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Climate of the Past Discussions

Interactive comment on "Tropical seaways played a more important role than high latitude seaways in Cenozoic cooling" *by* Z. Zhang et al.

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In this manuscript, Zhongshi Zhang et al. study the climatic effect of various ocean gateways (high and low latitude) using a coupled ocean-atmosphere GCM. The control simulation is a run with Eocene continental geometry and high atmospheric CO_2 concentration (2400ppm) and it is integrated to equilibrium. Starting from this control simulation various sensitivity experiments are performed in which different gateways are opened or closed while all other boundary conditions are kept fixed.

The authors draw several main conclusions from the experiments:

- The opening of Drake Passage and the subsequent development of a (weak) ACC is not enough to explain a strong cooling or even initialize Antarctic glacia-

tion at the Eocene/Oligocene transition. This is in line with earlier studies as e.g. Huber et al. Palaeoceanography 2004 or DeConto and Pollard 2003, 2008. Also the other (northern) high-latitude changes are not sufficient to initialize a transition to a northern-hemisphere dominated deep-water formation pattern.

- In contrast, the two low-latitude gateways seem to have a much stronger impact on the global ocean circulation pattern and associated heat transport. When closing the Tethys seaway, the meridional overturning circulation in the simulations changes from a Southern Ocean deep water source to a North Atlantic deep water source with associated strengthening of northward heat transport and consequently warming of the northern hemisphere and cooling of the southern hemisphere.

While these are important conclusions and well performed experiments, I have the feeling that the conclusions drawn in the manuscript concerning the relevance to Cenozoic climate cooling remain very vague and sometimes involve circular arguments. The main problem I have with the experiments is the fact that the CO_2 concentration is kept at a very high level in all simulations, while some of them clearly represent Miocene times with significantly lower CO_2 concentrations. Therefore, I don't agree with the first referee in accepting this limited approach. I strongly recommend the authors to include at least some of their planned future experiments with lower CO_2 in this present manuscript. Otherwise the conclusions drawn from this paper remain speculative as to their relevance to real climatic events in the Cenozoic.

Specific comments:

- Although the Tethys seaway may have changed a little across the Eocene-Oligocene transition, I think it is too far fetched to claim that the simulations would indicate that such a small change could have triggered the SODW-NADW transition (Page 978, line 27-29). This can be claimed only if a simulation with some-

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what shallower Tethys and fully open Panama Strait would also show NADW dominated ocean circulation.

- Sijp, England and Toggweiler 2009 indeed use present day topography in their study, which leads to a relatively strong ACC once Drake Passage is opened. But they also show that the sensitivity to CO_2 changes is very different in their model with open or closed Drake Passage. This is an important remark, and could be also the case for the Tethys seaway. There fore, it is essential to include a simulation with lower (Miocene realistic) CO_2 in the series of experiments where the low-latitude gateways are closed.

- In addition, as the experiments are meant to span quite a long time, it may be necessary to include the widening of the Atlantic through this time. This could also have an impact on the preferred pattern of the meridional overturning circulation (von der Heydt and Dijkstra, 2008). The authors should at least comment on this issue.

- Page 967, line 6-10: It is indeed controversial when Drake Passage opened, but not only with respect to earlier opening, but there is also a later opening (20 Ma) being suggested by Eagles and Livermore 2002, Lagabrielle 2009.

- Page 973, line 22-26: This is indeed a typical pattern when the MOC changes and has also been observed in (simplified) model studies without gateways, even for the Eocene-Oligocene boundary (Tigchelaar et al. 2011).

- Page 974, line 7: I am puzzled by the fact that the Tethys outflow provides fresh water to the North Atlantic. The Tethys should have been a highly evaporative area, so why would there freshwater enter the Atlantic from there? In the simulations by von der Heydt and Dijkstra (2006) the opposite is the case. In the present manuscript this statement should be made more quantitative by evaluating the relative effect of Pacific or Tethys inflow.

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- Page 978, lin 1-17: A strong reduction of CO_2 across the E/O boundary may not be necessary, if the climate system such as ice-sheets reacts non-linearly to certain thresholds.
- Page 980, line 1-4: Earlier in the paper the authors state that a ocean circulation pattern transition induces warming in the North and cooling in the South with only weak global mean temperature changes. This is in contrast to what they say here! Please comment.

Interactive comment on Clim. Past Discuss., 7, 965, 2011.