Review of: Large ensemble simulations of the North American and Greenland ice sheets at the Last Glacial Maximum with a coupled atmospheric general circulation-ice sheet model by Sherriff-Tadano *et al.*

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Sherrif-Tadano *et al.* present the results of a coupled ice sheet-ocean-atmosphere model (FAMOUS-BISICLES) applied to the Last Glacial Maximum (LGM) in North America and Europe. Their goal is to see what parameters control the extent and volume of the North American and Greenland ice sheets, using an ensemble of 16 parameters, related to ice sheet sliding and flow, albedo, and surface climate. The 16 parameters are randomly varied using Latin Hypercube sampling to produce an ensemble of 200 simulations. The simulations are first run for a 5000 year spinup starting with the GLAC-1D reconstruction using constant surface mass balance and air temperature using only the BISICLES ice sheet model. After the spinup, the model is coupled using FAMOUS and run for another 5000 years, after which the results are compared. One of the results of these simulations is that the global temperatures are strongly controlled by the parameters ct and $entcoef$, both related to the parameterization of clouds. Of the 200 simulations, 87 satisfy the set threshold for global temperature after 5000 model years. Overall, the resulting ice volume for North America is weakly dependent on the varied parameters, with only a small correlation with parameters related to albedo ($avgr$, $daice$, $fsnow$). In contrast, the Greenland Ice Sheet shows a very strong relationship with the ice-ground friction parameters, β. Global temperature provides a control on the southern extent of the North American ice sheets, while Greenland is relatively insensitive.

I appreciate the advance this study makes to create a coupled ice sheet-climate-ocean model that can be applied to paleo-simulations. Being able to explore a wide range of factors to discern ice sheet behavior is an exciting development. The main weakness of this study is with the use of Latin Hypercube sampling to determine the values of the parameters of the model simulations. I have mentioned this in a previous review of this model (Gandy *et al.*, 2021) that by varying a large number of parameters simultaneously, it becomes difficult to discern the relative impact that each parameter has on the evolution of the the simulation. This is the case here (*i.e.* Figures 8 and 9), where aside from the sliding parameter β for the Greenland Ice Sheet, there is only a weak relationship between the varied parameters and resulting ice sheet volume. Part of this is because some parameters (*e.g.* the parameters related to albedo and sliding) can cancel each other out. It would have been easier to determine the relationship between variables if a smaller number were selected, then varied in a controlled way. I suppose this may not have been known at the start of the study that this kind of cancellation would happen. However, I think a change of study design would lead to a more interesting result. I think the current results should be published, though I hope the authors consider this in the future. At the very least, the results from Greenland, where the ice sheet volume is controlled by basal conditions rather than global climate, is a very interesting result.

I think one way to improve this study would be to break up the North American ice sheets into smaller regions and see if different sectors are sensitive to specific parameters. For instance, I would

expect the Cordilleran Ice Sheet, which is underlain by mountainous topography, will be sensitive to β, similar to the Greenland Ice Sheet. I would also expect that there will be different sensitivities to the parameters for the southern, land terminating part of the Laurentide Ice Sheet, versus the marine terminating eastern part. Similarly, I would expect different sensitivities between the southern Laurentide and the Innuitian/Northern Laurentide Ice Sheets in terms of climatic parameters. Perhaps cluster analysis could also be applied to see if better relationships between the overarching parameters (*e.g.* related to sliding, albedo) can be deduced.

Southern extent of the Laurentide Ice Sheet and ice streams

Much of section 4 discusses how the model is unable to reproduce the ice streams and ice lobes that existed in the southern Laurentide Ice Sheet. However, the explanations given ignore what I would consider the most likely reason the ice streams and lobes existed – the presence of ice marginal proglacial lakes (*e.g.* Cutler *et al.*, 2001; Quiquet *et al.*, 2021). The proglacial lakes destabilized the ice sheet and encouraged the flow of ice in much the same way as marine terminating ice streams. The presence of shallow lakes that were insufficient to act as destructive calving margins would have increased the subglacial water pressure, encouraging a decoupling of the ice-bed interface, causing the ice sheet to advance in a lobe. When we added proglacial lakes in the PISM ice sheet model (Hinck *et al.*, 2022), we demonstrated the presence of lakes greatly enhanced ice flow, and we also had some limited success in simulating ice lobe formation in shallow lakes.

If this is correct, then it is not surprising that the FAMOUS-BISICLES model is unable to simulate the southern margin of the Laurentide Ice Sheet or terrestrial ice streams, since it lacks this mechanism. The simulation is also of an LGM climate. Since the ice streams and lobes are largely acknowledged to be a result of ice sheet dynamics rather than climatic impacts (Jennings, 2006), perhaps this should not be a target metric for the success of the model. The extreme southern limit of the ice sheet was not achieved at the LGM, because the dynamics requires large amounts of meltwater, which was inhibited by the cold temperatures at that time. Perhaps a simpler target, such as an ice margin near the Canada-US border, would be better.

Minor comments

- Figure 3: please explicitly define "GMT" in the caption.
- Figure 13: I would recommend adding details of which simulation was used to produce this (i.e. what were the atmospheric conditions in this model simulation).
- Some of the references mentioned in the text are not in the reference list, please check.

Best Regards,

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References

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