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Climate of the Past Discussions

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Interactive Comment

Interactive comment on "Rapid changes in ice core gas records – Part 2: Understanding the rapid rise in atmospheric CO_2 at the onset of the Bølling/Allerød" *by* P. Köhler et al.

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One important open question in the submitted manuscript raised by reviewer #2 was on the principle understanding of the filter function which we used to mimic the gas enclosure procedure of atmospheric CO_2 in the EDC ice core. Although the lognormal function which we applied as the age distribution PDF of CO_2 was fitted to the output of a firn densification model and the chosen width E of this function was for the onset of the Bølling/Allerød warm period also determined by a firn densification model it would certainly be a major support of our approach, if the behaviour of the filter can be tested against artificial and real data.

This was discussed extensively and in detail during the interactive discussion. However, since many arguments for and against the reliability of the filter were exchanged in various response letters (partly because of rather unclear descriptions of our performed test, partly because of not justified interpretation of the test) we feel that a brief summary of our position helps to clarify here.

1. Target of the suggested test:

The behaviour of the filter can be tested on the abrupt rise in atmospheric CH_4 which occurs in parallel to the abrupt rise of atmospheric CO_2 around 14.6 kyr BP. For this test the CH_4 record in an ice core with highest accumulation rate (namely a composite record from Greenland) might serve as a substitute for atmospheric CH_4. Applying the chosen filter function for the EDC ice core gas enclosure to ice core CH_4 record should provide a similar temporal behaviour — a similar slope or gradient m — to that recorded in CH_4 in EDC. Performing the same test not only on the Greenland composite CH_4 record but also on other ice cores might in principle extend the robustness of the filter, but the lower accumulation rates in Antarctic ice cores (implying also a lower temporal resolution) have already large effects on the recorded CH_4, which implies further difficulties in the interpretation .

2. Requirements of the suggested test:

It is essential that the gas enclosure characteristics in terms of age distribution PDF are similar for CH_4 and CO_2. This seems to be the case based on the output of a firn densification model (Joos and Spahni, 2008).

3. Limitation of the suggested test:

3.1. Because of the gas enclosure of CH_4 in Greenland already changed the true original atmospheric signal, a principle understanding of the filter is necessary. This can be obtained by using an artificial CH_4 time series as input data to the filter. Thus, by filtering for conditions typical for the EDC (*step a*), for Greenland (*step b*) and then finally by filtering the output for Greenland of *step b* a second time with conditions typical for EDC (*step c*) we can generate two artificial time series whose behaviour in terms of the slope m can be compared with that of the ice core data of Greenland and EDC.

The difficulty of this comparison of the behaviour of the filter for artificial and real input data is that the comparison works best, if the artificial CH_4 is as similar as possible to the original atmospheric CH_4 peak. However, this is not known, and thus the slope m in the artificial data can only be estimated to lie somewhere between infinity (instantaneous rise of CH_4) and the slope calculated in the ice core CH_4 data with highest accumulation rate (Greenland, $m = 171$ ppbv per century).

3.2 This comparison is further complicated by a potential interhemispheric gradient in CH_4. Although data analysis suggests a stronger interhemispheric gradient in warm interstadials than in cold stadials (Dällenbach et al., 2000), the change in the interhemispheric gradient in CH_4 in the very narrow time window of the transition into the Bølling/Allerød warm period is not precisely known (Brook et al., 1999).

3.3. Checking if the filtered Greenland CH_4 time series fits onto single CH_4 points measured in EDC is not meaningful, because the filtering affects the age model of the time series, which needs to be corrected accordingly.

3.4. For our problem at hand, which fosuses on the transition into the Bølling/Allerød warm period, the behaviour of CH_4 and the usability of the applied filter function at other times, e.g. at the beginning and the end of the Younger Dryas, is not of importance.

4. Results of the suggested test:

Within the given limitations and estimated uncertainties (typical CH_4 measurement uncertainty of 10 ppbv; 20% uncertainty in the suggested widths E of the age distribution PDF; ignoring errors and uncertainties in the gas age models) the filter produces slopes in the artificial CH_4 peaks which are similar to those of the ice core data (see Table and Figure). The artificial CH_4 did not include an interhemispheric gradient in CH_4 and therefore the difference in the slope Δm between Greenland and EDC should be larger or similar in the analysis of the ice core data than in the artificial data. This difference in the slope depends on the original slope of the assumed artificial atmospheric CH_4 and this knowledge can be used to suggest, that the slope m of the assumed artificial atmospheric CH_4 was likely smaller than 400 ppbv/century, probably m was between 200 and 350 ppbv/century.

We therefore conclude that the filter passed the suggested test and that the application for the rapid rise in CO_2 during the onset of the Bølling/Allerød warm period is well justified. This test based on ice core CH_4 data is therefore a very reliable support for our assumed gas enclosure characteristic assumed for the rapid rise of CO_2 into the Bølling/Allerød.

References

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CPD

6, C853–C858, 2010

Interactive Comment

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Slope m of CH_4 rise at onset of BA warm event in ppbv per century

ice core	ice core data original	artificial peak with different m: $m = 2000$	$m = 400$	$m = 250$
Greenland	171 ± 15	234 ± 50	181 ± 24	146 ± 15
Greenland filtered to EDC	28 ± 5	32 ± 7	32 ± 6	33 ± 7
EDC target	39 ± 4	36 ± 8	36 ± 5	35 ± 7
Δm difference (Greenland – EDC)	132 ± 16	198 ± 51	145 ± 25	111 ± 17

Interactive comment on Clim. Past Discuss., 6, 1473, 2010.

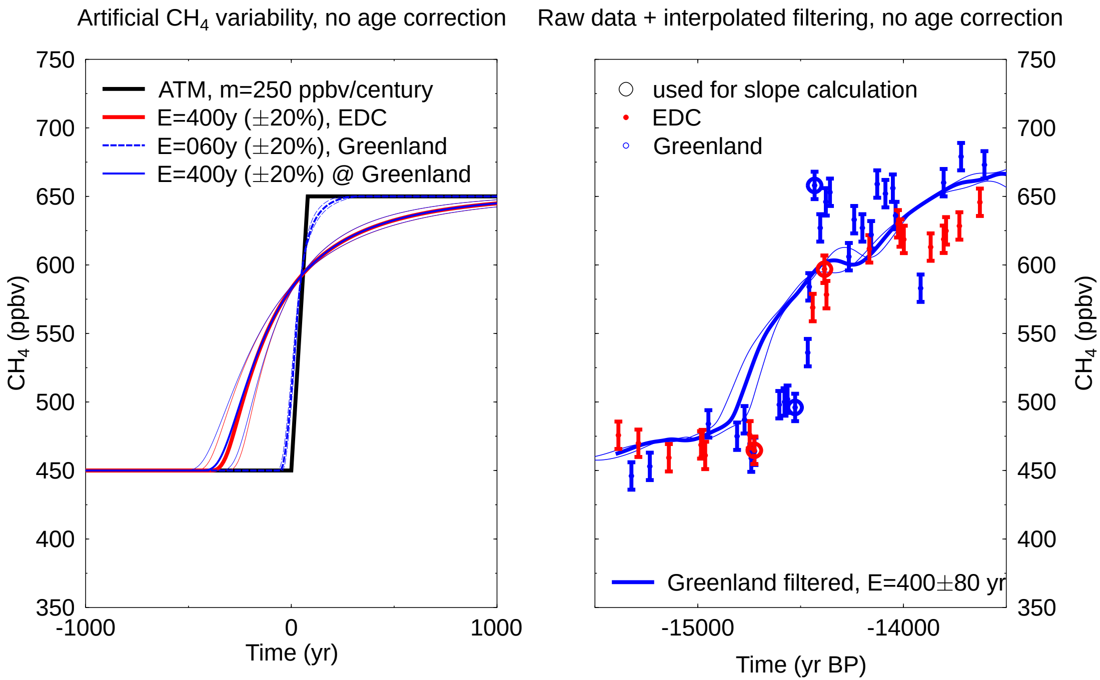

Fig. 1. Left: Artificial methane peak, filtered with the lognormal function with various E. Interhemispheric gradient in methane is not considered. Right: Ice core raw data and Greenland filtered data

CPD
6, C853–C858, 2010