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Climate of the Past Discussions

Interactive comment on "Comparison of Holocene temperature reconstructions based on GISP2 multiple-gas-isotope measurements" *by* Michael Döring and Markus Christian Leuenberger

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Doring and Lueebergre conducted a study for calculating temperatures from d40Ar and d15N in trapped air in an ice core. They investigated various calculation methods and provided further understanding on calculating temperatures. The resubmitted manuscript has been improved. However, critical points are ignored for the sake of author's favor as pointed below. The authors need to consider seriously these points before publication as Greenland temperature is a highly important climate variable to understand the future consequences of increasing atmospheric CO2. Some of the

comments are the same as I wrote for the earlier version.

Main comments 1. d15N and d40Ar in ice cores are believed to be caused by gravitational fraction and thermal fractionation in firn. The magnitude of fractionation can be theoretically calculated according to laboratory calibration. Therefore, by measuring d15N and d40Ar in trapped air in ice cores, we can immediately know past temperature gradients in the top and bottom of firn (ïĄĎT) and "firn column depth (Dfirn)". Using these data, Kobashi et al. (2010) invented a method to calculate surface temperature by integrating ïĄĎT using a firn-densification model. However, it was found that firn model outputs show firn depth cannot change as predicated by the isotopes (Dfirn). dNexcess (d15N-d40Ar/4) is highly robust temperature proxy as the calculation eliminate possible gas loss fractionation in the firn or from ice cores (Kobashi et al., 2008). Kobashi et al hypothesized that firn models are not capable to capture actual multidecadal temperature variability, and they produced Holocene temperatures avoiding utilization of firn model's densification process (Kobashi et al., 2017). On the other hand, Doring and Leuenberger hypothesize that firn model densification for a multidecadal scale is correct because the two firn models agree. Then, they calculate temperatures with the firn models. Therefore, two temperature calculations are based on two different hypotheses. As Doring and Leuenberger are not succeeding to reject the hypothesis of Kobashi et al. (2017), they provide only a hypothesis for Greenland temperature calculation, which is not fully tested with borehole temperature, oxygen isotopes of ice, or other climate proxies. 2. Kobashi et al. (2017) temperature is more advanced as it has been tested with various temperature proxies. Also, Holocene temperature variability (< 10,000 years) of Kobashi et al mostly arises from un-corrected dNexcess (orïĂăïĄĎT) (see Figure S2 in Kobashi et al. (2017)). Therefore, the different corrections such as time frame or argon correction has only minor effects on the calculated Greenland temperature. 3. Reconstructed temperature data using d15N, d40Ar, dNexcess, and hybrid should be submitted for others to securitize the results. 4. Authors did not demonstrate consistency with borehole temperature data. This is critical for the Holocene Greenland temperature from ice cores. Borehole temperature records are arguably the most important physical evidence of past temperature. The Goujon model calculate borehole temperature for each realization. Authors must show their borehole temperature results in comparison to the GISP borehole temperature record. 5. Authors also must show a plot with temperature reconstruction from oxygen isotope of ice. This may provide an independent evidence for the behavior of nitrogen and argon isotopes. In particular, I would like to point out the 9.2ka Event. This event can be clearly seen in Kobashi et al. (2017) reconstructions and oxygen isotope of ice, but not for temperature reconstructions for d15N. This may implicate that fast temperature changes are canceled by firn responses in d15N. Rapid cooling induce fast thickening of firn (increase in d15N) and surface cooling (decrease in d15N), cancelling each other, which possibly cannot be captured by the two firn models with slow firn densification processes. 6. Authors state that the late and early Holocene part of ice has impacted by gas loss. However, the late Holocene ice cores were good quality, and the past 1000 years have the highest quality data available to test the hypotheses (Kobashi et al., 2008). Authors cannot simply state the data is bad quality. Authors must compare the past 1000 years temperature reconstruction for d15N, d40Ar, Kobashi et al (2011), oxygen isotopes, and borehole temperature reconstruction to make your work useful. Note that Kobashi et al. (2011) has higher time resolution than Kobashi et al. (2017).

Detailed comments

Page 1. Line 14. This statement is based on a hypothesis that the firn-models they use are correct. However, the hypothesis is not sufficiently tested to reject another hypothesis that isotopic signals of dNexcess and dNgravi (or isotopically derived firn depth) are real. Therefore, it cannot claim that dNexcess based method is “problematic”. Because the basic assumptions are different between firn model-based method (densification) and dNexcess method, there are no surprises that the Kobashi et al temperature is radically different from Author’s and Buizert temperature reconstructions.

Page 1. Line 18. Early to middle Holocene part of ice is very good quality. Middle to

late Holocene ice is brittle (Kobashi et al., 2008). The authors need to look into physical properties of ice or other information, not only isotopic data to draw conclusions.

P3, line 11. Basic constructs of Goujon and Schwander’s firn models are the same. You must explain what is different and what is the same between these two models in the method section. Then, it becomes clear what you are testing with the two models.

Page 4. Line 26, “we argue that only δ15N is suitable as a robust reconstruction target in the high-frequency case”. Why only d15N? It is easier to find signals in d15N, but d15Nexcess has also signals (Fig. 1). Also, the resolution and error of the data is different in different time span. For the past 1000 years or around 8200 B.P., time resolution is higher ($\sim$10 years) and uncertainty is smaller (more data for each depth).

Page 5. Line 10. The data show opposite of the author’s claim. Kobashi et al. (2008) conducted extensive tests for d15N and d40Ar from the same depth range in two different periods. Kobashi et al. (2008) found that d15N and d40Ar/4 from the same depth range have different values in the two periods by about 2 permeg most likely owing to standardization of gasses to atmosphere. The pooled standard deviation of these values are 4 permeg for the both gasses. For the same data, dNexcess has identical number in a permeg scale, indicating that dNexcess is more conservative proxy than d15N or d40Ar because the calculation of dNexcess (d15N-d40Ar/4) cancels out possible gas fractionation during handling or gas loss.

Page 6. The early to middle Holocene ice is in a brittle ice zone, where gases more likely leak from the ice from cracks. In these ice cores, d15N also is affected by gas-loss process (Kobashi et al., 2008). Indeed, d15Nexcess is more robust for gas-ross because the gas ross induces 1:4 for d15N and d40Ar as stated earlier.

Page 6, line 8, The firn depth (dNgrav) can be obtained from the residual of calculation of dNexcess. This could be used to constrain the model. However, we found that if dNexcess are used as inputs, the firn depth cannot be reproduced by the model. You can interpret it as the “firn model” is wrong, or “the data” is wrong.

Page 6. Line 4. “the executed correction” I did not find the explanation on the executed correction on d40Ar for the author’s calculation. I think it may be not enough for the author’s calculation. In Kobashi et al. (2017), we have conducted correction for each segment of time differently, and it worked fine within errors. This is necessary because the ice cores were analyzed in 3 years in different sets of time. In each time span, experimental settings were different, which caused slight shifts in isotope values during the standardization processes.

Page 14. 4.1.1. Absolute temperature is available from borehole temperature reconstructions for GISP2. Why you don’t try to calibrate the temperature to the borehole temperature? As the firn models are not linear, different absolute temperature will create different firn responses. The temperature calculation needs to be calibrated with the borehole temperature data.

Page 15. Line 13. This is the depth where ice core is good condition, and the middle to late Holocene is in the brittle zone. In good ice core zones, gas leaks from ice cores are less important.

Page 16. Line 3. As mentioned earlier, the temperature calculation using dNexcess is based on a different hypothesis. According to the hypothesis, the author’s temperature calculation using the firn model (densification) is not recommended for climate interpretation.

Page 16. Line 4. It is not clear what argon correction the authors used. Argon correction for Kobashi et al. (2015b) and Kobashi et al. (2017) are different. Kobashi et al. (2017) used more advanced correction of different values for different time spans. As mentioned earlier, isotopic experiments introduce slightly different values for both d15N and d40Ar during standardization. Therefore, even without gas loss, ïĄĎT integration method needs to have corrections for ïĄĎT for the different periods of experiments.

Page 17. Line 10. In the Kobashi et al. (2017), we created a method to correct d15Nexcess in different time spans. The correction is minor as most of the variability

in reconstructed temperature are originating in raw dNexcess (Fig S2 in Kobashi et al., 2017).

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