Response to Reviewer 1 comments

General Comment:

The paper describes a set of drought projections for Australia developed by dynamically downscaling CMIP6 global climate models. A possible range of future drought conditions is considered that span multiple emissions pathways and model configurations. Future drought conditions are described through event frequency, duration, spatial extent and time spent in drought, in terms of changes in two commonly used drought metrics. The paper is well-structured, the information is clearly presented and the key results appropriately discussed. I recommend publication after minor revisions, which I describe below.

Response:

We thank the reviewer for the time spent on our manuscript and for the positive and constructive comments provided. Our comments below indicate where we plan to make changes in the manuscript to satisfy these concerns.

Comment:

One key issue is the use of SPEI. This metric, being the difference between precipitation and potential evapotranspiration, is intended to reflect the atmospheric water balance and thereby give a complementary view to SPI-based drought. However, the use of potential evapotranspiration in the calculation of SPEI makes SPEI unrealistic in many water-limited parts of Australia, where actual evapotranspiration does not approach the potential upper limit. So, any projected worsening of PET-related conditions is merely an indication of an increase in atmospheric demand for moisture, rather than a conclusive reduction in water stores. I suggest this issue is more adequately discussed in the paper, including the implications in the interpretation of SPEI-based projections of drought.

Response:

We agree with the reviewer that this is a key limitation of the SPEI metric. We will strengthen our discussion of the interpretation of the SPEI-based drought projections. Specifically, as suggested by the reviewer we will expand the discussion of the implications (Section 4.3) to make it clear that increases to SPEI-based drought projections do not necessarily translate to an increase in agricultural and hydrological droughts in water-limited regions. We will also bring this point into the discussion of the differences between SPI and SPEI (Section 4.2).

Comment:

The second key issue is the lack of attention given to the uncertainty of the projections. While using a multi-model ensemble and multiple emissions pathways goes some way to addressing uncertainty, the drought projections should be presented along with quantified uncertainty estimates. Moreover, the issue of uncertainty propagation from GCM through to downscaling technique to RCM was not addressed.

Response:

We thank the reviewer for their suggestion. We have attempted to show the uncertainty from the multi-model ensemble and multiple emissions pathways using timeseries plots of all ensemble members (Figure 3 and 4), probability density function plots (Figure 5 and 6 and Figure 8 and 9), and boxplots (Figure 11). Our spatial maps, however, only show the multi-

model average. To address this, we will present spatial maps of the 10th and 90th percentile of changes along with the multi-model average. Due to the number of maps involved these figures will be added to the revised supplementary materials.

We have previously evaluated how projections of mean climate and extremes compare from these downscaled projections to the host models (Chapman et al., 2024). This analysis showed there to be very good agreement between the host GCMs and CCAM for temperature and good agreement for precipitation. For precipitation the spatial patterns were generally preserved, however, there were some changes in magnitude in some seasons. It was not possible to compare the PET used in this study to the GCMs, as it was derived offline using several climate CCAM output variables as input data. We will update the Methodology (Section 2.2) in our revised manuscript with this added information to inform the reader.

Comment:

The final key issue is that one of the most crucial findings of the study needs to be made more prominent. The results show that more time is projected to be spent under extreme conditions, both wet and dry, and less time under 'normal' conditions, for some parts of Australia (Table 3). This result should be made more prominent, for example by featuring in the abstract. This result is important because it suggests that the combination of projected changes in the climate system is shifting the dial towards more extreme climatic conditions and motivates future research in understanding the physical processes responsible for the shift.

Response:

We thank the reviewer for pointing this out and agree that this could be better highlighted as one of the key findings. Specifically, we will add a sentence to the abstract and the conclusion highlighting how the increased time spent under drought appears to have largely come at the expense of 'normal' conditions, while there seems to be little change or increases to the time spent in extreme wet conditions, indicating an overall shift towards more extreme climatic conditions. Additionally, we will expand on our discussion of this finding within Section 4.1.

Minor Comment:

L84: this is a bit of a throw away line. I suggest turning this around by stating that since RCMs have been shown to estimate regional rainfall features with higher precision than GCMs, RCMs are more appropriate to study drought on the regional scale.

Response:

We agree with the reviewer and will change this line to the following in the revised manuscript: "However, while research to date has largely focussed on applying coarse GCM outputs to assess future droughts, RCMs have been shown to have more skill in representing key rainfall features and may therefore be better suited to study droughts at regional scales."

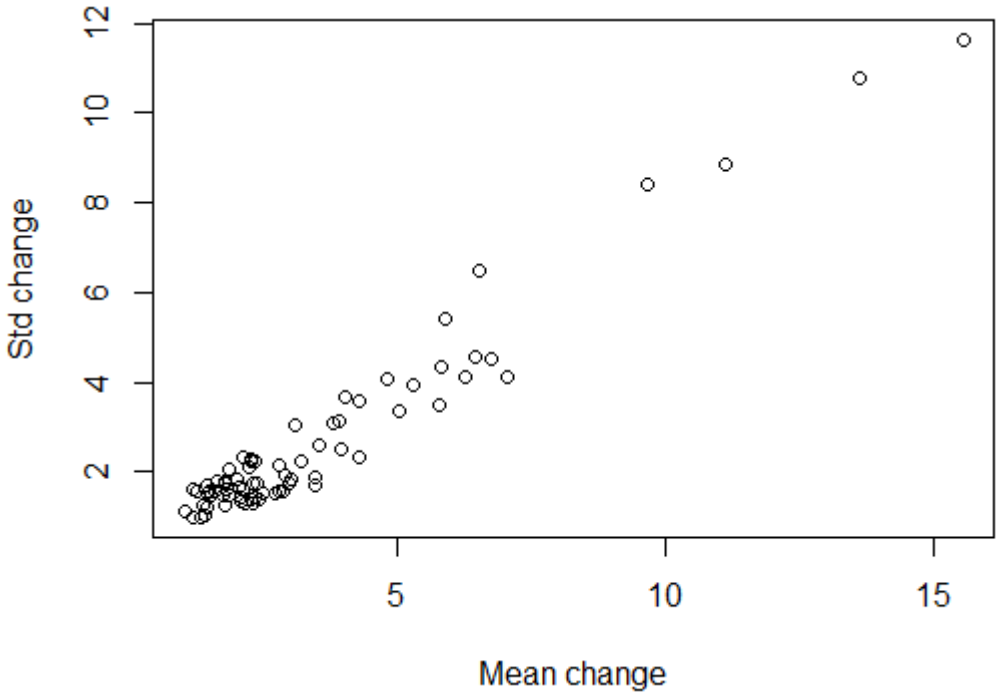
Minor Comment:

Inter-model variability (Figure 11) is shown to be higher for SPEI and some drought characteristics. Can an explanation be offered for why this is? What are the implications of this variability on the interpretation of future drought changes?

Response:

We thank the reviewer for this question. We believe the variability of the projected changes is

related to the mean projected change (i.e. the range of changes approximately scales with the mean change). For instance, we believe there is greater variability of projected changes for SPEI compared to SPI, as the mean changes to SPEI are larger. Additionally, the variability for SPEI is greater in water-limited regions (Rangelands and Southern Australia) compared to the more humid regions (Northern and Eastern Australia) as mean changes are also larger in these regions. To illustrate this point, we present the relationship between the mean change and the standard deviation of the change for all extreme drought metrics in all regions below, which appears to support this hypothesis. We will include some added discussion around these results in Section 4.1 of the revised manuscript.



References:

Chapman, S., Syktus, J., Trancoso, R., Toombs, N., & Eccles, R. (2024). Projected changes in mean climate and extremes from downscaled high-resolution CMIP6 simulations in Australia. *Weather and Climate Extremes*, *46*, 100733. https://doi.org/10.1016/j.wace.2024.100733