

# ***Interactive comment on “Rapid waxing and waning of Beringian ice sheet reconcile glacial climate records from around North Pacific” by Zhongshi Zhang et al.***

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In this final response, we focus on two questions. 1) Why do we use the climate records to address the debate of ice sheets during the past glacials? 2) Why do the uncertainties in ice sheet modelling not influence the conclusion of our current study?

## Question 1:

As demonstrated in our study, the BerIS waxes and wanes rapidly. The full BerIS only exists for a few thousand years. When the BerIS does not reach its full size or in the deglaciation stage, some regions in NE Siberia can receive sediments that indicate an

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environment without an ice sheet.

In other words, without absolute age controls in a “high-temporal-resolution”, interpretations of direct evidence on NE Siberia-Beringia still includes uncertainties. We use MIS4 as an example. Suppose we find ice-sheet-free sediments and get one absolute age control within MIS4, we often conclude that the whole MIS4 is ice-sheet-free. However, in NE Siberia-Beringia, a special region, these ice-sheet-free sediments are misleading. These ice-sheet-free sediments can be deposited in the early and late MIS4, but a full ice sheet happens in the middle MIS4. Based on this understanding, we point out the gaps, mass movements or reworked sediments in Lake El'gygytgyn, when we discuss with Juile and Martin.

On the other hand, the scenario with the BerIS waxed and waned rapidly does not have conflicts with these ice-sheet-free evidence. It allows the ice sheet and the ice-sheet-free sediments occurring on NE Siberia-Beringia. Note this possibility was never considered before.

Since the interpretations of direct evidence are highly controversial, it is difficult to resolve the debate only based on direct evidence. Why not look at evidence from a third side? This is the motivation of our current study. We use the temperature records (with precise absolute age controls) from around the North Pacific, and test which ice sheet scenarios can well explain these temperature records. We find that the Laurentide-Eurasia-only scenario fails.

Question 2:

Because the Laurentide-Eurasia-only scenario is the mainstream concept today, when models produce some ice sheets on NE Siberia-Beringia, these simulations are always attributed to model biases or badly selected parameters in ice sheet models, just like the criticisms from Lev. Modelers often face an endless loop, since no simulations are perfect. For example, even an ice sheet simulation is improved, a reviewer who does not like the simulation still can argue that the parameters should be further constrained,

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and the climate model resolution needs to be increased. Since this endless loop is not helpful for resolving the debate, why not jump out to look at the evidence from a third side?

In our current study, thanks to the temperature records from around the North Pacific, we use a good climate model to test which ice sheet scenario can reconcile these temperature records, the reconstructed Laurentide-Eurasia-only scenario, or the simulated scenario with the BerIS involved. (Since there are no reconstructions for the BerIS, the scenario with the BerIS must be simulated. We know that we can not unequivocally resolve the ice sheet limits due to the modeling uncertainties). However, with this method (tested with climate records), the ice sheet modelling uncertainties cannot influence the conclusion of our study.

Our climate simulations show that the ICE6G reconstructions cannot explain these temperature records. On the contrary, although the simulated scenario with the BerIS involved still includes uncertainties, this scenario does a better job. It reconciles the temperature records, and do not fall in conflict with direct evidence. In other word, the growth of the Laurentide-Eurasian ice sheet always decreases surface temperature in the mid-latitude North American west coast (both in ocean and on land), while the BerIS is needed to disturb this cooling trend, otherwise the early warming cannot occur there. This is the solid evidence that supports the existence of the BerIS.

We fully agree with Lev that the BerIS should be further constrained with high-resolution climate models and better selected ice sheet parameters. The better constrained BerIS scenario in future can be tested in climate models again by using the method suggested in our current study. They are future tasks that should be considered together by different model groups. However, if the possibility of the BerIS is simply rejected and thought to be wrong, no modelling groups will think it is valuable to consider an ice sheet on NE Siberia-Beringia.

Two years ago, we argued that an ice sheet should exist on NE Siberia-Beringia,

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though that pure modelling study was rejected due to ice sheet modelling uncertainties (<https://www.clim-past-discuss.net/cp-2018-79/>). In that study, we have pointed out the physical mechanism behind. “When only forced with orbital parameters and greenhouse gas levels, changes in atmospheric circulation are weak”. Thus, “during some glacials ice sheet expansion starts from a circum-Arctic configuration, rather than a gradual expansion into the Laurentide-Eurasian configuration, as is often assumed”. Then, the growth of BerIS leads to the ice sheet-climate feedbacks (warming in the North Pacific and cooling over North America), which melt the BerIS itself and favor the enlargement of the Laurentide ice sheet.

In summary, our current study provides solid evidence to reconsider the BerIS. The mainstream Laurentide-Eurasia-only concept must reconcile these climate records summarized in our current study to strengthen itself.

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