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Climate of the Past Discussions

Interactive comment on "New constraints on the gas age-ice age difference along the EPICA ice cores, 0–50 kyr" *by* L. Loulergue et al.

Anonymous Referee #3

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Review of "New constraints on the gas age-ice age difference along the EPICA ice cores, 0-50 kyr" by Loulergue, L., Parrenin, F., Blunier, T., Barnola, J.-M., Spahni, R., Schilt, A., Raisbeck, G, Chappellaz, J.

General remarks

This paper presents new empirical constraints on ice-gas age difference (delta age), an important quantity for precise estimates of leads and lags between greenhouse gases and climatic changes recorded in polar ice cores. The uncertainty of the delta age is particularly large for Antarctic inland ice cores (Dome C, Dome Fuji, Vostok) and thus seriously obscures the estimation of the leads/lags. This study uses new CH4 data from EDC and EDML ice cores to better synchronize the gas age scale

to well determined Greenland age scale, and also fine 10Be peak structures at the Laschamp event (˜40 ky BP) to constrain the ice age scale, in order to empirically constrain the delta age around that period for EDC and EDML cores. They found a large overestimation of the delta age by a densification model in comparison with the empirical delta age. They also use delta depth (depth difference for the same age of gas and ice) in order to identify the cause of the discrepancy. Their analyses point to error (missing or misrepresented processes) in densification models as the source of the error of the delta age. The result has an important implication that the lag of CO2 behind Antarctic temperature at the onset of the last Termination, estimated to be 800+/-600 years by Monnin et al. (2001, Science), may actually be much smaller.

The paper makes important advancement on the enigmatic delta age problem, which eventually has to be accurately estimated to investigate the leads/lags for Termination II and older, where Antarctica-Greenland synchronization is not available. On the other hand, this paper is rather a technical one, so that it needs improvements in terms of clarifications of numbers used for calculations and of results. It also needs, in introduction and discussion, to make clearer what are the important contributions of this study are for reducing the delta age error, as well as for climatic implication. Therefore, this paper should be published after minor but many improvements mainly in terms of clarifications.

Specific comments

(The page, section and line numbers are referred according to the corrected manuscript sent to the reviewer through the editor, thus may not be the same with those in the manuscript publicly available online.)

Introduction

The first two paragraphs are on N-S synchronization, which seems not the central issue discussed in this paper (although it is an important tool in the paper). I therefore suggest moving them to later. A paragraph explaining delta age and its current limitation

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on the climatic interpretations should be described first.

P. 3

3rd paragraph: Please give first the definition of delta age, and how to estimate it in different ways.

3rd paragraph, 5th line; This is not a useful description. Please give numbers for 'small and well determined' delta age in warm and cold periods. Do not assume the readers familiar with the magnitude of delta age for every core. Try being as exact as possible throughout the paper, as the technical details are important in this paper.

3rd paragraph, 6th line; Please give number for "high accumulation rate".

P. 4

1st line; suggestion for change, "determined accurately for Greenland ice cores by gas measurements".

Put somewhere in introduction the description about lead/lag between Antarctic temperature and CO2 for terminations to explain the importance of accurate estimate of delta age. It is necessary as it is described in abstract and discussion.

2.1. 1st line; The definition of delta age and delta depth should come earlier where it is presented first.

P.5 3rd paragraph; Please give the ages of the sulphate markers.

P.6

2nd paragraph Spell out "WE". Unit for accumulation rate should be consistent throughout the paper (water equivalent or ice equivalent, or kg/m2 to follow the SI system).

What is meant by 'smooth modifications'?

Please quantify the 'some artifacts of the accumulation rate'. Also, it is not clear if EDC or EDML is discussed here, because you mention EDML accumulation rate in the

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previous sentence.

2.3. Please give the final data resolution for DO 8-11.

2.4.

1st paragraph Please detail "full structure of the peak". How many sub-peaks can you identify distinctively, and how many do you actually use for the matching in this paper?

Please give the number for the synchronization uncertainty from the reference paper.

2nd paragraph Please give exact depths for the volcanic layers.

Please clarify what is 'corresponding relative depths'.

3.1.

First paragraph Isn't the uncertainty of 35 yr only for the depth of the volcanic signal? How large is the uncertainty at the depth of the methane signal?

Is the age broadening due to gradual bubble close-off process taken into account for the matching? The mid-transition for abrupt change at lower accumulation site could be delayed because of the heavier smoothing function. It could matter if the paper is dealing with less than 100yr of difference. If such error is not significant, please clarify that. In general, the authors should give exact numbers for quantities and state how it is significant for the final result.

2nd paragraph

1st line; The comparison for Laschamp event appears only later, so this sentence does not convey the meaning.

2nd line; suggestion for change, "only relative. Namely, it cannot provide independent validation on the absolute numbers of delta age, because systematic errors in both cores could lead to an incidental agreement of the gas timescales of the two cores."

3.2.1. Please quantify each error.

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3.2.2. Please quantify each error.

5th line from the last; What is the reason that EDML Ddepth error is twice as that of EDC despite the fact that Ddepth itself is only half?

4.

You should be able to give number for glacial-interglacial temperature amplitude that can account to eliminate the error of the delta age and delta depth. The same is true for accumulation scenarios. It would be valuable to give such numbers and discuss their feasibility, not only to test a few scenarios. I suggest categorizing the modification of the climatic parameters into two sections, (4.2) fixed relationship of temperature and (4.3) accumulation rate to the basic scenatio, after the description of (4.1) basic scenario.

4.1.

2nd paragraph; Why do you present the number like 1/6.04 (not decimal number)?

3rd paragraph; Replace "get worse" with "increase".

Last paragraph; Please give numbers also in years for the empirical error estimate (for the following ones too). Ultimately the error in years is important for comparing records for an climatic event (e.g. onset of Termination).

4.2.

1st paragraph; “with a factor 1/a=7.13 L’/K.” Is there a mistake here?

1st paragraph, Last sentence; Please detail this sentence and give appropriate references for borehole temperatures.

P.10, top line; Replace "a little bit" with "slightly". Please give numbers for Delta depth error for EDC and EDML.

4.3. 2nd paragraph, 3rd line; Missing EDML values? Please give numbers also in years.

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4.4.

1st paragraph; What is the reason to use these values (0.0094 for EDC and 0.0120 for EDML)?

3rd paragraph Ambiguous expression ("almost or well within").

What is the meaning of the last sentence of this paragraph? Did you conduct a new inversion calculation with the ice flow model of Parrenin with reduced accumulation amplitude?

4th paragraph 4th line; Replace “a wrong” with “an error in the”.

Please clarify the last sentence of this paragraph.

5.

I suggest giving first the three possibilities (assumptions) to account for the error of delta age and delta depth, to guide the discussion. Examples: (1) correct densification model, incorrect temperature in the glacial. (2) correct densification model, incorrect accumulation in the glacial. (3) incorrect densification model, correct temp and acc.

2nd paragraph, last word; replace “scenario” with “error”.

P.12

3rd paragraph You should state here that the error estimate in Schwander paper (also used in Monnin paper) are likely too small. It is important to make your contribution clear to readers.

I agree that the densification models may be missing important processes, but I disagree with the description in the manuscript. The model may be valid for present condition only for the sites used for calibration of the parameters. For example, the densification models constrained by Vostok and Dome C (and other warmer sites) conditions significantly overestimate the close-off depth at Dome Fuji (see table in Landais

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et al., 2006 QSR), which leads to overestimation of delta age at this site already for present condition. Thus, the error is clearly not restricted to the 'uncalibrated' conditions.

P.13, 4th line; after the all above discussions, this statement seems too weak. It seems very important to argue to broad climate scientists that the previous CO2 lag estimate should likely be reduced.

6. 2nd paragraph; It is not clear if it could be "well become a lead" and by how much. Give more quantitative discussion in the discussion chapter, or change the description to something like "should be significantly smaller than previously estimated".

Editorial problem

I do not see some of Greek letters in the file I reviewed.

Interactive comment on Clim. Past Discuss., 3, 435, 2007.