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Hydrology and Earth System Sciences Discussions
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Interactive comment on "Increased incidence, duration and intensity of groundwater drought associated with anthropogenic warming" *by* John P. Bloomfield et al.

Anonymous Referee #3

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The study of Bloomfield et al., presents empirical evidence for growing influence of groundwater drought driven by evapotranspiration associated with anthropogenic warming. This is done by studying the relationship between drought patterns in groundwater observations (at two locales without presumable impact of abstractions or land use) and modelled temperature and precipitation data with different statistical methods. The interesting and well-written paper addresses relevant scientific questions, namely investigating changes in drivers of groundwater drought patterns anthropogenic change in a compartment of the water cycle. The work and line of thought is well documented and referenced. By additionally covering two out of three scopes of the journal, appropriate for publication in HESS.

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Discussion paper

Despite the novelty of the results and importance of the conclusions of the study, I have some concerns, which I think should be addressed. In my view there are some open questions mainly with regard to the application of the statistical methodology.

(1) Given that temperature rises throughout the three periods, this also means that high temperatures will coincide with groundwater drought more often. That means that over average STI values, e.g. STI > 1 will in this setup automatically be more common during the third period both for drought and flood conditions in groundwater, which can be seen in Fig 2. How much of the increase in temperature-related groundwater droughts does this account for? Groundwater droughts due to temperature could have been just as frequent in the earlier periods, but due to the trend in the STI values, just below the hard detection threshold of STI > 1.

(2) When finding the highest correlating SGI to SPI aggregation periods, you get correlation coefficients between .7 and .8 at 6 and 7 months respectively. Even though these values are considerably high, showing the SPI/SGI on a cross-plot would reveal a considerable number of events where SPI does not predict SGI well. I wonder therefore, whether there is a bias in the aggregation period. The SPI with selected aggregation period (e.g 6 months) over time could become a worse predictor, such that droughts associated with precipitation deficit become rarer (as seen in the third period)? A longer aggregation period would possibly show a smaller change in precipitation-related droughts. When looking at the study by two of the authors (Bloomfield and Marchant, 2013), the same locales were used among others, but DH had a longer aggregation period of 10 months, while using a shorter, more recent time period. Has a shift in the recharge regime occurred, which has been observed in other locations? If this is the case, surely the driver also is due to changes in the hydrological cycle.

(3) It did not become clear to me from the method section of the paper what was done with STI and why. As I understand, at different aggregation periods correlation coefficients between SGI and STI were calculated. These are generally weak 0 - -.2

(Supplement) and have a minimum (absolute maximum) at around 6 months, meaning that generally cold spells lead to more recharge and vice versa. There is quite some uncertainty involved though, at these low correlations, the relationship will be positive almost as often as it is negative. Despite this, I agree that this is the expected general tendency, I wonder though if this 6 month aggregation is still valid in the case of extreme events. My expectation would be that this behaviour changes and that for droughts only relatively short periods of relatively hot weather is needed for severe entailing groundwater droughts. If this is the case/could be shown, the findings would be even more interesting.

(4) 30 meters and more of thickness in capillary fringe seems unusually high. In Ireson et al. (2009) data was modelled for two locations different from CH and DH. Are these representative for CD and DH locations?

Technical comments

L234ff: Clarify that the indices are calculated over the entire period.
L240-241: Put maximum correlations into text
L269-272: Unclear what is meant by "probability of the difference", please specify what has been done here. Statistical significance?
Fig2: Very information-dense. The percentage values mean different things in the different panels, it should be possible to clarify within the figure.
Fig 3: Instead of using integers 1-3 for periods, use the interval of years on the y-axis.
Fig 4: Add location to the figure (CH, DH) so it becomes clear directly what the reader is looking at. Additionally it would be beneficial to see which of the non-drought months come from the specified period.
Fig 6: Why not include the second period? I get the impression from Fig 5 that drought durations are not dissimilar for the second and third period, especially for CH.

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Discussion paper

L412-416: Difficult sentence to digest, not clearly conveyed what the conclusions of the paper by Maxwell and Condon (2016) are.
Supplement, FigS4: Add locations CH/DH to the figure.

References

Bloomfield JP, Marchant BP. 2013. Analysis of groundwater drought building on the standardised precipitation index approach. Hydrology and Earth System Sciences, 17: 4769-4787. DOI: 10.5194/hess-17-4769-2013.

Ireson AM, Mathias SA, Wheater HS, Butler AP, Finch J. 2009. A model for flow in the chalk unsaturated zone incorporating progressive weathering. Journal of Hydrology, 365: 244-260. DOI: https://doi.org/10.1016/j.jhydrol.2008.11.043.

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