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Hydrology and Earth System Sciences Discussions

Interactive comment on "Contributions to uncertainty in projections of future drought under climate change scenarios" *by* I. H. Taylor et al.

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This study calculates the uncertainty in future projections of drought based on a perturbed parameter ensemble of the HadCM3C ESM. Uncertainty is calculated across three drought indices, five drought thresholds, 57 ensemble members and two emission scenarios. The uncertainties in significant changes in time spent in drought are greatest among the indices and least among the thresholds. Despite this, there are robust signals regionally that are driven by robust signals of precipitation changes, whereas robust signals that are associated with increasing temperature depend on the index examined.

Overall, this is a well-written paper with some interesting results and good insights.

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Interactive Discussion
Discussion Paper

There are many points of clarification that need to be addressed and some further discussion required on the interpretation of the results. These are detailed below.

One issue is the conclusion that the drought index contributes the largest uncertainty. I would think that this is expected, as different indices reflect different types of drought and different parts of the hydrological cycle. For example, if you quantify the uncertainty in future climate by looking at an index of precipitation versus an index of temperature they will show quite different changes and you will conclude that there is large uncertainty in future climate projections. Similarly for drought, if you look at the SPI (dependent on precipitation only) versus the PDSI (mainly dependent on temperature according to the results here) you will get very different answers (because they represent different things) and therefore large uncertainty. So, if one of the goals of the study is to help inform drought management and planning, then the message should be to choose the correct index for the impact rather than taking into account the uncertainties across a range of indices, which assumes that they are all plausible for the particular management problem. The large number of available drought indices reflects this, because there is a large range of impacts that are of interest. You state this on page 12616, line 1-3. Another way of thinking about this is by asking ourselves whether it really matters whether we use a set of different indices or not, as the choice of index should be dictated by the impact we are interested in and is therefore under our control. The real uncertainties arise from things that are out of our control and not known – i.e. uncertainty in future emissions scenarios; uncertainty in model physics; uncertainty in model structure or natural variability (not included here). Therefore it may be more informative to look at the uncertainties derived from different indices of the same drought type and based on the same variable(s).

Specific comments

Page 2614, line 13: Why the A1B and RCP2.6? It would have been better to have scenarios from the same family. I see you discuss this later.

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Page 2614, line 16: “representing the 2080s” – I’m not sure what this means here?

Page 2614, line 17: statistically significant?

Page 12616, line 11. Why choose these three indices? Do they reflect the three types of drought type (met, agric, hydro)? See later comment.

Page 12616, line 13-17. Is this paragraph needed? It seems a little out of place and doesn’t add much.

Page 12616, line 20-24. This has been revisited since the 4AR (see IPCC SREX, 2012; Sheffield et al., 2012).

Page 12616, line 24-25. Why? Because the observed changes are related to anthropogenic climate change?

Page 12616, line 27 “Temperature is projected to increase everywhere” and page 12617, line 3 “Evaporative demand is also likely to increase everywhere”. These are hanging sentences that need some context, such as a few words that link them to changes in drought.

Page 12617, line 7. So, do you account for these?

Page 12617. I think you need a statement somewhere around line 9 giving the overall objective of the paper, in the context of the previous discussion. And also mention what is the difference between this and the previous paper by Burke and Brown (2008) or how it builds on that study?

Page 12617, lines 19-22. But do you discuss the importance of these in relation to your results? For example, the uncertainty due to different models (structural uncertainty) and due to internal variability, which may be comparable to the other types of uncertainties? Okay – I see that you do this later in the discussion.

Page 12617, lines 23-27. Again, some discussion is needed of why the impact assessment (i.e. choice of index) is an uncertainty.

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Page 12617, line 28 to end of paragraph. Why choose the SMA and PDSI which both represent the same type of droughts? It may be better to use a hydrological drought index such as the SRI to cover all three types of drought.

Page 12618, lines 20-23. Less uncertainty means a more robust projection, but if the model/index is wrong in the first place then less uncertainty places more confidence on an incorrect conclusion. What do you mean by "messages"?

Page 12620, lines 8-11. The acronyms have already been defined.

Page 12620, lines 19-20. Bit awkward. Perhaps rewrite as: "This represents the variation of the impacts of reduced precipitation with event duration (Sivakumar et al., 2010)"

Page 12620, lines 21. How does this time scale relate to those from the other indices? If they are different, then you are introducing a difference in what they represent.

Page 12621, lines 3-4. I know you define the time periods later, but it may be better to do that at the front of section 3.

Page 12621, line 11. Soil moisture measurements are routinely collected in many regions – it is the lack of spatial coverage of routine measurements that is the greater problem. Perhaps better to say "not collected over large areas" rather than "not routinely collected".

Page 12621, line 12-15. So does the model include these effects or not?

Page 12621, line 16-17. Can you provide a brief description of how the SMA is calculated, because it is important for comparison with the other indices, such as the timestep it is calculated over and any scaling that is done. Similarly for the PDSI – are the monthly values used as is?

Page 12622, line 18. "simplification of soil moisture across regions". I'm not sure what this means?

Page 12622, lines 24-28. Perhaps rewrite as: "and potential evaporation. Potential

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evaporation is calculated with the Penman–Monteith equation (using temperature, relative humidity, pressure, wind and short and long wave radiation) following the methodology of Burke et al. (2006) as this is more suitable for application to climate change scenarios"

Page 12624, line 4 onwards. I understand the need for the exemplar member, but its selection based on country-based ranks (which will bias it towards larger countries and regional specific biases) seems a little counterintuitive for a global study.

Page 12625, line 10. Can you give a reason here why you exclude cold regions? Also, is there an argument for excluding arid regions also?

Page 12626, lines 3-4. This is not quite clear to me. I understand that you calculate the variance of each uncertainty source, but what do you mean by the "mean of each resultant variance"? You have a variance value for each uncertainty source at each grid cell, but what are you calculating the mean of? How do you calculate the variance of the sources of uncertainty, which only have 2 (emission scenarios) or 3 (drought indices)?

Page 12626, paragraph starting on line 23. Can you give any (brief) explanations of the differences from the two scenarios? In particular it would be good to have some insight into why you see large spread for the A1B than the RCP2.6 (for both temp and precip) – is this expected?

Page 12628, line 21. Is this because the SPI is a 12-month index and so will tend to smooth out any seasonal changes? If you calculated the 1- or 3-month SPI, would you get more similar results to the other two indices?

Page 12628, line 9 onwards. Are the differences between the SMA and PDSI in higher latitudes related to snow? Presumably the Hadley model has a representation of snow/ice that influences the soil moisture, whereas the PDSI has no such representation.

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Page 12628, line 24-25. Presumably this is also the case for the other two indices?

Page 12628, line 26 onwards. For the PDSI, the time spent in drought is > 80% in many regions. This seems very high.

Page 12630, line 7 onwards. You start talking about the 2050s now, without any mention of this in the introduction. Perhaps a sentence in section 3 would help.

Page 12632, line 20-24. Do you know why the PDSI is so strongly influenced by temperature, given that it is based on the whole water balance? Temperature should only come into play in the PM formulation for PE, which implies that trends in net radiation and VPD are well correlated with temperature, and that the PDSI is highly influenced by PE, relative to precip and runoff.

Page 12634, lines 19-22. It is interesting that even under the mitigation scenario, there are still large increases in drought in many regions.

Page 12635, line 9-10. How do you know that temperature changes have a larger influence on the PDSI than precipitation? Can you quantify "mainly"?

Page 12635, lines 11-15. This is an interesting point, that different scenarios give different signs of change. If you are basing this on the changes from the exemplar member (rather than the mean across members) is there any influence here of decadal (natural) variability coming into play that gives an increase in one scenario and a decrease in the other for a particular time period, even though the overall trend may be increasing (or decreasing) in both?

Page 12635, line 26 onwards. This paragraph repeats a lot of the results section, rather than discussing the results and providing insights, perhaps by referring to figure 1 (or the actual distribution changes for a representative grid cell). For example, can you explain why the decreases in time spent in drought are sensitive to the threshold whereas increases are not?

Page 12636, line 20. Do you have a sense of whether the model structural uncertainty

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(i.e. CMIP5 ensemble) would have similar uncertainty to the ESE?

Page 12638, line 14-16. This is just repeated from the previous section. Suggest deleting it.

Page 12638, lines 20-23. This is also essentially a repetition from the previous section. Suggest deleting it.

Page 12638, lines 24 onwards. Again, this repeats much from the previous section. Why not merge everything on page 12637 with the conclusions?

Figure and table captions. Suggest replacing "HADCM3C Earth System Ensemble" with "ESE" as you have this defined in the text. No sense in repeating the full name for every caption.

Table 1. Does "land points" exclude the cold regions? Suggest including units in the table itself, e.g. "Land temperature change (oC)"

Figure 3. "avereaged"

Figure 4 and 5 and others. "exluded"

Figure 7. Can you increase the label font size?

Figure 8. No need to explain the color scheme in the caption as you have a legend.

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