RESPONSE TO REFEREE 1:

Please find below the reponses to the review of referee 1 on *Analytical constraints on layered gas trapping and smoothing of atmospheric variability in ice under low accumulation conditions.*
The blue italic text is the text of the review, and the corresponding responses are below in black.
When we intend to change the manuscript text or figures, it is stated so in the response.

This paper analyses CH4 across Dansgaard/Oeschger event 17 (DO-17) from the Vostok ice core with a CFA-based measurement system in order to improve understanding of layered gas trapping and smoothing of atmospheric variability in an ice core drilled in low accumulation areas. A thus dervied CH4 record is then postprocessed and finally compared with CH4 from the higher resolving WAIS Divide ice core (WDC) to conclude that gas age distribution (GAD) - or smoothing - in Vostok seems to be similar for modern and DO-17 conditions. The paper is well written, especially the post-processing procedure described to some detail. The detection of artifacts in CH4 from such a high-resolution system as presented here is convincing.

However, the paper falls so far short in one aspect, that is the application of a previously assumed LGM gas age distribution used for EPICA Dome C (EDC) to transfer WDC CH4 data into potentially signals recorded in Vostok, from which it was concluded, that gas age distribution are probably independent from climate background.

Our conclusion that smoothing during DO17 is weaker than expected is mostly based on the comparison between the gas age distribution (GAD) tuned to our CH_4 data and the GAD estimated by Witrant et al., 2012 for modern conditions at Vostok.

Here, they use what has been used as gas age distribution in Köhler et al (2011), who used a log-normal function, and for LGM assumed a mean width of the GAD of 590 years. This GAD allowed large overshoots in the true atmospheric signal of CO2, when compared with the EDC ice core record of CO2, and was again used in Köhler et al. (2014). However, the new WDC CO2 paper of Marcott et al (2014) showed, that the assumed GAD used by Köhler in 2011 was probably too wide since a much smaller GAD was able to transfer the WDC CO2 (potentially very close to the true atmospheric variability of CO2) to the CO2 record obtained from EDC (Extended Data Fig 5 in Marcott et al., 2014). This revised narrow GAD was also then applied for the question of interest by Köhler, but I have to admit, so far only published in a conference proceeding, not widely known (Köhler et al., 2015, pages 135–140 in http://www.leopoldina.org/uploads/tx_leopublication/NAL_Bd121_Nr408_LR.pdf). Figure 2 of this 6-pages proceeding contains a transformation of a simulated atmospheric CO2 into a signal recorded at EDC around the onset of the Bølling/Allerød (B/A) warm period around 14.6 kyr BP using the same log-normal function as introduced in Köhler et al (2011) of

$$y = \frac{1}{x \cdot \sigma \cdot \sqrt{2\pi}} \cdot e^{-0.5(\frac{ln(x)-\mu}{\sigma})^2} \qquad (1)$$

with x (yr) as the time elapsed since the last exchange with the atmosphere, which leads to an expected value (mean) E of the GAD of

$$E = e^{\mu+\frac{\sigma}{2}}. \qquad (2)$$

From the two free parameters μ and σ, in 2011 Köhler has chosen for simplicity σ = 1, but now in

the revised application in 2015 uses σ < 1 to reproduce the shape of the GAD suggested in Marcott. In detail σ = 0.5 was used and μ defined in a way which guarantees the pre-defined mean values E of 150 yr. So, not only the mean width of the GAD has be reduced by a factor of 2.7, from formally 400 yrs to now 150 yrs (for this application to the B/A), but also the shape of the GAD. I believe the authors are challenged now to also use a GAD that agrees with the WDC-EDC CO2 comparsion, as brought up by Marcott, and in a first step probably at best also start with a revised log-normal function using different parameter values. Only then can they conclude (or not) if the GAD is indeed similar for modern and DO-17 climate or not. For any such exercise, please always state the used parameter values of the function, e.g. as given here, both the chosen form-shape factor σ, and at best the mean value E (directly derived from μ once σ is given). So far, no details on the applied log-normal function has been given. This will probably lead to a revision of the final conclusion and figure 5, but the rest of the paper is largely unaffected.

We will add the new GAD by Köhler et al., 2015 in Figures 5 and 6. This new GAD leads to a somewhat lower smoothing than the modern one based on Witrant et al. (2012). But there are large uncertainties in GAD estimation as we mention p18 l20-25 of the manuscript. However, the main conclusion is unaffected. The smoothing during DO17 is comparable to the modern one at Vostok, despite the lower accumulation.
We will also add a Table with the parameters of all the GADs used to facilitate the comparison with other estimates. Note that we did not assume $\sigma=1$ but adjusted this parameter in our estimates.

Further minor comments in chronological order:

1. Throughout the paper: Units are sometimes weight, with a dot (.) inbetween, e.g. "3.8 cm.min−1 ", which should be "3.8 cm min−1 ".

We will remove the dot in between units.

2. Figure 1: Labels in insert (top right corner) are much too small.

Figure 1 will be redrawn with larger zoom and labels.

3. Page 9, line 4: " As explained in Rhodes et al. (2016), such a mechanism affects trace gases record only during periods of significant atmospheric variations." Variations of what? Probably "variations in concentrations of atmospheric gases".

Yes we meant variations in concentrations of atmospheric gases. The text will be modified accordingly to 'during periods of variations in concentration of atmospheric gases'.

4. Page 9, line 11: "monotonous variations", change to "monotonous in/decrease".

The text will be changed to 'monotonous increase/decrease'.

5. Page 11, line 21: What are the coldest sites in Breant et al (2016)? Please name here.

The sites are Dome C, Vostok, and Dome A. This will be added to the text.

6. Page 12, line 4: "... the methane record from the WAIS Divide ice core (Rhodes et al., 2015), with gas ages with gas ages converted on the AICC2012 scale (Buizert et al., 2015)." Now, this needs some more explanation and probably correction. Buizert et al., 2015 does NOT plot WDC CH4 on AICC2012, as suggested by this sentence. There is also the effort of explaining the gas age adaption of WDC CH4 to AICC2012 in the SI Fig S11 (and corresponding SI section), which I also

did not understand in detail. Please be precise here, and describe this step in the main text, not hidden in the SI.

We will add to the manuscript: 'The WDC gas age chronology (WD2014) was scaled to the GICC05 chronology (with present defined as 1950) dividing by a factor of 1.0063 as in Buizert et al. (2015). For the rest of the article we used this scaled WD2014 chronology to express WDC gas ages.'

7. Page 14, line 3: I believe, a spline normally comes along with a cutoff-frequency, which has not been given here.

We are using an interpolating spline, which does not smooth the signal but goes through each data point. The smoothing is taken care of by the averaging over 50cm wide bins, and this averaging length works as the cut-off frequency. The text will be changed to 'A spline of degree 3 is used to interpolate between the binned points on the original CFA depth scale. This interpolating spline does not further smooth the signal, and is used as a guess of the chronological signal.'

8. Section 4.4 (removing artifacts) page 13-14, versus Fig 1. My understanding of the description of Section 4.4 was, that the spikes caused by layering artifacts are removed, and a continous CH4 time series without artifacts is generated. However, the black line in Fig 1 (which according to the text should be such a time series) does not contain any data in the periods, in which artifacts has been removed. I would think the post-processing should give you some data points in exchange to the removed artifical peaks. Please refine text, or change Figure 1 accordingly.

Even in the absence of layering artifacts, the CFA signal is discontinuous due to missing ice sections, kerosene and ambient air infiltrations. This fact will be clearly specified in the text. During cleaning of layering artifacts, we do not wish to mix the experimental data with interpolated data that are not independent from the real data. For example such artificial data could induce a bias in the RMSD minimization procedure of section 5.2. This is why we discarded data corresponding to layering artifacts without replacing them.

9. Caption to Fig 5: You need to say explicitly WHICH signals you convoluted, e.g. green solid is probably the convolution of the WDC CH4 with the Dome C GAD estimated for LGM of Köhler et al 2011.

We will modify the text to: 'WDC CH_4 signal convolved with different GADs: the Dome C GAD estimated for last deglaciation in green, etc'. We will also add the new GAD estimate by Köhler et al. (2015) in Fig. 6 and the result of its convolution with the WDC methane record in Fig. 5.

10. Page 16, line 20: "modifying its two parameters", probably refers to the same 2 parameters given above in Eq 1. Please state, which values you choose in the end.

Yes, the two parameters we optimize are the location and scale (σ and μ in Eq. 1 provided by the Referee). The optimization is multivariate and finds the best (in the sense of RMSD minimization) location and scale simultaneously.
We will provide a Table with the parameters of all the used log-normal GADs (location, scale, mean and standard deviation)

11. Fig 6: Needs a new GAD based on the Marcott WDC-EDC CO2 comparison, and/or the new approach of Köhler 2015.

We will add the new GAD estimate by Köhler et al. (2015) in Figure 6 and the resulting smoothed signal in Figure 5.

12. SI: Please either put all Figures to the end, or in the section, in which they are discussed.

All figures will be placed at the end of the supplement.

13. Please check references to Figures in main text, on SI page 5, line 4 a reference is given to Figre 6, but the correct Figure refered to here is Figure 5.

We thank the referee for noticing this error. The references will be checked and made consistent.