Clim. Past Discuss., 6, C420–C429, 2010
www.clim-past-discuss.net/6/C420/2010/

Climate of the Past Discussions

Interactive comment on "Effects of CO_2, continental distribution, topography and vegetation changes on the climate at the Middle Miocene: a model study" *by* A.-J. Henrot et al.

A.-J. Henrot et al.

alexandra.henrot@ulg.ac.be

Received and published: 12 July 2010

We thank Referee #1 for taking the time to thoroughly analyse our manuscript. The suggested changes will be addressed in the revised version of the manuscript.

General comments:

We agree with Referee #1 that we should better highlight the outcome of our study and notably the analysis of the vegetation contribution to the Middle Miocene climate that has not been done before. Nevertheless, let us emphasize that the studies of

Herold et al. (2009), Tong et al. (2009) and You et al. (2009) are all based on the same AGCM version: NCAR (model CAM v.3.1) and Community Land Model (CLM v.3.0) coupled to a slab ocean model. In that sense, we are convinced that using another AGCM to perform sensitivity tests on the Middle Miocene constitute some new results in itself. Von der Heydt and Dijkstra (2006) used an AOGCM (Community Climate System Model (CCSM v.1.4)) to study the effect of ocean gateways on global ocean circulation patterns in the Late Oligocene to Early Miocene. In their setup, they prescribed a flat bottom ocean of 5000 m depth, a flat land with a constant elevation of 350 m and a zonally constant vegetation distribution. Therefore, we consider that the aim of that study differs from ours.

Specific comments:

Introduction: As requested by both Referees, we will amend the corresponding part of the Introduction to present the results of previous Miocene climate modelling studies we cited in a more comprehensive way. We will also emphasize the results of our study regarding the vegetation contribution.

We think the term "warming at MMCO" has been misunderstood by Referee #1. We used this term here to describe a warmer climate at MMCO with respect to present and not to a transient warming throughout the period. We will replace "warming at MMCO" by "warm MMCO" in the revised text.

Ideally, we would have used the topography reconstruction of Herold et al. (2008) instead of using a scaling factor. However, as explained in the Experimental Setup section, using the Herold et al. (2008) reconstruction would have introduced inconsistencies in the land-sea mask. Furthermore, as also stated, the differences between the results from the two procedures remains largely within the error bars even in those parts of the world where the discrepancies are the largest. In this case, we feel that the simple approach remains appropriate. We would also like to precise that Herold et al. (2009) prescribed fixed sea-surface temperatures which precluded a response of the ocean, whereas we prescribed an ocean heat flux distribution, allowing a larger range of sensitivity of the slab model to topography changes.

Due to the large uncertainties that remain in the pCO_2 reconstruction for the Middle Miocene, we simply tested the effect of different atmospheric CO_2 concentrations. As also suggested by Referee #2, we will add in the revised manuscript a paragraph discussing the climate sensitivity of the model and the possible difference in its sensitivity under present-day and Middle Miocene conditions.

Model and experimental design, p494 lines 18-19: The land-sea distribution used in the whole series of Miocene experiments indeed includes an open Eastern Tethys Seaway, unfortunately the land-sea mask used to produce the maps is not correct. This mistake will be corrected and all the Miocene plots will be modified in the revised manuscript.

The Bering Strait is indeed closed in the Middle Miocene land-sea distribution because we consider that it did not open before the Late Miocene (Gladenkov et al., 2002). We will mention this point in the revised text. Generally, we believe that an open Bering Strait have a negative effect on the NADW formation, due to the low-saline water that enters from the Pacific to the Atlantic via the Bering Strait.

p495 lines 2-3: We agree that in the absence of ice on the pixels, using a thermo-dynamic or a dynamic ice-sheet model does not make any difference. We meant to emphasize that, since there is no dynamic ice-sheet model included in the Planet Simulator, this modification translated primarily into an albedo change, as the model was not able to make an ice-sheet grow back. The sentence will be rephrased as "This mainly affects the surface albedo on land."

p495 lines 23-24: The term "initial" in the caption of Fig. 1 will be added as requested, although we mentioned several times in the text that we used LSG outputs as initial oceanic conditions. All Miocene experiments were forced with the same initial oceanic conditions. All the simulations of this study have been run for 50 years and the results reported here are means over the last 20 years, allowing 30 years for the model to equilibrate.

The LSG spinup is 10,000 years long and the LSG sea-surface temperatures and sea-ice cover used as initial conditions are averages over 50 years. These precisions will be added in the revised text.

p495 lines 24-29: Following the recommendation of Referee #1, we will use past tense when citing previous studies results. We will also refer to Butzin et al. (in revision) at the end of the mentioned sentence. The AMOC in the Miocene LSG run is indeed very weak, which leads to a cooling of the North Atlantic. This point will be mentioned in the revised manuscript.

p465 lines 4-5: The term "ocean flux correction" will be replaced by "ocean heat flux" in the text.

p497 lines 12-13: The surface parameters (surface albedo, roughness length and rooting depth) of the emerging land-points at Miocene were extrapolated from the surface parameters of the nearby land-points, taking into account the distance between the land-points (inverse distance weighted mean). A precision will be added in the revised text.

p498 lines 1-3: By "Middle Miocene Climatic Optimum" we refer to a time span of about 2 million years integrated over several orbital cycles, which explains why we decided to fix the orbital parameters and solar constant to their present-day values. Nevertheless, by making this choice we simulated the Middle Miocene climate in a "warm" orbital configuration, in line with the warm climate that prevailed at that time. We have now tested the potential effect of such an orbital configuration on the Miocene climate by performing an additional run, similar to the MM4 experiment, but using an LGM orbital configuration (eccentricity 0.018994°, obliquity 22.949° and longitude of perihelion 114.42°). This change in the orbital configuration produced a slight global cooling of about -0.1°C in comparison to experiment MM4. A weak response to orbital parameters change was also obtained in the LGM simulation experiments we performed (Henrot et al., 2009). The low sensitivity of the model to orbital configuration changes is mainly due to the simple representation of the components of the climate system that does not fully reproduce the feedbacks occurring in the real Earth system. This supplementary information will be added in the revised manuscript.

Middle Miocene simulations as compared to the preindustrial control run: We compared here each of the Miocene experiments to the control simulation in order to present them as potential Miocene climates. The EXPERIMENT-CTRL differences could also be easier to compare to proxy-based reconstructions than the relative differences between the effects. Nevertheless, the comparison of the relative effects of ocean gateways, topography, CO_2 concentration, etc are discussed in the text. We preferred not to show the relative maps in order to limit the number of maps in the paper. As also suggested by Referee #2, we will break down the section into subsections in order to present separately the results of each Miocene experiment and improve the clarity of the results description.

As mentioned above, all the results shown here are means over the last 20 years of 50-year simulation, allowing 30 years for the model to equilibrate. As the maximum

drift over the last 20 years of simulation of the global mean surface air temperatures is below 0.004°C, we don't think that adding a supplementary plot showing the time series of the surface air temperature will provide any indispensable information.

p498 lines 4-5: As we will re-structure the Results section in order to present and discuss separately the global and regional results of the Miocene simulations, the incriminated sentence will be removed from the text.

p498 lines 14-15: By "local and opposed effects" we meant to say that the temperature increases in some regions in response to the reduction of topography are counterbalanced in the global mean temperature by the temperature decreases occurring in other regions. The sentence will be rewritten in the revised text.

In our model, the mass of the atmosphere is indeed conserved. Therefore, the increase of the surface pressure on land, due to topography reduction, leads to a decrease of surface pressure over the oceans that in turn contributes to cool the oceans. However, local surface pressure increases or decreases also occur, due to the displacement of high/low surface pressure cells in response to the reduction of the topography. We will mention the surface pressure effect in the revised manuscript.

p499 lines 2-6: The mentioned sentence will be more clearly rewritten. The absence of ice on Antarctica and Greenland strongly modifies the surface albedo, as stated by Referee #1. This induces large warming in these regions, and a decrease of the snow cover, leading to a positive albedo feedback during summer in each Hemisphere.

p499 line 21: Here, "modified sea surface temperatures" refers to the sea surface temperatures that change in response to the prescription of a modified ocean heat release at Miocene. We will rewrite the sentence in order to avoid such a misunderstanding. Indeed, the largest changes in surface air temperature occur in Antarctica, as stated above in the manuscript. The sentence pointed out by Referee #1 refers to the regions outside Antarctica. The sentence will also be clarified in the revised manuscript.

p500 line 8: "in the Mexican Gulf" will be changed to "along the south-west coast of North America", which is what we intended to say.

p500 lines 13-16: The term "induce" is indeed not correct. The sentence will be rewritten as "However, the decrease of precipitation of about -400 mm/yr over the northern part of South America and the east coast of North America, linked to a decrease of surface evaporation, leads to a surface temperature increase of more than 1°C."

p500 lines 17-18: The incriminated sentence will be rewritten and the term "induce" removed. It is indeed possible that the open Panama Seaway is not the main driver of the North Pacific warming, as the closure of the Bering Strait could impact on the low-saline water transfer from the Pacific to the Atlantic and therefore modify the sea-surface temperatures. This point will be mentioned in the revised text. Nevertheless, as the warming is already present in the LSG sea-surface temperatures used as initial conditions for the Miocene simulations, we suppose that the absence of ice on the continents is not responsible for this effect.

p500 lines 23-25: The strong reduction of topography over the region of the Tethys Seaway could indeed significantly contribute to the SAT increase in the region. The sentence will be corrected.

p502 lines 18-19: As suggested, the mentioned sentence will be clarified in the revised manuscript. It is the reduction of surface evaporation, leading to a decrease of precipitation, that contributes to warm the surface.

p506 lines 17-20: We initially decided not to show the surface albedo and rooting depth differences in order to limit the number of maps in the paper there are already. Nevertheless, we agree that including them will complete the description of the vegetation impact on climate.

p506 lines 12-14 vs lines 21-22: The first sentence mentioned refers to global effects of vegetation changes, whereas the second one refers to local effects. We will add the term "locally" at the beginning of the second sentence to clarify this.

p506 line 29 to p507 line 3: Fig. 15b shows the precipitation differences between experiments MM4-veg and MM4 and therefore refers to the precipitation differences produced by vegetation changes. The large increase of precipitation in Asia on Fig. 15b is due to the replacement of desert by forests. The decrease of precipitation over Northeastern China mentioned in the sentence and responsible for the opening of the landscape occurs in experiment MM4 and is shown on Fig. 13b. We will add "obtained in experiment MM4" at the end of the sentence to clarify.

Discussion: The greater warming found by Micheels et al. (2009) with the Planet Simulator could be explained by the differences in the boundary conditions between their experiments and ours. Micheels et al. (2009) simulated the late Miocene (Tortonian) and used a different set of boundary conditions. They notably prescribed present-day ocean heat flux, a different topography on land, lower than that used here in some continental regions, and forced the model with a reconstructed Tortonian vegetation, where all the desertic areas were replaced by forest or grasslands ecosystems and boreal forests shifted further North. Such a change in the vegetation cover could explain the greater warming produced even with 280ppm of CO_2.

Technical corrections

We have taken into account all of the technical corrections suggested by the Referee.

References

Butzin, M., Lohmann, G., and Bickert, T.: Miocene ocean circulation inferred from marine carbon cycle modeling combined with benthic isotope records, in revision.

Gladenkov, A., Oleinik, A. E., Marincovich, L. J., and Barinov, K. B.: A refined age for the earliest opening of the Bering Strait, Palaeogeogr., Palaeoclimatol., Palaeoecol., 183, 321–328, 2002.

Henrot, A.-J., François, L., Brewer, S., and Munhoven, G.: Impacts of land surface properties and atmospheric CO_2 on the Last Glacial Maximum climate: a factor separation analysis, Climate of the Past, 5, 183–202, 2009.

Herold, N., Seton, M., Müller, R. D., You, Y., and Huber, M.: Middle Miocene tectonic boundary conditions for use in climate models, Geochem., Geophys., Geosyst., 9, 2008.

Herold, N., You, Y., Müller, R. D., and Seton, M.: Climate model sensitivity to change in Miocene paleotopography, Australian Journal of Earth Sciences, 56, 1049–1059, 2009.

Micheels, A., Bruch, A., and Mosbrugger, V.: Miocene climate modelling sensitivity experiments for different CO_2 concentrations, Palaeontologia Electronica, 12, 2009.

Tong, J. A., You, Y., Müller, R. D., and Seton, M.: Climate model sensitivity to atmospheric CO_2 concentrations for the middle Miocene, Global Planet. Change, 67, 129–140, 2009.

Von der Heydt, A. and Dijkstra, H. A.: Effect of ocean gateways on the global ocean circulation in the late Oligocene and early Miocene, Paleoceanography, 21, PA1011, 2006.

You, Y., Huber, M., Müller, R. D., Poulsen, C. J., and Ribbe, J.: Simulation of the Middle Miocene Climate Optimum, Geophys. Res. Lett., 36, 2009.

Interactive comment on Clim. Past Discuss., 6, 489, 2010.