

Interactive comment on “A new Himalayan ice core CH₄ record: possible hints on the preindustrial latitudinal gradient” by S. Hou et al.

S. Hou et al.

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Thanks to Referee 1 for giving a number of useful comments. In the following, comments are addressed in the same order as in the review.

The manuscript by Hou et al. presents and discusses results of atmospheric CH₄ mixing ratios, analyzed in two ice cores recovered from the Himalayan East Rongbuk Glacier on Mt. Qomolangma (Everest). The derived CH₄ record is spanning the last 1200 years, but the major part of the record is affected by artifacts which are assumed to originate from in-situ production. The authors thus applied different criteria to filter the record in order to remove biased samples. The filtered record, which may represent the true atmospheric mixing ratio is discussed and compared with model simulations of the CH₄ latitudinal gradient. The paper concludes that either the models might not

C2006

get a correct balance between high and low latitude CH₄ or that also the filtered CH₄ profile may still contain some bias due to artifacts. The authors point to the fact that additional CH₄ records from high mountain ice cores are necessary in order to obtain more robust data. Due to disturbances related with melting and the warming of such glaciers, retrieval of such records becomes urgent. This study makes a further effort to use glaciers from low latitudes to access CH₄ records from those regions. Such records have the potential to provide observational constraint for a better understanding of the relative weight of different CH₄ sources with time. This is an important addition to the existing and future records of CH₄ mixing ratios and stable isotope ratios obtained from the polar regions. The paper is clearly written and well structured. It openly and honestly discusses the remaining uncertainties in the conclusion of this study. This manuscript is an important contribution to the field as it may initiate further efforts, potentially with improved analytical techniques (laser based online measurements) in this direction of investigations. For the above reasons I can recommend the manuscript by Hou et al. for publication after minor revisions.

We thank Referee 1 for the positive opinion of our manuscript.

Specific comments: Page 2474 Line 8-11: In total it seems that 3 cores have been retrieved. One from 2001 and two from 2002. However, the three cores are referred to only 2 acronyms: Core2001 and Core2002. This is a bit confusing. Are the two cores from 2002 combined into one record? How do they compare (profiles of proxies used for dating etc), how is their dating matched, why are they of different length etc? Please clarify.

Apologies for the confusion. Yes two cores to bedrock (108.83 m and 95.80 m deep, respectively) were recovered from the East Rongbuk Glacier in 2002, but the CH₄ measurements were performed on only the 108.83 m core of 2002 and Core2001 as well, therefore we refer the 108.83 m core as “Core2002”. Changes have been made accordingly in the revision.

C2007

Line 14: The borehole temperatures (around -10°C) are relatively warm compared to polar sites. An increase of the ice temperature to -5°C does not seem to really accommodate for gas analysis since it is known that storage temperature has a significant effect and should be as low as possible (e.g. Bereiter et al., GRL, 2009). I would therefore assume that in an optimal scenario, the core should at least have been kept at temperatures lower than measured in the borehole in order to accommodate for gas analysis. I am of course aware that this may not have been possible under the given circumstances of extreme environment (e.g. altitude) and logistic challenges. Nevertheless, the text implies such an optimal scenario. I suggest to change along the lines: due to circumstances of extreme environment and the apparent logistic challenges, the core temperature was tried to be kept as low as possible in order to accommodate for gas analysis but slight warming of the ice compared to the natural existing temperatures in the glacier (as determined by borehole measurements) could not be prevented." A resulting potential (presumably small) increase in the in-situ production should also be shortly discussed.

We agree with the reviewer, and include the following sentences in the revision. "After the drilling was finished, the ice cores were packed into the insulated boxes, which were hauled down the mountain by yaks to the base camp (more details in the Supplementary material), where the ice cores were transferred into the refrigerators. The core temperature inside the insulated boxes was tried to be kept as low as possible ($<-5^{\circ}\text{C}$) in order to accommodate for gas analysis but slight warming of the ice compared to the natural existing temperatures in the glacier ($<-8.9^{\circ}\text{C}$) could not be prevented. However, this slight warming condition was retained for less than 20 hours, a potential increase of CH_4 due to this slight warming might be negligible, together given the fact that the 1 cm thick veneer ice was removed when preparing the samples for the CH_4 measurements (Bereiter et al., 2009). We maintained the core temperature well below -8.9°C at other times."

Page 2474 Line 15.: Is the bubble-free ice melted when adding and measuring the

C2008

standard gas over it? If yes, might the blank correction not be too high since bubble-free is not necessarily equal to gas-free ice. Please comment and add to the text in order to clarify.

This is a routine method for performing a blank test of the ice core gas measurements. In the revision we included a note behind the "artificial bubble-free ice" to clarify this confusion. *artificial bubble-free ice (totally degassed ice produced from ultrapure water).*

Chapter 3: What was the achieved measurement precision for those samples? This seems important due to the applied criteria to remove biased data points (see comment further down).

Each sample was measured three times, and average with one standard deviation was calculated. Among the 112 samples of Core2002, 34 measurements with one standard deviation >20 ppbv were excluded before the criteria filtering. In other words, all measurements applied for the filtering are with one standard deviation <20 ppbv.

Page 2477 Dating: As mentioned before, Core2002 is in fact two cores, correct? How do those cores compare, are they independently dated? Is the presented CH_4 data a combination of measurements done on both cores? Please clarify in the text.

Core2002 is referred to the 108.83 m core of 2002 only, and changes have been made accordingly in the revision.

Page 2477 and 2478 - Discussion to line 27: 1) The criterion does not seem to consider any measurement uncertainty. I would assume that this uncertainty is bigger than the used per-industrial growth rate criterion of $\max \pm 1$ ppmv applied to adjacent samples? If considering the uncertainty the resulting record might look different. Please comment.

We calculated the perindustrial growth rate of the nine filtered measurements covering the perindustrial period, taking into account one standard deviation of each measurement, and all the results are within the criterion of $\max \pm 1$ ppbv applied to adjacent

C2009

samples. For this reason, we suggest that the resulting record is stable when considering the measurement uncertainty.

2) Page 2478 line 19-20: "We then reject the high CH₄ values when the growth rate calculated before or after them overruns this criterion." I do not understand this sentence. Why after them? Would you in this case not remove the following point instead? I might have a general problem in understanding how this was done. Do you not need to assign one point (for which its value has to be assumed to reflect the true atmospheric signal) as the starting point and then successively apply the criterion to the points around it? Once you removed one point, is the criterion further applied to samples which are not next to each other (i.e. are not adjacent samples)? Dependent on how these criterion are applied and which point is used as the starting point a quite different "final" record may result. Please clarify and discuss in the text.

The following sentences were included in the revision. We applied the filtering from the top. For any comparison of the neighboring measurements, we just choose the lower value after satisfying growth rate criterion. Once one measurement was removed, the criterion was further applied to samples that were becoming next to each other.

Figure 4: For better understanding of the text on page 2479 and the understanding of Figure 4 it would be helpful if the values derived in this study (ER) and the measured values in the GRIP ice core would be included as data points (with error bars). This allows direct, optical comparison between the shown model output and the proxy data.

Changes have been made accordingly in the revision.

Page 2480 Line 14: change " : : are also affected by less pronounced artifacts" to " : : are still affected by artifacts which could not be removed with the applied criteria".

Changes have been made accordingly in the revision.

Technical corrections: Page 2472 Line 8-9: In order to be consistent with the notation in the main text (e.g. line 19-20), change " : : which is 36 ± 17 (73 ± 18) ppbv higher than

C2010

the atmospheric levels recorded respectively in Greenland and Antarctic ice cores." to " : : which is 36 ± 17 (73 ± 18) ppbv higher than the atmospheric levels recorded in Greenland (Antarctic) ice cores." Line 12: replace "infected" by "biased"

Changes have been made accordingly in the revision.

Interactive comment on Clim. Past Discuss., 9, 2471, 2013.

C2011