Clim. Past Discuss., 5, C848–C850, 2009
www.clim-past-discuss.net/5/C848/2009/


Climate of the Past Discussions



# *Interactive comment on* "Northern high-latitude climate change between the mid and late Holocene – Part 2: Model-data comparisons" *by* Q. Zhang et al.

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Received and published: 23 October 2009

We would like to thank very much Eduardo Zorita for his positive and constructive comments and suggestions. We are inspired to think and discuss more carefully on the mechanism study on our topic.

For the first comments from Eduardo Zorita, we admit that the weight factor in the equation in page 1671 line 11 is not proper, which is also pointed out by the other referees and emphasized by editor. It should be the variance itself to normalize the variance of temperature differences. We have corrected it in the revised manuscript. The new results differ from the previous one by less fluctuation in the magnitude of the cost function in summer temperature, for which we have more reconstructions. This fluctuation in magnitude does not affect the selection of the models which better match the reconstructions. In the revised manuscript we also have compared this sigma squared weight with the equal weight for all the reconstructions, confirmed that taking into account of uncertainties is important to find the models closer agreement with the reconstructions.

The second comment on the mechanism of the Arctic warming during winter is an important but also difficult part in our study. One originality of our study is that we have been able to put in evidence a winter warming during mid-Holocene despite the less insolation, which has not been given much attention until now. We proposed that ocean thermal inertia responsible to the arctic winter warming by showing the change in surface heat flux in Fig.8c.It is shown from May to September, that ocean receives more heat from atmosphere, and from October to April, ocean releases more heat to the atmosphere. From analyses of the spatial pattern of the ocean heat flux change and sea ice fraction change, it can be seen that the prominent change in ocean surface heat flux and sea ice fractions both occur over the same region such as Barents Sea and Eurasian Arctic. In fact, as suggested by Eduardo Zorita, the change in ocean surface heat flux could also be affected by the meridional heat transport from the lower latitude to Arctic region. However, the change in the meridional heat transport in atmosphere could in turn be related to the change in sea ice as well. In fact, several recent studies proposed that the anomaly in atmospheric circulation during the early 20th century warming in the Arctic was most likely due to a reduced sea ice cover, mainly in the Barent Sea (Goosse et al., 2003; Guemas and Salas-Melia, 2008; Crespin et al., 2009). A reduction in sea ice fraction can cause local decrease atmospheric pressure and increase the pressure gradient over the region, enhance the northward inflow of warm air into the region, as illustrated in Fig.7. Eduardo Zorita pointed out that the maximum warming occurs in ice covered ocean regions in winter, where ocean heat flux cannot be freely released to the atmosphere. Eisenman et al. (2007) reported that the thickness of sea-ice and snow is important for the strength of the flux of heat upward through the ice. Although this upward heat transport from the ocean to atmosphere through the sea ice is much smaller than atmospheric meridional heat transport, some discussion on this point will be helpful to understand the surface energy balance over the Arctic in winter. These mechanism speculations will be discussed in more detail in the revised version of the manuscript, accompanied by illustrations on meridional heat transport, and changes in sea ice thickness and snow cover.

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Interactive comment on Clim. Past Discuss., 5, 1659, 2009.