

Interactive comment on “Arctic warming induced by the Laurentide ice sheet topography” by Johan Liakka and Marcus Lofverstrom

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Received and published: 1 June 2018

We thank Anonymous Referee 2 for the insightful comments on the manuscript. Please see below for the responses to the specific comments.

Reviewer comment 1

P3L29: Is the q-flux taken from Liu et al. (2009) also the one used in the PI-experiment? If not, please say so and discuss the impact of this. It shouldn't be important for your conclusions as they follow from comparisons of the various LIStopo experiments. But the PI experiment does enter into Figs 1 and 2 and Table 1, and the interpretation thereof could be influenced by the q-flux used.

Reply from authors Thanks for noticing this. The q-flux in the PI experiment is derived
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from the surface energy balance in an atmospheric model experiment with (prescribed) observed sea-surface conditions, PI insolation, and PI greenhouse gas concentrations (same as in Lofverström et al. 2014 and Liakka et al. 2016). We have clarified this in section 2 of the revised manuscript.

Reviewer comment 2

P4L4: A little more detail on the construction of the LIStopos is warranted given that they are the centerpiece of the study. In the text it sounds as if you simply multiply the actual elevation by a number, N. But is it rather the anomaly of the LGM topo wrt to PI topo that you scale with N? The fact that the N=0 case corresponds to PI topo tells me that this is rather the case. Otherwise, N=0 would mean completely flat topography.

Reply from authors Yes, the LIS topography scaling factor (N) has been applied to the LIS topography, which is evaluated as the difference from the PI topography. Therefore, N=0 corresponds to the PI topography in North America with the albedo from the LGM LIS. We have clarified this in section 2.

Reviewer comment 3

P4L13-14: Does the qflux change also contribute to the change?

Reply from authors Yes, potentially it does. We have highlighted that the q-flux is a potential candidate for explaining the differences between LIStopo0 and PI in section 3.1.

Reviewer comment 4

Fig 1: - Consider showing this as in a polar stereographic projection instead. Given that “Arctic” enters into the title of the paper, a highlight of Arctic changes could be in place. - Also, consider showing some standard pressure level height (say Z500) as contours on these plots, to illustrate the stationary eddy changes (if they are visible). The paper talks a lot about the changes in circulation, but nowhere are these changes visualized.

Reply from authors This is a very good idea. We have updated the figure so that it now also includes the eddy Z500 field and is shown in polar stereographic projection.

Reviewer comment 5

P7L24: Given the importance of this analysis, spend a few sentences outlining the principle in the APRP method.

Reply from authors We have added a sentence which briefly explains the essentials of the APRP method in section 3.3 of the manuscript.

Reviewer comment 6

P8L2: Perhaps add "(not shown)" after the discussion of changes in precipitable water.

Reply from authors Thanks. We have added that.

Reviewer comment 7

P10L16-16: Do you perform the vertical integrals on the time-mean output from the model? This often leads to problems if the output is on (hybrid) sigma levels. Usually this has to be taken care of by performing the vertical integrals on-line on the time-step model state and then outputting time means over the vertically integrated quantities. How did you do it?

Reply from authors The integrals were computed on pressure levels. The heat flux quantities were first interpolated from the 26 hybrid levels to 20 equally spaced pressure levels, ranging from 25 hPa to 975 hPa. In the numerical integration, each pressure level then represents the mid-point pressure of a 50 hPa thick pressure layer. The integration for each vertical column was carried out from the top of the atmosphere to the surface, which is represented by the climatological monthly-mean surface pressure. We have added some explanatory sentences about this to Appendix A.

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P11L2-4: Could you write a little more on how you arrive at these expressions for the split-up in contributions?

Reply from authors We arrived at those expressions from the following observations:

- The surface temperature contributions to the net outgoing LW change between two simulations is simply the difference between the outgoing LW from the surface between those simulations (Eq. B1 in the manuscript).
- The cloud contributions are estimated to be the difference between the total and clear-sky (i.e. non-cloud) LW changes (Eq. B3).
- The contributions from water vapor and lapse rate are assumed to be equal to the LW change in the clear-sky variables minus the LW change at the surface (Eq. B2). The reason why the surface LW needs to be subtracted is to account for lapse-rate changes (determined by the difference in LW between the TOA and surface).

Note that any change in other radiative forcing agents (e.g. CO₂ and aerosols) would also influence Eq. B2. However, because the LIStopo simulations use identical aerosol datasets (representative for PI) and have the same concentrations of CO₂ and other greenhouse gases, only changes in water vapor and lapse rate are important for Eq. B2 in our case.

The accuracy of the individual contributions is (at least partly) validated by the fact that summing up Eqs. B1 to B3 yields the total LW change at TOA. Hence, an alternative way to understand the split-up equations is to first subtract the (relatively straightforward) surface temperature and cloud contributions from the total LW change. The residual term then contains "everything else", which in our case reflects changes in water vapor and lapse rate, as the other radiative forcing agents are the same in all LGM (LIStopo) experiments.

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We have added some of this discussion to Appendix B.

References

Löfverström, M., Caballero, R., Nilsson, J., and Kleman, J.: Evolution of the large-scale atmospheric circulation in response to changing ice sheets over the last glacial cycle, *Climate of the Past*, 10, 1453–1471, <https://doi.org/10.5194/cp-10-1453-2014>, 2014.

Liakka, J., Löfverström, M., and Colleoni, F.: The impact of the North American glacial topography on the evolution of the Eurasian ice sheet over the last glacial cycle, *Climate of the Past*, 12, 1225–1241, <https://doi.org/10.5194/cp-12-1225-2016>, 2016.

Interactive comment on *Clim. Past Discuss.*, <https://doi.org/10.5194/cp-2018-26>, 2018.