Earth System Dynamics Discussions

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Reply on RC1

Nicola Maher et al.

Author comment on "The future of the El Niño-Southern Oscillation: Using large ensembles to illuminate time-varying responses and inter-model differences" by Nicola Maher et al., Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2022-26-AC2, 2022

Review of "The future of the El Nino-Southern Oscillation: Using large ensembles to illuminate time-varying responses and inter-model differences"

I find the paper to be informative and I believe that the community would be interested in this work. The paper is generally well written. My detailed comments are listed below.

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

- Line 19 P2, add Cai et 2012 Nature https://www.nature.com/articles/nature11358; 2014 NCC https://www.nature.com/articles/nclimate2100#citeas, as these are among the earliest papers on the topics?

We will add this citation.

- Line 23, the difference between Cai et al., 2022 and [Wengel et al., 202, Callahan et al., 2021] lies in that one is transient and the others are stabilised CO2. This should be clarified so as not to create further confusion. Line 45 seems to reinforce the confusion.

We will modify line 45 to make this difference in forcing clearer.

- Lines 55-60, paleoclimatic proxy suggests that there is no relationship between mean zonal SST gradient and ENSO variability (Cai et al 2021).

Thanks for the reference we will add it to this discussion.

- Line 93, please cite a butterfly effect paper https://www.nature.com/articles/s41586-020-2641-x as it is easy to understand. I think the paper also suggests that there is an effect on future ENSO evolution from the initial period.

While this is an interesting paper line 93 references the comparison of CMIP spread to the spread of a single model for which the references Maher et al, 2018 and Ng et al 2021 are more relevant. As such we choose to leave the citation as is.

- Line 155 onward, it is not clear if anomalies are constructed referenced to climatology of individual experiment or the ensemble mean. It should be the former. By definition, a climatology is the average of all years that contribute, such that the anomalies sum to zero. If it is the latter, then the inter-experiment difference in climatology needs to be assessed, and the anomalies might not sum to zero.

We remove the ensemble mean. This is because we aim to construct anomalies where the forced signal is removed. The forced signal is well estimated by the ensemble mean (see https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019MS001639 for details on use of ensemble mean to estimate the forced response).

We will make this methodology clear in the Figure caption.

- Lines 166-167, "CESM2 is an exception that has opposite changes in El Nino SST

amplitude and La Nina duration between the two periods.” The Cai et al. 2020 seems to provide a mechanism for this?

This result is not directly comparable to Cai et al, 2020 which looks at the evolution of individual ensemble members, while we consider the ensemble mean as a estimate of the forced signal.

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Figure 1, it is interesting that for a SMILE, most experiments behave in a similar way, either unidirectional or reversing, suggesting that it is strongly model dependent. What causes the dependence?

Given a SMILE consists of experiments that are all run with the same model, it makes sense that the overall trajectory is similar. We note that individual experiments are not shown in Figure 1 – what we show is the ensemble mean and the 5-95% range across the ensemble. This means that the internal variability or trajectory of of each individual member within the ensemble spread is not illustrated in the model. The individual members while following the same overall trajectory will show much more noise than the ensemble mean and spread.

Model dependence could be related to the following:

-Different climatological biases

- Different patterns of transient mean-state warming

-Different ENSO feedbacks and dynamics

See following references:

Planton et al, 2021: https://journals.ametsoc.org/view/journals/bams/102/2/BAMS-D-19-0337.1.xml

Bellenger et al 2014: https://link.springer.com/article/10.1007/s00382-013-1783-z

Wills et al, 2022: https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2022GL100011

Capotondi et al, 2015: https://repository.library.noaa.gov/view/noaa/31041

We will add text around this model dependence citing the references above in the revised manuscript.

- Line 175, what is the dynamics for increased ENSO seasonality?

We cannot answer this without a full feedback analysis, which is out of the scope of this study. We will add the following text to the manuscript.

Determining the dynamical cause for the increased ENSO seasonal synchronization in most of the models will require a detailed ENSO feedback analysis (e.g., Chen & Jin 2022), including assessing potential future changes in the "southward wind shift" mechanism (e.g., McGregor et al. 2012, Stuecker et al. 2013).

References:

https://agupubs.onlinelibrary.

https://journals.ametsoc.org/

https://www.nature.com/

- Line 220, are you able to further test the idea of nonlinearity controlling mean state change by relating them in an inter-model/experiment relationship?

We will update the text on line 220 to read

The internal variability relationship (Fig. 8a) clearly shows the role of rectification into the mean state (e.g. Hayashi et al., 2020), but for the forced changes this is only one of several mechanisms going on, so the forced changes can depart from this linear relationship.

- Lines 229 and 289, what is the dynamics for increasing aerosols to drive an increase in ENSO variability? One would expect increasing aerosols to have an opposite impact to that of increasing CO2. Is it possible that internal variability plays a role in the result?

This is currently unresolved. Aerosol forcing, however, is not the simple inverse of CO2 forcing as it is hemispherically asymmetric unlike greenhouse gas forcing. This leads to ITCZ shifts that can influence ENSO.

See following references:

Luongo et al, submitted: https://www.essoar.org/pdfjs/10.1002/essoar.10512160.1

Kang et al 2020: https://www.science.org/doi/10.1126/sciadv.abd3021

For stratospheric volcanic aerosol:

Pausata et al , 2020: https://www.science.org/doi/10.1126/sciadv.aaz5006

We will add discussion on this point citing the above literature in the revised manuscript.