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Hydrology and Earth System Sciences Discussions

Interactive comment on "A generic method for hydrological drought identification across different climate regions" *by* M. H. J. van Huijgevoort et al.

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We thank Anonymous Referee 1 for the constructive and positive comments on our manuscript. We will provide detailed answers to the comments made by the Referee in the following lines.

1. *The first point that requires a stronger justification is why a single metric for drought identification is needed. Instead, a proper identification of a drought demands a more comprehensive approach that looks at various aspects of drought manifestation rather than just runoff (Kallis, 2008). That results from the*

fact that the very definition of a drought event is still a subject of controversy. As mention by the authors and other conceptual papers, droughts are perceived differently according to the many study fields involved (Dracup et al., 1980; Mishra and Singh, 2010, for a review). Thus, a uniform metric necessarily leaves out important aspects of the phenomena. On the other hand, a multi-metric approach leads to different drought identification results that convey more clearly the complexity of the drought phenomena.

We will include the following lines in the Introduction to justify the need for a uniform metric for hydrological drought and to clarify the position this methodology could take within multi-metric approaches.

Since drought is such a complex phenomenon, which affects all parts of the hydrological cycle (i.e drought propagation, e.g. Van Loon and Van Lanen, 2011), characterizing drought requires multiple climatological and hydrological parameters (Mishra and Singh, 2010). Clearly, this applies to the natural hazard (i.e. physical drought aspects). Additionally, Kallis (2008) argues that interdisciplinary analyses of drought as natural hazard are needed in the next step to determine its impact. As a final step, policy and management options need to be identified to reduce drought vulnerability, and hence the risk of future drought (e.g. Kampragou et al., 2011). For a complete and comprehensive assessment of drought events from the hazard to the drought management measures, the nature of each individual drought component has to be understood (Dracup et al., 1980), which urges for a step-wise approach. The methodology presented in this paper contributes to the first step, identification of hydrological drought as part of the natural hazard. For the first time, as far as we know, a methodology is given that allows presentation in a single robust metric of a drought event that starts in a period with normally runoff and continues in the period afterwards with generally no runoff. Such a metric is essential, for instance, to intercompare large-scale models that have to

handle very different climate conditions in one run.
Obviously, depending on the aim of the drought analysis, the proposed methodology could be integrated in a multi-metric approach (i.e. composite index), including meteorological, soil moisture and hydrological drought indices as is done for example with several indices in the U.S. Drought Monitor (http://droughtmonitor.unl.edu/) and the European Drought Observatory (http://edo.jrc.ec.europa.eu).

2. *Therefore, although the proposed uniform identification approach provides for gains in terms of automatic identification of drought events across different regions, the paper does no present a convincing justification of why different methods should not be applied in different regions.*
There are several disadvantages of using different methods in different regions, especially for drought analysis at large scales, e.g. global and continental scale. Drought studies applied to other variables than the runoff, covering the whole globe, have often been carried out with a single metric, for example PDSI (e.g. Dai et al., 2004). For droughts in runoff, one method that enables drought analysis for the whole globe was still missing. For instance, for the determination of synchronicity of drought at global scale, comparison between regions is needed. This can only be achieved with a similar method across the globe.
When performing a multi-model analysis at large scale, runoff in a region might be simulated differently by each model, in particular some models will simulate runoff and others no runoff for a certain region, which would require different drought identification methods. Comparison between models using different methods for such a region will then be very difficult.
Another advantage of using one method is clear in climate change studies. When using different methods depending on regions, these regions might change in the future (change of periods with runoff to no-runoff, or the other way around),

meaning that results from different methods have to be compared for one specific period. This can be avoided by taking one single method. We will include these arguments in the Introduction to convince the reader of the need of a uniform method.

3. *Moreover, it should be justified why use only the monthly percentile to identify a drought when many other metrics that are useful for drought identification can be derived from the methods TLM and CDM. For example, by using the same threshold approach, one can identify as droughts only those events that reach certain duration, severity or magnitude. Also, the spatial coverage of drought events, extensively explored by Andreadis et al. (2005), could be analyzed with both TLM and CDPM for identification of droughts.*
The authors acknowledge that other metrics can be derived from the proposed method to select drought events. These metrics are a next stage after identifying drought with the combined method and can be seen as characteristics selected from the drought events. The spatial coverage indeed can be analysed, but this is again a next stage in the drought analysis. In this paper, we only wanted to focus on the first stage, the combined method, since this is a new approach. The purpose of a drought analysis study will determine which drought metric is relevant to characterize the natural hazard and possibly to explore the impacts, policy and management options in following steps (see point 1). In the manuscript, the part in the discussion about pooling of droughts on page 2049, was meant to clarify this. We will expand this paragraph with the drought metrics mentioned by the Referee and explain how they are linked to the combined method by including the following lines.
End of page 2049: By including all periods, the combined method considers the entire time series, leading to more minor drought events. To reduce this number, pooling of droughts can be done in the same way as after

the traditional threshold level method (Tallaksen et al., 1997; Fleig et al., 2006). Several metrics can be used to make a selection from the identified drought events, e.g. certain duration or certain severity. However, due to zero runoff periods, not all drought characteristics can always be selected. For example, the deficit volume simply can not be determined from the periods with zero runoff, whereas in other periods this is possible. Depending on the purpose of a drought analysis study, spatial coverage of droughts can be investigated using a cluster algorithm (Andreadis et al., 2005; Corzo Perez et al., 2011) after the identification of droughts with the combined method.

4. *Firstly, a more clear explanation is needed about how the proposed method combines the information from both methods to derive a new percentile statistics for each time step. Specifically, the scaling procedure used to obtain those percentiles mentioned in section 3.2 is not clear. That is a key information to understand how the proposed method classify a period as a drought and should be better described.*
We agree with the reviewer that the scaling procedure is key information to understand the combined method. We propose to extend step 6 on page 2044 to:
Next, the corresponding percentile statistics are estimated for each time step with zero runoff. This is done by comparing $N_{dry,drought}$ of the combined series (step 5) to the statistics obtained from the consecutive zero runoff series only (step 3). If a time series has both zero and positive runoff in the given period of interest, both methods contribute to the transformation to percentile statistics. It should be noted that the maximum percentile value for a zero runoff time step can never exceed the value $100 - F_{wet}$, where F_{wet} is the fraction of positive runoff values observed at

the given period of interest. Therefore, the percentiles fraction as calculated according to the CDPM for dry periods are scaled. For example, if a monthly threshold is used, not all months January in the entire time series have the same characteristics. In some years, runoff might be positive, while in other years a no-flow situation occurs. In this case, both the TLM and CDPM contribute to determining the percentile values. If runoff occurs in 60% of the time series, percentiles derived from CDPM are rescaled to the lowest 40 ($100 - F_{wet}$) percentiles. In other words, the 50th percentile derived from the CDPM part of the method will become the 20th percentile of all months January.

5. *Secondly, it should be justified why the results for perennial rivers should be presented since they are exactly the same of the TLM results, as can be readily noticed from the methodology. Also, since the advantages of the method are only clear for the rivers with intermittent flows, it should be justified why the proposed method should be used in perennial rivers.*
Indeed the results for perennial rivers are exactly the same as the TLM results. We have included these results to help readers who are not or less familiar with the TLM as drought identification method. This way, it is clear what happens in different time series from different climate zones.
The comment on why this method should be used in perennial rivers relates back to the comment about why a uniform method should be used across the globe as described above (point 2). The aim of the proposed method was to enable robust drought identification in studies covering the whole globe or continents with very different climate conditions as well as under changing climatic conditions with the same method. Therefore, the method was presented in both perennial and intermittent rivers.
We will add a line to make this clear to the reader.

Line 20 page 2045: As was expected the two methods determine the same drought events in this period. Since the aim of this paper is to present a robust drought identification method for studies covering the whole globe or continents with very different climate conditions as well as under changing climatic conditions, results of the perennial rivers are shown here. This illustrates the ability of the combined method to identify drought events in the completely different climates of both rivers.

6. *Additionally, it was not clear why the median of the runoff values resulted from five different LSMs was used, since each model use a different method to compute the runoff. If they were applied individually, each LSM would lead to the identification of different drought events. It should be noted that the range of runoff values resulted from an ensemble of LSM runs has no relation with the natural variability of runoff values, but it is just a result of the differences between methods. Therefore, if it is runoff the variable of interest, it would be more reasonable to compare each LSM result with historical observations and just use the model that better reproduce the observed runoff values. Thus, a justification for the use of the ensemble median should be presented.*
   We will include the following lines in Section 2.2 (Line 15, page 2039) to justify the use of the ensemble median.
   In large-scale climate and hydrological studies the use of a multi-model ensemble instead of single models is quite common and even advocated for simulated river flow (e.g. Stahl et al., 2012). Several studies have shown that the ensemble mean or median is often closer to the observations than either of the individual models (Gao and Dirmeyer, 2006; Guo et al., 2007; Tallaksen et al., 2011). Because this paper focuses on regions with zero runoff, we have chosen to use the ensemble median instead of the mean. By taking the ensemble median, one model with anomalous values has

less influence.

References

Andreadis, K. M., Clark, E. A., Wood, A. W., Hamlet, A. F., and Lettenmaier, D. P.: Twentieth-century drought in the conterminous United States, Journal of Hydrometeorology, 6, 985–1001, 2005.

Corzo Perez, G. A., van Huijgevoort, M. H. J., Voss, F., and van Lanen, H. A. J.: On the spatio-temporal analysis of hydrological droughts from global hydrological models, Hydrology and Earth System Sciences, 15, 2963–2978, doi:10.5194/hess-15-2963-2011, 2011.

Dai, A., Trenberth, K. E., and Qian, T. T.: A global dataset of Palmer Drought Severity Index for 1870-2002: Relationship with soil moisture and effects of surface warming, Journal of Hydrometeorology, 5, 1117–1130, 2004.

Dracup, J. A., Lee, K. S., and Paulson, E. G.: On the Definition of Droughts, Water Resources Research, 16, 297–302, 1980.

Gao, X. and Dirmeyer, P. A.: A multimodel analysis, validation, and transferability study of global soil wetness products, Journal of Hydrometeorology, 7, 1218–1236, doi:10.1175/JHM551.1, 2006.

Guo, Z., Dirmeyer, P. A., Gao, X., and Zhao, M.: Improving the quality of simulated soil moisture with a multi-model ensemble approach, Quarterly Journal of the Royal Meteorological Society, 133, 731–747, doi:10.1002/qj.48, 2007.

Kallis, G.: Droughts, Annual Review of Environment and Resources, 33, 85–118, doi:10.1146/annurev.environ.33.081307.123117, 2008.

Kampragou, E., Apostolaki, S., Manoli, E., Froebrich, J., and Assimacopoulos, D.: Towards the harmonization of water-related policies for managing drought risks across the EU, Environmental Science & Policy, 14, 815 – 824, doi:10.1016/j.envsci.2011.04.001, 2011.

Mishra, A. K. and Singh, V. P.: A review of drought concepts, Journal of Hydrology, 391, 202–216, doi:10.1016/j.jhydrol.2010.07.012, 2010.

Stahl, K., Tallaksen, L. M., Hannaford, J., and van Lanen, H. A. J.: Filling the white space on

maps of European runoff trends: estimates from a multi-model ensemble, Hydrology and Earth System Sciences Discussions, 9, 2005–2032, doi:10.5194/hessd-9-2005-2012, 2012.
Tallaksen, L.M., Stahl, K., and Wong, G.: Space-time characteristics of large-scale droughts in Europe derived from streamflow observations and WATCH multi-model simulations, WATCH Technical Report 48, available at: http://www.eu-watch.org/publications/technical-reports, 2011.
Van Loon, A. F. and Van Lanen, H. A. J.: A process-based typology of hydrological drought, Hydrology and Earth System Sciences Discussions, 8, 11 413–11 483, doi:10.5194/hessd-8-11413-2011, 2011.

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