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Interactive comment on "A global evaluation of streamflow drought characteristics" *by* A. K. Fleig et al.

A. K. Fleig et al.

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Author Comment

We want to thank the referee Dr. Vicente Serrano very much for his positive response to our article and his valuable comments. Please find below our response to the comments regarding the content of the article. Technical comments will be accounted for in the revised text and are only mentioned here in case we do not agree completely.

Dr. Vicente Serrano: "1. Authors use a fixed threshold to select the drought episodes (by means of different percentiles). They also indicate that this approach can be a problem in the rivers with a marked seasonality. For this reason they suggest the use of different seasonal thresholds in some basins. I think that to have a better identification of the drought episodes it would be more convenient the use of a non-fixed threshold (i.e., following a moving-threshold procedure). I think that the application of a standard-

ised procedure to the river discharges previous the pooling procedure would be more convenient to avoid seasonality. This procedure could be based on the weekly/bi-weekly averages following a moving average procedure. For this purpose, the daily river discharge could be subtracted to the moving weekly/bi-weekly average for each day. New series of differences in relation to average would be obtained and, therefore, seasonality would be eliminated. Following this approach, the drought periods could be identified independently of the streamflow regime. I think that this approach would be more correct because the drought is usually described as a deficits in the water resources (precipitation, river discharges, soil moisture, reservoir storages,...) in relation to the average."

- In the paper we suggest to study droughts from different seasons separately rather than using different seasonal thresholds. Separate seasonal studies are suggested for a frequency analysis of droughts when droughts belonging to different seasons are caused by different processes in order to avoid a non-homogeneous drought series. For separate seasonal studies we suggest to define the threshold level based on data from that season only rather than from the whole year and prefer in this case a fixed threshold. We see that the paragraph starting in line 10 on page 2439 might be misleading and it will be rephrased. We agree that a varying threshold level as presented by Stahl (2001) can be preferable in an all-year study, and this will be commented on in the revised text. However, for frost influenced regions a variable threshold level would not solve the seasonality problem. In these regions the major difficulty is to decide which low flow periods are caused by a deficit in precipitation and which ones are caused by low temperatures and freezing of the water in the catchment. As start and end of the winter season (i.e. the period with temperatures below zero) vary from year to year, the origin of drought events occurring in late summer or early winter cannot be identified neither with a varying nor with a fixed threshold level. In such environments seasons have to be defined prior to the selection of events and droughts belonging to different seasons have to be studied separately.

HESSD

2, S1389–S1398, 2005

Dr. Vicente Serrano: “2. After the evaluation of the pooling procedures the authors deal with a frequency analysis to determine the probability of drought episodes of a given duration/magnitude. I think that more details, analysis and discussion are needed about this subject.”

- We agree, please see the answers to the specific comments below.

Dr. Vicente Serrano: “In the Page 2445 (3rd paragraph) the authors indicate that they obtain the PDS following two thresholds based on percentiles: Q90 and Q70. They also filter the minor droughts according a duration/magnitude rule. Nevertheless, the authors do not explain if they use the whole series of drought duration/magnitude based on the 90 and 70 percentiles to obtain the probabilities or if they set a threshold to model exclusively the extreme drought events. If the whole events obtained from Q90 and Q70 are included, it is possible that they not be modelled correctly by means of a GP distribution since the series would include non-extreme events. The adequate selection of the thresholds to obtain PDS is an important task since the results (probabilities and return periods) may change as a function of the selected threshold. This has been addressed previously by Vicente- Serrano and Beguería (2003), Beguería (2005) and Lana et al. (in press). I think that this subject should be taken into account by the authors when they calculate the probabilities and return periods of droughts of different duration and magnitude.“

- We agree that a threshold to filter out minor droughts is important to obtain a series of extreme events. In our paper the term “threshold” is not used in this context in order to avoid confusion with threshold level used to identify the deficit periods. It is instead referred to as a “limit”. As mentioned in the last paragraph on page 2445 we do not use all events obtained from Q90 and Q70, but filter out minor droughts based on two limit criteria: “Minor droughts are excluded when the deficit volume is smaller than a certain percentage, alpha = 0.5 %, of the maximum observed deficit volume, and the real drought duration is smaller than dmină=ă3 days. This combination of alpha and dmin was found to be the best choice comparing the nine tested combinations with

HESSD

2, S1389–S1398, 2005

Interactive Comment

alpha = 0, 0.5 or 1ă% and dmină=ă1, 3 or 5 days. Higher values of alpha and dmin have the advantage of excluding a larger part of minor droughts, often implying less model bias and thus a better fit to the most extreme droughts. However, the number of drought events has to be sufficiently high to avoid large uncertainties in the estimated design event. The optimum number of events is found as a compromise between selecting extremes following an extreme value distribution and a sample size needed for sufficiently precise estimations."

The mean excess plot and a plot of the shape parameter of a fitted GP distribution as a function of the limit are common ways to determine the limit referred to above. Hisdal et al. (2002) tested these two methods for extreme value modelling of streamflow droughts on a data set which included several of the stations from our data set. They found that the plot of the shape parameter is a very informative tool to determine the limit. The mean excess plot on the other hand is often difficult to interpret and thus seldom helpful. Our choice to define extreme drought events based on two limit criteria (alpha and dmin) made the application of the shape parameter plot more complicated as different combinations of the two limit criteriaăresulted in the same number of events. We therefore selected the optimum values of the limit criteria based on a comparison of the fitted GP / Poisson model to the observed annual maximum series.

Dr. Vicente Serrano: "Page 2446, 1st paragraph: The L-moment diagrams are widely used to select the best distribution to model the PDS (i.e., Hosking and Wallis, 1997). I would recommend to include some examples of these diagrams to be sure about the best selection (distribution of probability) in PDS modelling."

- L-moments have now been calculated for PDS obtained with threshold levels Q90 and Q70. The corresponding diagrams will be included in the revised text, and it will be shown that they support the conclusions for the selection of a probability distribution model in this study.

Dr. Vicente Serrano: "Also more details about the method used to calculate the param-

HESSD

2, S1389–S1398, 2005

eters of the distributions should be added. Do the authors use conventional moments, maximum likelihood or L-moments?. I recommend the use of the last method due to its robustness and versatility (see Hosking and Wallis, 1987)."

- As stated in the 1st sentence on page 2446 the maximum likelihood method is used to determine the distribution parameters.

Dr. Vicente Serrano: "More details about the GP distribution should be included (see Hosking and Wallis, 1987, 1997)."

- The reference to Pickands (1975) will be added as the theory of the GP distribution dates back to his work. Besides that more theory about the GP distribution can be found in the included reference (Tallaksen et al., 2004). This reference is chosen as it similar to this study deals with streamflow drought derived from discharge series with a daily time resolution.

Dr. Vicente Serrano: "Page 2446, last paragraph: I think that the non-exceedence probability is not the best approach to show the drought risk. I recommend the use of return periods, exceedance probabilities or the probability that an event of magnitude/duration X will occur at least once in a period of t years."

- Instead of Figure 10 a new figure presenting the return period of drought events will be included in the revised manuscript.

Dr. Vicente Serrano: "In summary, I would suggest to focus the paper in those topics related to the pooling procedures, the filter of minor droughts and the creation of "true" drought duration/ magnitude series. In my opinion these topics deserve an independent study without the need to include the frequency analysis of drought series. A more complete analysis and details about the pooling procedures in the different basins would be preferable than to join this to the frequency analysis of the drought magnitude/duration series."

- The objective of the study was to find a standard procedure to derive drought char-

HESSD

2, S1389–S1398, 2005

acteristics which can be used to study droughts in different or large regions including catchments with different hydroclimatological characteristics. One of the most important tasks of regional drought studies is to assist in the planning of regional actions to mitigate the impacts of droughts, for which a frequency analysis is an important tool.

Dr. Vicente Serrano: “Page 2429, 1st paragraph: It is necessary to include more references about the drought concept and its nature as a natural hazard (See i.e., Obasi, 1994; Wilhite, 1993; Dracup et al. 1980). The authors list different drought types: meteorological, agricultural (authors indicate soil moisture drought) and hydrological drought. This has been previously addressed, between others, by Wilhite and Glantz (1985).”

- We agree that a reference for the concept of different drought types should be added. In the 1st paragraph the reference to Wilhite and Glantz will be included as this is the first work that summarises drought definitions into four different drought types according to a disciplinary perspective: meteorological, agricultural, hydrological and socio-economical drought. For a more general overview of the drought topic we refer to Tallaksen and van Lanen (2004) (page 2429, line 16). This is a recent textbook about hydrological drought focusing on streamflow and groundwater droughts which includes a large number of references to previous works.

Dr. Vicente Serrano: “Page 2430: 1st paragraph: The authors indicate that “it can be expected that more detailed information can be obtained from a drought characteristic operating...on daily time resolution”. The authors should indicate what information could be derived using daily series. Drought is the best example of a “penetrating” natural hazard, which is opposite to “instantaneous hazards” such as floods, earthquakes, tsunamis, etc. To be identified, drought needs of long water deficits during months or seasons. A water deficit of some days can not be considered as a drought. For this reason, monthly records are usually used to analyse droughts (The time scale -monthly or daily- does not involve different problems in relation to the threshold level method used to obtain the drought duration/magnitude series. Therefore, the methods

HESSD

2, S1389–S1398, 2005

proposed in the paper could be also used to obtain drought duration/magnitude series from monthly records).”

- We agree that a water deficit of a few days is not considered to be a drought. In many regions severe droughts last several months or years so that drought indices adapted to data with a monthly time resolution are a suitable tool. However, in some regions such as in cold regions, where the growing season lasts only two to eight months (Skaugen and Tveito, 2004), droughts lasting one month can be quite severe. When an one-month drought starts in the middle of a calendar month it might not be recognized using a streamflow series with a monthly resolution. Also for some kinds of water usage a drought analysis based on daily streamflow data is needed such as for navigation as mentioned by A. Cancelliere in his comment. A monthly time resolution implies a discrete series for drought duration instead of a continuous series when a daily time step is used. It was therefore considered favourable that a standard procedure to derive drought characteristics suitable for streams in different regions should be adapted to data with a daily time resolution. This explanation will be included in the revised text.

Dr. Vicente Serrano: “Page 2431, 1st paragraph: A most complete description of the PDS and BM approaches should be included or some references about this topic be added (i.e. see Hershfield 1973; Smith 1990 and 2003; Reiss and Thomas 2001). Also the use of the PDS is recommended because it allows to include more cases in the sample, resulting in much accurate estimation of parameters of a given distribution of probability (Madsen et al. 1997).“

- In this paragraph two more references will be included: “Ěbased on an extreme value analysis (Coles, 2001). A review of drought frequency analysis for a single site is given in Tallaksen (2000) and Tallaksen et al. (2004)Ě”. As mentioned before, the references to Tallaksen (2000) and Tallaksen et al. (2004) are preferred as they deal with the variable of interest: streamflow drought with a daily time resolution. The advantage of the PDS due to more events in the sample will be mentioned in the last sentence of

HESSD

2, S1389–S1398, 2005

the paragraph in the following way: “They therefore recommended the use of the PDS as this results in a larger amount of events in the series and thus the standard errors in the design event estimates will be reduced. “

Dr. Vicente Serrano: “Page 2432, Figure 2: It would be interesting to include the variability of the hydrological regimes (measured by means of standard deviations or coefficients of variation). Variability can be more important than average in some regions/seasons.“

- Due to the length of the article we decided to omit figures showing the monthly variability of the regime and refer to the daily coefficient of variation (see Table 1, page 2453).

Dr. Vicente Serrano: “Pages 2437-2439: The section 3.3 should be moved to the discussion.”

- Section 3.3 will be moved into Section 4 as section 4.1. The title of section 4 will then be changed to “Evaluation of the threshold level method for daily streamflow series”.

Dr. Vicente Serrano: “Page 2444, Last paragraph: I think that the calculation of the number of extreme events occurring in a given time interval has not interest for the drought management. The duration/magnitude of the drought events are the most important parameter. I recommend to delete the stochastic analysis about the number of droughts and to focus the analysis in the duration/magnitude.”

- The number of extreme events occurring in a given time interval (here one year) is a necessary parameter when calculating the annual probability (return periods) of extreme events based on the PDS approach (see Equation (4), page 2445).

Dr. Vicente Serrano: “Page 2444, Last paragraph: Authors indicate that GP distribution can be shown to be the limit distribution of scaled excesses over a certain limit and is thus suited to model PDS of magnitudes. I would recommend to include some references about this subject. i.e. Pickands (1975) showed that the series generated

HESSD

2, S1389–S1398, 2005

by exceedances over a threshold tend to converge to a Generalized Pareto (GP) distribution. The same in the page 2445 for GEV and AMS: i.e.: Alexander et al. (1969), Kirkby (1969)."

- In the last paragraph on page 2444 the reference to Tallaksen et al. (2004) will be replaced by a reference to Pickands (1975), and in the first paragraph on page 2445 a reference to Fisher and Tippett (1928) will be added for the GEV distribution.

Dr. Vicente Serrano: "Page 2445, 3rd paragraph: Why do the authors use the 5-day IT-method as a pooling procedure to derive the PDS when previously they have indicated that the MA-procedure is the most flexible approach?."

- As stated in the second paragraph on page 2444 one of the drawbacks of the MA-procedure is, that it might introduce dependency between pooled drought events. As one of the assumptions for a proper extreme value analysis is, that the events are independent, we chose to use the IT-method for this study.

Additionally included references

Cancelliere, A.: Interactive comment on "A global evaluation of streamflow drought characteristics" by A. K. Fleig et al, HESSD 2, 1221–1224, 2005.

Coles, S.: An Introduction to Statistical Modeling of Extreme Values, Springer Series in Statistics, Springer-Verlag, London, 2001.

Fisher, R. A. and Tippett, L. H. C.: Limiting forms of the frequency distribution of the largest or smallest member of a sample, Proc. Cambridge Phil. Soc. 24(2), 180–190, 1928.

Hisdal, H., Tallaksen, L.M and Frigessi, A.: Handling non-extreme events in extreme value modelling of streamflow droughts, in: FRIEND 2002 - Regional Hydrology: Bridging the Gap between Research and Practice, IAHS Publ. no. 274, 281–288, 2002.

Pickands, J.: Statistical inference using extreme order statistics, Ann. Stat., 3, 119-131,

HESSD

2, S1389–S1398, 2005

1975.

Skaugen, T. E. and Tveito, O. E.: Growing-season and degree day scenario in Norway for 2021-2050, Clim. Res., 26, 221–232; 2004.

Stahl, K.: Hydrological Drought - a Study across Europe. PhD Thesis Albert-Ludwigs-Universität Freiburg, Freiburger Schriften zur Hydrologie no. 15, Freiburg, Germany, also available at: <http://www.freidok.uni-freiburg.de/volltexte/202>, 2001.

Wilhite, D. A. and Glantz, M. H.: Understanding the Drought Phenomenon: The Role of Definitions, Water Int., 10, 111–120, 1985. Res., 23(1), 156–168, 1987.

Interactive comment on Hydrology and Earth System Sciences Discussions, 2, 2427, 2005.