

Response to reviewer 3

Review of Maher et al., “The future of the El Niño-Southern Oscillation: Using large ensembles to illuminate time-varying responses and inter-model differences.”

This manuscript clearly and effectively shows the effect of global warming on ENSO in an unprecedented set of model simulations, using well-established methods from large ensembles. The findings are well-explained, the figures are clear, and the analysis appears technically sound.

My basic impression from the first round of review is that I share reaction of other reviewers that the manuscript could go further in terms of physical insight and takeaways. The fact that the models differ but we don't really know why is ultimately somewhat unsatisfying. That being said, that is ultimately the state of the science on ENSO and not the authors' fault. Additionally, the forced responses shown in this paper could provide a basis for further investigation, making it a useful and important advance. For example, the non-monotonicity shown in Figure 1 is fascinating and, on its own, a worthwhile subject of research that I hope the authors (or others) are pursuing.

Therefore, I recommend this manuscript be published. I do have some very minor comments, but nothing that should strongly impede publication.

We thank the reviewer for their positive review and helpful comments.

Line numbers refer to the revised, non-tracked-changes manuscript.

The definitions of the Pacific SST gradient are inconsistent in places. In Figures 7 and 8, it's defined as “the difference between the eastern equatorial Pacific and the western equatorial Pacific” (Fig. 7) and “E-W Pacific SST difference” (Fig. 8), but in the Fig. 10 caption it says “west – east.” This may be just be a typo, but I recommend making sure these definitions are consistent since it can get confusing.

We apologize the Figure 10 caption was incorrect. It has now been updated.

Personally, I'd prefer everything to be defined as west minus east rather than east minus west (for example, like this study defined the Walker circulation: doi:10.1038/nature04744). Positive values on the x-axis in Figure 8 refer to “El Niño-like warming,” but that's really referring to decreases in the SST gradient, so it's counterintuitive for positive values to refer to a decrease in something. But either way, just make sure it's consistent and clearly defined.

We choose to keep east minus west as noted by the reviewer this keeps the weakening as a less negative value rather than the counter-intuitive positive values. We have checked the manuscript to make sure everything is well and consistently defined.

Line 41: A recent paper (<https://doi.org/10.1038/s41467-023-36053-7>) showed the contributions of both anthropogenic warming and multidecadal variability in shaping 20th-century ENSO changes and could be cited/discussed here. The strong contributions of natural variability apparent in their results further emphasize the need for large ensembles.

We have added the citation on line 41 with the following text:

“A recent study also noted the strong contribution of internal variability in the observed record (Gan et al., 2023). Gan et al. (2023) conclude that 65% of the observed increase in extreme El Niño events is attributable to the internal variability (largely multi-decadal variability from the Atlantic Multidecadal Oscillation) with the rest of the increase attributed to a changing climate.”

Figure 10: I recommend switching the panels (make the change in ENSO variability the top panel), since you discuss the ENSO variability portion first (lines 252-259) and then move to the SST gradient later.

This has been updated.