

Atmos. Chem. Phys. Discuss., referee comment RC1
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Comment on acp-2022-259

Anonymous Referee #1

Referee comment on "Southern Ocean cloud and shortwave radiation biases in a nudged climate model simulation: does the model ever get it right?" by Sonya L. Fiddes et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2022-259-RC1>, 2022

Overall comments:

The study presents a k-means cluster analysis of the recent ACCESS model in the spirit of (Williams and Webb 2009) and (Haynes et al. 2011). The paper could do more to concretely link biases in cloud properties to biases in radiation- radiative biases are suggested to be related to biases in various cloud properties, but this appears to be by eye rather than quantitative. In several places the writing is difficult to follow and especially in the analysis section it is hard to follow whether cloud RFO or cloud properties are being referred to (in several cases clouds are referred to as being simulated correctly or incorrectly, but it is unclear what that means in the regime framework) and often the ability of the model to replicate these quantities is described in vague relative terms. It is also not clear if the authors are comparing in-cloud and area-averaged water paths.

Abstract:

In several places the authors refer to incorrectly or correctly simulating clouds. It is ambiguous what they mean by this. It seems to be only referring to phase and frequency (which I think it equivalent to cloud fraction). If this is the case, it would be good to clarify that we only care about phase and frequency in the abstract and not other things like optical depth and condensed water path (for instance).

L44: what ensemble is being referred to?

L60: What aspect of Bodas-Salcedo 2014 demonstrates a need for consistent evaluation techniques?

L62: it is unclear what the first two sentences of this paragraph are referring to. What are climate-scale runs? Why wouldn't the synoptic meteorology be the same? I think what the authors are getting at is the difference between coupled and AMIP runs. However, there is not any guarantee that the synoptic state will be the same across AMIP runs and the authors just discussed Field and Wood 2007 above, which composites on synoptic state-making it immaterial whether low pressure centers and other synoptic features are occurring in the same place.

L75: It is somewhat vague what the authors mean by 'incorrectly' or 'correctly' simulated... Is this just in terms of phase and frequency, or in terms of all characteristics in a more abstract way?

L175- It's a little ambiguous here whether the authors are referring to IWP and LWP averaged over the grid box, which is what the model outputs (aka clivi and clwvi-clivi), or if they are talking about in-cloud liquid and ice water path, which is what MODIS would see. It is also somewhat mysterious how propagating errors would affect LWP and IWP and not other cloud properties in COSP. Some additional discussion of this is needed to instill confidence in their evaluation.

L193: Consistent with which previous studies?

L235 and 245: Is CFL/CFI random overlap, or just what is seen from space? Could biases be driven mostly by this cirrus in the model if it is just what is seen from space, with minimal relevance for the PBL cloud that drives SWCRE?

L249: Consider citing:

Mülmenstädt, J., Salzmänn, M., Kay, J. E., Zelinka, M. D., Ma, P.-L., Nam, C., et al. (2021). An underestimated negative cloud feedback from cloud lifetime changes. *Nature Climate Change*, 11(6), 508–513.

Field, P. R., & Heymsfield, A. J. (2015). Importance of snow to global precipitation. *Geophysical Research Letters*, 42(21), 9512–9520.
<https://doi.org/10.1002/2015GL065497>

L253: again, it is unclear if the authors are comparing in-cloud LWP and IWP to area-mean LWP and IWP.

L273: This discussion is fairly qualitative in terms of relating various cloud properties to

radiative bias. Quantitative estimates of how (for instance) cloud fraction relates to radiation exist:

Bender, F. A. M., Engström, A., Wood, R., & Charlson, R. J. (2017). Evaluation of Hemispheric Asymmetries in Marine Cloud Radiative Properties. *Journal of Climate*, 30(11), 4131–4147. <https://doi.org/10.1175/JCLI-D-16-0263.1>

Can the authors show whether the CF bias in their simulations can explain the actual radiative bias?

Section 5.2.1: this section and the associated figure 7 are quite hard to follow. The authors may benefit from more clearly distinguishing errors in RFO and in cloud properties for a given cluster. The writing is somewhat ambiguous- clouds are referred to as being 'correctly' simulated- is this in terms of getting enough of them, or in terms of them looking right when they show up? In particular, the second paragraph of this section could be improved by using fewer vague qualifiers ('comparatively well captured', 'relatively well captured', 'somewhat correct',...) what is the baseline for these statements? These statements are then used to make causal statements about what biases in clouds are leading to biases in radiation, but without any support – wouldn't it be possible to do a more quantitative assessment of where biases in SWCRE are coming from?

Figure 7 is pretty hard to follow. The authors may need a cartoon with annotations or something to illustrate this. There are dots, colors, outlines, months, clusters, and 5 different quantities. A single cartoon for one of the subplots would be helpful.

Overall, I would suggest moving the summary of the findings before section 5.2.1 to give the reader an overview of what is going to be discussed.

L555: the authors bring up a good point- is some of their RFO bias simply due to nudging? Can the k-means clustering be replicated on a free-running simulation to see what the biases look like?