Review of Zhiang et al.

The authors introduce a newly developed global ice sheet-climate coupled model which aims to explore the evolutions and variabilities of ice sheet-climate system on very long time scale. They first describe several changes applied in the GREB climate model and then introduce a new ice sheet model. Several suits of test experiments are performed to assess the ability of the model in simulating responses of ice sheet-climate system to idealistic forcing. They conclude that the model reproduces the general behavior of ice sheet variabilities reasonably well and state that it can be used for studies on very long time-scale, such as ice sheet-climate evolution over the Quaternary.

The manuscript is well written, easy to follow and its content matches the concept of GMD. In addition, as a paleoclimate modeller using comprehensive AOGCMs, I find this study and model quite interesting since it enables the community to explore the interactions and variabilities of ice sheet and climate in a global scale. On the other hand, I also find several concerns in the model as well as ambiguities in the aim of sensitivity experiments. For these reasons, I recommend major revision before accepting the paper for publication. Below summaries my main concerns, followed by specific comments.

Major comments

1. My main concern appears in the ambiguity on what kind of insights could the model provide in future studies. This model is clearly not meant to reproduce the ice sheet and climate precisely, but rather meant to reproduce them crudely so that the authors can discuss their interactions on global and long time scale. However, there is still a big problem in the spatial distribution of the simulated ice sheet; thickest glacial ice sheet exists over Siberia (Figs. 10 and 16). Previous studies have shown that the longitudinal locations of ice sheets affect their dynamical characteristics, which is important for interpreting the evolution of glacial-interglacial cycle (e.g. Abe-Ouchi et al. 2013, nature, Fig.2b). Given that, how reliable a model with such a bias could be in discussing dynamics and evolutions of ice sheet and climate (e.g. glacial-interglacial cycle across the MPT, the effects of regolith on the ice sheet and so on).Therefore, I strongly encourage the authors to 1. put more efforts to reduce the thickest ice sheet in Siberia and 2. to discuss on what kind of insight could the model provide in understanding the ice sheet-climate system of the Quaternary.

2. While the ice sheet model simulates the ice shelf component of the ice sheet, I couldn't find discussions on the effect of basal melting at ice shelf-ocean margin. Perhaps this effect is partly incorporated through sea ice dynamics, but the authors should discuss possible effects of not including ice shelf basal melting in the model, especially over Antarctica. I assume this is partly causing the too thick west Antarctica in modern climate. Also, it might be related to the small sensitivity of Antarctic ice sheet to climate changes (L466-467).

3. The aim of transient test experiments of ice sheet is unclear to me (L434-L437). The authors apply a reconstructed Greenland temperature used in Greve (1997) to their ice sheet model over the entire northern high latitudes. This method may be appropriate for Greve (1997), which focused on Greenland ice sheet, or a 2D (latitude and height) ice sheet model. However, it is clearly not suitable for a study focusing on 3D Northern Hemisphere ice sheets, since it overestimates/underestimates glacial-interglacial temperature differences outside the Greenland area (e.g. Kageyama et al. 2021, Climate of the Past, Fig. 2b, https://doi.org/10.5194/cp-17-1065-2021). Partly as a result, the thickest ice sheet develops over Siberia, which is affecting the simulated

sea-level change. I would recommend the authors to use different methods such as that used in Niu et al. (2019, Journal of Glaciology, doi: 10.1017/jog.2019.42). In this study, they force the ice sheet model with a similar index method, but utilise information from climate models in considering the regional dependences in temperature changes. In this method, one can assess whether the ice sheet model can simulate the geographical location and volume of ice correctly when reasonable atmospheric forcing is applied.

4. Metrics of assessing model's reproducibility are sometimes vague to me. For example, the authors state their model generally reproduces the ice velocity (Fig. 8 & L432) and sea level change reasonably well, but I couldn't find how they defined that (sorry if I missed). Is it because the model reproduces the order of magnitude correctly? Please add an explanation on this.

Specific comments

L30: "procession" -> "precession"?

L53: Perhaps you may also cite a recent study by Willeit et al. (2019, Science advances, eaav7337) here.

L91 and Table 1: I don't understand what "air thermal heat" means. Could you add an explanation in the main text or table?

L99: It may be useful to add a sentence describing how you estimated the correction terms for temperatures. (Sorry if I missed them)

L140: Is there any reason behind the choice of 10 m threshold? If so, please add a short explanation.

L168: What is Lice? Is it explained in the manuscript or is it a typo of Lm?

L180 and Fig.3: How does the simulated ice cover (or thickness) compare to modern observation? This tells the biases in the model, which is important to know when interpreting the evolution of the ice-climate system of the past.

L272-273: Making a bold assumption is sometimes inevitable in relatively simple models, but the authors should present some evidences supporting this assumption.

L288 and equation (32): Why do you set a maximum ice thickness for ice growth? Please add a sentence on it.

L379: Would be helpful for readers if you refer to Table 3 here.

L398: Do you mean Experiment B is warmer by 5K compared to Experiment A?

L423: Isn't it simply because your model does not account for strong ice shelf basal melting in West Antarctica? Perhaps you can crudely account for this effect by increasing the calving in this area.

L447: As far as I know, Greenland ice core data extends back to 130ka. How did you force the ice sheet model before this period. Perhaps, it may be written in Greve (1997), but please add a sentence on this point.

L453: Do you have any possible explanation why the model underestimate the amplitude of the sea level variability? A sentence would be sufficient.

L459: “EIVM”, do you mean by LIG here?

L465: Do you mean “our simulation of”?

L516: Why does the mean ice volume increase after the first cycle?

L564: Could you further elaborate on how the coarse resolution of ice sheet model causes the bias in West Antarctica?

L567-568: Since the authors use Greenland temperature record to force the ice sheet model, I assume that the effect of changes in ocean circulation on ice sheets are already partly incorporated. Could you further elaborate on how the absence of ocean circulation affects the the biases in simulated North American and Eurasian ice sheet?