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Climate of the Past Discussions

Interactive comment on "Instability of Northeast Siberian ice sheet during glacials" *by* Zhongshi Zhang et al.

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Dear Editor and Reviewers,

Since we believe that our study is a fundamental advance for understanding ice sheet evolution during past glacial-interglacial cycles, we once tried to submit our paper for reviews on Nature, Science Advance and EPSL. We got a few round of reviews. Some reviewers criticized the equilibrated simulations in our study, and some reviewers did not like our non-mainstream view about NH ice-sheet evolution. However, we would like to use this opportunity to thank all reviewers. All reviewers' constructive suggestions and tough criticisms illuminate us to carry out new studies to make our conclusion more robust. Here, we would like to summarize the major criticisms, and give them replies.

Criticism 1. The appearance of NE Siberian ice sheet is due to the cold biases of CAM atmosphere model. The CAM outputs were used directly in the PISM simulations. It is likely the cold biases that cause an ice-sheet simulated over NE Siberia.

This is not case. Although CAM could have some cold biases in the simulated surface air temperature, our experiment show that an ice sheet can not grow on NE Siberia without changes in vegetation cover there. It is the vegetation-albedo feedback causes a strong cooling over NE Siberia, allow an ice sheet grow there. As Marcus Lofverstrom and Alexander Robinson mentioned in their comments, "the vegetation feedback is often omitted in climate modelling as reliable reconstruction for glacial condition remain elusive – e.g. preindustrial vegetation is specified for the LGM in the PMIP1-4 boundary conditions – make this study somewhat unique."

Criticism 2. As pointed out by the Anonymous Referee, the swings of two ice sheet configurations found in this study are based on the idealized experiments, with equilibrated ice sheet simulations. Although a NE Siberian ice sheet is not totally impossible, in reality (or a fully coupled model system), it is likely that an ice sheet can not grow large on NE Siberia, due to it's warming feedback. In a precession cycle, the short duration could also limit the growth of ice sheet on NE Siberia. Since the NE Siberian can not grow large, it can not trigger the swing to the Laurentide-Eurasian configuration.

We acknowledge that, based on the experimental design in the current study, it is difficult for us to answer this criticism. However, we do carry out new simulations with much short time steps for ice sheet model, we do find the similar result that the NE Siberian ice sheet grows large, and is unstable. In the current study, although we run the PISM ice sheet model to an equilibrium, the time series in Fig.4 show that, with the ice sheet model running for 4000$\sim$6000 years, the NE Siberian ice sheets reach $\sim$1500 m high, which is high enough to influence atmospheric stationary waves.

Criticism 3. The simulated influence of ice sheets on atmospheric stationary waves is model-independent, and remain uncertainties.

We acknowledge this criticism. We once tried to impose a NE Siberian ice sheet in the IPSL atmosphere model. The IPSL does not give similar responses as we simulated with CAM in the current study. A modelling study is always model-independent. However, it does not mean the simulated ice sheet-stationary waves feedbacks are wrong in our study. Based on the modern climate study, it seems that CAM has a better ability in simulating atmospheric stationary waves.

Actually, the "well-established" idea about the gradual enlargement of the Laurentide-Eurasian configuration during glacials is not irrefutable. Some geological evidence does support that NE Siberia was once glaciated. Despite new evidence continuously arise, hinting at the occurrence of an ice sheet in this region, the idea of NE Siberia ice sheet is discounted in favour of a focus on the dominance of only one ice sheet configuration. Some geological and modelling studies suggest that NE Siberian ice sheet was once large during MIS6, which is definitely against the well-established idea. If NE Siberia can be glaciated during the penultimate glacial, why it must be unglaciated during the last glacial?

The evidence provided in our current study is not strong enough to challenge the "well-established" idea. However, it opens a new window to rethink if the "well-eastablished" idea is really right. Our asynchronous coupling method, with constant climate forcing, although criticize by reviewers, highlights vital ice-vegetation-ocean-atmosphere feedbacks, – something that is not be possible for previous transient simulations. The mechanism revealed in this study is very likely the key for reconsidering the complex ice-sheet development during past glacial-interglacial cycles.

Regards

Zhongshi Zhang on behalf of all co-authors

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