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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.

Anonymous Referee #1

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General comments

The paper presents modelling results which in part add to the understanding of the Middle Miocene Climate. The topic is within the scope of CP. The authors study the contributions of Middle Miocene - preindustrial ocean gateway and ice cover differences, topographic differences, pCO2 differences, and vegetation differences to the surface climate differences.

As the authors state themselves, sensitivity studies with respect to the Miocene ocean gateways, topography, and atmospheric pCO2 have been done before (Von der Heydt

and Dijkstra 2006, 2008; Herold et al. 2009; Tong et al. 2009, You et al. 2009). As the paper is written now, it is not clear to me which scientific gaps the authors want to fill by more or less repeating these sensitivity studies.

To my understanding, the separate vegetation sensitivity test as presented here has not been previously done for the Middle Miocene. An important outcome is that vegetation differences probably contributed to the higher than preindustrial surface temperatures during the Middle Miocene.

The presentation of key methods and scientific results is frequently inconcise and sometimes wrong. Examples for that poor technical quality are given below.

I recommend major revision.

Specific comments

1) Introduction

In the introduction, the authors describe the results of previous studies, and they briefly describe what they are doing (technically). However, the differences between previous studies and the scientific motivation of this study need to be worked out concisely. The term 'warming at MMCO' used throughout the paper (e.g. page 490 line 5, page 491 line 9) suggests that the paper is about a transient warming towards the MMCO, but actually it is about 'temperature differences' between the preindustrial climate and the Miocene. What is the topography sensitivity study good for when Herold et al. 2009 have done that already (and they seem to have done it more accurately, using reconstructions rather than a scaling factor)? What is the pCO2 sensitivity test good for? Is it about finding a CO2 concentration which leads to the best fit with paleodata? The Miocene pCO2 uncertainty from reconstructions seems quite large. Can we hope to constrain pCO2 climate sensitivity? How come I do not find any sentence

in the introduction saying something like 'We are the first ones to simulate the effect of Miocene-preindustrial ice sheet / vegetation differences.'?

2) Model and experimental design

p494 lines 18-19: *"we have assessed the effects of ... the opening of the Central American and Eastern Tethys Seaways, ..."* Really? This statement disagrees with the land sea distribution shown in Fig. 3b (and all other Miocene lat/lon plots in this paper). Figure 3b shows a closed Tethys Seaway for the Miocene. Moreover, Fig. 3b shows a closed Bering Strait, whereas the preindustrial Bering Strait is open (Fig. 3a). An open Bering Strait may largely effect the global ocean circulation and North Pacific SSTs. But the authors do not mention this land sea mask difference anywhere in the paper.

p495 lines 2-3: *"This mainly affects the surface albedo on land as the model does not include a dynamic ice-sheet model."* I would expect that removing the ice sheets also leads to a reduced surface height. What differences would a dynamic ice sheet model cause when there are no more ice sheets?

p495 lines 23-24 / Fig. 1 / general question regarding method: *"The LSG sea-surface temperature and sea-ice cover for the preindustrial and the Miocene are shown in Fig. 1." / "Fig. 1. Sea-surface temperatures for (a) the CTRL experiment and (b) the Miocene experiments. Sea-surface temperatures below -1.5degC indicate the presence of sea-ice on the corresponding pixel."* I think the caption of Fig. 1 should also say that these are only INITIAL fields for the experiments. How long is the LSG spinup? Are the initial fields long-term averages from LSG? Do all Miocene sensitivity experiments start from the same initial conditions? How long are the sensitivity runs?

p495 lines 24-29: *"In the Miocene LSG simulation, the opening of the Central American Seaway freshens the upper part of North Atlantic while salinities increase in the other oceans. Changes in the Meridional Overturning Circulation (MOC) in the Atlantic Ocean also lead to a cooling of the upper North Atlantic and a warming in the South Atlantic. The Eastern Tethys Seaway weakly impacts on Indian Ocean heat transport."*

Are these results of this paper or of Butzin et al. (2010)? Hard to check for the reader because Butzin et al. (2010) is not yet published. I suspect the AMOC in the Miocene LSG run is very weak or switched off? (The clarity and style of this paper would improve if the authors used present tense for what they have done here and past tense for whatever happened in previous studies.)

p496 lines 4-5: *"The flux corrections obtained are shown in Fig. 2."* To my understanding this is not a flux correction but an ocean heat release.

p497 lines 12-13: *"All of the experiments have been forced with the preindustrial vegetation distribution..."* What about "dry" Miocene points that are "wet" in the preindustrial setup (e.g. around Labrador Sea, Bering Strait)?

p498 lines 1-3: *"Finally, in the whole series of experiments, we applied a present-day orbital configuration and solar constant."* What is the motivation to use preindustrial orbital parameters and total solar irradiance? The differences and potential effects should be discussed.

3) Middle Miocene simulations as compared to the preindustrial control run

I do not understand why each of the Miocene experiments MM1/2/3/4 is compared to the preindustrial control simulation? This method seems inappropriate to separate the different effects from each other. I would have expected comparisons of

1. CTRL -> MM1: to assess the effect of removed continental ice and ocean gateways,
2. MM1 -> MM2: to assess the effect of reduced topography, and
3. MM3 <-> MM2 <-> MM4: to assess the effect of various CO2 concentrations.

Are all the results based on the last 20 years of 50 year integrations? Please mention in the text. Are the runs sufficiently equilibrated? A plot with timeseries of, for example,

the global mean 2m air temperatures from CTRL and all Miocene experiments would be helpful here, I think.

p498 lines 4-5: *"The four Middle Miocene experiments generally produce global temperature and precipitation increases when compared to the control run (experiment CTRL) (see Table 2)."* No, MM3 shows decreases.

p498 lines 14-15: *"The weak global impact of the topography reduction on temperature can be attributed to local and opposed effects. We even obtain a cooling over the oceans while the continents warm."* Is it possible to name the opposing effects? Why would one expect a large change of the global mean surface air temperature? At least in some atmosphere models the global mean surface pressure is hard-coded, the total mass of the atmosphere is conserved. A reduction of the topography, which leads to an increased surface pressure over land, must cause a decreased surface pressure over the ocean. The decreased surface pressure over the ocean is equivalent to an increased longwave emissivity ("less atmosphere above the ocean absorbs less longwave radiation"), which explains the cooling over the ocean.

p499 lines 2-6: *"Moreover the absence of ice on Antarctica and Greenland generates a positive albedo feedback that reinforces the initial warming of these regions."* Which initial warming? Where does the positive albedo feedback come from? Reduced snow or cloud cover? Or the 'manual' prescription of a surface albedo of 20%?

p499 line 21: *"The strongest changes in the surface air temperature in response to the modified sea surface temperatures and land-sea mask mainly concern the oceans and continents of the Northern Hemisphere, whereas the precipitation disruptions mostly occur in the tropics."* I thought the experiment was to modify the ocean heat release, not the sea surface temperatures!?! No, Fig. 6a clearly shows the largest surface temperature difference over the Antarctic continent. Fig. 6b also shows major precipitation differences in the subtropics and in the North Atlantic.

p500 line 8: *"Colder and drier conditions are obtained in the Mexican Gulf..."* From Fig.

6b it is not clear to me that the Mexican Gulf is drier.

p500 lines 13-16: *"However, the colder and drier conditions in the Equatorial Atlantic induce an increase of SAT of more than 1degC linked to a decrease of precipitation of about -400 mm/yr over the northern part of South America and the east coast of North America."* For example, how do colder and drier conditions in the Equatorial Atlantic induce a warming in South America?

p500 lines 17-18: *"In the Pacific Ocean, the opening of the Central American Seaway induces strong warming..."* How can we be sure that the opening of the Central American Seaway is the actual reason and not the lack of ice sheets or the closure of the Bering Strait?

p500 lines 23-25: *"A strong increase of SAT is observed over the Tethys Seaway and is mainly linked to the decrease of surface albedo produced by the change of land-sea mask."* I doubt that the albedo is the main driver. As far as I can see from Fig. 3a, the opening of the Tethys Seaway leads to a reduction of the surface height of more or less 1000m. As a rule of thumb, assuming a dry adiabatic lapse rate, this height reduction leads to an increase of the surface air temperature by 10K. This is a longwave emissivity effect, not a surface albedo effect.

p502 lines 18-19: *"This leads to a decrease of precipitation in summer that contributes to warm the region."* Maybe this is clear to a proper Meteorologist... but why does such a decrease in precipitation lead to a warming?

p506 lines 17-20: *"As described in Sect. 2, vegetation cover changes affect surface albedo and roughness length, but the albedo impact on surface temperature is dominant, because of its direct impact on the energy balance. However, the changes in rooting depth mainly affect the water cycle and therefore precipitation."* To me, it is not at all trivial to convert the biome distribution maps (Fig. 14) into rooting depth or surface albedo maps. I think that an additional figure with surface albedo and rooting depth differences would contribute to the more detailed understanding of the surface

climate changes.

p506 lines 12-14 vs lines 21-22: *"...the vegetation changes produce an additional global warming of +0.5degC(+0.4degC on the oceans and +0.6degC on the continents)..."* versus *"The vegetation cover changes produce a warming of 1 to 2degC essentially on the continents."* 1 to 2K or 0.6K? Essentially?

p506 line 29 to p507 line 3: *"However, SAT decrease[s] in the Center and South of North America as well as in Northeastern China. This effect is linked to the increase of surface albedo induced by the opening of the landscape in response to the reduction of precipitation in these regions."* Fig. 15b does not show a clear reduction of precipitation in the Center and South of North America nor in Northeastern China. Quite the contrary, there is a large increase in precipitation over China.

4) Discussion

p508 lines 10-12: *"Micheels et al. (2009a) used the Planet Simulator to test the sensitivity of the Late Miocene climate to various CO2 concentrations. They obtained similar warmings, between +2.3degC for 280 ppmv and +3.7degC for 460 ppmv in comparison to a preindustrial control run with a CO2 concentration of 280 ppmv. The model results consistently indicate that a higher than present-day CO2 concentration is necessary to produce a warm Middle Miocene climate (You et al., 2009; Tong et al., 2009)."* I am surprised that Micheels et al. (2009a) found a warming of +2.3K while the warming in this study only amounts to +0.3K (Table 2, MM2), even though Micheels et al. also use the Planet Simulator. I know this might be difficult to find out, but where does this difference come from? At least the difference needs to be discussed.

Technical corrections

p496 line 21: *"h = 400+(h0-400)/2 where h0 > 400m"* I know it is self explanatory, but

h and h0 should be defined; add 'm' to the first two '400's to make the units fit.

p500 lines 4-5 and 23: The word *"observed"* should not be used for model results.

Fig. 1: The color bar starts at -15degC but there are no temperatures below -2degC Adjusting the color bar and/or including an isoline at the sea water freezing point might improve the clarity.

Fig. 9-12: The velocity vectors are too small.

For my eyes, the labels of the color bars in all colored lat/lon plots (except Fig. 14) are too small.

There are many typos in the manuscript. I do not correct the typos now because I anticipate a major revision anyway, and because some of the typos are detectable by a simple spell checker.

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