Controls on hydrologic drought duration in near-natural streamflow in Europe and the USA
E. Tijdeman, S. Bachmair, and K. Stahl

Hydrol. Earth Syst. Sci. Discuss., 12, 12877–12910, 2015, doi:10.5194/hessd-12-12877-2015

In the study, cumulative drought duration distributions (DDCs) have been calculated using time series of observed daily streamflow from over 800 near-natural gauging stations in the USA and Europe. These DDCs were related to climate classification systems (e.g. Köppen–Geiger), climate data (e.g. long-term annual precipitation) and catchment characteristics (e.g. Base Flow Index) to investigate through a large-scale study too what extent duration of long droughts is influenced by climate and catchment controls. A visual comparison (ensemble average deviation from global average) and statistical comparison (Kolmogorov–Smirnov and Mann–Whitney U tests) have been carried out. Authors conclude that the Köppen–Geiger climate classification system does not sufficiently discriminate drought duration for climate types occurring in the USA and Europe. Individual controls have to be added.
This large-scale study is important because it is based on observed flow data rather than on modelling experiments as in previous studies and it has led to interesting outcome on climate and catchment controls on drought duration. The manuscript is well written and the figures adequately support the text. It is worthwhile to be published in HESS, but improvements and some clarification are required before it can be accepted.

Major comments:

- An important justification for the paper is that large-scale studies (many gauging stations) are needed based on observed streamflow data. Generic results are needed on drought duration and controls. It is strange that from the beginning (except for distinction of the 5 classes for the individual controls, Section 2.3) the USA and Europe are separated. First results of all 808 gauging stations together should be studied and presented (e.g. extension of Figs. 3, 5 and 6), which then can be followed by a separate treatment of the USA and Europe, as done in the current manuscript. I realize that the authors eventually will show that there are some differences between USA and Europe (e.g. in the higher PET > P or AI classes).
- Authors have decided to select the drought duration as a drought characteristic. In the Discussion (Section 4.2) drought frequency is mentioned as another characteristic, although there is a strong link between average duration and frequency when using the threshold approach. In the Discussion the (standardized) deficit volume or intensity should also be addressed. These two characteristics are as important as long duration droughts in their effect on natural and socio-economic systems (lacking water for water resources).
- Previous more limited studies (e.g. few catchments, only simulated flow) have shown that both climate and catchment properties control drought duration. This is confirmed by the current paper in the Abstract (pg. 12878, line 20), Discussion (pg. 12891, lines 5-11), Conclusions (pg. 12896, line 18). However, in the Discussion (pg. 12894, lines 6-8), it is suggested that climate classification systems only can be used to discriminate drought durations. This cannot be concluded based on the selected catchment characteristics. The BFI shows a substantial control. We know that storage processes are important in the propagation of a drought in a catchment, but the two other selected catchment characteristics (i.e. catchment area, elevation) do not address storage properties. If soils or lakes would have been included then likely stronger catchment controls would have been found. In the Discussion (Section 4.2) representativity of the selected catchment is discussed. For good reasons only near-natural catchments have been selected (almost no human disturbances), but probable these are biased to headwaters, which have lower storage (steeper topography, thinner

soils, less aquifers). For instance, the BFI of 80% of the selected catchments is < 0.7. I wonder, if the percentage of catchments with a BFI<0.7 would not have been lower, if not only near-natural catchments were selected (headwaters). In summary, I believe that a catchment classification system that adequately discriminates drought duration should include both climate and catchment controls.

- It is strange that the manuscript makes a difference between climate classification systems (incl. Köppen–Geiger, Aridity Index, number of months with T<0 and number of months with PET > P) and individual controls (long-term P, long-term T, Area, Elevation and BFI). I believe it is confusing that climate-related controls (number of months with T<0, number of months with PET > P, long-term P and long-term T) are in two different groups. I recommend to make two different groups along other lines, i.e. climate-related controls (incl. Köppen–Geiger, Aridity Index, number of months with T<0, number of months with PET > P, long-term P and long-term T) and catchment-related controls (incl. Area, Elevation and BFI).
- I wonder if climate classification systems, such as Köppen–Geiger¸ are often used in drought monitoring and early warning systems to stratify regions with similar hydro-climatic drought properties, as mentioned in the Abstract (pg. 12878, lines 1-3). and Conclusions (pg. 12897, line 4). I do not believe that the manuscript needs such mandate. The results on the relationships between drought duration and climate and catchment controls derived from observed flow already justify the paper.

Minor comments:

- pg. 12878, lines 4-6: I do not believe that what is currently lacking is a large-scale evaluation of the relation between climate and hydrologic drought characteristics. There are a number of papers to which you also refer which deal with this topic. What is missing, is the use of observed flow from many basins rather than simulated data.
- pg. 12880, line 1: “their” can be removed.
- pg. 12882, lines 20-21: Add a reference for “This study focuses on long duration droughts since they most severely affect natural and socio-economical systems.”
- pg. 12883, lines 2-3: there is no justification / hypothesis for using the Area (see also pg. 12888, line 29) and the Elevation as catchment characteristics that control drought duration. Add reference(s).
- pg. 12883, line 15: add how many of the 808 gauging stations are in the USA and how many in Europe.
- pg. 12883, line 19: do you use 40 year of data or for some gauging stations more than 40 year of data?
- pg. 12883, line 20: Elaborate in the Discussion whether there is influence of using different periods (1965–2004 for Europe and 1970–2009 for the USA). Are there more long duration droughts than normal in the periods 1965-1999 and 2005-2009?
- pg. 12883, line 22: “time step” not defined. It becomes clear in following sections that the time step is a week.
- pg. 12884, line 25: transformation from daily to weekly flow is a kind of smoothing. Does this not contradict with the remark in the Discussion (pg. 12895, line 16) that no smoothing has been applied.
- pg. 12885, line 15: what type of interpolation (linear, spline, ..?
- pg. 12885, line 18: Add a sentence which describes that “long duration droughts” are not defined in an absolute way (minimum number of weeks) but in a relative way (81-100 percentile).

- pg. 12885, line 27: I recommend to calculate your own Köppen–Geiger class for each gauging station, like it has been done by Wanders (Figure 2, 2015), which makes the KG class consistent with the climate data.
- pg. 12885, lines 28 – pg. 12886 (line 6): the procedure is not fully clear. Pg. 12886 (line 3): "equal size", do you mean that each class consist of 20% of all (808) basins? Pg. 12886 (line 5): "class size" do you mean number of basins (there should be 10 or more basins in a class)? Is the smaller number than 10 caused by the separate investigation of the USA and Europe?
- pg. 12886 (lines 13-14): meaning of "average". I suggest the following phrasing: "…..of the average DDC per class, we plot them as departures from the overall average to make differences easier…".
- pg. 12886 (lines 13-14): motivate why the average has been used instead of the median.
- pg. 12889 (lines 8-15): It is bit strange to start with "It reveals for the KG that basins in the Cfb climate in the USA have lower average DDC compared to Europe…". The general impression by looking at Fig. 4 (upper) is that the DDCs for the USA are larger than for Europe. I would start with this finding.
- pg. 12890 (lines 21-29): Figure 4 needs to be split up in two separate graphs. The upper graph is about the visual comparison approach (Section 3.1), whereas the lower graph is about the statistical approach (Section 3.2). In between you describe Figure 5 (pg. 12889, line 16 - pg. 12890, line 20).
- pg. 12893 (line 16): the phrasing "…annual actual evaporation calculated with the Thornthwaite formula…" is incorrect. Thornthwaite provides an estimate of the PET. The actual evapotranspiration that is mentioned by Van der Schrier et al. (2011) is from a simple water balance model that uses Thornthwaite PET.
- pg. 12893 (line 27): replace "a suitable" with "suitable".
- pg. 12902 (Table 1, caption): replace "class size" with "number of basins", or "class size (number of basins)".
- pg. 12902 (Table 1, AI column): replace "90" with "90+".
- pg. 12904 (Figure 2): parts are hard to read, too small.
- pg. 12904 (Figure 2, B, left): the x-axis label "USA Europe Region" is confusing. It can be left out.
- pg. 12904 (Figure 2, C2): Duplication of the x-axis label (--------81------/ /-------91-----/ /------100---/) would improve readability. Add x-axis label below the box plots.
- pg. 12905 (Figure 2, caption): (a), (b) etc. Capital in the graph. Make it consistent.
- pg. 12905 (Figure 2, caption): replace "….values for basins in both Europe (red) and the USA (blue)…" with "….values for basins in both the USA (blue) and Europe (red) …". Use same sequence as in graph.
- pg. 12905 (Figure 2, caption): replace "….exemplary ensembles of DDC groups for classes 1, 2 and 3 for the USA…" with "….exemplary ensembles of DDC groups for precipitation classes 1, 2 and 3 for the USA…".
- pg. 12906 (Figure 3): add set of figures that show the relationship of the drought duration with climate classification systems and individual controls for the USA and Europe (all basins together); see previous major comment.
- pg. 12907 (Figure 4): needs to be split into two figures, Figure 4 (only upper graph) and new Figure 6 (lower rows). Revise caption, hard to understand.
- pg. 12908 (Figure 5): add set of figures that show the similarities for climate classification systems and individual controls for the USA and Europe (all basins together); see previous major comment.
- pg. 12909 (Figure 6): add box and whiskers for the USA and Europe (all basins together); see previous major comment.
- pg. 12909 (Figure 6, caption): replace "End of lines: percentiles 5 and 95" with "End of whiskers: percentiles 5 and 95".

- pg. 12910 (Figure 7, caption): replace “..(left column)..” and “..(right colum)..” with “..(left)..” and “..(right)..”.

Wanders, N. & Van Lanen, H.A.J. (2015): Future discharge drought across climate regions around the world modelled with a synthetic hydrological modelling approach forced by three General Circulation Models. Natural Hazard Earth Syst. Sci, 15, 487–504, doi:10.5194/nhess-15-487-2015.