

Review of Kim et al. “Dynamical Mechanism behind the Southern Hemisphere Westerly Intensification during the Last Glacial Maximum: A Linkage between Sea-ice and Polar Front Jet”

General Comments

This paper uses the CESM1.2 Earth System model to examine the mechanisms controlling shifts in the position and intensity of the Southern Hemisphere Westerly winds during the Last Glacial Maximum (LGM). It first examines changes in the SHW between the LGM and pre-industrial (PI) simulations and then conducts a series of sensitivity tests to examine the effects of step-wise sea-ice expansion on changes in the SHW.

The paper demonstrates that the CESM 1.2 model simulates a poleward shift and intensification of the SHW during the LGM, via two mechanisms: (a) the intensification of the meridional temperature gradient, and (b) enhanced baroclinity that intensifies eddy heat fluxes and storm tracks. The authors argue that these factors outweigh the competing factor driving equatorward shifts in the SHW (i.e. cooling of the upper-troposphere in the tropics).

My concern is with the set-up of the sensitivity experiments, which superimpose sea-ice changes on an atmosphere-only PI simulation where the SSTs are prescribed to match modern ocean conditions. The authors use these conditions so that they are solely examining the effects of sea-ice expansion; however, we know that sea-surface temperatures during the LGM averaged 1.5-5 °C cooler in the Southern Ocean and were as much as 6-8 °C in parts of the subantarctic zone (see Figure 3, Kohfeld et al., 2013). These substantially cooler SSTs would undoubtedly reduce the surface meridional temperature gradients called upon in these experiments to drive a poleward intensification of the SHW through amplified atmospheric baroclinicity and increased eddy activity. As such, I think that the design of the sensitivity experiments artificially enhances a surface meridional temperature gradient to invoke the anticipated result.

RECOMMENDATION 1: I suspect that the authors could get around this problem with one additional sensitivity experiment in which they select one of their sensitivity tests (e.g., ICE75) and run it again with LGM SSTs prescribed, at least in the Southern Hemisphere. This would allow the authors to isolate the effects of the artificial surface meridional T gradient imposed by their choice of prescribed conditions.

RECOMMENDATION 2: Aside from this issue, the analysis of the LGM-PI simulations is interesting and seems sound to me. That said, I suspect that the authors may come up against some challenges, because there is a strong, very vocal contingent in the paleo-community who strongly believes that the SHW shifted equatorward during the LGM. I

believe that the data in Kohfeld et al. (2013) are open enough that a poleward shift is possible. The authors have been careful to focus on mechanisms, but I think their argument would be strengthened if they conducted some form of comparison with paleodata, as was done in Sime et al. (2013), showing that even a poleward shift in the westerlies could be consistent with the moisture proxies originally used to infer an equatorward shift in the SHW.

Specific Comments

METHODS: Based on Sime et al. (2016) it seems important to know how the CESM 1.2 simulates the modern sea-ice extent. Can you provide a one-sentence clarification?

METHODS: It would be helpful to state in the text the latitudinal expansion of the sea-ice extent in the sensitivity experiments – these values look like they are imbedded in Figure 1 but it would be good to have a one-sentence addition stating them explicitly in the text.

FIGURE CAPTIONS: It would be useful to indicate in the Figure Captions which figures are using the fully coupled earth-system model and which are based on the sensitivity experiments.

LN 422-424: Many readers/ authors overlook the fact that Kohfeld et al. (2013) left the interpretation of their results quite open. They actually concluded that a 3-5° equatorward expansion was ONE POSSIBLE interpretation of the paleo data. Kim et al. make this point earlier in the paper (and should here as well); there are several OTHER interpretations that are consistent with the paleodata reconstructions.

Technical Corrections

Ln 20: Do you mean surface or upper troposphere cooling?

STRUCTURE: It is unusual and strange to have a section entitled “Summary and Conclusions” BEFORE you begin the Discussion section. I recommend either (a) retitling the section “Summary” and making it part of Section 3, or (b) expanding the section and moving it AFTER the Discussion.

LN 444-446: I’m not actually sure which model-proxy discrepancy you are referring to here. Can you be more specific, because you haven’t actually done any data-model comparisons in this paper.