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Climate of the Past Discussions

Interactive comment on "Investigating the evolution of major Northern Hemisphere ice sheets during the last glacial-interglacial cycle" *by* S. Bonelli et al.

Anonymous Referee #1

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General comments

The paper of Bonelli et al. (2009) describes the effect of insolation and CO_2 on the glaciation and deglaciation of the main ice sheets in the Northern Hemisphere between 126 kyr BP and today. They use an Earth System model of intermediate complexity (CLIMBER 2) coupled to a 3D ice sheet model (GREMLINS), forced by reconstructed CO_2 and orbital changes. The article shows very interesting results on the different reaction of the Fennoscandinavian and North American ice sheet to CO_2 forcing during the last glacial-interglacial cycle.

The manuscript is very well written, the results and experimental procedure are well

presented, and it fits perfectly within the scope of CP. The simulation of the full last glacial-interglacial cycle with a model of intermediate complexity is novel and shows interesting results. However, as pointed out below in the specific comments, results from Calov et al. (2005a, b) should be discussed in more detail, as Calov et al. (2005a, b) used a very similar parametrization of dust in CLIMBER coupled to SICOPOLIS, and applied it to the last glaciation (126 kyr BP to 100 kyr BP), with different results in the spatial distribution of ice sheets than shown in Bonelli et al. (2009). A comparison with some of the results of Calov et al. (2005b) would be useful to understand the differences between the two simulations between 126 kyr BP and 100 kyr BP, would increase the confidence in the results presented here, and could help to further improve ice sheet models used to simulate the glacial-interglacial cycle. The article should therefore be published after minor revisions.

Specific comments

1. Page 1014: The abstract should mention the name of the climate model and of the ice sheet model used, as that will make it easier for interested readers to find the article when searching for articles using CLIMBER or GREMLINS.

2. Page 1015, line 4: Calov et al. (2005b) also showed the important effect of the ice-albedo effect on glaciations. Please add a reference to this article in the list of references cited here.

3. Page 1016, line 24: Please add a reference to Loutre and Berger (2000) to this list of references. They used the LLN 2-D NH model to simulate the last 200 ky, looking especially at the effect of CO_2 on the glacial-interglacial cycle.

4. Page 1019, line 3-6: In earlier versions of CLIMBER, the snow aging process might not have been accounted for. However, in later versions of the model (i.e. CLIMBER 2.3, which is used here, as well as in many other more recent studies, e.g. Calov et al. (2005a, b), Claussen et al. (2003, 2006), Jahn et al. (2005),

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Kubatzki et al. (2006)) the snow albedo depends on the surface temperature and snow age (see section 2.3 in svat.f of the CLIMBER 2.3 source code), and, if coupled to the ice sheet model SICOPOLIS, contamination by dust is also accounted for (see Calov et al. 2005a). Some important processes affecting the ice sheet mass balance are still missing, but the ice age and temperature effect on the snow albedo is accounted for. Please adapt this statement accordingly.

5. Page 1019, line 12 to page 1020, line 7: A very similar parametrization of the effect of dust on the snow albedo was already used in Calov et al. (2005a, b), and needs to be cited here. The only difference between the parametrization used here and the one used by Calov et al. (2005a, b) appears to be that Calov et al. used a weight based on the ice volume at a given time compared to the LGM ice volume, whereas here the weight is a function of the atmospheric CO_2 variations. In order to be able to use this parametrization in other models, it would be useful to give the details of how the weight is calculated here. The reasons for choosing a different weight than Calov et al. (2005a, b) should also be explained. Calov et al. (2005b) also show in detail how the inclusion of the dust improved the simulation during glacial times, which should be mentioned here.

6. Page 1019-1020: Since Calov et al. (2005a, b) used the CLIMBER-SICOPOLIS model for studies of the glacial inception, with some difference in the results compared to the results presented here, it would be helpful for the reader to briefly mention how the GREMLINS model differs from SICOPOLIS.

7. Page 1027, line 8-21: In Calov et al. (2005b), it was shown that the inclusion of the dust parametrization helped to reduce the occurrence of ice over Alaska, bringing the model in better agreement with observations. It would be good to know whether this is also the case here, or which other model or forcing differences (e.g., slightly different CO_2 forcing dataset and slightly different dust parameterization) might contribute to these differences in the simulation of the ice

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sheets, since in both cases the ice models are forced by CLIMBER. Based on the outcome of this analysis, the last sentence of the paragraph should be adapted, since the glaciation of Alaska in the CLIMBER-GREMLINS model appears to not only be due to the coarse resolution of the climate model if the simulation with CLIMBER-SICOPOLIS shows a smaller glaciation of Alaska.

8. Page 1027, line 22 to page 1028, line 2: As noted above, the simulated ice cover in CLIMBER-SICOPOLIS in Calov et al. (2005b) differs significantly from the one produced by CLIMBER-GREMLINS, also in regards to the formation of ice over Hudson Bay, which occurs by 110 kyr BP in CLIMBER-SICOPOLIS (see Fig 3 and 4 in Calov et al., 2005b). A more detailed analysis should be performed to explain these differences, especially since the initial conditions (start at 126 ky BP, 5 kyr integration under 126 kyr BP forcing) and the forcing for the two experiments are almost identical.

9. Page 1037, after line 10: Either in section 4.2 (or a new Discussion section 4.3), the results from the sensitivity study of the CLIMBER-GREMLINS model should be compared with the other studies mentioned in the introduction (page 1016) that also simulated the last glacial-interglacial cycle (or parts of it), to show whether the larger sensitivity of the Fennoscandinavian ice sheet to atmospheric CO_2 (compared to the North American ice sheet) is a new results, in contradiction to earlier results, or in agreement with earlier results obtained by simpler models.

References:

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Loutre, M. F. and A. Berger (2000), No glacial-interglacial. cycle in the ice volume simulated under a constant astronomical. forcing and a variable CO_2, *Geophys Res Lett*, 27(6), 783–786.

Technical. corrections

- Page 1026, line 15: Should be Calov et al. (2005a, b) (two Calov 2005 papers in reference list, but not clear which one this reference links to).
- Page 1027, line 1: precipitation is (not precipitations are).
- Page 1034, line 22-23: ; "on the contrary, this..." Meaning is not clear. Contrary to what? Please clarify.
- Page 1040: line 10 and 13: missing ‘n’ in Claussen, and should have a) and b) to make clear which Calov et al. 2005 article is meant when cited in manuscript

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