Referee comments in regular font
Our responses in italics

RC2: 'Comment on egusphere-2023-3126', Ilya Usoskin, 06 Feb 2024
The manuscript by Petrenko et al. presents a programmatic paper presenting and quantifying a novel approach to measuring 14CO in ice as a proxy of the long-term flux of high-energy (>100 GeV) cosmic rays. It is shown that this method is feasible and can indeed be used to study the GCR consistency on the time scale of thousands of years. The authors describe the physics behind the approach very well and provide a quantitative assessment of the method's sensitivity to demonstrate that it is sufficient for the task. The authors also correctly specify the related challenges.
I found this work very important expectedly becoming a reference paper for the new method.
I am happy to recommend this manuscript for potential acceptance subject to a minor revision related to some clarifications in the methodological description as specified below.
We thank Dr. Usoskin for his detailed and helpful review and address individual comments below

A reader would benefit from a brief general description of how 14CO is measured in ice.
We will add a brief description in the revised manuscript

Line 24: “insensitive” -- > “almost insensitive”.
We will make this change in the revised manuscript

Line 33: after “solar irradiance” a reference to Wu et al. (2018b, doi: 10.1051/0004-6361/201832956) can be added.
We will add this reference

Line 35: please add a reference to a review by Usoskin (2023, doi: 10.1007/s41116-023-00036-z) focused on the cosmogenic method for solar activity reconstructions.
We will add this reference

Line 44: In addition to meteoritic studies, cosmogenic isotopes in lunar rocks can provide an estimate of the very long-term (mega-years) flux of cosmic rays (see, e.g., Poluianov et al., 2018, doi: 10.1051/0004-6361/201833561 and references therein). This method is free of geomagnetic shielding and uncertainties related to the orbit and erosion, but of course, is strongly affected by solar modulation. This can be briefly mentioned here in addition to the meteoritic data.
We will add a brief mention of this study to the discussion

Line 57: the statement about the isotropy of the GCR flux at the level of 1 permil needs clarification and a reference. The flux of GCR (in the GeV energy range) near Earth has a level of anisotropy of about 1% due to the orbital motion and diffusion+convection of particles by solar wind. Probably, the authors’ statement is related to higher energies. A reference is needed.
The reviewer is correct that we are referring to the GCR flux at 100 GeV and beyond. There are two anisotropic signals observable at these energies:

1. *A dipolar anisotropy due to the Earth’s orbit around the Sun, producing an annual modulation due to Earth’s relative motion through the “wind” of the local GCR flux.*

2. *An approximately dipolar anisotropy (with statistically significant components on angular scales down to a few degrees), most likely due to cosmic-ray diffusion from unresolved sources of cosmic rays within roughly 1 kpc of the solar system. The amplitude of the dipole, projected onto the celestial equator, varies between 10^{-4} and 10^{-3} between several hundred GeV and 1 PeV. Above 1 PeV, to 10 EeV (the highest reported energies) the dipole increases to 10^{-2}.*

A technical detail is that the solar anisotropy is a contaminant of the galactic anisotropy, but it can be estimated and removed by transforming cosmic-ray arrival directions to the so-called "anti-sidereal" reference frame (details are available in Farley & Storey, Proc. Phys. Soc. 67:996, 1954, Guillian+ Phys. Rev. D75:062003, 2007, and Aartsen+ ApJ 826:220, 2016).

We will add relevant references in the text that document the 0.1% GCR anisotropy at TeV energies and clarify the energy range this applies for.

Line 113: "Hmiel et al. (2023)" -- > "Hmiel et al., 2023)".
We believe we have the correct format for this citation, since "Hmiel" is used as part of the sentence.

Line 118: for what conditions (geomagnetic and solar) is the P_{n, SLHL}^Qtz(0) defined?
The Borchers et al. (2016) study that is the source of this value applies the scaling model of Lifton et al. (2014; reference already in our manuscript) to define this reference production rate for 2001-2010 mean solar modulation and geomagnetic field conditions. We will clarify this in the revised manuscript.

Line 119: should the units be molecules (viz. 14CO) or atoms (viz. 14C)? Referring to to the text above, it should be atoms. Please check.
We thank the referee for catching this, it should indeed be "atoms" -- we will update in the revised manuscript.

Description after Eqs 2 and 3 are quoted from Hmiel et al. (2023) but this is not optimal since some important information is missing there as probably provided elsewhere in the cited paper. The authors are advised to describe the formulas, especially Eq.3, in full detail. In particular, it is not described how \beta(h) is obtained.
We will revise the manuscript to have a more complete description of these equations

Line 140: since the ablation exposes ancient ice to neutrons, the additional production of 14C by neutrons needs to be considered and possibly corrected for. From the subsequent narrative, I understand that this effect is neglected, but this is not clear.
Our model does consider production from the neutron mechanism, but its contribution is negligible for samples at 6.85 m or deeper at Taylor Glacier. We will further clarify this in the revised manuscript

Line 203+, also 270: while parameters R1 and L1 are described, it is unclear how they are used. Please provide a formula for that.

These parameters were explained more completely in the cited Hmiel et al. (2023) study, but we will clarify further / provide any applicable formulas in the revised manuscript.

Figure 4a: The Y-axis can be plotted logarithmically (optional).
We would prefer to keep the linear scale, as very low values (which would be given more prominence on a logarithmic scale) are not measurable / negligible for the purposes of this study

Lines 350-351: please remove quotation marks.
We think the quotation marks are useful and appropriate here for clarity, as we are exactly reproducing text from a figure legend.

The unnumbered equation in line 354 is unclear. I am ignorant of this but it doesn't look like the probability (e.g., can it be greater than unity if Delta a is small?). Please explain this formula and/or give a reference.
We thank Dr. Usoskin for catching the fact that equations in Section 3.3 were unnumbered -- we will add equation numbers in the revised manuscript.
This particular equation is a probability density function (PDF) defined to be uniform between a_{min} *and* a_{max} *and 0 elsewhere. It is normalized to 1 when integrating over all values of the rate of change a, and thus takes on the value* $1/(a_{max} - a_{min}) = 1/\Delta a$ *after normalization. It is a proper probability distribution: even though it is possible for* $1/\Delta a > 1$*, the integral of the PDF over all possible values of a is unity. We note that improper (non-normalizable) uniform priors are valid and are often used in Bayesian statistics (though not in this case). This is allowed as long as the marginal distribution using an improper prior is normalizable. We will explain this equation in more detail in the revised manuscript.*

Line 376: please check that the term "frequentist probability" is correctly used here.
While the term is jargon, it is used correctly. We use it to distinguish the notion of probability as the expected outcome in many repeated measurements ("frequentist") from the interpretation of probability reflecting ignorance or prior information ("Bayesian"). In our sensitivity calculation, the p-value expresses the number of times we expect to measure B_{01} *as small or smaller than what we observe in our actual measurement, in the case that no temporal effects are present in the GCR flux. Since we have used a Bayesian statistic, the Bayes Factor, to perform the model comparison, we feel it is important to note that our sensitivity is a frequentist calculation.*

Lines 382-384 repeat what is said in lines ~330.
That is correct and the repetition is intentional for clarity. Lines ~330 describe depth-14CO profile shapes on the figure, with the intention of giving the reader a visual introduction to how temporal variability in GCR flux could affect the shape of the profiles. Lines ~383 summarize the temporal variations trialed in the sensitivity analysis.

Line 388: was the step-like increase at 3.5 ka or 3 ka as stated in line 331?
For the sensitivity analysis (line 388), the transient step-like increase is at 3.5 ka. For the visual introduction to the effects of temporal variability (Figure 4b, line 331), this increase was at 3 ka, so both are correct.

Line 405: lunar rocks can be also mentioned here.
As the lunar rock evidence would already be added in the Introduction (as per Dr Usoskin's earlier comment), and as lunar rocks provide only an indirect indication that the GCR flux could have been constant, without quantifying uncertainties, we would prefer to not mention it again here.

Line 411: measurements of d15N were not discussed in the text and appear out of the blue here. It needs to be removed or introduced somewhere.
We will remove mention of d15N to avoid confusion