), 1907–1919. doi:10.1007/s10113-013-0562-z

Stagge, J.H., Kingston, D.G., Tallaksen, L.M. et al. Observed drought indices show increasing divergence across Europe. Sci Rep 7, 14045 (2017). https://doi.org/10.1038/s41598-017-14283-2

Line 349 - The word "severe" is misspelled.

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