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Interactive comment on “Effects of melting ice sheets and orbital forcing on the early Holocene warming in extratropical Northern Hemisphere” by Y. Zhang et al.

Anonymous Referee #1

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The study by Zang et. al. present climate model results for a period (11.5ka to 7ka) that has not received a lot of attention despite it being a period of large changes in ice sheets and climate. Zang et al. present a number of transient simulations with different forcing that allow them to discuss spatial differences in the climatic evolution over this period as well as what forcings and feedbacks lead to the simulated climate changes. The manuscript is in general rather descriptive and long and could greatly be improved by including a more solid model-data comparison, a comparison to previous transient modelling work and a general discussion of how these results can be used to inform future modelling exercises and the interpretation of proxy-based climate reconstructions of the period under consideration. Below I will firstly discuss a number of general

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comments because listing minor comments, technical comments and some comments related to tables and figures.

General comments: 1) The manuscript is fairly long and there is a little too much repetition in the abstract, results and conclusions sections.

2) The model-data comparison that is presented is very descriptive. Why not use a temperature compilation (such as the one from Marcott et. al. mentioned in the manuscript) to actually compare model and data. A model-data comparison of all the other reconstructions that are discussed in the manuscript is perhaps difficult because they all registered different 'things' (atmospheric temperatures, sea-surface temperatures, sea-ice cover etc). Nonetheless, it would be very useful if the authors can come up with a way to make the model-data comparison more visual because in its current form it is very difficult to follow for the reader and get a good overview of the model-data matches and mismatches.

3) There is very little discussion on what model-data mismatches can potentially tell us about our interpretation of climate proxies, on the validity of the applied model forcings or the realism of different feedbacks in the climate model.

4) How does the LOVECLIM early Holocene simulation compare to previous model runs? For instance a comparison to the results from the TraCE-21K could be very interesting (<http://www.cgd.ucar.edu/ccr/TraCE/>).

5) The conclusion on what GIS evolution fits best (page 6369 lines 21-24) seems based on rather little evidence and should be weakened a little in the text. What is the influence of the differences in the FIS meltwater flux between the two meltwater scenarios? A more general discussion on the use of different meltwater fluxes to capture the uncertainty in reconstructions of ice sheet decay would be useful. Questions that come to mind are: Are the simulated differences in surface climate (sort of a fingerprint) large enough to use proxy-based reconstructions to discriminate between the two scenarios? Would additional reconstructions from certain key regions allow you to do so?

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6) The latest version of the LOVECLIM model (iLOVECLIM) also includes a permafrost module, and permafrost is potentially very important for the early Holocene at high northern latitudes. Can the impact of permafrost changes be taken into account in an additional simulation? Or otherwise, can the effect be discussed based on previous work?

7) Results from a 11.5ka equilibrium simulation are presented and the transient simulation is started from these initial conditions. As described in the manuscript, the deglacial climate is likely far from equilibrium, how does this impact your results?

8) What is the benefit of describing the results of the equilibrium experiments rather than simply an average over the first, say 500-years, of the transient simulations?

9) Include, if not already there, a short introduction at the start of every section and a short summary at the end. This will greatly improve the readability of the manuscript.

10) I would suggest to focus on the OGIS simulations in the results sections since this is the most 'realistic' forcing scenario. Then the experiments without ice sheet changes can be used to illustrate the role of individual forcings and feedbacks.

Minor comments:

Page 5346 line 1: “a critical period for climate change”. Please rephrase, do you mean a critical period to study large changes taking place in the climate system that can help us understand future climate change? Or perhaps simply an important climatological period since the last glacial maximum?

Lines 14 page 5346 to line 28 page 5347: The abstract is rather long and includes a lot of details. Perhaps these two paragraphs can be shortened by about half by solely summarizing the main findings (for instance large spatial differences accompanied by two examples). On the other hand, the abstract lacks any discussion of the comparison of the results to proxy-data or on the importance of the different forcings, especially the two different freshwater forcings. These points could be of much interest to the reader

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and should therefore be mentioned in the abstract.

Page 5348 line 5: what 'many other' records from further east in Eurasia are you referring to here? Please be more specific.

Page 5348 lines 10-14: A suggestion for the introduction is to shift this line to the beginning. One could start out by mentioning the general early Holocene NH extratropical temperature evolution based on temperature stacks, how this general trend has previously been explained in modelling work, but how it fails to identify large regional differences. Differences that are potentially important in improving our understanding of the impact of climate forcings and feedbacks.

Page 5348 lines 15-18: Is this in case one looks at greenhouse gas changes as an internal feedback or more general?

Page 5349 lines 8-10: Is this really as clear as you make it sound?

Page 5353 line 1: Do we know what a 'reasonable' sensitivity of the climate to a fresh-water perturbation is?

Page 5353 line 4: I'm not sure if I understand the forcings of all the different experiments. What forcings are included in OGIS11.5? See also my comment to include a table describing the different experiments.

Page 5353 line 25: Where they excluded in this study or in the PMIP protocol?

Page 5353 lines 26-28 and page 5354 lines 1-10: Please be more specific about the ice sheet evolution that has been applied in the simulations. Is it based on previous estimates? How does it compare to previous deglacial model experiments? How often is the ice sheet mask, topography and albedo updated?

Page 5354 line 16: Please also provide the corresponding meter sea level equivalent for easier comparison for the reader.

Page 5354 line 21: What is meant here with 'a lack of climate imprint'? Please explain.

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Page 5354 line 26: On what basis are these two different freshwater scenario constructed? What is the evidence for a faster or more gradually decreasing FIS melt rate?

Page 5354 line 28: We are perhaps more certain about the total contribution, but what about the spatial pattern of the freshwater fluxes?

Page 5355 lines 15-19: An experiment with only different freshwater fluxes is interesting because it allows one to isolate this effect. However, it seems that the other characteristics of the GIS and FIS are equally uncertain. What is the reasoning not to perform experiments in which those aspects are also changed? If there are reasons to believe that their might be significant differences in either elevation or extent it would be good to test the impacts with a climate model simulation.

Page 5356 line 25: These numbers are without correcting for the changes in elevation of a particular site? Please clarify in the text.

Page 5358 line 26: What is the cause of this rapid increase in Arctic winter temperatures around 7ka?

Page 5359 lines 22-24: What causes this summer cooling? One could think that the impact of freshwater on the continental climate is through ocean circulation and or sea-ice, both of which often have the largest impact on winter temperatures, quite different from the response described here.

Page 5365 lines 15-21: This section on the influence of ice sheet changes on atmospheric circulation is somewhat similar to lines 9-22 of page 5363. Consider condensing it into one paragraph.

Page 5366 line 19: “From the record side”, please explain.

Page 5366 line 20: The changes in dust concentrations during the early Holocene are they caused only by circulation changes or perhaps also influenced by changes in dust availability?

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Page 5367 lines 5-8: How do insolation changes drive temperature decreases in both summer and winter, please explain.

Page 5371 lines 8-9: “The summer temperature was similar to the preindustrial then these two factors were in similar magnitude.” Please explain.

Page 5371 line 26: ‘in spite of’? Please explain.

At several places in the manuscript you describe 11.5ka temperatures as “reaching maximum cooling” (for instance page 5370 line 8). This suggests that 11.5 is a temperature minimum, but since your simulation starts at 11.5ka we cannot know if this is true. What I mean to say is that 11.5ka is during the deglaciation and thus somewhere between minimum (LGM) temperatures and maximum (Holocene thermal maximum) temperatures and it is thus not likely that 11.5ka was in fact a temperature minimum. Please go through the manuscript and carefully check your wording.

Technical comments:

Page 5346 lines 5-6: components of the climate system

Page 5346 lines 6-7: Perhaps it is not necessary to say “ice sheets in cryosphere” and “vegetation in biosphere”.

Page 5346 line 6: ocean circulation.

Page 5348 line 18: The increase did not peak at that moment, please rephrase.

Page 5348 lines 26-29: line is difficult to understand, please rephrase.

Page 5348 line 29: suggests

Page 5349 lines 18-20: The impact of ice sheets relative to insolation? Please explain.

Page 5349 line 23: “For example”, this makes it sound that geological constraints are prone to introduce uncertainties. Perhaps the words “For example” can simply be removed.

Page 5350 line 3: “Interactions” is too vague. Perhaps simply state that they influenced atmospheric CO₂ concentrations.

Page 5350 line 14: ‘Internal forcings’ sound a little strange. Agreed, in models climate feedbacks are often prescribed and are thus treated as forcings (like vegetation and ice sheets), nonetheless this terminology is a little confusing to me. I would suggest to rephrase it and make clear if you are talking about forcings and feedbacks of the climate system or of a climate model.

Page 5351 line 6: Please rephrase this sentence.

Page 5352 line 1: The land-surface model is already discussed later on, perhaps remove it here.

Page 5356 line 20: Perhaps a detail, but it appears to me that the term ‘temperate regions’ should be avoided in the context of palaeoclimate research since its meaning is depending on the climate that one is describing.

Page 5356 line 22: ‘As expected’, better to leave it to the reader to determine if this was to be expected or not.

Page 5360 line 19: Avoid the use of subjective words like ‘impressive’.

Page 5360 line 21: ‘represents’, perhaps better to use ‘shows’.

Page 5360 line 23: Use until instead of till.

Page 5361 line 14: temperature instead of temperatures.

Page 5362 line 6: “climate reconstructions based biological proxies”, please rephrase.

Page 5365 line 10: consider replacing ‘It is obvious’ with something along the lines of ‘from our results it is clear’.

Page 5366 line 25: ‘corresponding’ to what?

Page 5367 lines 5-6: Consider changing into “ground, which has a higher albedo than

boreal forest, at 11.5 ka”.

Page 5370 line 16: was

Page 5370 line 22: ice sheets instead of ice sheets’

Page 5371 line 25: was

Tables and figures:

Tables: Please include a table outlying the different forcings that are included in the different simulations that are presented in this study.

Figures in general: Although perhaps a personal preference, readers are not used to seeing the time axis of model output depicted from right to left. Consider changing.

Figure 4: the numbers on the axis are difficult to read.

Figures 5-9: Why is the OGIS11.5 simulation not included? It could highlight the effects of ice sheets vs meltwater (same for figure 15). Another question: How are thermal maximum periods calculated?

Figure 14: Why are maps shown for 10ka temperatures?

Figure 15: Between 8ka and 7.5ka the AMOC jumps back to a ‘full strength’ state. I’m surprised that this is not reflected in the NH sea ice area (Figure 15b) or in the temperature evolution of the Arctic or NW Europe (Figures 5-6). Please explain.

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