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Discussions

Interactive comment on "From meteorological to hydrological drought using standardised indicators" *by* L. J. Barker et al.

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We would like to thank the reviewer for the positive feedback on our manuscript and are grateful for the comments on how it can be improved including the very useful suggestions for additional references. Here, we respond to each comment in turn – full details of the implementation will be provided in the revised manuscript.

1) 12830 L4: We agree that it would be useful to give an example of a drought monitoring and early warning system that incorporates streamflow and we will add some examples in the revised manuscript.

2) 12830 L10-14: We will revise the manuscript to give an overview of the shortcomings of the SPI, including the references suggested by the reviewer.

3) 12832 L8: We agree that the study by Lopez-Moreno et al. 2013 could be cited here and will add this to the revised text.

4) 12833 L15-19: The UK Benchmark catchments aim to characterise those catchments with both 'natural' flow regimes (i.e. little effected by abstractions or regulation) and 'natural' catchments (i.e. little effected by urbanisation, industrial activity etc.) over the short-term scale of the gauged record. The widespread nature of land modification in the historical period means very little of the land cover in the UK is completely natural, but in many catchments (at least those classes as 'Benchmark'), little has changed over recent centuries. As such, the Benchmark catchments are the closest approximation we have of natural catchments. We will add some text describing the near-natural state of the catchments, emphasising that as well as near-natural flow regimes and good hydrometric performance, they are also little impacted by anthropogenic activity.

5) 12833 Section 2: In the revised manuscript we will more clearly explain the origins of the catchment monthly rainfall data which is based on observed UK Met Office data. The data have been sourced from the UK Met Office and have been quality controlled prior to its release (Marsh and Hannaford, 2008; Met Office, 2001).

6) 12837 L25: In the revised manuscript we can make our selection method more clear and give an overview of the proportion of missing data in both precipitation and streamflow series. We can also mention the implications of missing data – particularly during in a drought event. However, to infill gaps is beyond the scope of this paper. The use of Benchmark catchments means there are fewer analogue catchments available to use for infilling with the appropriate climatology, catchment properties and factors affecting runoff than would be available for many other UK catchments. Harvey et al. (2003) discuss and test the available methods for infilling streamflow data, using a Benchmark catchment as an example. They found that when a combination of donors were used and the different flow regimes were accounted for, the flow variability of the target catchment was captured. However, the timing and magnitude of flow estimates showed notable differences meaning it was not representative of the flow patterns in

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the missing period.

7) Section 3.1: We will make clear in the revised manuscript that SPI values were calculated using catchment averaged monthly rainfall (using observed data – see response 5) and that SSI values were calculated from monthly mean flow data at the catchment outlet.

8) 12836 L11-20: Details of the amended, non-standard methods used to calculate SPI for the same set of UK catchments are the subject of a paper currently being revised for Water Resources Research by Svensson et al. (2015b). Svensson et al. (2015b) show that across durations of 1, 3, 6 and 12 months for the 121 UK catchments, the Tweedie distribution is rejected in considerably fewer cases compared with the Gamma distribution, for both precipitation and streamflow. We do not wish to present detailed results of Svensson et al. (2015b) in the present Barker et al. paper, as we feel this would not be helpful for the publication process of the Svensson et al. (2015b) paper.

9) Section 4.1: Although we agree that in hindsight using time-scales longer than one month for streamflows was, in some sense, redundant, the aim of the study was to undertake a thorough analysis of both SPI and SSI and find the appropriate accumulation periods for UK data (where these standardised indicators have rarely been used). In the paper we initially start out using accumulation periods of 1-24 months but then, in the propagation section move to using SSI-1. Although we state that we start to use SSI-1 only in the propagation section, we do not explain why. The one month SSI gives a good description of low flows, similar to the 30-day mean flow, often used in studies of annual minimum flows (e.g. Gustard et al. 1992). For monitoring and early warning purposes knowing which accumulation of precipitation has caused the deficit in river flows enables you to monitor precipitation deficits in future events. We will state this reasoning for switching to SSI-1 from the full range of SSI accumulation periods in the revised text. We would also argue to keep reference to streamflow accumulation periods of 6 and 18 months in the text because of the interesting results found for the longer accumulation periods of longer, more severe droughts in Scotland than

in the south and east of England for the 18 month accumulation period. Removing these accumulation periods would mean this section of the discussion would need to be removed and we feel that this is an important outcome of the paper, highlighting the problem of calculating SPI/SSI using data with long term trends.

10) 12840 L5-10: We feel that Figures 6 and 7 nicely show the long term trends in increasing precipitation and flows in Scotland and the problem this causes when SPI/SSI is calculated. As mentioned in the previous response (9) we would argue against removing reference to the longer SSI accumulation periods completely, as this would mean removing an important finding from the paper. However, we could consider moving Figures 6 and 7 to the supplementary material if it is thought that the figures would be better placed there.

11) 12840 Section 4.2: The references mentioned (Vicente-Serrano and Lopez-Moreno, 2005 and Lopez-Moreno et al. 2013) indeed have some interesting results in the seasonal changes in the SPI and SPEI accumulation periods most strongly correlated with the one month SSI. Although it is beyond the scope of this paper to look at the seasonality of UK drought characteristics and propagation (from meteorological to hydrological), the importance of groundwater in the south and east of the UK mean that the recharge season (mainly winter) is important to avoid summer hydrological droughts. As suggested by the reviewer we will stress this in Section 5.5 ‘Further Research’.

12) 12835: We used the Gustard et al. 1992 reference to indicate the method used, however if this is not clear we can add a brief description of the methods used to this section in the revised text.

13) Figure 11: We realise we should have made this more clear – the caption for Figure 11 and 12 should include ‘hydrological drought characteristics’ as we calculated them using the one month SSI. We will amend this in the revised manuscript.

14) Section 4.3: We agree that Section 4.3 is particularly long and we will add some

sub-headings to make it easier to navigate.

15) 12845 L20: We thank the reviewer for pointing us in the direction of relevant references, and we will incorporate these in the discussion. We feel that at present we cannot be more precise than we currently are regarding the influence of the atmospheric mechanisms that govern precipitation in central and southern UK.

References

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