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Climate of the Past Discussions

Interactive comment on "The Middle Miocene climate as modelled in an atmosphere-ocean-biosphere model" *by* M. Krapp and J. H. Jungclaus

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Response to Review #2

We also thank the anonymous reviewer helpful suggestions to improve the manuscript. In the following we refer individually to each of his comments.

In this manuscript, Krapp and Jungclaus describe simulations of the middle Miocene climate using a coupled atmosphere-ocean-biosphere Earth system model (the MPI-ESM). Proxy reconstructions of the middle Miocene climate suggest signiïňĄcantly warmer then present global mean temperatures as well as a reduced equator-to pole

temperature gradient. A number of Miocene model studies has been performed previously, and in general these studies were not able to fully capture the reduced meridional temperature gradient. As in the earlier studies, except for more idealised studies (von der Heydt and Dijkstra, 2006), no dynamic ocean has been included, the aim of the present study is to explore the role of ocean circulation changes on the meridional temperature gradient, i.e., meridional heat transport.
While the model setup is appropriate, I fully agree with the previous referee in that the analysis of the model output should be much more thorough and focused on the main question of the study. Though the main goal is well formulated, the results and conclusion sections are much too descriptive and unfocused.

answer: (General answer) As has been stated in the "Response to the Review #1", a re-structured manuscript now guides the reader more focused through the different aspects of our study, namely 1) the analysis of the mean Middle Miocene climate, 2) the role of atmospheric and ocean heat transport, 3) the role of the large-scale ocean circulation, and 4) the comparison to proxy data.
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Comparisons with the previous model studies (You et al., 2009; Tong et al., 2009) could be much more critical and need to acknowledge that different models are being used. Some of the differences may be attributed to model differences and others to the experimental setup, and this needs to be discussed. Climate sensitivity is, for example much larger in the present study than in You et al., but why is that? Does the MPI-ESM show a larger sensitivity than the CCSM also in present-day (IPCC) simulations? This issue needs more analysis.

answer: The comparison to previous model studies in terms of model sensitivity to doubling of CO2 is combined in an extra subsection. We also acknowledge the different GCM sensitivities obtained from the last IPCC simulations.
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The changes in the ocean meridional overturning circulation need to be analysed much more carefully, this is indeed an interesting result and in addition contribute to the main aim of the study. The MOC remains about equal in the CTRL and MIOC360 simulations, even though the Panama Seaway is open in the MIOC360, but it seems that this is due to the fact that the Greenland Scotland Ridge is deeper at the same time. What is puzzling is that the Atlantic-Pacific salinity difference increases while there should be a vigorous exchange of water between the two basins. Further analysis should include, e.g., the salt transport between the basins. It remains a bit suspicious that the figures of the barotropic stream function in the ocean does not include the ACC region. What happens there? Wind changes and ACC strength could also inïňĆuence the MOC strength.

answer: In the section about the large-scale ocean circulation we address the interesting result of a near modern AMOC despite the ocean gateway changes. We explain why the surface salinity contrast between Pacific and Atlantic is as large as today and refer to the “Response to the Review #1” for details. Regarding the barotropic stream function, we update the figure for the global oceans which now also includes the ACC. However, we do not address the impact of the ACC on the MOC.
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Another interesting result that needs further attention is that the oceanic heat transport changes are basically compensated by atmospheric heat transport. Why is that?

answer: That is indeed an interesting result and we attribute this phenomenon to a kind of Bjerknes compensation. However, it is not within the scope of our study to analyse the underlying mechanisms because we assume that this compensation is not specifically linked to the Middle Miocene but the climate system itself.
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In conclusion, I recommend the paper to be considerably revised and further analysis necessary before it can be published in Climate of the Past.

Minor points: Page 1941, l. 5-10: I don’t understand the estimate of the temperature increase due to the “direct” effect of topography. How is that estimated? From the table I get to different values.

answer: We withdraw the former explanation, remove the 1000 hPa temperature from Table 2, and now refer to the effect of topography in terms of the atmospheric lapse rate. In that sense, the 150 m lower Middle Miocene continents would account for a warming of $0.150\,\mathrm{km} \cdot 9.8\,\mathrm{K/km} \approx 1.5\,\mathrm{K}$ for the dry adiabatic lapse rate, or of about 1 K with the environmental lapse rate of 6.5 K/km. The land surface temperature temperature difference between MIOC360 and CTRL is 1.2 K, suggesting that the continental warming can be solely attributed to the lapse rate.
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Page 1941, l. 25: remove “due to”
Page 1944, l.24: can be contributed → I would say “can be attributed to...
Page 1948, last line: my → may
Page 1949, l. 17: remove “to that”

answer: We also include the technical corrections in the revised version.
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References

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