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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Historic hydrological droughts 1891–2015: systematic characterisation for a diverse set of catchments across the UK" *by* Lucy J. Barker et al.

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Anonymous Referee 2
Author Response

The authors present a study of hydrological drought events over the 1891-2015 period utilizing newly established datasets. I think it is a valuable contribution to the hydrological and low flow and drought community. I would suggest to publish the paper after some minor revisions.

We would like to thank the reviewer for their positive feedback on our manuscript and are grateful for the comments on how it can be improved. Here, we respond to each comment in turn with the author responses to each point given in bold below.

General Comments

Little information is given on the basic datasets used for driving the hydrological model. Please elaborate in more detail on the digitized meteorological data. Is this raw data or have they undergone a homogenization procedure? I also think that a reference for a paper in "preparation" is not suitable. Moreover I think that there has to be a more in-depth description of the hydrological modelling. E.g. Smith et al. (2019) used six evaluation metrics some of the specific for low flows. What are these metrics and what is the performance? Please provide some information in this respect.

Reviewer 1 also had the same concern and we appreciate that we shouldn't cite in preparation papers. In regards to Legg and McCarthy (in prep), we will remove this 'in preparation' reference and replace it with the references for the finalised data sets (i.e. Met Office 2018, 2019). These datasets have benefitted from additional daily data from ongoing digitisation of daily climatological returns from UK observing stations held in the paper records of the National Meteorological Archives. We feel that citing the catalogued datasets is more appropriate than adding the detail of how data were digitised in this paper. There is a paper in preparation which will sit alongside Met Office (2018) – Hollis et al., however it is still at the 'submission' stage and so it may not be appropriate to cite this paper.

As stated in our response to Reviewer 1, we will add more detail on the per-

formance metrics used in Smith et al. (2019) as well as how well the models performed spatially to the revised paper. However, the results of the multi-objective modelling approach, including the performance is described in detail in Smith et al. (2019) and we feel that it is more appropriate to guide the reader to the detailed Figure 3 in Smith et al. (2019) and the performance data available in Smith et al. (2018), than to include detailed information on model performance in this study.

You use the SSI as a standardized hydrological drought indicator. What about the uncertainties considering the fitting of the distribution and how do these translate in terms of derived drought metrics? Since you use mostly rankings of the top events it is rather crucial how the fitting performs particularly at the tails of the distribution. Could you just exemplarily give an indication of possible change in the ranking of some drought metric from fitting uncertainty?

There are clearly uncertainties in the fitting of a distribution (which ever distribution is selected), however we used the Tweedie distribution because it has been shown by Svensson et al. (2017) to fit best for UK flow data for 121 Benchmark Catchments in the UK (the majority of which overlap with the 108 LFBN catchments used in this study). Tweedie was recommended as the distribution of choice for the UK after rigorous testing by Svensson et al. (2017) of 12 distributions (including those commonly used for standardised drought indicators such as Gamma and GEV) with special attention paid to the tails of the distribution (see Svensson et al. 2017 Section 4.3); the Tweedie has the advantage of being a flexible three parameter distribution that has a lower at zero. We will add the benefits of the Tweedie distribution to the revised paper, and add a brief discussion of the uncertainty to the discussion, recognising Reviewer 1's comments about the length of this section we will sure this addition (and the rest of the section) is concise.

Figure Layout For Figures 3, 5 and 10 I suggest to place the acronyms for the region outside the plot area along the y-axis for better readability. Also rethink the arrangement of catchments along the y-axis, perhaps there is a better way than a strict North/South (driven by climate) alignment (e.g. low flow characteristics).

In the revised paper we will move the region labels to outside the plot area to improve the readability for the plots mentioned.

Currently, the catchments are ordered by their gauging station ID number which are assigned based on the on the Hydrometric Area in which the gauging station is located (for more information see the National River Flow Archive website here: https://nrfa.ceh.ac.uk/station-number and https://nrfa.ceh.ac.uk/hydrometric-areas). The catchments are in general, therefore ordered by areas that are climatically and physically similar. However, the arrangement of catchments was also mentioned by Reviewer 1, and we will investigate whether changing the order of the catchments (e.g. ordered by Q95 within regions) improves the interpretation of the plots.

Figure 5: The colorbar as a gradient from red to yellow is in general appropriate for this kind of data in terms of figure layout guidelines. However, since the displayed data is a ranking, I think that the reader would like to see first of all where the top ranked events are. This is not easy in this case. Perhaps you could try a colorbar with more colors? (in R: RColorBrewer palette "Spectral") Or combine two colorbars, one for the top 3 (or 5?) and one for the rest. Don't know how it would look, but it is perhaps worth a try to get the essential information better across.

We appreciate it is not always easy to see which is the top ranking event on these plots. We would prefer not to use the spectral colour palette because as

it includes green and red can cause problems of interpretation for those with colour blindness, the colour palette we used also works when printed in grey scale. We will however, work to improve this plot and ensure it is easy to see when the top ranking event(s) occurred in the revised paper, e.g. by adding additional colours to the palette.

Several times across the manuscript I stumbled over the terms droughts, drought event or drought periods. I0d like to see more consistency with these terms. The list of major droughts (Table 1) is mostly termed events, however, the 1890-1910 period is not an event from an event definition point of view. This comes rather clear in Figure 10a, where the "long drought" is clearly made up of several individual events(!) all of them with a distinct beginning and end. On the other hand, 1921 (Figure 10b) is clearly an event itself, it has a distinct beginning and end. I suggest to define the names of the major droughts as in Table 1 and stick to the terms, e.g. "1890-1910 drought period", "1921 event", "1976 event", etc. I think that an event stretching over several years could be termed as the "year xxxx event", with the year being that with maximum drought intensity for example, which has to be defined obviously.

The Long Drought was indeed a period of many shorter deficits and 1903-1905 was a wet interlude in this prolonged dry period. We explain this in both Section 3.1 and Section 3.4, and we introduce that this period (1890-1910) was called the 'Long Drought' by Marsh et al. (2007) on P2L12 and classed it as a major 'event'. We would prefer to keep the event (or period) names as they are, e.g. 1975-1976, 1921-1923, 1891-1910 as this most clearly captures when the event occurred, but will ensure that the 1891-1910 period is referred to as a 'period' rather than 'event' in the revised manuscript to avoid this confusion.

Specific Comments

P2L20: ". . .short periods of warm and dry weather. . ."

We will modify this text as suggested in the revised paper.

P2L24: "Moreover, greater climatic variability could mean an increase in persistent blocking episodes and multi-year droughts" please provide a reference for this statement.

We will cite Folland et al. (2015) in this sentence in the revised paper.

P2L24: P6L5: "Smith et al. (2019) also" please be generally careful with the citations, there are some other inconsistencies.

We will change this citation style in the revised paper and ensure the rest of the references are in the correct style.

P2L24: P6L11: "Low Flow Benchmark Network (LFBN)"

We will capitalise Low Flow in the revised paper.

P2L24: P6L11: P11L3: suggestion: "For both time scales considered, events tend. . ."

We will modify this sentence in the revised paper.

P2L24: P6L11: P19L6: ". . . e.g. 1895 saw extreme flow deficits across Scotland and Northern Ireland. . ."

Thank you for this correction, we will change this sentence as suggested in the revised paper.

P2L24: P6L11: P22L10: In this section some recent research would be appropriate to cite, since there are some events detected in the present paper also listed as extreme droughts in other regions of Europe for example in:

Hanel, M., Rakovec, O., Markonis, Y., Máca, P., Samaniego, L., KyselÃÂą, J., Kumar, R. (2018). Revisiting the recent European droughts from a long-term perspective. Scientific Reports, 8(1). https://doi.org/10.1038/s41598-018-27464-4

Haslinger, K., Blöschl, G. (2017). Space-Time Patterns of Meteorological Drought Events in the European Greater Alpine Region Over the Past 210 Years. Water Resources Research, 53(11), 9807–9823. https://doi.org/10.1002/2017WR020797
Thank you for these suggestions of additional references, we will ensure to include them in the revised paper.

References

Folland, C. K., Hannaford, J., Bloomfield, J. P., Kendon, M., Svensson, C., Marchant, B. P., Prior, J., and Wallace, E.: Multi-annual droughts in the English Lowlands: a review of their characteristics and climate drivers in the winter half-year, Hydrol. Earth Syst. Sci., 19, 2353-2375, https://doi.org/10.5194/hess-19-2353-2015, 2015.

Hollis, D., M. McCarthy, M. Kendon, T. Legg, I. Simpson, 2019: HadUK-Grid – a new UK dataset of gridded climate observations, Geoscience Data Journal, submitted.

Met Office: HadUK-Grid gridded and regional average climate observations for the UK, Centre for Environmental Data Analysis, 10.5285/4dc8450d889a491ebb20e724debe2dfb, 2018.

Met Office: MIDAS Open: UK daily rainfall data, v201901, Centre for Environmental Data Analysis, 10.5285/ec54d5e5288a4ebb8c7ad2a1ef6aec42, 2019.

Smith, K.A.; Tanguy, M.; Hannaford, J.; Prudhomme, C. (2018). Historic reconstructions of daily river flow for 303 UK catchments (1891-2015). NERC Environmental Information Data Centre. https://doi.org/10.5285/f710bed1-e564-47bf-b82c-4c2a2fe2810e

Smith, K., Barker, L., Tanguy, M., Parry, S., Harrigan, S., Legg, T., Prudhomme, C., and Hannaford, J.: A Multi-Objective Ensemble Approach to Hydrological Modelling in the UK: An Application to Historic Drought Reconstruction, Hydrology and Earth System Sciences Discussions, https://doi.org/10.5194/hess-2019-3, 2019.

Svensson, C., Hannaford, J., and Prosdocimi, I.: Statistical distributions for monthly aggregations of precipitation and streamflow in drought indicator applications, Water Resources Research, 53, 999-1018, 2017.

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