Hydrol. Earth Syst. Sci. Discuss., 8, C6259–C6267, 2012
www.hydrol-earth-syst-sci-discuss.net/8/C6259/2012/

Hydrology and Earth System Sciences Discussions

Interactive comment on "A process-based typology of hydrological drought" *by* A. F. Van Loon and H. A. J. Van Lanen

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Received and published: 5 March 2012

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1 General comments

We want to thank Dr. Giovanni Laguardia very much for his positive response to our manuscript and his valuable comments. Please find below our response to the comments regarding content and presentation of the research.

2 Major points

2.1 Point 1

2.1.1 comment Dr. Giovanni Laguardia

"As I understand, the part related to the hydrological modelling on the five catchments is meant to be used as a case study. Instead, it seems to have a quite relevant role within the article, being as important as the typology definition. This is in contrast with the little number of catchments considered, which could be enough for providing some examples, but it is not for drawing relevant conclusions. Try to reshape the article structure for giving the right weight to your major goal."

2.1.2 reply authors

In this research, the catchments were not only used as an example for the drought typology. The hydrological drought typology was actually derived from drought analysis in these catchments. In the paper, we want to show clearly on which analyses the proposed typology is based. Although contrasting catchments and long time series were used, the selection of catchments is not presented as being inclusive. The typology reflects the current knowledge of processes underlying drought propagation.

2.1.3 proposed action

Because of the reasons mentioned above, it is very hard to reverse the order of the paper. We will try to make the focus of the paper more clear by changing the phrasing of the Section 4.4, in which the catchments are used as an example of the application of the typology.

2.2 Point 2

2.2.1 comment Dr. Giovanni Laguardia

“For massive processing, which would give much more control points in figure 14, do you believe that it is feasible to tackle the modelling problem by means of simplified methods, i.e., for base flow separation and snow assessment?"

2.2.2 reply authors

The use of simplified methods would certainly support the analyses. In principle, hydrological drought types can be distinguished if the processes underlying the drought are known. Base flow separation and snow assessment could be helpful tools to derive these processes. However, the use of simple, independent approaches is only feasible if data of all fluxes and state variables are available. Unfortunately, this is often not the case. Furthermore, when analysing the different hydrometeorological variables in a different way, the internal consistency of the variables might be lost.

The suggestion of Dr. Laguardia is very valuable and we will focus our future research on this topic. We plan to investigate which (simplified) alternative methods/ models can be used to classify drought events using the drought typology.

2.2.3 proposed action

For this manuscript, no action is proposed, because a description of alternative methods would increase the length of the manuscript and would give too much focus. In future research, we plan to look into this issue.

2.3 Point 3

2.3.1 comment Dr. Giovanni Laguardia

“Moreover, is it possible to check literature data for populating figure 14? Perhaps the material usually published doesn’t allow to assess the occurrence of the different drought types."

2.3.2 reply authors

This is a useful suggestion. We searched the papers mentioned in Section 4.3 for information regarding climate and catchment control to be able to pin-point them in Figure 14. In almost all cases this information was not provided in the papers. Using the catchment’s locations, we have searched for generally available information. General climate information is relatively easy to obtain, e.g. from large-scale datasets. Catchment characteristics, like reaction to precipitation, groundwater influence or even detailed geology, however, are much more difficult. Therefore, it was not possible to populate Figure 14 with literature data.

2.3.3 proposed action

We propose no action on this point.

2.4 Point 4

2.4.1 comment Dr. Giovanni Laguardia

"As I understand, you have inspected the data implementing an expert-based drought type classification. What about defining the drought typology by means of some logical formulations? A piece of code allowing other researchers to classify their own droughts would be an asset, also considering the previous point of discussion!"

2.4.2 reply authors

We agree with Dr. Laguardia that finding a piece of code allowing other researchers to classify their own droughts would certainly be very helpful. The remark encourages us to focus on the development of a drought typology code in the future. However, it is beyond the scope of this study to capture the expert knowledge in a script that consists of logical formulations.

2.4.3 proposed action

For this manuscript, no action is proposed, but we hope to address this issue in a future study.

3 Minor points

3.1 Point 1

3.1.1 comment Dr. Giovanni Laguardia

"Have you considered the role of catchment area when dealing with drought duration and deficit? In this work Upper Guadiana is 100 times larger than the other catchments and it is the only one with semi-arid climate and a relevant number of composite and wet-to-dry-season droughts."

3.1.2 reply authors

Yes, we have considered the role of catchment area. Instead of using the entire Upper-Guadiana, we wanted to use one or two small headwater catchments in the Upper-Guadiana (Veenstra , 2009). However, we encountered several problems: 1) the quality of the streamflow observations in those smaller headwater catchments was very bad, 2) the lateral flow of groundwater over the catchment boundaries was considerable, 3) the streamflow of the smaller rivers had an intermittent nature (i.e. many zero values). Consequently, the HBV model gave a bad fit to observed streamflow in these headwater catchments. The larger Upper-Guadiana catchment did not have these problems (Veenstra , 2009). Therefore, we decided that using the larger catchment was more suitable in this analysis.

A large catchment area can influence the drought characteristics in Table 3 of the manuscript in the sense that using a smaller headwater catchment, the average number of droughts would have been slightly higher and average duration and deficit would have been slightly lower (Smakhtin, 2001; McMahon and Finlayson, 2003). However, this might not be the case when the headwater streams are intermittent, as is the case

in Upper-Guadiana.

Furthermore, a large catchment area mainly influences drought characteristics if the catchment includes various climate zones, for example if it covers a large altitude range. In that case, frost periods and snow accumulation can vary within the catchment and difficulties with drought analysis can arise (Fleig et al., 2006). In the Upper-Guadiana catchment, no snow accumulation occurs, so the larger catchment area should not cause major difficulties. But even if the numbers in Table 3 would have been influenced by catchment area, the conclusions drawn in the manuscript regarding propagation in the Upper-Guadiana catchment would still be valid.

3.1.3 proposed action

We propose to add a few sentences on the difference in catchment area between the study areas and the consequences of this difference for the analyses and conclusions.

3.2 Point 2

3.2.1 comment Dr. Giovanni Laguardia

"Figure 5 and similar: consider to add the grey line also for precipitation, soil moisture, groundwater, and discharge. This would help in understanding how large is the variability of each parameter, i.e., how far is the average line for groundwater in figure 5, panel C?"

3.2.2 reply authors

The grey line in Figure 5 is a daily variable 50-percentile of the duration curves. It is added only for variables for which no drought analysis is done, i.e. temperature and snow accumulation. For the other variables in the figure, i.e. precipitation, soil moisture storage, groundwater storage, and discharge, the smoothed monthly 80-percentile line is included (i.e. the threshold). This line also gives an indication of the intra-annual variability of those variables. Adding the daily variable 50-percentile line in the graphs of these variables would certainly give extra information, but at the same time it would decrease readability of the figure significantly. Therefore, we have chosen not to add the grey line for precipitation, soil moisture, groundwater, and discharge.

3.2.3 proposed action

We propose no action on this point.

3.3 Point 3

3.3.1 comment Dr. Giovanni Laguardia

"Some parts of the text sound a bit rough or not that fair, such as the following examples. Have a further reading and try to clean such expressions."

3.3.2 reply authors

Thanks for the suggestion. We will rephrase the examples provided by the reviewer (see below) and read through the manuscript to improve other rough expressions.

3.3.3 proposed action

- “Hydrological (groundwater and discharge) drought" (p. 11414, line 22): We will delete “(groundwater and discharge)"

- “Droughts in developed countries primarily result in economic loss: in the USA on average 6 to 8 billion USD per year (Andreadis et al., 2005; Below et al., 2007) and in the EU more than 100 billion EUR in the period 1976–2006 (EU, 2006, 2007)." (p. 11415, lines 3-6): We will consider to split this sentence in two.

- “finding the best drought index" (p. 11416,line 6): We will change this in: “finding the “best" drought index" (p. 11416,line 6)

References

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