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Climate of the Past Discussions

Interactive comment on "Using beryllium-10 to test the validity of past accumulation rate reconstruction from water isotope records in East Antarctic ice cores" *by* A. Cauquoin et al.

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Firstly, we want to thank all the referees for their comments that help to improve the quality of the paper. We give some answers hereafter for the main comments on the different aspects of the paper addressed by the different referees and will take all comments into account in the revised manuscript. We will send another reply listing in

detail all the corrections made in the manuscript during the revision process.

1 - ^{10}Be Data

L. Sime: It is not clear why the interval of 269-355 kyr BP was selected for the study. It would appear that uncertainties on all aspects of the work would be reduced if the interval was longer, and particularly if it contained the more recent LIG and LGM. Please provide an explanation for the 269-355 kyr BP interval.

The reason of the selection of interval 269-355 ka for this study is that these data have been prepared and measured by A. Cauquoin in the framework of his PhD. It completes a high resolution ^{10}Be record between 170 and 800 ka at EDC that will be published separately (Raisbeck et al., in prep). Two advantages of using the period 269-355 ka for this study are (1) it has the largest glacial-interglacial range of δD and thus estimated temperature and accumulation (see below), (2) it has relatively small geomagnetic variations, as compared for example to last climatic cycle (Blake and Laschamp excursions). Thus the sensitivity of ^{10}Be concentration due to accumulation variations compared to those due to production variations should be particularly favorable.

E. Wolff: I also echo the comment by Parrenin about data availability. I request that the dataset of ^{10}Be concentration at least (but preferably the derived datasets of flux as well) be placed either on the CP website as supplementary material, or at a recognised open database (NCDC palaeo, or Pangaea) with a link in the paper to where it can be found.

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It was planned since the beginning to add the data as supplementary material (txt and xlsx files) on the CP website.

2 - Accumulation reconstruction from ^{10}Be

2.1 - General message of the paper

F. Parrenin: The fact that deuterium underestimates accumulation for the optimum of MIS 9.3 is perfectly in agreement with the study by Parrenin et al. (2007, "1D...") which suggested that deuterium-based reconstructions underestimate accumulation for the optimum of the Holocene. This certainly should be mentioned in the manuscript because it gives more strength to one of the main discovery.

L. Sime: The authors find some intriguing results. Whilst they show that differences between the reconstructions are mostly small, which is indeed quite reassuring, they also find that accumulation rates during peak warm intervals are underestimated by around $\sim$1 cm-ie-yr-1 when based on water isotope measurements. These low warm period water isotope based accumulation rates are underpinned by the traditional water isotope - temperature conversion. I think this result is quite noteworthy, since if read alongside the 0.23cm-ie-yr-1K-1 conversion rate, it implies that water isotope based temperature reconstructions of optimum temperature over the MIS 9.3 peak warmth may be underestimated by 3-4K. Given the paucity of other peak interglacial ice core based temperature information, this result seems worth highlighting.

Anonymous referee #3: I was also wondering if LGM/Holocene climate can be compared to MIS-10/MIS-9 climate. This is implied in the model-data comparison. A key

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sentence in this context is: "Still the accumulation rate vs. temperature slope reconstructed from water isotopes in ice core is the same for the transition between MIS 10 and MIS 9 and the last deglaciation". This sentence needs more explanation or at least a reference.

The initial philosophy of this paper was to compare the relationship mean interglacial – mean glacial period inferred from water isotopes and our ^{10}Be data for the MIS9-10 with the CMIP5-PMIP3 outputs. We did not look at warmer periods than pre-industrial because CMIP5-PMIP3 outputs were not available for periods like the optimum of the Holocene, MIS 5.5 or the optimum of MIS 9.3. Still, we agree that the reconstruction proposed here from ^{10}Be data suggests a significant increase of accumulation rate (and possibly temperature) not in line with prediction by water isotopes. We will thus follow the suggestion of the referees to expand this result both in the abstract and the conclusion, mentioning references suggested by Sime and Parrenin.

2.2 - Constant flux approach

The constant flux approach includes a geomagnetic field intensity correction on ^{10}Be concentration in ice. One can deduce then the resulting accumulation rate with Accumulation = Flux (= 53.44 at.m^{-2}.s^{-1}) / [^{10}Be concentration (corrected for radioactive decay and geomagnetic modulation) x density of ice]. The optimum of MIS 9.3 is 4.03 and 4.66 cm-ie/yr for the EDC3 and ^{10}Be-based accumulation rate reconstruction respectively (so $\sim$3K of difference when using the 0.23 cm-ie.yr^{-1}.K^{-1} slope). This underestimation concerns only the MIS 9.3 interglacial maximum. We will insist on this

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result in the conclusion of the paper.

2.3 - Adjustment of β

Anonymous referee #3: In spite of these uncertainties, I think the approach by Cauquoin et al. is interesting. Varying the δD-accumulation rate relationship according to formula 5 to minimise the residual ^{10}Be flux variance is an interesting approach and could indeed provide useful information on the δD/accumulation rate relationship (again assuming that dry deposition is the only process for ^{10}Be deposition). However, this approach needs to be explained (how has it been done).

Using the equation (5) $A = A_0 \exp(-\beta \Delta\delta D)$ with A the EDC3 accumulation rate from Parrenin et al. (2007a, b) and A_0 = 2.841 cm-ie/yr, we have added a correction factor "$corr$" in the exponential of the equation (so $A = A_0 \exp(-corr\ \beta \Delta\delta D)$) and applied this "optimized" accumulation rate to calculate ^{10}Be flux from ^{10}Be concentration in ice. By varying the value of this correction factor "$corr$", we modify the ^{10}Be flux record (previously corrected for geomagnetic field intensity changes) and so its variance. So one can deduce the necessary correction by minimizing as much as possible the variance of the resulting ^{10}Be flux.

F. Parrenin: It is not clear how β was tuned to obtain the value of 0.0160-0.0171 given in p. 3433, l. 5 (note that the line numbers are incorrect on CPD print version). Again, this needs more explanations and maybe a figure.

The interval of "$corr$" x β between 0.0160 and 0.0171 corresponds to a variation of the ^{10}Be flux variance by less than 1% around its minimal value. All these precisions will

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be integrated in the revised version.

3 - GCM experiments

F. Parrenin: Regarding GCM experiments, I disagree with the statements made in the abstract and in the conclusion that the temp-accu relationship is comparable when using ice core data and AGCM simulation. People will take as bring-home message that AGCM work, but this is far from being true. The spread of AGCM results and the difference with the deuterium-based and Be-10 reconstructions are so large that my personal conclusion is that "AGCM do not work well for simulating the temperature-accu relationship (although they work in average and some work) and they need to be improved in the future".

L. Sime: The analysis of the GCM results shows that there is a rather wide spread in the accumulation versus temperature (preindustrial to LGM) relationships within the CMIP5 model dataset. The authors might conclude from this that some current CMIP5 models are not yet accurate at simulating changes in polar precipitation during large climate shifts.

We have stated in the conclusion that “Finally, the relationship between temperature and accumulation rate is comparable when using water isotopic inferred data and results from several AGCM simulations for LGM–PI climate changes despite a larger spread in the model outputs.” In the revised version, we will not only mention the relatively good agreement between the average accumulation rate vs. temperature slope of the models with the different reconstructions, but also highlight the large spread of the different models. We will more strongly insist that some current CMIP5-PMIP3 models do not accurately simulate changes in precipitation on the Antarctic plateau between

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glacial and interglacial period, and need to be improved. To avoid any misunderstanding, we have decided to use the terminology "CMIP5-PMIP3 output" as suggested by the referees. The control runs are preindustrial, as will be corrected in the manuscript.

4 - ^{10}Be dry deposition statement

Anonymous referee #3: As already commented by F. Parrenin the whole ^{10}Be discussion relies on the assumption of dry deposition being the determining (and only) process for ^{10}Be deposition. This can be questioned considering that the reconstructed accumulation rate changes by a factor of 3 over a glacial-interglacial cycle i.e. making it likely that the deposition processes could also change. I think this possible problem needs to be discussed in much more detail. This uncertainty also implies that the ^{10}Be approach is not a strict "test" for the validity of other reconstructions (as implied by the title). It is rather very useful additional information that can support or question other approaches. I think this has to be reflected in the title.

While we have indeed stated (and believe) that ^{10}Be falls mainly by dry deposition on the Antarctic plateau, our analysis does not depend on this assumption. It depends only on the assumption that the ^{10}Be flux is constant. One possible explanation for this hypothesis on the Antarctic plateau is that ^{10}Be in the ice sheet is dominated by dry deposition (Yiou et al. 1985). As noted by Yiou et al. (1997), and pointed out by reviewer #3, such an explanation is unlikely for Greenland, where dry deposition is probably much less important. In that case, an alternate possibility is that global (or at least polar) precipitation rates are inversely correlated with polar temperatures (Raisbeck et al. 1981; Yiou et al. 1997). Once again this would lead to an anti-correlation between ^{10}Be concentration and accumulation rate. Concerning the title,

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we suggest “Comparing past accumulation rate reconstruction in East Antarctic ice cores using ^{10}Be, water isotopes and CMIP5-PMIP3 models”.

5 - Geomagnetic field correction

Anonymous referee #3: I think it is necessary to explain the details of the underlying assumptions for the geomagnetic field correction. Is it assumed that the ^{10}Be record reflects the globally averaged ^{10}Be production rates? Is a “polar bias” assumed? Are the records normalised before the geomagnetic field correction (i.e. only relative changes considered).

Concerning the different assumptions for the geomagnetic field correction on ^{10}Be flux, we have assumed that ^{10}Be record reflects the globally averaged ^{10}Be production. We have however also carried out calculations using the “polar bias” assumption (polar ^{10}Be flux 20% less sensitive to geomagnetic field intensity changes, Field et al. 2006), the difference in the accumulation reconstructions is negligible.

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