

## ***Interactive comment on “Variability of surface climate in simulations of past and future” by Kira Rehfeld et al.***

**Anonymous Referee #2**

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Thank you for asking me to review paper: “Variability of surface climate in simulations of past and future” by Rehfeld et al. Do please accept my apologies for the delay in returning this review.

Any high-quality paper on climate variability is useful, and to say the obvious, it is changes to inter-annual variability that could as much of an effect on society as background climatic changes. This paper provides quite critical information on how the climate system might evolve by a careful scanning across available climate model simulations. The Abstract is clear and captures what the analysis does. The paper builds on what is an under-utilised resource of paleoclimate simulations.

The Reference list is comprehensive, and that in itself makes the paper useful to the climate modelling community.

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A few comments:

The research has been undertaken well, and so I can only really offer a few points which the authors might like to consider.

(1) The decrease in local variability as global temperatures increase is always a fascinating feature of the climate system. This reduction also goes against much-perceived wisdom that a warmer world will be a more climatically-volatile world. The authors might like just to note that, possibly in the discussion?

(2) The approach taken is predominantly statistical, which is correct and proper. However, ultimately it would be nice to understand better the background physical processes behind all of the discovered correlations and features. This understanding is not easy when using outputs from climate models developed at research centres across the global, because it can be difficult to “get inside” the models for extra diagnostics. However, a few sentences saying that this analysis could trigger future investigations of the driving processes might help (and possibly with references). For instance, one suggestion is that lower sea-ice coverage in a warmer world will suppress yearly variations in temperature – fitting with the findings of this paper. Other authors have investigated “teleconnections” between the key oceanic forcings and related adjustments to meteorology over land areas. Some of these authors will have offered how atmospheric advection has a role to enforce such connections.

(3) As so much of this paper describes common features between Earth System Models, then maybe at least some sort of mention should be made of the Emergent Constraint (EC) technique? ECs could potentially use the discovered inter-model agreements, in tandem with any additional contemporary measurement, to constrain future projections? Just a sentence or two hinting at this might be useful.

(4) There are substantial sets of paleo measurements that are rarely used by the climate modelling community. Again, maybe for Discussion, but this paper, with its thoughtful aligning of both paleo and future climate simulations, illustrates their huge

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potential to constrain climate projection. In other words, if the past can tell us more about the future (e.g. Figure 1, hydrological sensitivity is a valid statistic both for the past and the future), then any past records of simultaneous precipitation and temperature estimates provide valuable extra information.

(5) One thing I especially like about the manuscript is the emphasis on oceanic modes of variability (ENSO, IPO, IOD etc). And this is obviously important given the paper is about variability. The authors will know (i.e. in numerical code) where the boundaries are. Would it be appropriate to give a map somewhere, with each of the oceanic modes of oscillation marked? Most will know where ENSO is, but some of the others are less well known.

(6) Do please work through the paper checking clarity. In general, the manuscript reads well, but in some places, it takes time to fully appreciate the analysis, along with a risk of ambiguity. In addition, the captions should be self-contained. As an example, the Caption for Figure 5, it takes some time to realise that the key point is for each location (as in the subplot headers) corresponds to high rainfall amounts. The vague “selected regions” should be expanded more. Or even mark the epic-centre of each region with an annotated arrow for instance.

(7) Some sentences are difficult to read. For instance, in the Conclusions “Global mean precipitation increases with temperature from cold to as-warm-as-preindustrial to warm scenarios.”. Maybe better something like: “Modelled global mean precipitation is found to increase as global temperatures also increase. This finding is valid for simulations from pre-industrial periods into a future warmer world, as adjusted by the burning of fossil fuels. However, our paleo-simulations also show this finding to be true, in the transition from colder periods to the warmer period at the beginning of the industrial revolution”.

(8) The diagrams are good and informative, but a little attention to formatting and detail could turn them into something exceptional. Just check the basics, such that in each,

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all annotation are clear and in sufficiently large font size. Figure 6, make it standard format – so remove the dotted lines maybe?

I am very happy to look at any new version of the manuscript.

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