

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

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I was asked to review this manuscript but missed the deadline. I find myself in agreement with Jerry's Comments, but the below review was written before I had seen any of the other comments.

My overall opinion is that, from a paleoceanographer's point of view, this is a potentially interesting contribution to the debate on Miocene climate, but it needs a certain amount of rewriting in order to optimize its value for this community. As is, =it seems not quite up to data as to recent papers on Miocene climate. I do not have expertise in climate modeling and a review by someone competent in the topic should be provided.

2688. Line 1. The gradual cooling of the Cenozoic . . .was punctuated by..'; it thus was

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not a gradual cooling; delete 'gradual'. Line 6: 'the emerging Antarctic ice sheet'. This suggests that the Antarctic ice sheet had only just come into existence by the early Miocene, but most people would argue that this ice sheet had started to develop in the late Eocene, reaching sea level in the earliest Oligocene, i.e., about 10 millions years before the beginning of the Miocene. It had probably been changing in volume (e.g., Paelike et al., 2006, Science 314 doi 10.1126/science.1133822) but calling it emerging in the Miocene seems to me like underestimating its volume in the Oligocene. Line 17: 'The Miocene is a geological epoch extending from about 23 to 5.3Ma and is a time of continuous cooling' – as the authors say in the abstract, and further on, the cooling was NOT continuous but alternated with warming periods (although there was net cooling). Line 19: 'Paleogene cooling trend': the Paleogene (Paleocene, Eocene, Oligocene) ended at the beginning of the Miocene; it is better to use Cenozoic cooling, since cooling continued in the Neogene. Lines 21-24: 'After opening of Drake Passage in the Oligocene and emerging of a paleo analog of the present-day Antarctic Circumpolar Current (ACC) – proto-ACC, climate cooling had accelerated (e.g., Barron and Peterson, 1991; Bice et al., 2000; Seidov, 1986)' – there is no agreement at all that Drake Passage opened in the Oligocene – estimates of the timing of opening Drake Passage range between middle Eocene (e.g., Livermore et al., 2007, G3, 8:Q01005), late Oligocene (Lyle et al., 2007, Geology 35: 691-694) – see also Barker and Thomas 2004 (ESR 66, 143-162, doi 10.1016/j.earscirev.2003.10.003. And what is the relevance of opening of Drake Passage if cause of glaciation was decreasing pCO₂? See also DeConto & Pollard 2003, Nature 421. 25: 'then': at what time? Almost certainly at least since the earliest Oligocene.

2689. 2: sea level, not seal level. 1-5: these are all outdated references, and there are excellent and much more recent papers on climate variability in the Miocene, e.g., Holbourn et al 2005, Nature doi 10.1038/nature04123; Pagani et al 2009, Nature doi 10.1038/nature08133; Pekar & de Conto, 2006, paleo3 231: 101-109. The numerical ages of these events (and their definitions) have been changing over time so more recent references should be included. The overall climate variability is probably orbitally

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controlled (Holbourn et al., 2005; Abels et al., 2005 *Paleoceanography* 20, PA 4012), so that one could argue that an explanation in terms of pCO₂ (for which no orbital-scale resolution records are available) can not be expected at the present state of our knowledge – see also discussion in Holbourn et al., 2005. This does not mean that the idea of the authors to look at possible southern ocean salinity control is invalid – one can argue that such salinity variations themselves may have been orbitally controlled. Lines 6-9: I have no clue why the Miocene sea level history could suggest things about late Eocene ice sheets. I think that indeed at some time the late Eocene was supposed to have been ice-free, but many authors before Miller et al 2005 (including earlier papers by Miller, Zachos et al. 2001) argued for at least small and possible intermittent ice sheets in the late Eocene (see also de Conto & Pollard 2003). I would also say that one would expect expansion of ice sheets to have occurred at orbital frequencies, including 100 kyr. Lines 15-20: I would like to see a somewhat better definition of the time slices investigated. As mentioned above, Miocene climate varied at orbital time scales: would be good to have time slices defined relative to an orbitally tuned timescale (Lourens et al., 2004), or relative to general Miocene climate events (Pagani 2009). Paleo-community readers would like to see a clear statement whether the 14 Ma event was indeed occurring before the middle Miocene cooling or not; the timing in numerical terms of this event has been changing over the time of manuscripts cited in this paper. Maybe add a figure as in Pagani et al 2009 indicating where these time slices are? In the latter both intervals would be comparable in pCO₂ and ice volume.

2690: 28: why present day orbital configurations if the configurations for the time periods to be studied are known? Are pCO₂ levels set at pre-industrial or is the irrelevant as long as there was no difference between the two runs?

2691: lines 1-5: how does paleogeography for 15 Ma compare that in Herold et al., 2008, *G3* vol 9, no 10, Q10009? I suppose that the geographical resolution is too low to resolve a Tethys Ocean, but this is of importance. In the early Miocene there probably

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still was an opening between eastern mediterranean and western Indian Ocean, and this has been the proposed pathways for WSBW, also called 'Tethyan Outflow Water (TOW)'. see below for more comments.

2692: line 4: why 'young' cryosphere when it's older than 10 Ma?

2693: typos in line 8: noticeably stronger, northbound line 9: 'has precedent over'; I suppose it is meant to say 'has precedent over', but I suggest 'is more important than'; I do not think that 'has precedent over', i.e., 'has the right to go before', is the correct meaning here. Line 14: Common, not commonly. Why was the deep-sea expected to warm? Line 28: here it says that the deep ocean did warm in the middle Miocene (14 Ma) run; I had understood earlier on (line 14) that the deep ocean did not warm in both sets of experiments, which I understood to mean the early Miocene and the middle Miocene case. Please make clear to the reader what is meant by 'both sets', if these are not the middle and early Miocene.

2694: Lines 4-6: it seems to me not very relevant to discuss WSBW formation during Greenhouse climates when discussing the Miocene. I think, however, that it also has been suggested for the Miocene – i.e., warm salty water flowing out of the proto-Mediterranean into the area which is now the Arabian Sea - F. Woodruff and S.M. Savin, *Miocene deep water oceanography, Paleoceanography* 4 (1989), pp. 87–140. In my opinion these authors did not present a correct interpretation of the isotope data (see references in the following for other authors arguing for the existence of TOW): Smart et al., 2007, *Palaeo* 3 247: 402-420, doi:10.1016/j.palaeo.200611.003. I do not think models have been able to reproduce TOW under Miocene conditions. Lines 10-12: see also Huber, M., and Thomas, E., 2008. *Paleoceanography: Greenhouse Climates. Encyclopedia of Ocean Sciences*, J. H. Steele, S. A. Thorpe and K. K. Turekian, eds., 2nd edition, (Elsevier), p. 4229-4239; doi: 10.1016/B978-012374473-9.00701.3 Line 14: extent rather than extends Lines 20-24: what is argued to have caused the different sensitivity due to salinity changes in the closing of the CAS? What has the proto-ACC configuration to do with the closing of the CAS? What is different in the configuration

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of the ACC between the two sets (20, 14 Ma)? The ACC was according to at least some authors well into existence by the early Miocene – had been for millions of years. I do not think it is generally accepted that the warm intervals were 'disruptions'; I think many would argue that they were responses to changes in orbital configuration. Line 27: typo in paleoclimates

Figure 1 is not easy to read – arrows are very small. Is a slightly different lay out possible? Color contours?

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