Interactive comment on “Historical drought patterns over Canada and their relation to teleconnections” by Zilefac Elvis Asong et al.

Anonymous Referee #2

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We thank the reviewer for reviewing in detail our manuscript and providing extremely useful and constructive comments and insights especially on the observational uncertainties and uncertainties associated to PET estimation methods. Please find below our replies to comments and remarks. Comments are listed first (in black) followed by replies (in blue). Where appropriate, all changes in the revised manuscript are marked in blue.

Summary

The authors identify the distinctive patterns of drought in space and time over Canada. They characterize drought using SPEI at different time scales and calculated from two different data sets. The authors find two major patters of spatial coherence of drought using REOFs and evaluate trends in drought incidence. They also do several analyses using wavelet coherence to identify the relationship between relevant climate oscillations and drought occurrence over Canada. The paper is well-written, and the work is interesting and relevant to the journal. I recommend this paper for publication upon performing a few revisions outlined below.

Comments

- Lines 173-194: Given that the authors raise the issue of sparse monitoring stations as an uncertainty source, it would be good if they included a map in the supplementary material showing the location of the stations.

We have now added two maps of the stations used for deriving ANUSPLIN (Figure S1) and CANGRD (Figure S2) products. These two Figures are also referenced in the manuscript. Note that the number of stations may not be constant over time for both data sets. Thus, the maps are meant to give an idea about the distribution of stations over Canada.

- Lines 222-223: These data exist from reanalysis and hybrid products over Canada. I recommend that the authors write a more convincing argument for not using these other approaches to calculate PET that are more robust.

An explanation of the PET method which was constrained solely by data availability has been added to section 2.3:

‘Re-analysis products are an alternative data set for historical drought analysis in Canada and could lead to robust estimates of PET based on the Penman–Monteith algorithm (Maidment, 1993). However, they have been found to be very uncertain compared to observations (Wong et al., 2017). A more suitable product with close performance to observations is the Global Environmental Multiscale (GEM) numerical weather prediction model output (Côté et al., 1998). However, it is limited in record length (2002 – present). Therefore, the Hargreaves method (Hargreaves, 1994) which simply uses Tmin and Tmax for estimating’

- Lines 223-225: It is worth discussing the uncertainty that the use of this method introduces. A review of the literature could help. For example, Sheffield et al. (2012):
Sheffield, J., Wood, E. F. & Roderick, M. L. Little change in global drought over the past 60 years. Nature 491, 435–438 (2012).

We have now added the following text to the last paragraph in the results and discussion section to highlight this source of uncertainty:

'In addition, only one PET estimation method was used in this study and its selection was constrained by data availability during the study period. We recommend the use of other simple or complex methods to calculate PET and assess their impact on drought analysis over Canada since the Hargreaves method is known to underestimate PET relative to Penman–Monteith method (McMahon et al., 2013). Furthermore, the Hargreaves method responds only to changes in temperature and can lead to misleading results under global warming, e.g. (Sheffield et al., 2012)'

- Lines 316-329 and Lines 367-375: These results should be placed in the context of results from, for example, Sheffield et al. (2012) cited above. They find that false trends may appear when using oversimplified characterizations of PET.

We have now added the following text to the last paragraph in the results and discussion section to highlight this source of uncertainty:

'In addition, only one PET estimation method was used in this study and its selection was constrained by data availability during the study period. We recommend the use of other simple or complex methods to calculate PET and assess their impact on drought analysis over Canada since the Hargreaves method has been known to underestimate PET relative to Penman–Monteith method (McMahon et al., 2013). Furthermore, the Hargreaves method responds only to changes in temperature and can lead to misleading results under global warming. For example, Sheffield et al. (2012) found little change in global drought over the past 60 years (1950 – 2008).'

- Lines 384-386: The range stated in Line 384 is between 8-32 months, which seems to mix intra- and inter-annual variability. How can this be? And how does this translate to the 2-6 year frequencies? Do the authors mean that this 0.67-2.67 years period is similar to that of ENSO? This seems like a weak argument since this period is on the lower end. Similar case in Line 391 and for the conclusions drawn in Lines 505-521.

In Section 3.5, we only looked at the dominant frequencies present in the drought time series. The statement 'For SPEI6Apr-Sept, from the WPS of RPC1 in Fig. 8, significant interannual variability of between 8 and 32 months is evident throughout much of the entire lengths of the SPEI time series, coinciding with 2–6 year frequencies usually associated to ENSO, e.g., (Shabbar and Skinner, 2004;Gobena and Gan, 2006).' is somehow confusing and has been changed in the revise manuscript to:

'For SPEI6Apr-Sept, from the WPS of RPC1 in Fig. 8, significant interannual variability of between 8 and 32 months is evident throughout much of the entire lengths of the SPEI time series.'

Definitely, there are components of sub-annual as well as interannual variability in the time series as revealed by the continuous wavelet transform. In Line 477, we recommend that:

‘Also, a lead/lag response of the identified drought frequencies as well their correlations to positive and negative phases of various teleconnections constitute an area for future research’

We realized the presence of this sub-annual components from Figure 8. If we extract the positive anomalies from the MEI, for example, and correlate it with the drought time series, clear seasonal patterns will be revealed. However, we didn’t address this issue in the current work, however, recommendations for future investigations are made.

- Figures 8-11 and Figures S1-S3: Need to label the colorbars.

Thank you. Done.