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Interactive comment on "Arctic sea ice in the PlioMIP ensemble: is model performance for modern climates a reliable guide to performance for the past or the future?" *by* F. W. Howell et al.

Anonymous Referee #1

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This study examines the sea-ice simulations from the eight models that constitute the PlioMIP ensemble, aiming among others to gain insights regarding model reliability. Based on its analysis, this study suggests that sea-ice models tuned for pre-industrial climate conditions might not be suitable to simulate sea-ice conditions under different climate conditions.

Unfortunately, in my opinion this paper is not suitable for publication in its current form and requires a major revision before it might become acceptable for Climate of the Past. This is because this paper does not reflect our current physical understanding of sea ice as discussed in the wealth of literature analyzing the modeled past and future evolution of sea ice for example from the CMIP5 ensemble. This physical understand-

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ing strongly suggests that some of the major findings of this paper are not supported by the evidence presented here. An analysis of the PlioMIP sea-ice ensemble is clearly worthwhile, and I believe that interesting insights can be gained from such analysis, but such work would have to reflect what we already know about sea ice. Re-writing this paper along these lines, rather than primarily presenting a statistical analysis, would make for an interesting paper that could then indeed offer insights also regarding the future evolution of sea ice.

A new version of this paper would have to reflect at least some of our current knowledge of sea ice, including:

- The areal extent of thin ice is more sensitive to warming than that of thick ice, because thin ice can more easily melt completely for a given warming. In contrast, thick ice simply becomes a bit thinner for some warming, which then does not lead to a substantial areal change. Hence, the main finding of this paper that pre-industrial sea ice is less sensitive to temperature changes than the much thinner ice of the PlioMIP ensemble is neither surprising nor new.

- The thickness of sea ice that is output by climate models is usually the average thickness that the ice would have if it were to cover the entire grid cell while conserving volume. To obtain actual thickness which then could be compared with satellite observations, one simply has to divide this so-called equivalent thickness by sea-ice concentration. This is apparently not done here (at least it is not mentioned), making the comparison to IceSAT simulations somewhat hard to interpret. It also renders some of the other discussion of sea-ice thickness hard to interpret, since this discussion seems to be based on the equivalent thickness but interprets it as if it were actual thickness.

- The paper suggests a number of times that areal patterns of sea-ice thickness can be tuned for. However, I do not know of a single modeling group that would know a reasonable way of how to achieve this. Tuning of sea-ice models usually only involves a very simple metric, like for example March mean sea-ice thickness or the like, but

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not a tuning of any patterns. I also find the discussion of the tuning of CICE to most likely not reflect the reality at climate modeling centers. I would expect the developers of NorESM-L to tune CICE according to their needs. CICE itself cannot be tuned meaningfully, because it is a stand-alone sea-ice model that requires a given forcing to produce tunable results. The entire discussion of tuning also fails to appreciate the fact that tuning is necessary for any large-scale model, simply because necessarily the parameterizations cannot fully reflect the physical processes that occur on smaller length scales.

- Throughout, this paper seems to assume that it is primarily the formulation of the sea-ice model that is responsible for the resulting sea-ice evolution. It fails to acknowledge that in all coupled climate models, it is by far more important to expose the sea-ice model to realistic oceanic and atmospheric forcing to obtain reasonable sea-ice results.

- We have pretty reliable observations of sea-ice concentration from 1953 onwards, which should be much closer to pre-industrial sea-ice conditions than those of the past three decades. It would be helpful to compare the simulations against this earlier data set to obtain more robust insights into model quality compared to the recent period with its rapidly changing sea-ice conditions.

- For sea-ice thickness, once it is correctly divided by sea-ice concentration, again the comparison of pre-industrial thickness to single-point observations from two months of satellite observations in 2009 is not very meaningful. Over the past decades, summer sea-ice thickness in the Arctic has decreased by roughly 50 %, and it will be very hard to gain robust insights into the quality of a pre-industrial simulation based on satellite observations from 2009.

- The discussion of albedo vs. warming vs. sea-ice evolution remains unclear. Why should the ice-albedo feedback lead to a stronger relationship between T and extent during the Pliocene? The same ice-albedo feedback acts during the pre-industrial period as during the Pliocene, suggesting that the relationship between a change in T

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and a change in extent should be similar in both periods if the ice-albedo feedback was indeed the driving mechanism.

- I strongly recommend to focus less on statistical relationships, or to at least try to interpret those based on physical grounds. For example, the higher value of CV for Pliocene sea-ice extent is probably simply a reflection of the thinner and smaller mean ice cover, but is geophysically in my opinion not relevant. Geophysically, the actual areal change is much more relevant than the percentage change relative to some mean sea-ice cover.

- Many of the insights found here for the PlioMIP period have been found before by existing studies that deal with CMIP-type ensemble simulations of future sea-ice evolution. These studies should be cited here, and the progress made relative to these studies should be discussed.

These are just some of the major issues that this paper needs to address before becoming publishable. I do believe that interesting and important insights can be gained from this study, and some of the figures clearly suggest that this is indeed the case, but in order to reach this aim, clearly much more work is needed.

Interactive comment on Clim. Past Discuss., 11, 1263, 2015.