Reply to referee2

Thank you for your valuable comments. Our responses and the changes we plan to make in the revised manuscript are explained below. Our replies are in blue, the changes we plan to make are in red and reviewer comments are written in black italic letters.

The article "Fractionation of O2/N2 and Ar/N2 in the Antarctic ice sheet during bubble formation and bubble-clathrate hydrate transition from precise gas measurements of the Dome Fuji ice core" by Ikumi Oyabu presents new δO2/N2 and δAr/N2 data, measured on Dome Fuji ice cores using the method of Oyabu et al. 2020. The authors are able to provide data from samples stored at low temperatures of -50°C in the freezer and show that under these conditions gas loss fractionation after coring is almost negligible. They also discuss their data in the context of a wide range of δO2/N2 and δAr/N2 measurements from other ice core sites and other measurement and storage strategies. They examine their data in four depth intervals attributed to different fractionation mechanisms (bubble ice, upper BCTZ, deep BCTZ and clathrate zone) through a simple regression analysis of δO2/N2 versus δAr/N2 and δO2/N2 versus δ18O-O2 to disentangle possible fractionation mechanisms (mass-independent/size-dependent vs. mass-dependent fractionation). Furthermore, the authors show that using a simple diffusion model to model permeation in conjunction with high-resolution data can explain the reduction in data variance due to diffusive smoothing in the clathrate hydrate zone.

The paper is well written and structured. I enjoyed reading this paper and look forward to its publication. Most of my "major" criticisms of this work have already been addressed by reviewer 1, and I am pleased to see how the authors have responded. In particular, the new schematic illustration about the different fractionation mechanisms will help the reader to understand the work better. There are only a few minor points to change, which I list below.

Minor points:

Line 15: Please avoid expressions like "high precision" or specify with numbers.

We will remove “at high precision”.

Line 21: Yes, analysing long ice samples can help to average the data scatter later, but how long should these samples be? Please specify a number here.

We will add the proposed length as the following.

"… and the insolation signal may be reconstructed by analyzing long ice samples (more than 50 cm for the Dome Fuji core)."

Line 72/73: Please combine minus sign and number in the same line.

Yes, we will check the format in the proof.

Line 160ff: For the data shallower than 800 m, I do not see much agreement with the insolation data. The depth range is too short to support this statement. For the deeper depth range, I agree.

We agree that the age range for the data shallower than 800 m is too short to robustly compare with the insolation curve as we could for the deeper part. However, for the shallower depths, we think we can identify the similarity of $\delta O_2/N_2$ and insolation curve in that both curves show two peaks at ~350 m (12 kyr) and ~700 m (32 kyr), and that the second peak (~700 m) is larger than the first one. The comparison of $\delta Ar/N_2$ with the insolation curve is even less robust perhaps because the signal-to-noise ratio of $\delta Ar/N_2$ is smaller than $\delta O_2/N_2$. We have also observed that $\delta Ar/N_2$ has sometimes slightly different phasing with respect to $\delta O_2/N_2$ (in our ongoing measurements for older ages).
We will modify the text as follows.

"Variations in $\delta O_2/N_2$ and $\delta Ar/N_2$ for the depths ~~shallower than ~800 m and~~ deeper than ~1200 m have similarity with local summer insolation curve, while little similarity is found for 800 – 1200 m with extremely large scatters (Fig. 4). For the depths shallower than ~800 m, the comparisons between the gas records and insolation are less robust than for the deeper depths because of the short length (in terms of age) and small insolation amplitudes (small signal-to-noise ratio). Nevertheless, we find similarity between $\delta O_2/N_2$ and local summer insolation in that both curves show the two peaks at ~350 m (12 kyr BP) and ~700 m (32 kyr BP) and that the second peak (at ~700 m) is larger than the first one."

Line 161: "We evaluate ... low-pass filtered curves": Please indicate here the cut-off period used and explain how the low-pass filtering was performed.

We will explain the filter as follows. It is the same filter as used by Kawamura et al. (2007).

"We assess the scatters in the data by taking residuals of $\delta O_2/N_2$ and $\delta Ar/N_2$ from their low-pass filtered curves (Fig. 3d and 3e). The low-pass filter (cut-off period: 16.7 kyr) and its usage are the same as in Kawamura et al. (2007). Briefly, we put the $\delta O_2/N_2$ and $\delta Ar/N_2$ data on the DFO-2006 time scale, lineally interpolated them at 0.1 kyr intervals, and applied the filter to extract their orbital-scale variations."

Line 255/256: As already stated, the similarity of the bubble-ice data to the solar radiation curve is not robust in my opinion.

We agree that the similarity is less robust than for the deeper depths, which may be mostly due to the (inevitable) short length for comparison as discussed above, thus we will weaken the statement and describe this part as a simple observation and consistency with the proposed mechanism (occurring in association with the bubble formation processes). We will modify the text as follows.

"The $\delta O_2/N_2$ and $\delta Ar/N_2$ data ~~for the bubbly ice, upper BCTZ and~~ below BCTZ show variations similar to the local summer insolation (Fig. 4). In addition, ~~For the first time,~~ we find the possible insolation signals in the bubbly ice zone and upper BCTZ (see 3.1) ~~top part of the ice sheet~~, ~~supporting~~ as expected from the proposed link between the local summer insolation and close-off fractionation through the effects on the snow metamorphism (Bender, 2002; Fujita et al., 2009)."