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Climate of the Past Discussions

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Interactive Comment

Interactive comment on "Changes in terrestrial carbon storage during interglacials: a comparison between Eemian and Holocene" *by* G. Schurgers et al.

G. Schurgers et al.

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We would like to thank the reviewers for their remarks on our manuscript. As the main comments of both reviewers are along the same line, we would like to give some general comments to both reviews first, followed by more detailed answers to specific comments, and remarks about the changes made.

Incorporated processes and boundary conditions
Every model simulation of (paleo-) climate is limited in its representation of the actual state by processes not resolved by the model. In this sense, the simulations presented in the manuscript for the Eemian and the Holocene should merely be seen as an answer to the question "How much of the variations in atmospheric CO_2 concen-

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tration can we explain with the processes resolved by the model, and which important processes might be missing?" than as the best representation of the actual CO_2 concentration. We will not claim to know all processes that were important for shaping the CO_2 concentration, which is clear from the deviation of the simulated Holocene CO_2 concentration from the measured one. There are some important processes lacking, or some processes are not well-represented, and the fact that we underestimate the increase will mean that we should search for processes that emit (more) CO_2 during the Holocene. However, this would be a good reason for a sound discussion on the processes not resolved, which -regarding the comments of both reviewers- might have been a bit too short in the presented manuscript. Improvements to this will be made in the final version.

- peat growth (reviewers 1 and 2)

Peat dynamics are one of the major uncertainties for constraining the terrestrial carbon budget for the last thousands of years, and are potentially important as sink of carbon during the Holocene. However, peat storage would not be an additional sink in the model without affecting the other numbers, it would rather replace areas that are currently simulated to be covered mainly with boreal forests or grasslands. From Gajewski et al. (2001), figure 7, I derive an average density of about 20 kg C m^{-2} for peatlands in North-America and Eurasia, which is slightly less than the density of soil carbon for boreal forests as presented by the IPCC (24.7 / 34.4 kg C m^{-2}, Houghton et al., 2001), and slightly more than soil carbon storage for grasslands (9.9 / 23.6 kg C m^{-2}, Houghton et al., 2001). Compared to our simulation, it is less than soil carbon storage simulated by our model for most of the high latitudes. Smith et al. (2004) come up with a much higher density for the West Siberian Lowland (70.2 Pg C / 600,000 km^2 = 117 kg C m^{-2}), which is clearly above the estimates of the other biomes from the IPCC and the average density simulated by our model. The net effect of a simulated conversion into peatland is unclear, and might thus be minor when using the total Northern Hemisphere estimates by Gajewski et al. (2001). However, a density of the order of 100 kg C m^{-2} would increase carbon storage, even when replacing vegetation types

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with high soil organic carbon content. An offline sensitivity with peatland modelling, as suggested by reviewer 1, is unfortunately not quite possible, as for the simulation of atmospheric CO_2 concentration (which would be the main reason to include peatland) the whole model setup is required. More emphasis is put on the lack of peatland modelling, both in the model description and in the discussion.

- changes in weathering (reviewer 2)
Changes in weathering are not taken into account in our study. Release of CO_2 from weathering is prescribed at a fixed rate equal to the average sedimentation rate in the control run. Several studies were performed on glacial-interglacial changes in weathering (e.g. Munhoven, 2002), however during interglacials, when climate conditions are relatively stable compared to the glacial-interglacial changes, the assumption of a fixed rate seems reasonable. A remark on this is added.

- limitations of the dynamic global vegetation model (reviewers 1 and 2)
The vegetation model LPJ was developed to represent vegetation dynamics and land-atmosphere exchange of carbon and water at a temporal scale of up to 100 years. Processes much slower than this (e.g. soil formation) are not simulated. Neither is peat growth (see above), and soil organic matter dynamics are represented in a rather coarse way, which is mainly caused by the high uncertainty and the poor basis of observations for this. In this sense, there is no great difference with other studies on the terrestrial biosphere for the Holocene (Brovkin et al., 2002; Joos et al., 2004). A remark on this is added.

- ocean processes (reviewer 1 and 2)
A short summary of the ocean carbon cycle will be added, more details on this can be found in a later stage in a paper submitted to Paleoceanography (Gröger et al., submitted).

An extra paragraph will be included in the model description in the manuscript to describe these omissions of the model.

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Initial conditions

Setting initial conditions for paleoclimate experiments is hard, and can be of major importance for the outcome of the study. In the study presented, the initial state was derived from a pre-industrial control run (with a stable atmospheric CO2 concentration varying around 280 ppm and orbital parameters set for present-day conditions), followed by a 1000-year spinup for which the orbital parameters were changed according to 129-128 ky B.P. (Eemian) or 10-9 ky B.P. (Holocene), and for which the atmospheric CO2 concentration was allowed to develop freely (which resulted in a decrease of the CO_2 concentration for both Eemian and Holocene). As ice sheet dynamics are not incorporated and thus the melting of ice caps towards the interglacials is not represented, the spinup will never give a true development for these times. Besides that, as the model is computationally expensive, choosing for a longer spinup would mean to shorten the period to be presented as actual outcome. However, reviewer 2 is right that this means that especially the beginning of both simulations might be biased. A remark on this is added at the end of paragraph 2.1.

Eemian CO_2 concentration, figure 3 (Reviewer 1 and 2)

The course of Eemian CO_2 concentration is hard to determine from the few datasets available, especially because of the temporal resolution and the high variability. An important difference is that dating for the Eemian CO_2 concentration is much harder, which makes the timing of the decrease around 112 ky B.P. (this does not pop up in the figure, because our simulations run up to 113 ky B.P.) uncertain. Data from Vostok ice core record will be included in figure 3 for the final version.

Cold bias of the climate model in the North (reviewer 2)

The climate model has a cold bias in the high latitudes of the northern hemisphere, which is related to an underestimation of wintertime clouds over the Arctic. This influences the control state of the vegetation, as well as the insolation experiments (fig. 2). The cold bias causes carbon storage in boreal soils to be higher than observed, and local changes might thus be overestimated. A global consequence of this effect on the

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difference between insolation experiment and control experiment is hard to determine, and this is one of the uncertainties in the model. A remark on this will be added.

Title (reviewer 2)
We would like to adopt part of the proposal by reviewer 2 and change the title to "Dynamics of the terrestrial biosphere, climate and atmospheric CO2 concentration during interglacials: a comparison between Eemian and Holocene".

page 451, Brovkin et al. land carbon release
Carbonate sedimentation is added here.

page 454, line 1 (reviewer 2)
Will be changed to "with the soil temperature from the land surface scheme of the atmosphere model".

page 454, last para (reviewer 2)
paragraph will be shortened to one sentence.

page 455, line 9 (reviewer 2)
Units will be changed, and relative amounts will be given in brackets.

page 455, line 23 (reviewer 2)
"control run" will be replaced by "control simulation"

page 456, line 10 (reviewer 2)
Vegetation data will be replaced by vegetation reconstructions.

page 457, line 21 (reviewer 2)
Increase in ppm will be added in brackets. Pg C are used here to ease the comparison with the absolute changes in terrestrial and marine carbon storage.

Brovkin, V., Bendtsen, J., Claussen, M., Ganopolski, A., Kubatzki, C., Petoukhov, V., Andreev, A., 2002. Carbon cycle, vegetation, and climate dynamics in the Holocene: Experiments with the CLIMBER-2 model. Global Biogeochemical Cycles, 16, 1139,

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doi: 10.1029/2001GB001662.
Gajewski, K., Viau, A., Sawada, M., Atkinson, D., Wilson, S., 2001. Sphagnum peatland distribution in North America and Eurasia during the past 21,000 years. Global Biogeochemical Cycles, 15, pp. 297-310.
Houghton, J., Ding, Y., Griggs, D., Noguer, M., Van der Linden, P., Dai, X., Maskell, K., Johnson, C., 2001. Climate change 2001: the scientific basis. Contribution of working group I to the third assessment report of the IPCC. Cambridge University Press, Cambridge, United Kingdom.
Joos, F., Gerber, S., Prentice, I., Otto-Bliesner, B., Valdes, P., 2004. Transient simulations of Holocene atmospheric carbon dioxide and terrestrial carbon since the Last Glacial Maximum. Global Biogeochemical Cycles, 18, doi: 10.1029/2003GB002156.
Munhoven, G., 2002. Glacial-interglacial changes of continental weathering: estimates of the related CO2 and HCO3- flux variations and their uncertainties. Global and Planetary Change, 33, pp. 155-176.

Interactive comment on Clim. Past Discuss., 2, 449, 2006.