

***Interactive comment on “Effects of orbital forcing on atmosphere and ocean heat transports in Holocene and Eemian climate simulations with a comprehensive Earth system model” by N. Fischer and J. Jungclauss***

**Anonymous Referee #1**

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The authors analyze the changes in atmospheric and oceanic heat transport between pre-industrial, mid-Holocene and Eemian orbital boundary conditions in a coupled atmosphere-ocean-sea-ice-biosphere general circulation model. Although several studies have been devoted to those time slices, the majority of them were not focused on the processes investigated by the authors here. The present study is thus welcome. The authors show that in their model the changes are enhanced in the Nordic Sea and the Barents Sea because of a larger heat transport to this area and a larger ocean-atmosphere heat flux in some regions. Those results are not unexpected but

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documenting them precisely in a sophisticated model is instructive. The paper deserves thus publication in Climate of the Past to my point of view. However, at several occasions imprecise sentences (and sometimes mistakes) are quite disturbing for the reader. This must be modified before publication.

Detailed review

1/ Many studies have been devoted to the response of the Arctic to a warming in the framework of the recent and future rise in greenhouse gas concentration in the atmosphere. The forcing is different compared to the mid-Holocene and Eemian but comparing the mechanisms involved would be very interesting. In particular, I have in mind the paper of Bitz et al. (2006) that also analyzes changes in heat transport when the ice edge is retreating.

Bitz CM, Gent PR, Woodgate RA, Holland MM, Lindsay R. The influence of sea ice on ocean heat uptake in response to increasing CO<sub>2</sub>. JOURNAL OF CLIMATE 19 (11) 2437-2450, 2006

2/ All the figures are very small so it is often hard to see the signals described by the authors.

3/ Page 2314, line 17. To my knowledge, the model used by Renssen et al. (2006) does not include heat flux corrections.

4/ Page 2318, line 4. I see well the decreased of 1 K south of Iceland in the Eemian simulation on Fig. 2b but not on Fig 1a. I see no blue patch in the Atlantic in the latter figure. Is it the same field that is plotted on the 2 figures as suggested by the text?

5/ Page 2318, line 5-10. The explanation attributing the temperature decrease to a reduction in albedo is a bit short for me. Without additional effects, I would expect a warming associated with a reduced albedo. I imagine that we also have to take into account hydrological changes but the authors must at least mention their impact on temperature (related to clouds, latent heat flux ...).

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6/ Page 2318, line 18. Would it be possible to diagnose the shifts in the ITCZ?

7/ Page 2319, line 25. If the dry and moist components compensate each other, there is no net change in heat transport. Do the authors mean TEND TO compensate each other, or simply that these two components have opposite signs?

8/ Page 2322, line 4. The definition of the barotropic streamfunction is a bit strange to me. As I am reading it, because of the integration on both  $x$  and  $z$ ,  $\psi$  would be only a function of  $y$ . I guess I am wrong because if  $\psi$  is only a function of  $y$ , it could not be used to describe ocean gyres.

In a more general way, the definition of all the integrals would be much clearer (and more precise) if the intervals on which the integral is computed were given.

9/ Page 2323, line 24. I agree that for BAR, "the relative increase in heat transport is larger than (not then I guess) the increase in volume transport (in absolute values)". However, this is not the case for ISR as claimed in the manuscript. This is indeed consistent with the explanation given page 2324 lines 1-2.

10/ Page 2324, line 17-18. For me, it is not straightforward that the increase in the heat flux is associated with a northward shift of deep convection. It could be due to the reduction of the ice cover only (see line 11-12, same page). If a link is seen in the model between heat flux and deep convection this must be shown or at least discussed more precisely.

11/ Page 2325, line 23. In winter, at high latitudes the insolation is very low (and even equal to zero at many places) and its changes are thus low too.

12/ Page 2325, line 28. If I understand well, it is said that the oceanic heat loss to the atmosphere increases in the Nordic Seas (mentioning in the manuscript "increased heat flux" is not very clear) while the numbers given page 2324 give a decrease in the heat flux. Is this compatible?

13/ Page 2326, line 1-2. I must admit that I am not at all convinced by this feedback

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loop. First, I do not understand the argument related to the increased heat loss (see above). Second, if deep water formation were more active and the AMOC more vigorous at the Iceland-Scotland ridge, we should see that on Fig. 6 but this is not the case. Only a very small increase in the AMOC is seen close to the surface, northward of  $70^{\circ}\text{S}$ , if I am right. The authors do not mention the role of the winds in the increased transport which appears to be a much more likely candidate to explain the changes in ocean currents to my point of view.

14/ Page 2326, line 9. Do you mean Eastern Europe or Northern Europe? For me Romania, for instance, is part of Eastern Europe while the influence of the Barents Sea in this region is probably weak.

15/ Page 2326, line 18. What do you mean by "multimodel mean does not display regional amplification in high northern latitudes"? The majority of the models have a clear polar amplification of temperature changes (see for instance figure 6a of Braconnot et al. 2007).

16/ Page 2327, line 12-14. In the introduction, the authors mention that the maximum temperature is delayed compared to the maximum in insolation because of the inertia of the climate system. Here, the authors said that the response in previous study (Schurgers et al. 2007) is larger than in their study because they analyzed an earlier period. Is this compatible?

17/ Page 2327, line 18. Adding references for the temperatures on the western coast of Europe and Northern Africa would be helpful. In addition, precisising which part of Western Europe is discussed would clarify the discussion.

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