

## ***Interactive comment on “Comparison of past and future simulations of ENSO in CMIP5/PMIP3 and CMIP6/PMIP4 models” by Josephine R. Brown et al.***

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General response: We thank the reviewer for their thoughtful and detailed comments.

Comment 1: I can understand the framing with respect to the Pliocene but no Pliocene model output is incorporated into the discussion. This may be because the PlioMIP2 simulations were not available when this manuscript was being prepared. If this output is available now I would include it otherwise the framing of the paper is distracting. With respect to the Pliocene there are a few key citations missing. In addition to the zonal temperature gradient, several studies have characterised the thermocline conditions and its coupling to the cold tongue (e.g. Steph et al, 2006; 2010; Ford et al.

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2012; 2015). Also, a recent study by White and Ravelo (GRL, 2020) shows reduced ENSO when the thermocline is deep during the early Pliocene. They suggest mechanistically a weak thermocline feedback dampened ENSO during the Pliocene because the thermocline was deep during the Pliocene. I wouldn't use the Ford and Ravelo 2019 as evidence for ENSO. Ford and Ravelo show that the variability in the western Pacific during the Pliocene was similar to the Holocene. The ENSO variability itself is very weak in the western Pacific and the reconstructed variability largely reflects the seasonal cycle. Response: The reviewer is correct in surmising that the introduction was written without a complete knowledge of the simulations that would be available for inclusion in this manuscript. As we do not include the Pliocene simulations (which are the subject of other studies), we will greatly reduce the discussion of the Pliocene in a revised manuscript. We are also very happy to update the references in the light of the reviewer's suggestions.

Comment 2: Some paleodata reconstructions that are missing from the paper introduction/ discussion: LGM: Leduc et al., 2009; Koutavas and Joanides (2012); Sadekov et al., 2013; Ford et al., 2015. Mid-Holocene: White et al., 2018. Last Millennium: Rustic et al., 2015. Response: These reference will be added, thank you for the suggestions.

Comment 3: Can you expand on Line 186-187? What do you mean there has been substantial progress toward it? Given the average residence time of a deep-water parcel is 1000 years how is 150 years close to equilibrium? In what respect? Response: We will revise the description of the abrupt4xCO2 simulations to clarify the limited progress towards equilibrium after 150 years.

Comment 4: Lines 403-410: This paragraph is confusing to me because “mean state” can suggest different things. I usually think about it as the zonal temperature gradient rather than the eastern Pacific meridional gradient. Can you re-write this to be specific about the gradient you're referring to? Response: A revised manuscript would have a rephrased paragraph about the mean state, because if it confuses this reviewer then it may also confuse the our intended readers.

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Comment 5: Line 420: The paleo reconstructions indicate the cold tongue was productive during the Pliocene (or at least similar to today, Lyle et al., 2015) and the winds were similar (Hovan 1995, Proceedings ODP). Response: This paragraph will be edited to reduce the focus on the Pliocene as noted in response to Comment 1.

Comment 6: Line 480: This also included a deep thermocline which is mechanistically important for ENSO. This has also been suggested for the LGM: Ford et al. 2018. Response: This paragraph will be edited to reduce the focus on the Pliocene as noted in response to Comment 1. The potential role of a deep thermocline in the LGM will be noted.

Comment 7: Figure 13 is not red green colour-blind friendly. I think for the discussion it would be useful to have two separate comparison between the CMIP5 and CMIP6 grade models. It doesn't sound like there has been much improvement in model performance between the CMIP3 synthesis done for the IPCC report and the models here. It would be nice to know how the models are mechanistically improving or where there are known model errors. Response: We apologise for not having considered the Accessibility of the figures and will be revising Figure 13 accordingly. The point raised about the comparison between subsequent generations of CMIP models was also raised by another reviewer and we agree that a specific paragraph on this question should be added to the discussion.

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