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Climate of the Past Discussions

Interactive comment on "Modeling geologically abrupt climate changes in the Miocene" *by* B. J. Haupt and D. Seidov

Anonymous Referee #1

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The working hypothesis of this study is that changes in sea surface salinity in the Southern Ocean, caused by the dynamics of the Antarctic ice sheet, are (partly) responsible for the warming events during the Miocene. To test the hypothesis the authors perform sensitivity experiments forced by an input of fresh ("hosing") or salt ("salinizing") water in the Southern Ocean at two different time periods (14 and 20 Ma). The main initial difference between 14 and 20 Ma is the land-sea distribution.

The concept of salinity-induced abrupt climate changes in the Miocene is very interesting and I find the manuscript promising. However, significant revisions are required before I can recommend publication of this study. I hope my (extensive) comments and suggestions will help the authors to improve the manuscript.

General comments

Land-sea distribution (p. 2691): As far as I know, there was still a flow through the Tethys Sea (predecessor of the Mediterranean Sea) connecting the Atlantic and Indian Oceans in the early and middle Miocene (see also Scoteses maps). Probably your model grid size is too large to capture the Tethys Sea. However, this through flow largely influences the general ocean circulation and could totally change your results. Please discuss the Tethys flow (or the lack of it) in your manuscript.

Computation of freshwater rate (p. 2692): Why do you use the value of 0.01 Sv in the sensitivity experiments? Can you put it in context with changes in ice volume or sea level? For example, very roughly: 0.01 Sv over 500 years gives in total about 1.6e14 m3. A small ice sheet in the early-middle Miocene would be approximately 5e15 m3 or $\sim$10 m sea level equivalent (see Langebroek et al., 2010 and references therein). A freshwater flux of 0.01 Sv therefore corresponds to approximately 3% of a small ice sheet or $\sim$0.4 m sea level decrease. You can also mention that although the total amount of ice volume change is small ($\sim$3%) and occurs over a short interval (500 years), the rate of freshwater flux is in the same order of magnitude as large-scale ice sheet changes. According to modelling experiments, Antarctic ice sheet growth is approximately 15e15 m3 in 30 kyrs (DeConto and Pollard, 2003) to 20e15 m3 in 50 kyrs (Langebroek et al., 2009), which corresponds to 0.01-0.02 Sv.

Discussion: A robust discussion of the results and description of the mechanism of the proposed scenario (freshwater forcing climate changes) is lacking. Discuss how exactly the freshwater changes ("hosing" or "salinizing") affect the surface temperatures ("warm events"). This is not clear from the figures or the text.

Discussion: Furthermore no comparison to (deep-sea) proxy data (e.g. Lear et al., 2010) is provided.

Discussion: Also a (short) discussion of already proposed and published mechanism (atmospheric CO2, insolation, weathering) should be included.

Discussion of WSDW (p. 2694): Move to Discussion section. Wright and Miller (1996)

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discuss the present-day and Cenozoic (mostly Neogene) periods, not the Mesozoic (era before the Cenozoic). More importantly they mention “While there is some evidence for periodic existence of WSDW during the Cenozoic, existing records of WSDW production show little to no correlation of WSDW with Cenozoic climate change” (page 166, last section). Wright and Miller (1996) refer for the poleward WSDW water flow to a paper by Woodruff and Savin (1989). These authors suggest that this flow occurs, due to the open Tethys Sea. As the Tethys/Mediterranean Sea is not included in your model set-up, it is no surprise that you do not find the poleward WSDW flow.

Check for inconsistencies in the text and figures, for example: - Do you focus on 22 and 15 Ma (Introduction) or on 20 and 14 Ma (remainder of manuscript)? - Are the cross-sections located at 25 and 170 W (p. 2692) or at 24 and 168 W (figures)? Is the high precision of these longitudes in the figure labels necessary? - Are the contour lines in the figures showing the same information as the colour bars (if yes, why are they indicating different values)? - Do you want to link the ocean changes to sea ice fluctuations or to Antarctic ice sheet dynamics? The two effects are different, but are used intertwined in this manuscript.

Specific comments

Title is too general, does not capture content of manuscript.

p. 2689 line 3: Why do you refer here to a Cretaceous paper (Bush and Philander, 1997)? It would be better to refer to one of the Zachos, Lear, Kominz or Miller papers covering the Miocene.

p. 2689 line 6: Do you have a reference for the sea-ice interactions that fit the timing of the disturbances?

p. 2691-2692: If I understood well, the control experiments ran for 10000 years and hosing experiments for 500 years. But the last sentence of page 2691 indicates that after 500 years of hosing, the simulation was continued to 10000 years, where the

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ocean-atmosphere system reaches a complete equilibrium in the deep ocean. Please clarify.

p. 2692: Over which time periods are the results averaged? Over the entire 10000 and 500 years?

p. 2698: Why do you refer to a paper concerning the Arctic freshwater anomalies (Aagaard et al., 1991) in Table 1? Are the freshwater fluxes from Antarctica in the Miocene similar to the present-day freshwater fluxes in the Arctic?

p. 2693 lines 19: The overturning south of 40 S increases according to Table 1.

p. 2693 line 21: “increase” instead of “decrease”, or?

p. 2693 line 29: “decrease” instead of “rise”, or?

p. 2694 line 1: Explain why “Counter-intuitively”.

p. 2694 lines 9-11: As the Cretaceous has a totally different land-sea distribution this sentence is not relevant to the manuscript and can be removed.

p. 2694 lines 15-17: Actually, this is not shown. Would be nice to include the results of the referred Stouffer et al. (2007) paper in Table 1 in order to support this conclusion.

p. 2694 lines 17-19: And other possible explanations?

p. 2694 line 25: Rewrite “for at least two prominent disruptions”. Now it suggests that you tested more “prominent disruptions” and that two of these were responsible for the warm events.

Technical corrections

p. 2689 line 2: “sea level” instead of “seal level”

p. 2689 line 3: brackets around “e.g., Abreu . . . 1997”

p. 2689 last sentence Introduction: rewrite, not clear what you mean

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p. 2691 lines 4-5: check brackets

p. 2692 line 4: change “the elements of young southern cryosphere” into “the Antarctic ice sheet”

p. 2692 from line 10 onwards: the remainder of this section should be called “Results”

p. 2692 line 13: include “the fact that” between “However, despite” and “the Miocene land-sea geometry”

p. 2692 lines 21-23: not clear, better would be: “However, . . . middle Miocene (compare Exps. m14-1 and m14-2) than in the early Miocene (Exps. m20-1 and m20-2).”

p. 2693 lines 4-5: rewrite to: “However, there is no significant increase in deepwater formation in the NH at 14 Ma (Table 1), contradicting a simple bi-polar seesaw scheme.”

p. 2693 lines 5-8: check spelling and rewrite to something like: “ If the bi-polar scheme would have been valid, the significant drop of deepwater production in the Southern Hemisphere (SH) from 85 Sv to 55 Sv in the 14 Ma hosing experiment (Table 1) would have led to a noticeably stronger northbound overturning.”

p. 2693 lines 8-10: “precident”? Maybe: “Therefore, we argue that ocean-land geometry has the major control on deepwater formation in high latitudes.”

p. 2693 line 14: add: “different for 14 and 20 Ma”.

p. 2693 lines 14-15: change to: “In contrast to the 20 Ma simulation, the expected warming of the deep ocean did not happen in the 14 Ma experiment.”

p. 2693 line 17: move sentence to discussion

p. 2693 line 18: increases what or why?

p. 2693 line 23: add: “on temperature in the early Miocene simulation.”

p. 2693 lines 23-25: move to discussion

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p. 2694 line 22: remove “which”

p. 2694 line 23: start new subsection with “Moreover”

p. 2699 figure 1: This figure is very unclear. Showing the velocities in background colours and plotting only few arrows to indicate directions would largely improve the figure.

p. 2700-2701 fig. 2&3: Left and right axis labels can be simplified (“depth [km]” and “temperature difference” with less digits (example: 5.0 instead of 5.00). The figures can then be enlarged, which increases the readability.

Concluding

In summary, I find idea put forward in this study very interesting. However, the forcings (sensitivity of 0.01 Sv and different land-sea distributions) and the results should be evaluated against Miocene proxy data and (modelling) studies, before the manuscript can be published. Furthermore, the many technical errors and inconsistencies in the text and figures should be corrected.

Interactive comment on Clim. Past Discuss., 6, 2687, 2010.