Review of "The new Kr-86 excess ice core proxy for synoptic activity: West Antarctic storminess possibly linked to ITCZ movement through the last deglaciation." by Christo Buizert et al, Climate of the Past.

General:

The manuscript presents a new, exiting interpretation of older and younger ice core elemental and isotope ratio results. I enjoyed reading it. The results of combined proxy, called $^{86}Kr_{ex40}$, are based on relative difference of $\delta^{86}Kr$ ($^{86}Kr/^{82}Kr$ ratio values) and $\delta^{40}Ar$ ($^{40}Ar/^{36}Ar$ ratio values) to $\delta^{40}Ar$. It thus corresponds to a delta value of delta values expressed in permeg/permil when the primary delta values are expressed in permil. This relative double difference results in very small values and are therefore they expressed in permeg, which is a permil of permil. The measurements show that the values corrected for thermal diffusion are in the small negative range of 0 to -160 permeg/permil for $^{86}Kr_{ex40}$. The authors state that $^{86}Kr_{ex40}$ is a direct proxy of large-scale atmospheric circulation (synoptic-scale pressure variability). Yet, they are careful with their interpretation as there are still insufficient knowledge of the underlying firn air transport and gas trapping which may influence $^{86}Kr_{ex40}$. There are a couple of major points that should be addressed before the manuscript can be published.

Major points:
(1) Figure 3 is one of the major Figures and these values depend on two corrections applied (gas loss and thermal diffusion) which are detailed in Figure A3. Looking at the supplementary Figure A3 that displays the uncorrected and corrected values for gas loss and thermal diffusion independently, I saw that there must be an interdependence of these two corrections as they are not adding up. For instance for DF the uncorrected mean value is around 33 permeg/permil, the gas loss corrected about 55 permeg/permil which leads to a gas loss correction of around 22 permeg/permil. The correspondent thermal correction amounts to (33-(-10) = -43 permeg/permil both for individual or mean ΔT. This in combination would lead to correction of -21 permeg/permil (-43+22). I therefore would except overall corrected value of around 12 permeg/permil (33-21). The values plotted are, however close to +40 permeg/permil? Could you explain how and why they are interlinked, or is there a mistake for the DF values? The other site value corrections are more or less additive, maybe with the additional exception of GISP2.
Actually, the same issue concerns Figure A4.

(2) There is hardly any information/discussion about the many more elemental and isotope ratio measurements that have been measured (section 2.2) to strengthen or weaken their arguments, i.e. $^{84}Kr/^{86}Kr$, ^{84}Kr being the most abundant and therefore the precision should be better.

(3) The expression of $^{86}Kr_{ex40}$ being a direct proxy for synoptic-scale pressure variability comes at several places and is actually quite misleading as they correctly state that the gas measurements represent a time-averaged value. The average times are large (years to decades) compared to synoptic circulation events (days).

(4) Calibration of the $^{86}Kr_{ex40}$ has been done with reanalysis data of the time range 1979 to 2017. This data show a large spatial variability in the Antarctic. However, whether the stability of the spatial calibration will hold for temporal interpretations is difficult to judge but

this is certainly one major weakness. Yet, I see that it will be difficult to find arguments to support it.

(5) In section 1.2, the authors discuss several processes that alter the isotope ratios, such as gravitational settling and thermal diffusion, advection, convection and dispersive mixing. The latter three they state do not distinguish between isotopologues. This is correct but they do lead to a disruption of the maybe already established isotope equilibrium through molecular (gravitational and/or thermal) diffusion, which requires time to be re-established. This is the starting point of their definition of the $^{86}Kr_{ex40}$ proxy. However, there are several processes that can and will affect this proxy as nicely discussed in sections 1.2 and 3.3. This is of course a weakness of this proxy despite the author's transparent writing. For instance, they state that the major influence on $^{86}Kr_{ex40}$ comes from pressure variations at the surface, but what about the pressure variations from the gas close-off process? Pressure variations may be weak but gas velocities of expelled molecules in the tiny channels at close-off depths might be very high and could lead to significant alterations in the gas compositions.

Minor points:

L144: it would be worthwhile to explain why this definition is less sensitive to thermal diffusion (give corresponding reference). Yet,

L144ff: What about close-off fractionation? We know that Ne, He, will expelled during close-off. Therefore, large molecules such as N_2 will be less affected than O_2, Ar etc. Kr is obviously between N_2 and O_2. Especially, Ar will be subject of expelling. In this regard, the second definition with $\delta^{15}N$ would be preferred.

L225ff: I would prefer the gas splitting. As it can be tested by many gas species measurements in contrast to the different ice core samples. There only replications can help.

L239f How extended is this bubble-clathrate zone as the signals are extremely small. What was the criteria for the given number in the depth or time range.

L242ff "Some of the EDC samples analyzed had clear evidence of drill liquid contamination, which acts to artefactually lower $^{86}Kr_{ex40}$; the late Holocene data used here were not flagged for drill liquid contamination." Give a reference for this statement.

L247 22 per meg /permil: I do not understand this, error propagation leads to a higher combined uncertainty and not a lower!, this does not make sense or do I miss something here?

L248 this would be necessary. At least you can split a 1600 g samples in two sub-samples

L253 BP also denotes Before Present, consider changing it.

L257ff Are there additional indications that melting has occurred, for instance from water isotopes or changed greenhouse gas concentrations?

L268 Can you specify what modern climate means (time range)

L274 How can a daily variable be compared to a decadal variable ($^{86}Kr_{ex40}$)?

L278f If such a calibration is made, it should be done on firn air samples as they are not smoothed by the process of gas enclosure. Have you tried to do this?

L288f This is only the case when the argon correction for gas loss has been made correctly.

L299ff Refer to Figure 3.

L304ff This is disconnected, the link is not clear. Further explanation is needed here.

L310ff This is indeed a critical point.

L332f This is again a critical point as I can imagine that the firn structure acts as a column retarding the gas species differently. It would be worthwhile to do such experiments. Maybe you find a corresponding reference?

L346ff This is also important. Elemental ratio should be in line with isotope ratios. Yet it points indeed to a difference in diffusion coefficient ratio of real and lab conditions. Column effect (adsorption/desorption)

L361f if one argues that the diffusion of noble gases may be retarded in the firn column, one should consider this effect also for the thermal corrections. These, however is based on $\delta^{15}N$ and $\delta^{40}Ar$ measurements.

L368ff this is also a very critical correction as obliviously ΔT varies considerably from site to site without a clear understanding why this is the case.

L378 give a reference for (1)

L379 (3) yes, this indicates the large uncertainty of this correction. Yet, Figure 3B is quite convincing as a counter-argument. See also main comments above.

L 410 How has the elevation changed over the course of the investigated period? And how relevant are these changes?

L416 …(by limiting …), not clear, needs further explanation

L429f …we anticipate $^{86}Kr_{ex40}$ to be a qualitative proxy for synoptic variability…
this is indeed a good point as the used calibration is standing on weak grounds.

L456ff Why have you only investigated Antarctic sites and not Greenland locations? This would proof that different locations on Earth would be similarly influenced. There is GISP2. What would be a good choice for additional stations in Greenland?

L549f or is there indeed a higher variability present. How do you explain or underline that less care has been taken for these later campaigns?

L575f Campaign 3 data shows quite a large scatter.

L600ff this might be tackled with measurements in Greenland compared to those in Antarctica

L702ff Such a shift is not …after accounting for site elevation effects
this again is quite a critical point. This depends on ice flow modeling and accumulation rates changes.

L730ff But a similarly strong correlation is seen with mean annual site T and with site elevation.

L756 …and gradually increases …
maybe due to low number of data points?

L773f Gas loss correction,
this is a critical but important correction which still sits on shaky grounds.

L803f Why do you define this correction like this? There is also a very good correlation for mass spectrometry measurements. If the MS measurements are not well done you might introduce a wrong correction.

Fig. 2 It would be worthwhile to plot also the temporal variability. This would allow the reader to compare the uncertainty of annual means and to compare it with the seasonality.

Fig. 3 Over which time range are the circles mean taken? Is this firn air or ice core data?
B: Sensitivity study. This is nice. It would be worthwhile to show a similar sensitivity study for $^{86}Kr_{ex}$ for $\delta^{15}N$ based. N_2 is believed not to be influenced from gas loss!!

Fig. 6 The variability of the grey circles (calibration data) is as large as the variations of all other measurements. Hence, the interpretation seems to be quite speculative. In particular, that also other process could have caused similar variations (convective zone changes).