“A refined TALDICE-1a age scale from 55 to 112 ka before present for the Talos Dome ice core based on high-resolution methane measurements”
by S. Schüpbach et al. (cp-2011-46)

Response to Referee #1 (Dr H. Schaefer)

The study presents a revised age scale for a substantial period of the time covered by the TALDICE ice core and reports strongly reduced dating uncertainties. The results are a marked improvement with potential implications for the interpretation of palaeoclimatic ties between different regions. The work showcases the power of a newly developed continuous flow technique for high-resolution methane records that can be closely matched between different cores. A comparison of dust fluxes is used to evaluate the refined results in a useful and illustrative exercise. I consider the study a valuable contribution that should be published in Climate of the Past.

Several details can and should be improved before publication as described in the following.

General comment: the choice of new tie points is well documented and discussed for the period 50-90 ka BP. In contrast, the period from 90-120 ka BP is only documented in Table 1 and Fig. 3, which leaves room for questions. How do the new age tie points relate to those defined by Buiron et al. at the maximum of DO 24 and at the minimum between DOs 23 and 24? How big are the changes in assigned age at the inception of the last ice age? What is the estimated dating uncertainty in that interval? A short discussion of these and maybe related points would be a useful and arguably necessary addition to the manuscript.

The procedure as described in detail for the period from 50-90 ka BP is the same for the whole period discussed in this study, i.e. 50-112 ka BP. The period 50-90 ka BP is shown in detail as the most considerable changes in the age scale are caused in this section and most of the new tie points can be found here. By showing this period in detail, the changes become apparent to the reader, which would not be the case by only showing the entire CH_4 record with the new tie points due to a compressed time axis (see Fig. 3). A more detailed description in the text of all the new tie points covering the whole period discussed in this work would - in our opinion - not add to a better understanding to the reader. With the data from Buiron et al. (2011) and this manuscript available, a detailed comparison of the entire period can be done easily.
In the period 89-112 ky BP we have six tie points in total, three are adopted from Buiron et al. (2011), three new tie points have been selected, while Buiron et al. (2011) provides 5 tie points in this period (see Fig. 1 A or Table 2 in Buiron et al. 2011 and Fig. 3 or Table 1 in our manuscript, respectively). The changes in assigned gas ages in the interval 90-112 ka BP are less than 400 years, i.e. below the changes of the period from 55-90 ka BP. More considerable are the improvements in the dating uncertainties in that interval, e.g. in the period from DOs 23 to 24 the uncertainty is reduced from approx. 1000 years to below 600 years thanks to the much improved resolution of the methane record.
All this information is available from the tables in either this manuscript or the manuscript by Buiron et al. (2011). We refrained from mentioning all these numbers in the text. Instead, an additional figure (new Fig.4) has been added, showing (a) the age differences of the two age scales covering the entire depth interval discussed in this paper and (b) a comparison of the uncertainties of the original ice age scale with the uncertainties of the refined TALDICE-1a ice age scale. A sentence has been added to the text (line 170 of the new manuscript) to clarify that we did apply the same procedure for the whole period and not different procedures for 55-90 and 90-112 ka BP, respectively. Additionally, a description of the new Fig. 4 has been added to the text (lines 181-185 and 194-195, respectively, of the new manuscript).

Page 1177 Lines 10-11: a short note that these are present-day estimates but most probably didn't change substantially under the past conditions of the studied periods would be worthwhile.

A corresponding remark has been added to the text (lines 45-48).

Lines 18-22: the Köhler (2010) discussion paper has received criticism for likely overestimating the quantified offset and for being unclear in its arguments (CPD discussion forum). Personally, I agree at least with the latter, given that Köhler's Fig. 4(B) gives the impression that the mid-points of fast CH_4 transitions are mostly back-dated because he first adjusts the transition onset. Thus, he ignores the reason why mid-points were chosen as tie-points in the first place. I am possibly mistaken in this, but the authors may wish

to discuss Köhler's results more comprehensively. I note that in the current version the authors take a conservative stance, as Köhler's mechanism worsens their dating uncertainty.

The reviewers comment is in agreement with the CPD discussion forum and as a consequence the discussion paper of Köhler (2010) has not been published in Climate of the Past, but the relevant parts have been included in the supplemental material of the Köhler et al. (2011) publication in a modified form. The age uncertainties reported in Köhler et al. (2011) are indeed not as large as in the original Köhler, (2010) discussion paper. The values indicated for these uncertainties are adjusted in our manuscript.
It is not the intention of our paper to discuss the results of Köhler et al. (2011) but to point the reader to the fact that additional age uncertainty might be introduced by synchronizing Antarctic ice cores featuring different bubble close-off characteristics. Additionally, the uncertainties indicated in Köhler et al. (2011) are given for a synchronization of EDC and NGRIP, which are about 1.5 times larger (according to the calculations given in Köhler 2010) than for a synchronization of EDC and EDML (which has similar close-off characteristics as TALDICE). Therefore, it can be estimated that the tie points presented in this study are affected by this additional uncertainty by max. 150 years, thus well below the 200 years indicated in Köhler er al. 2011. This uncertainty - with the age uncertainty values updated in our manuscript (see also the last answer to reviewer #2) - lies well within the indicated uncertainties of the tie points.
The reference in the manuscript is changed from Köhler (2010) to Köhler et al. (2011), and the value for the uncertainty induced by this effect is updated according to the two mentioned manuscripts (lines 55-56, respectively).

Lines 22-27: as above, the authors list a mechanism that has the potential to introduce uncertainty in their age matching. However, the matching is usually based on inflection points, which are independent of absolute methane values in the two hemispheres. Given that modern CH_4 variations are mirrored between the highest latitude northern and southern monitoring sites of the ESRL network on a year-by-year basis, it is not clear why the palaeo-situation should be different. I may be unaware of an argument here, if so it should be presented and referenced properly for the interested reader.

The reviewer is right. The interhemispheric gradient has, if at all, a negligible effect on synchronization of CH_4 records when using inflection points as we do in this study, and not absolute values. This effect has only been mentioned for the sake of completeness when discussing CH_4 synchronization in general. But in this context it may rather contribute to confusion, and since we are synchronizing Antarctic ice cores only these lines are deleted in the final manuscript.

Page 1178 Lines 7-10: is this a reversal of the real argument? Buiron et al. matched the record to the Greenland ensemble and in so doing derived the age uncertainty.

The reviewer is right; these two sentences are mixed up. The text has been revised accordingly.

Page 1179 Lines 10-14: I agree with the assessment that accuracy and precision of the method are not limiting for the study. In terms of the latter, quoting the magnitude of atmospheric CH_4 variability would be helpful for the reader here.

The corresponding values of atmospheric CH_4 variability have been added to the text (lines 101-102).

Line 28 and Page 1180, lines 1-2: the reason for applying a filter to the continuous flow data during the ACR, namely to subtract measurement noise from the real atmospheric signal, is no longer valid if the temporal resolution of the discrete measurements is lower than the temporal variability of the atmospheric signal. As the authors state, in the time period that is of interest for this study temporal resolution of the methane CFA is considerably lower than during the ACR (while the filtering process remains unchanged). Is it still higher than time scales of CH_4 variability? If not, the filter has the potential to mask true atmospheric variability. Although I don't see this issue having implications on the results of the study, the point should be discussed more quantitatively.

The reason why the same filter is applied in this study as in the record during the ACR is because we assume that the variability in the CFA-CH_4 record introduced by the measurement itself is the same over the whole TALDICE CFA-CH_4 record with respect to depth. The very high temporal resolution of the ACR period was used to determine an optimal filter, since temporal resolution of this section of the CH_4 record is much higher than atmospheric variations and bubble close-off time and is therefore optimally suitable for determination of filter criteria. We are aware that by using this filter in the deeper part of the TALDICE CH_4 record fast atmospheric variations may be masked as the reviewer mentions. But by using a weaker filter in the deeper part, measurement artefacts might not be filtered out reliably, since the measurement noise

stays the same with respect to depth, not to time. As the reviewer states, potential masking of atmospheric variability does not have implications on the results of the synchronization, we prefer the risk of filtering too much of the atmospheric signal than introducing additional variability from the measurement artefact. The mean temporal resolution of the CFA-CH_4 record in the period discussed in this study is 100 years, which is indeed lower than the fastest atmospheric variations observed in this period, but in the order of magnitude of the bubble close-off process.
An explanation of this procedure has been added to the text (lines 117-122).

Page 1180 Line: a short note how the uncertainty was quantified would be helpful.

The gas synchronization uncertainty is only dependent on the resolution of the records. The uncertainty is calculated as the square root of the sum of squares of the EDC and TALDICE time resolution at the respective tie point. This explanation is added to the text (lines 130-132).

Lines 10-14: see previous comments on the Köhler (2010) study.

See the answer to the previous comments on Köhler (2010).
The manuscript has been changed accordingly in this section (lines 133-137).

Page 1183 Lines 26-27: it would seem more appropriate to say that the Ca records show a high degree of correlation rather than synchrony, as the latter is a product of the assigned age scale and the former an inherent quality of the data.

“synchrony” has been replaced by “correlation”.

Figures 1-3: Personally, I find the black and blue diamonds hard to distinguish. I would recommend a different choice of symbols or colours so that details in the records can be distinguished.

Dark blue diamonds have been changed to light blue.

Figure 1: a main purpose of Fig. 1 is to illustrate the additional structure in the CH_4 record that the CF method reveals in comparison to the discrete measurements of Buiron et al. I think that this could be better achieved by presenting the latter as a line plot (or data points connected by a line). This would show at first sight where the new data resolve, e.g., a precursor event and a DO where the discrete data give the impression of one single peak.

The data points of the discrete measurements of Buiron et al. (2011) have been connected by a line to compare better with the continuous measurements.