Response to the comments of Anonymous Referee 2

This manuscript nicely introduces an important topic, anthropogenic influences on streamflow drought, and outlines and investigates a core challenge when studying, identifying and monitoring streamflow droughts in the Anthropocene: human influences potentially changing the normal relationships, characteristics and descriptions of drought. The paper is well written and fits the scope of HESS. Overall I believe that it gives a good outline of the issues involved in investigating the human influence, however there are a number of small changes which I believe should be addressed before acceptance.

We thank the reviewer for the elaborate and constructive feedback on the manuscript and are grateful for the valuable input. Below we respond (in blue) to the reviewer comments (which are in black).

Were all catchments analyzed for the time period 1974 -2013, or did they vary in length (as the supplementary figures suggest).

All catchments were analyzed for the time period 1974-2013. In the supplementary material, we zoom-in to some periods where the human influence was clearly visible. We will clarify this in the revised version of the manuscript and the supplementary material.

Furthermore, it is mentioned how many catchments were useable after the missing data criteria (187), however it would be useful to be more transparent about how many catchments were used for the analysis in this paper specifically.

We used all available NRFA streamflow records for England and Wales and removed those records that at the time of the analyses did not cover the complete time-span between 1974-2013 or had one or more months within this time span with five or more days of missing data. We will emphasize this in the revised version of the manuscript.

Figure 8 shows all 23 that are identified in Figure 7, however these 23 are not just the groundwater abstraction and storage FAR-codes that the paper has a focus on, and which are mentioned in the results section.

In the revised version of the manuscript, we will remove these “other” graphs from Figure 8 and mention that only the catchments with “G” and “S” are shown.

Title: I would suggest a small edit to the title as you are not only looking at streamflow drought characteristics, but also at relationships. Perhaps this can be incorporated into the title if the authors agree that it is important too?

Thanks for this suggestion. We considered using other titles that include words like propagation but in the end decided to use the broad term “characteristics”, as the focus of the paper is on the screening approach and not really any specific drought (propagation) characteristics / processes. We therefore would like to leave the title as it is.

Page 1, L16: You currently introduce BFI but this should be changed to introduce BFIHOST as you use this in the paper.

We will change: “… the Base Flow Index, BFI (specifically: BFIHOST, the BFI predicted from the hydrological properties of soils)”

Page 1, L24: Change ‘towards the end of record was found. . .’ to ‘towards the end of their records was found. . .’

We will change as suggested in the revised version of the manuscript.

Page 1, L26: Change ‘screening approaches were successful’ to ‘screening approaches were sometimes successful’

We will change as suggested in the revised version of the manuscript.

Page 1, L30: Change ‘approach’ to ‘approaches’

We will change as suggested in the revised version of the manuscript.

Page2, L2: Change ‘They are monitored. . .’ to ‘They are identified and monitored. . .’,

We will change as suggested in the revised version of the manuscript.

Page 3, L16: Change ‘A first approach’ to ‘One suggested approach’ L19 – 27:

We will change as suggested in the revised version of the manuscript.

Page 3, L 19-21 – do you mean 2 discharge stations or 1 discharge station and 2 time periods?

We mean one streamflow record. We will emphasize this by changing. “… on a comparison between the influenced and non-influenced part of the record for a particular location.” to “… on a comparison between the influenced and non-influenced part of one particular streamflow record.”

Page 3, L27: Change ‘However, the above described approaches. . .’ to ‘However, all these approaches. . .’

We will change as suggested in the revised version of the manuscript.

Page 3, L29: Suggested paragraph break at “An alternative”

We will split the paragraph at the suggested point in the revised version of the manuscript.

Page 4, L8-10: rephrase

“This study aims to close this gap, e.g following the recommendation of Barker et al. (2016). It seeks to understand the human influences on streamflow droughts in England and Wales which are densely populated regions with a long settlement history and thus prevalent human influences on river flow.”

Rephrase L12: Change ‘here we propose a screening approach that seeks to’ to ‘here we propose screening approaches that seek to’ given that you use three different approaches, in varying results.

We will change as suggested in the revised version of the manuscript.

Page 4, L15: Change ‘This study used a diverse’ to ‘This study uses a diverse’

We will change this as suggested in the revised version of the manuscript.

Page 5, L1: Introduce the abbreviation for NRFA here

We will add the abbreviation to the full name of the National River Flow Archive written out in this sentence.

Page 5, L8: 1973– should that be 1974 as that is the date used elsewhere and on the plots?

1973 is correct as for the calculation of, e.g., the precipitation accumulated over 12 months (P12), precipitation of the current month and 11 previous months are needed. Thus, P12 of January 1974 is based on data from 1973.

L12-15: You introduce BFIHOST, but it might be useful to explain that it runs from 0 to 1 and what these mean to help the reader interpret your figures (Fig. 3 and 4) later on.

Thanks for this suggestion. We will add more explanation, including also the suggested ranges and a more detailed explanation/interpretation of these ranges, to the text in the revised version of the manuscript.

Page 6, L6: typo?: NRA., 1993.

No typo as the NRA refers to the "National Rivers Authority"

L13-15: be clearer about introducing the streamflow and then the precipitation data. A suggestion for this would be in insert 'For precipitation droughts' in front of 'monthly accumulated precipitation P(t). . .' on line 14, to have that clear distinction to the reader.

We will change as suggested to have a clearer distinction between streamflow and precipitation droughts.

L15: Reference McKee et al. 1993 when you introduce SPI

Thanks for this comment; we indeed missed some key references here. We will refer to McKee et al. (1993) in the revised version of the manuscript.

L19: Reference Yevjevich 1967 when you mention threshold level approach

We will refer to Yevjevich 1967 (and Zelenhasić & Salvai, 1987) in the revised version of the manuscript.

Equation 2: I would question if this is needed

We prefer to keep equation 2 as this is in line with Tallaksen et al. (2009).

Page 7, L1: suggested break or slight rearrangement to separate 'The following two characteristics were used in the . . .' from the text before.

We will add the suggested break in the revised version of the manuscript.

L5: I would recommend keeping point 2 as brief as point one, and finding a way to explain it separately like you did for the duration.

We will explain the cumulative sum of drought occurrence in the paragraph prior to the list and shorten bullet point 2.

In general – look to relate this section more to your hypothesis, in the structuring and/or the statements you make.

Thanks for this suggestion. In the revised version of the manuscript we will start each subsection (4.1, 4.2, 4.3) by repeating/linking to the specific hypothesis.

I also believe that you don't state enough that the results from the other human influences do not seem to be outside the N 95% confidence ellipse. & Look to add that the other FAR (other than G) fit within the N 95% confidence ellipse.

We will mention/emphasize on these results to the text of the results section in the revised version of the manuscript.

Page 8, L7: change 'the remaining catchments. . .' to 'the remaining G catchments'

We will change 'the remaining catchments. . .' to the 'the remaining catchments labeled with FAR=G. . .' in the revised version of the manuscript.

Page 10, L7: after 24.3 add '(indicated on Fig. 7)'

We will add: '(indicated in Fig. 7)' in the revised version of the manuscript

L22-24: state which figure/figures show this

We will state the corresponding Figures in the suggested sentence. We will further add a link to these figures in the following sentences of this discussion section.

Page 10, L24-25 "Some of these catchments showed a change in streamflow drought occurrence over time (fewer drought months towards the end of the record, Figure 8), …"

Page 11, L4-5: "Overall, this study also found that reservoirs reduce the correlation between streamflow variability and meteorological drought indices, especially in summer months (Fig. 6)."

L27: typo: bracket before Rangecroft should actually be before 2016.

We will correct this typo in the revised version of the manuscript.

L22-24: interesting, do you have any abstraction rate data that can help illustrate this point?

Although we share the opinion of the reviewer that this is an interesting point, we think that including such detailed information is outside the scope of the current study. Like any other catchments, we do not look at the specific changes in, e.g., abstraction schemes, groundwater levels or reservoir operations and purely use the indicative Factor Affecting Runoff codes and station descriptions. Therefore, we state later on in the discussion the importance of more case study scale research and that "True attribution requires specific case study scale research." (Page 13, L1). The Darent (to which the reviewer comment is related), or any other of the identified catchments with deviating drought characteristics, would be a good starting point for such detailed case studies.

We will, however, more elaborately describe the low flow alleviation measures taken for the Darent in the discussion section, including some references where these alleviation measures are described (e.g., NRA, 1993).

Page 12, L4: add in the word ‘meteorological’ into ‘severe 995-1997 drought’ & L6: add ‘meteorological’ into ‘1976 drought’ if that is what you are referring to

1976 and 1995-1997 were not purely meteorological as many surface and subsurface water systems were affected. Therefore, we prefer not to specify and thus limit to ‘meteorological’ in the revised version of the manuscript.

Page 12, L9: Suggest ways forward here after mentioning this risk of false alarm or misses of relevant drought conditions?

We will add the following sentence to the end of Section 5.2:
“Therefore, the capacity of streamflow drought indices derived from heavily influenced records in reflecting the overall impacts of drought should be evaluated in large-scale drought monitoring systems”

Page 12, L31: typo: Vicente-Serrano et al. (2014)

We will correct the typo in the revised version of the manuscript.

Page 13 L7-9: add in ‘and different types of groundwater abstraction’ as they can affect the impact.

We will change: “of these groundwater abstractions” with “different types of groundwater abstraction” on Page 13, L8

Page 13, L14: typo: brackets missing for Van Loon et al. (2016a).

We will correct this typo in the revised version of the manuscript.

Page 13 L29: make into: ‘National River Archive (focusing on “groundwater abstractions” and “storage or impoundments”).

We will change as suggested in the revised version of the manuscript

Table 1: Suggestion to add some visual marker/flag to the FAR codes used in this study (N, S and G)

In the revised version of the manuscript, we will add a visual marker (*) to the table and refer to it in the caption of the table.

Figure 1 and 7: Suggestion to use different shapes as well as different colours to represent the different FAR-codes due to the consideration of black and white printing, if the authors deem this a good idea. [What is the spatial distribution spread of the BFIHOST categories? Just curious]

We will apply the suggested change to the Figure.

Figure 4 and 5: the plots could be labelled on the top outside margin above each one as headings instead of needing a colour key to the right?

We would like to keep the color coding to make it consistent with other graphs. We will add descriptive labels to the headers of the other graphs in the revised version of the manuscript.

Figure 5: Y axis could have clearer outside margin labelling – P1 and P12

We will emphasize on the Y-axis that the first row is P1 and the second row is P12

Figure 6: Consider adding data points and data lines to legend

We will improve the legend

Figure 7: Specify the use of the 95th quantile in the caption (you currently state the threshold value used, also useful)

We will specify the use of the 95th percentile in the caption in the revised version of the manuscript.

Figure 8: I would suggest moving the catchment codes to the left hand side of each plot to be closer to their labelling.

We will move the labels as suggested in the revised version of the manuscript

You focus on FAR-codes G and S for most of the paper, but then in Figure 8 you include a whole series of different activities. Furthermore you only make reference to the G and S plots of Figure 8 in the text (section 4.3) so do you need all 23 plots?

We will remove these "other" graphs from Figure 8 and mention that only the catchments with "G" and "S" are shown in the revised version of the manuscript.

Supplementary What I gather from the supplementary data is that a lot of the catchments have different periods of data availability, they were not all 1974 – 2013? If this is correct, that it might be worth making this clearer in the methods. Where the thresholds all calculated using the ~40 years data, or were some done using much shorter time periods? (e.g. S2, S3, S4)

All catchments have 40 years of streamflow data between 1974-2013. In the supplementary material for some catchments (e.g. S2, S3, S4) we zoom in to time periods where the human influence was clearly visible. We will state this in the captions of the supplementary Figures that we zoom in to a specific time period and emphasize in the main text that each record has a 40 year length between 1974 – 2013.

Overall, the supplementary data could be more obvious about the FAR-code at the start of each one. I recommend having the FAR-code with the current heading of catchment code for each catchment, e.g. S1 Mimram at Panshanger Park (38003) 38003 (FAR = GI)

We will add FAR codes to the title of the plots in the revised version of the supplementary material

S2: only 1 year

We will mention that S2 is zoomed-in to one particular year of the 40 year period of record.

S3: label the two catchments better

We will add FAR codes to the plot labels.

S4: mismatch of dates. 1994-1998 in the plot but 1984 – 1998 in the caption/text

The caption of Figure S4 contains a typo and will be corrected in the revised version of the supplementary material.

S5: Add dates to figure caption

We will add the dates to the caption of the Figure S5.

S6: Add dates to figure caption, and add a horizontal line to indicate when the reservoir was build/ introduced into the catchment.

We will add dates to the capture of the Figure and the suggested line to the Figure to indicate when the reservoir was constructed in the revised version of the Supplementary material.

S8: Add dates. Y axis on top plot needs to be in full.

We will add dates to the Figure caption and change Y-axis.

S9: change your location of legend to be consistent with S8. Y-axis same as S8.

We deliberately placed the legend of Figure S9 in the right corner as it will cover the time series in when placed in the left corner. Therefore, we propose not to change the location of the legend. We will change the Y-axis as proposed in the revised version of the supplementary material.

References

McKee, T.B., Doesken, N.J. & Kleist, J., 1993. The relationship of drought frequency and duration to time scales. AMS 8th Conference on Applied Climatology, (January), pp.179–184. Available at: http://ccc.atmos.colostate.edu/relationshipofdroughtfrequency.pdf.

NRA, 1993. Low Flows and Water Resources. Facts on the Top 40 Low Flow Rivers in England and Wales, National Rivers Authority, Bristol

Tallaksen, L.M., Hisdal, H. & Lanen, H.A.J. Van, 2009. Space-time modelling of catchment scale drought characteristics. Journal of Hydrology, 375(3-4), pp.363–372.

Zelenhasić, E. & Salvai, A., 1987. A method of streamflow drought analysis. Water Resources Research, 23(1), pp.156–168.