Clim. Past Discuss., 5, C367–C371, 2009
www.clim-past-discuss.net/5/C367/2009/

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.

S. Bonelli

stefano.bonelli@lsce.ipsl.fr

Received and published: 22 June 2009

We would like to thank reviewer #3 for his/her constructive comments. We agree in particular with the fact that the addition of a discussion section would benefit the manuscript. This has now been done in the revised version of the paper. For the specific suggestions, please see the list below.

(1) Explanation on the climate: The work uses a coupled model, which is more than a energy balance model, to simulate the ice sheet evolution. For readers' understanding, more information on the performance of climate is needed than just showing the temperature in Fig. 3 for 3 time slices in the beginning of the ice age cycle. At least the

climate at present day (0ka, by showing the difference from the observation) and the LGM (at 21 ka, by showing the difference from 0ka) as many studies including PMIP experiments used in several works driving ISMs. It would help understanding the climate, since there are several sentences, saying the model has problem simulating the Kuroshio influence and the Rockies etc... The information may explain the missing ice sheet over Canadian archipelago or the overestimation in Alaska. We agree. We have now produced a new figure (Fig. 5) showing the simulated summer (JJA) surface air temperatures for the LGM, for present-day conditions, as well as those inferred from observations (0 ka, CRU dataset).

(2) Dust in the sensitivity study: The sensitivity study aims to show the relationship between the external forcing and the evolution of ice volume. It is not shown, however, whether the dust was changed when the change of CO2 was prescribed. Does the dust follow the equations in section 2.1 in every case? Does that mean the model is driven by both orbit and dust in the sensitivity studies? Please explain and discuss about the dust since it is important to understand the mechanism of termination of the ice age. The effect of dust on ice evolution is now discussed in the revised paper (sections 2.1 and 5). For further discussion please see point 7, answers to comments by reviewer #1. Concerning dust parameterization in the sensitivity studies, this is now described in section 4.1. The dust weight is always based on the CO2 concentration inferred from Petit et al. (1999), so that dust is the same for all the experiments. By doing so, we can compare similar simulations to each other, with atmospheric CO2 (or insolation) as the only difference.

(3) The model has several changes from the previous studies by authors but the role of changes are not described. Please explain it. Why was the coupling method changed from kageyama 2004? This is helpful for other modellers to improve their models. Compared to Kageyama et al. (2004), the coupling method now includes the freshwater flux from the ice sheets towards the CLIMBER oceans, as well as a parameterization to compute the inversion above the ice sheets. This has been done to include this phe-

nomenon in the coupled model, as well as the freshwater feedback that was previously missing. These changes are described in the section 2.3 of the revised paper. For further discussion on the inversion parameterization, please see point 8.

(4) The work shows an underestimation of ice volume near the North Atlantic, but how is this related to the NADW in the study? How is the NADW in this work? How is the time series of the strength of NADW if it is important? The underestimation of ice volume near the North Atlantic is correlated with surface air temperatures, as shown in Fig. 3 for different snapshots. Indeed, in the early phase of glacial inception, summer surface air temperatures are mostly positive, between 5 and 10 °C in most coastal high-latitude areas (at 123, 115 and 70 kyr BP). This may be linked to strong ocean circulation, since the simulated NADW intensity ranges between 23 and 27 Sv during most of the glacial period (126 kyr – 21 kyr BP). An abrupt increase of the NADW is observed around 14 kyr BP. This increase is correlated with the melting of LIS. NADW then progressively shuts down until 8 kyr BP due to the freshwater flux from LIS. At 0 kyr BP, it has not completely recovered (10 Sv). We have now performed a new experiment where the freshwater flux from ice melting is inhibited; the main difference with the standard test is represented by the fact that NADW does not switch off around 14 ka BP. Its effect on glacial build up is negligible, whereas the melting of the Laurentide ice sheet is anticipated by $\sim$ 2 ka when the freshwater flux is blocked.

(5) How was the basal sliding (in section 2.2) treated? Is it related to the result of rather thick ice sheet of 4000m? Basal sliding is treated as described in Ritz et al. (1997). Sliding is possible only if the basal ice reaches the melting point; on the contrary, when the ice base is below the melting point basal velocity is set to 0. GREMLINS implements the following basal velocity law:

In the present study, the sliding coefficient k is set to 0.4 x 10-5 m a-1 Pa-2. We have performed various tests on basal sliding parameterization; the coupled model produces thick ice sheets ($\sim$ 4000 m) also in case of higher sliding coefficients k.

(6) Please discuss the mechanism that makes the difference between Laurentide ice sheet and FennoScandian ice sheet. A possible explanation may be represented by the influence of the Atlantic Ocean on regional climate, which contributes to mitigate the temperature of nearby regions as Europe and the Quebec-Labrador sector (Fig. 3c for the BSL run). Therefore, to trigger an extensive, long-lasting glaciation, a further cooling due lower CO2 concentrations needs to be added to the orbital forcing, since its effect is partially counterbalanced by ocean mitigation. In the BSL run, long-lasting FIS is simulated when pCO2 remains below 220 ppm. Conversely, with the exception of the Quebec-Labrador sector, the North American ice sheet is less influenced by the presence of the Atlantic Ocean and is characterized by a more "continental" climate: in central areas, the effect of the solar forcing is not buffered by ocean mitigation, and surface temperatures are more strongly dependent on insolation changes. This is now added in the revised version of the paper. A verifier par rapport aux figures.

(7) Please create a section of "Discussion" for discussion since there is only conclusion and summary after the result. Please discuss about the result compared to other previous studies which simulate the ice sheet evolution for the last 125 kyr such as Berger and Loutre (1999), Tarasov and Peltier, (1997, 1999) Charbit et al, (2007), Abe-Ouchi et al. (2007). We agree. As also suggested by reviewer #1, we have now added a new section "Discussion" (section 5) in the revised version of the paper, where our results are compared with those of previous studies.

(8) How is the lapse rate calcluated and how is the result? (section 2.3) The atmospheric lapse rate is calculated as described in Petoukhov et al. (2000); to this calculation has now been added a parameterization to take into account the inversion phenomenon, in order to compute the lapse rate above the ice sheets. This procedure is described in the revised version of the paper (section 2.3). This parameterization contributes to improve the model performances in the first phase of the glacial inception (i.e. it favors glacial onset). The simulated NH ice volume at 110 ka BP is of 14.5 x 1015 m3 for the standard simulation described in the paper, whereas it is of 12.5 x

10^{15} m3 when inversion is not accounted for.

Interactive comment on Clim. Past Discuss., 5, 1013, 2009.