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Climate of the Past Discussions

Interactive comment on "Continuous and self-consistent CO_2 and climate records over the past 20 Myrs" *by* R. S. W. van de Wal et al.

Anonymous Referee #3

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This manuscript attempts to model atmospheric CO_2 concentrations from the Zachos et al. (2001) benthic δ^{18}O curve, a series of 1-D ice sheet models and four parameters relating bottom water temperature, atmospheric temperatures and CO_2. Reduced complexity models, such as this one, have a role in trying to understand processes and reduce highly complex systems down to their fundamentals. For all such models, it is important they are formulated in such a way to retain enough information or predictive ability to be able to accurately reproduce all the essentials of the system. To show this they need to reproduce known independent data, i.e. data not used in the calibration of the model. While this work is undoubtedly interesting and I'm sure that there is much to be learnt from these simulations, the efficacy of the model formulation and assumptions to accurately reproduce climate and CO_2 over the last 20 million years is questionable, particularly with the lack of testing against relevant independent data.

Probably the most problematic feature of the model is the amount of information that is required for the reconstruction of 20 million years of climate history and atmospheric CO_2. Essentially the only information driving the model is the benthic δ^{18}O curve. For this to be a sufficient proxy for the whole climate system and atmospheric CO_2 levels requires a number of assumptions, including that the partitioning of heat in the climate system is fixed, that all temperature change over the last 20 million years is coupled to atmospheric CO_2, that the ice sheet only responds to surface air temperature, that all the other factors affecting δ^{18}O (ocean circulation, ocean gateways, salinity, isotope fractionation etc.) are unchanged and that any climate change is globally coherent. Each of these assumptions can be relatively easily disproved, for example see Dowsett et al. (2010), Lunt et al. (2009), Schoof (2007), Spero et al. (1997) and Raymo et al. (2006) respectively. The problems of such assumptions are best illustrated by the middle Miocene (14 million years ago). Although this was a period of particular warmth and significant ice sheet retreat, no-one proposes that the Antarctic ice sheet returned to a pre-glacial state as in the Eocene. However, middle Miocene δ^{18}O values were similar to those found in the Eocene and hence this model shows an almost total collapse of the Antarctic ice sheet and a return to a pre-glacial climate.

Testing the results of this model is a particular problem, as the use of Pleistocene glacial-interglacial contrasts and the Eocene-Oligocene transition to calibrate the model leaves only the much less well-known Oligocene and Neogene for model evaluation. However, the predictions of the model for the Pliocene and Miocene do not seem to match existing knowledge of the climate and ice sheet in these periods, e.g. Dowsett et al. (2010), Denton et al. (1984) and Talarico and Sandroni (2009). Furthermore some of the implications of the equations derived for this model require the authors to be absolutely sure of the model efficacy. From their equations 4 and 5 it is easy to see that the sensitivity of palaeoclimate temperatures to a doubling of CO_2 ($\sim$ Earth System Sensitivity) is 27°C for the Northern Hemisphere and (from the authors reply to D. Rapp we see) this corresponds to 11°C for the globe. This is almost double the next highest estimate of Earth System Sensitivity from data and models (Hansen et al., 2008; Pagani et al., 2009; Lunt et al., 2009).

Any paper that is going to suggest alternative Cenozoic climate history and suggest much larger values than generally held for the sensitivity of the Earth System to increases in atmospheric CO_2, definitely needs to be well evaluated and tested and currently this paper does not achieve this. The model presented here seems too simple to reproduce CO_2 and climate over the last 20 million years. Either this paper needs to be reframed as an interesting sensitivity study or the authors need to provide much more justification for their results. As an absolute minimum the authors would have to do the following:

• justify the use of Pleistocene relations between bottom-water temperature, Northern Hemisphere temperature, Southern Hemisphere temperature and CO_2 for periods with hugely different boundary conditions (e.g. no large-scale Northern Hemisphere glaciation, open seaways in Panama and Tethys etc.).

• assess from a purely data perspective the assumption that these relations are constant over geological time.

• assess the model predictions of temperature, sea level and CO_2 against the available independent data, i.e. not Pleistocene or Eocene-Oligocene transition.

• explain why this analysis of ice core CO_2 records produces such a different relationship to that found by Hansen et al. (2008), who showed a longer term or Earth System sensitivity of 6°C (not 11°C).

• much greater analysis of the relationship between temperature and CO_2, including the following:

• improved analysis of ice core CO_2 record, including showing scatter and uncertainty in temperature relationship.

• justification of linear relationships for proxy CO_2 records when some seem to show a break in gradients, little relationship etc.

• why records that show very different development over the last 5 million years seem to have the same CO_2-temperature relationships.

• how ice core record can rule out stomatal records, when there is no overlap either in time or CO_2 concentrations.

• discussion of the implications of the formulation of the model and the retrodictions of past climate and CO_2.

References

Denton, G.H., Prentice, M.L., Kellogg, D.E. and Kellogg, T.B., 1984. Late Tertiary history of the Antarctic ice sheet: Evidence from the Dry Valleys. *Geology*, **12**, 263-267.

Hansen, J. et al., 2008. Target atmospheric CO_2: Where should humanity aim? *Open Atmospheric Science Journal*, **2**, 217-231.

Dowsett, H.J. et al., 2010. The PRISM3D paleoenvironmental reconstruction. *Stratigraphy*, *7*, 123-139.

Lunt et al., 2009. Earth System sensitivity inferred from Pliocene modelling and data. *Nature Geoscience*, **3**, 60-64.

Pagani, M., Liu, Z., LaRiviere, J. and Ravelo, A.C., 2009. High Earth-system climate sensitivity determined from Pliocene carbon dioxide concentrations. *Nature Geoscience*, **3**, 27-30.

Raymo, M.E., Lisiecki, L.E. and Nisancioglu, K.H., 2006. Plio-Pleistocene ice volume, Antarctic climate and the global δ^{18}O record. *Science*, **313**, 492-495.

Schoof, 2007. Ice sheet grounding line dynamics: Steady states, stability and hysteresis. *Journal of Geophysical Research: Earth Surface*, **112**, F03S28.

Spero, H., Bijma, J., Lea, D.W. and Bemis, E.B., 1997. Effect of seawater carbonate concentration on foramineferal carbon and oxygen isotopes. *Nature*, **390**, 497-500.

Talarico, F.M. and Sandroni, S., 2009. Provenance signatures of the Antarctic Ice Sheets in the Ross Embayment during the Late Miocene to Early Pliocene: The ANDRILL AND-1B core record. *Global and Planetary Change*, **69**, 103-123.

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