Interactive comment: Zhang et al. (2018): Instability of Northeast Siberian ice sheet during glacials, Clim. Past Discussions

This paper highlights the potential importance of vegetation and stationary-wave feedbacks on the spatio-temporal evolution of ice sheets during glacial cycles. The vegetation feedback is often omitted in climate modeling studies as reliable reconstruction for glacial condition remain elusive --- e.g. preindustrial vegetation is specified for the LGM in the PMIP1-4 boundary conditions --- making this study somewhat unique.

The stationary-wave feedback, on the other hand, has been extensively studied in recent years, but there is an apparent lack of relevant references on this subject throughout the manuscript, and the few references that are included are often old and/or used in the wrong context. In addition, several recent studies have discussed similar topics as examined here, rendering the novelty of this manuscript somewhat reduced.

Lastly, some of the conclusions presented are both unfounded and highly artificial as they are (undoubtedly) a direct result of the idealized experiment design.

We hope that the questions and comments raised here will be addressed if the manuscript is accepted for publication.

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Specific comments:

Page 2, lines 8-12 and elsewhere:

Stationary waves:
Although Cook and Held (1988) investigated interactions between ice sheets and stationary waves, this is arguably not the most appropriate reference on this topic (at least not mentioned alone as is currently the case). This paper is old --- not the first paper on the topic however, that title goes to Manabe and Broccoli (1985) --- and they used a very simple circulation model compared to modern GCMs. We have done a lot of work on this topic in the last few years, and at least a few of these paper ought to be mentioned:
Lofverstrom et al. (2014; 2015; 2016), Lofverstrom and Liakka (2016; 2018), Liakka and Nilsson (2010), Liakka (2012), Liakka et al. (2011; 2016), Liakka and Lofverstrom (2018).

Zonal LGM jet:
The way this part of the sentence is written is a bit misleading as both the size and location of the Laurentide ice sheet is important for the zonalisation of the North Atlantic jet, see:

Lofverstrom et al (2014, 2016), Lofverstrom and Lora (2017)

Two competing but not mutually exclusive explanations of the North Atlantic jet zonalisation were provided by:
Increased frequency of cyclonic wave breaking: Merz et al. (2015)
Stationary wave reflection: Lofverstrom et al. (2016), Lofverstorm and Lora (2017)

Weaker North Atlantic LGM stormtrack:
Donohoe and Battisti (2009), Riviere et al. (2018)

Wave breaking and internal atmospheric variability:
Ullman et al (2014) did not investigate wave breaking or internal atmospheric variability. A few more appropriate references:
Merz et al (2015), Lofverstrom et al. (2016), Lofverstrom and Lora (2017), Riviere et al. (2018)

Page 2, line 18:
Reconstructions -> Climate model simulations

Page 2, line 21:
Lofverstrom and Liakka (2018) showed that climate biases due to the model resolution can be suppressed (at least to a degree) by the choice of SMB parameterisation.

Page 2, line 22:
Liakka and Lofverstrom (2018) should be mentioned here as well.

Page 3, line 13 and elsewhere:
Neale et al. (2013) is generally considered the "go to" peer-reviewed reference for CAM4

Page 4, line 3:
A nominal 1-degree resolution is generally considered to be an intermediate resolution for climate models (FV1 is the operational resolution of CCSM4). The grid spacing has to be at least 0.25-degrees to be considered high resolution by modern standards.

Page 4, line 7:
Reference showing this?

Page 5, section 2.2:
Are you using the PI land-ocean configuration in all NorESM experiments (i.e. not updating the land-ocean mask based on the ice sheet geometry in PISM)? If so, how is this influencing the results/conclusions? Otto-Bliesner et al. (2016) showed that even relatively small changes in the ocean gateways through Bering Strait and the Canadian Arctic Archipelago can have large implications for the global climate due to changes in the salinity flux in and out of the Arctic basin and into the North Atlantic. Their results were based on Pliocene experiments with CCSM4 (which is using a different ocean component than NorESM), but the climate impact of these ocean gateways is explained by a physical process that realistically should translate to other time periods (and climate models) as well. Regardless, this choice of boundary condition is a huge step away from reality and should therefore be carefully motivated, and potential implications should be discussed.

Page 5, line 17-18:
Cook and Held (1988) used a low-resolution, dry, linear, primitive equations model, which is highly simplistic compared to modern GCMs. See comment above (referring to Page 2, lines 8-12) for more up-to-date references, also regarding the other topics mentioned in this sentence.

Page 5, line 25 and elsewhere:
Sunshine -> insolation (?)

Page 6, line 7:
Do you also change the sub-gridscale topography (fields SGH and SGH30) that are used in the surface drag parameterizations? If not, how is that influencing your results?

Page 6, line 21 and elsewhere:
Probably more accurate to refer to FV1 as an intermediate resolution as it is the default operational resolution of all NCAR models from CCSM4 to CESM2 and many other climate models of the same generation.

Page 7, line 23:
The model used in Cook and Held (1988) didn't have a dynamic ocean.

Page 8, line 9:
The same conclusion was reached in Lofverstrom et al (2014, 2016), Lofverstrom and Lora (2017) and Liakka and Lofverstrom (2018).

Page 10, line 15:
Again, Lofverstrom et al. (2014, 2015, 2016) and Liakka et al. (2011, 2016) showed this as well.

Page 10, line 18:
Assumed by whom? Both Svendsen et al. (2004) and Kleman et al. (2013) suggested that the Eurasian ice sheet had a pronounced east-west extension during the initial phase of the last glacial cycle (first ~20-40 kyrs after the inception), and slowly assumed its LGM configuration with the center of mass in northern Europe.

Page 10, line 20:
We would be careful with the wording here. It is true that these references are discussing “coupled climate--ice-sheet interactions”, however the atmosphere model used in these papers is essentially an energy balance model. Many feedbacks are therefore omitted, among them the stationary wave feedback, which is the cornerstone of this study. Lofverstrom and Liakka (2018) discuss potential shortcomnings of climate--ice-sheet interactions in coarse resolution models and models of intermediate complexity, and how these simplifications may help explain some of the systematic biases obtained in the papers referred to here.

Page 10, line 24:
Sentence starting with “Whilst...” is counterintuitive and has not been proven right by these experiments. Ice sheets form where the annual mass balance is positive over long periods of time, i.e. where the net accumulation exceeds the annual mass loss. Mass loss is to first order driven by summer melt (Milankovitch theory), however the climate conditions are also modulated by the atmospheric circulation that can yield warm/cold air advection and turbulent fluxes of sensible and latent heat that can help speed up or slow down ablation/sublimation processes. Similarly, mass gain is proportional to the sum of liquid and solid precipitation. In other words, both mass gain and mass loss are strongly tied to the atmospheric circulation, which in turn is influenced by the presence of ice sheets. It is therefore possible that changes in the circulation induced by growing ice sheets can trigger ice growth elsewhere.

A few papers on how ice sheets are shaped by the mutual interaction with the large scale atmospheric circulation:
Liakka (2012), Liakka et al. (2011), Lofverstrom et al. (2015), Lofverstrom and Liakka (2018)

Page 11, line 1:
Sentence starting with “Once developed...” is not well supported. It may be the case here, but you are also deliberately neglecting changes in several forcing agents (e.g. insolation and

greenhouse gas concentrations) and potentially important feedback loops (e.g. the stationary wave feedback is arguably omitted by letting the ice sheet model run for 100 kyrs before updating the atmospheric state). Also, Lofverstrom et al (2014, 2016), Lofverstrom and Lora (2017) showed that the relative location of the ice sheets in the westerly mean flow is often more important than their size to trigger stationary wave feedbacks.

Page 11, lines 10-14:
Similar questions have been raised and at least partially answered in these papers: Lofverstrom et al (2014, 2016), Lofverstrom and Lora (2017), Liakka et al. (2016), Liakka and Lofverstrom (2018)

Page 11, line 24:
The 100 kyr timescale obtained here is completely artificial and is a direct result of running the ice sheet model for 100 kyrs before updating the atmospheric state. The connection to the “mid-Pleistocene transition” is therefore unjustified.

Fig. 1:
The left panel (MIS4 ice sheet) is never referred to in the text.

References:

Donohoe, A., and D. S. Battisti (2009): Causes of reduced North Atlantic storm activity in a CAM3 simulation of the Last Glacial Maximum. J. Climate, 22, 4793–4808, doi:10.1175/2009JCLI2776.1

Liakka, J. (2012): Interactions between topographically and thermally forced stationary waves: Implications for ice-sheet evolution. Tellus, 64A, 11088, doi:10.3402/tellusa.v64i0.11088

Liakka, J, Lofverstrom, M (2018): Arctic warming induced by the Laurentide Ice Sheet topography, Clim. Past, 14, 887–900,https://doi.org/10.5194/cp-14-887-2018

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

Liakka, J., & Nilsson, J. (2010). The impact of topographically forced stationary waves on local ice-sheet climate. *Journal of Glaciology*, *56*(197), 534-544.

Liakka, J., Nilsson, J., and Lofverstrom, M. (2011): Interactions between stationary waves and ice sheets: linear versus nonlinear atmospheric response, Clim. Dynam., 38, 1249–1262

Lofverstrom, M. and Liakka, J. (2016): On the limited ice intrusion in Alaska at the LGM, Geophys. Res. Lett., 43, 11030–11038, https://doi.org/10.1002/2016GL071012

Lofverstrom, M. and Liakka, J. (2018): The influence of atmospheric grid resolution in a climate model-forced ice sheet simulation, The Cryosphere, 12, 1499--1510, https://doi.org/10.5194/tc-12-1499-2018

Lofverstrom, M. and Lora, J. M. (2017): Abrupt regime shifts in the North Atlantic atmospheric circulation over the last deglaciation, Geophys. Res. Lett., 44, 8047–8055, https://doi.org/10.1002/2017GL074274

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

Lofverstrom, M., Liakka, J., and Kleman, J. (2015): The North American Cordillera – An impediment to growing the continent-wide Laurentide Ice Sheet, J. Climate, 28, 9433–9450

Lofverstrom, M., Caballero, R., Nilsson, J., and Messori, G. (2016): Stationary wave reflection as a mechanism for zonalising the Atlantic winter jet at the LGM, J. Atmos. Sci., 73, 3329–3342, https://doi.org/10.1175/JAS-D-15-0295.1

Manabe, S. and Broccoli, A. (1985): The influence of continental ice sheets on the climate of an ice age, J. Geophys. Res., 90, 2167–2190

Merz, N., C. C. Raible, and T. Woollings (2015): North Atlantic eddy-driven jet in interglacial and glacial winter climates. J. Climate, 28, 3977–3997, doi:10.1175/JCLI-D-14-00525.1

Neale, R. B., J. Richter, S. Park, P. H. Lauritzen, S. J. Vavrus, P. J. Rasch, and M. Zhang (2013): The mean climate of the Community Atmosphere Model (CAM4) in forced SST and fully coupled experiments. J. Climate, 26, 5150–5168, https://doi. org/10.1175/JCLI-D-12-00236.1

Otto-Bliesner, B.L., Jahn, A., Feng, R., Brady, E.C., Hu, A., Lofverstrom, M. (2017): Amplified North Atlantic warming in the late Pliocene by changes in Arctic gateways. Geophys. Res. Lett. 44, 957–964. http://dx.doi.org/10.1002/2016gl071805

Rivière, G., Berthou, S., Lapeyre, G., and Kageyama, M. (2018): On the reduced North Atlantic storminess during the last glacial period: the role of topography in shaping synoptic eddies, J. Clim., 31, 1637–1652