We want to thank Reviewer # 2 for their thoughtful and helpful comments, which have improved the manuscript. We greatly appreciate your input. Our response is below.

**The manuscript presents new total air content (TAC) data from south pole core SPC14. The data covers 54kyr in quite high resolution and although measured in two laboratories in consistent quality. The manuscript is well structured and well written starting out with a comprehensive introduction lining out the problems with total air content (TAC). The manuscript makes it clear that it is not solving the riddle but adding another piece to the puzzle. It is a step forward in our understanding of TAC offering some hypothesis that are however not consistent with all features seen in TAC data from the northern hemisphere. I have a few questions and suggestions below and suggest publication with minor revisions.**

**Minor comments:**

**Page 4: Given that each flask will be slightly different and the amount of ice too, the volume of the setup is changing. How are you taking this into account?**

This is considered by utilizing Tgc/Vgc instead of calculating a precise volume for each flask and sample combination. We can do this because of the consistent ratio of pressures between expansions of sample air into the GC, and the calibration for Teff that was completed and explained in section 2.1 Equation 8 demonstrates how we use Tgc/Vgc instead of air sample volume to measure TAC.

To make it clear that the method can measure TAC independent of flask and array temperatures and volumes, we recommend adding the following line to the last sentence of paragraph 1, section 2.1:

*"Updates to the methods at OSU, allow the TAC measurements to be made independent of the flask and array temperatures and volumes. The methods allowing this are described in detail below."*

**Line 201: Clathrates close to the surface are probably opening when evacuated. A correction for this effect may be appropriate. I suggest to add a statement that the correction should probably be a constant in the clathrate zone and at most 1.9%.**

We agree that the correction would be small, and no more than recorded at the base of the bubbly ice. We added the following statement to the bottom of the last paragraph of 2.2 *"While clathrate ice will still have a gas-loss correction, it is likely constant and no more than 1.9%. We applied no correction after the base of the bubbly ice."*

**Line 278: see comment to figure 4**

The insolation and TAC are not shifted. We found a strong anti-correlation between the two parameters, which is in-line with previous findings, and strengthens the conclusion that ISI can be used for orbital tuning of ice cores (Raynaud 2007, Eicher et al., 2016).

**Line 320-340: Hard to follow and some repetitions, please revise this section. A more straight forward argumentation seem to me to plot the ice sheet elevation from where the ice originates versus age. –**

Deleted duplicate sentences, which reference figure 6.

We suggest, also due to comments from reviewer 3, that we delete figure 6. The comparison of bedrock elevation to TAC is hard to follow, and upstream elevation is previously published (Lilien 2018, Fudge 2020). Figure 6 detracts from the explanation, and the narrative of ice sheet elevation over time is a better explanation than the addition of a figure.

**Line 363: delete "when"**

Deleted.

**Line 365-376: I seem to understand that low accumulation leads to denser firn therefore lower TAC. What about d15N?**

This relationship is explained in paragraph before lines 365-376. Changed the last two sentences of the previous paragraph to clarify. D15N does not act on the firn column but is a secondary indicator of accumulation. Its correlation to TAC is further evidence of the accumulation effect on TAC.

"*As temperature variations are relatively minor at the South Pole, accumulation variation drives the observed changes in SPC14 $\delta^{15}N\text{-}N_2$. At this site, greater accumulation rates cause a thicker firn column and a subsequently higher $\delta^{15}N\text{-}N_2$. Winski et al., (2019) notes the close resemblance of $\delta^{15}N\text{-}N_2$ and the Holocene accumulation rate reconstruction, which is further evidence to support the use of $\delta^{15}N\text{-}N_2$ as an indicator of accumulation rate changes in SPC14.'*

**Line 377-385: If the orbital and millennial effects were the same you should also see an orbital signal in d15N. Do you?**

We do not observe a strong orbital signal in d15N. The r2 between ISI and d15N is 0.06, indicating a weak orbital signal in d15N. This is probably due to the d15N signal being dominated by millennial scale features.

**Figure 1: Please add a depth scale to that graph so that the location of the bubble-clathrate transition can be identified.**

Recommend revising figure 1 to include a depth -age inset as shown below:

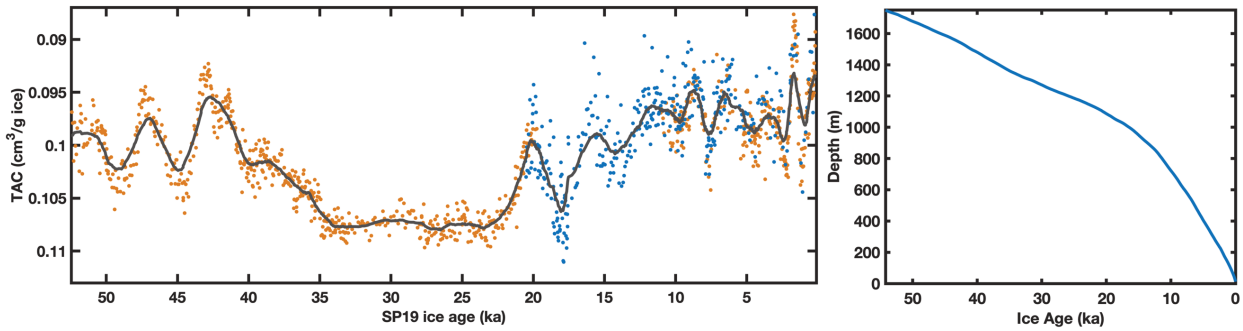


***Figure 1: Total air content of the SPC14 ice core.*** *(Left) Measurements are individually shown, plotted on the SP19 ice age scale (Winski et al., 2019). Black line is the smoothed record using a running 10-point average. TAC is expressed in units of $cm^3$ air at standard temperature and pressure, per gram of ice. Orange markers are TAC measurements collected at OSU (depths 130 – 841m, 1150-1751 m, pooled standard deviation = 0.0006 $cm^3$/g). Blue markers are TAC measurements collected at PSU (depths 130-1150 m, pooled standard deviation = 0.002 $cm^3$/g). (Right) Ice age as a function of depth. Data from Winski et al., (2019).*

**Figure 3: Should refer to section 3.2. Please explain how the standardization is constructed, although it is explained in the referenced papers. What is the purpose of the standardization?**

Changed the caption to reference 3.2.

Added to the sentence after Line 252: *"Following Raynaud et al. (2007) and Lipenkov et al. (2011), we then create standardized versions of TAC and Vcr, TAC* and Vcr*, in order to compare TAC and the non-thermal residual. The standardized data sets were created by subtracting the mean value (of TAC or Vcr, respectively) and then dividing by the respective standard deviation."*

**Figure 4: I don't understand how the minima and maxima from the insolation and the and from TAC from linear regression can be shifted. Please explain.**

The insolation and TAC are not shifted. We found a strong anti-correlation between the two parameters, which is in-line with previous findings, and strengthens the conclusion that ISI can be used for orbital tuning of ice cores (Raynaud 2007, Eicher et al., 2016).