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Giulio G.R. Iovine
Editorial Support Team, ESSD

Dear Giulio,

Thank you for the opportunity to review the manuscript "Radon-222 monitoring at German ICOS atmosphere stations" (essd-2024-551) by Gachkivskyi et al., presently under consideration for publication in Earth System Science Data.

The manuscript summarises a range of caveats that apply to atmospheric radon monitoring conducted by "indirect" (single-filter) Heidelberg Radon Monitors, which are routinely used for radon monitoring at many German ICOS stations, and then focuses specifically on problems associated with high relative humidity conditions (related to aerosol scavenging). A method is proposed to limit influences of high humidity conditions on existing and future radon datasets collected using these monitors, and an updated database is provided where potentially affected data has been flagged out.

For potential users of these datasets in the climate and atmospheric science research communities, I see this improvement in quality of archived radon datasets being of great value and significance, since it is a step closer to harmonising these datasets with radon observations made in other parts of Europe (and the world) using direct radon monitoring techniques. I recommend publication of this manuscript after minor revision. I make some general and specific comments below.

General

In the abstract and introduction there is discussion about both the utility of radon to distinguish between oceanic and continental air masses (i.e. as an indicator of "baseline" atmospheric conditions; things that might happen at a remote WMO GAW station), and the utility of radon as a tracer of transport and mixing in the atmospheric boundary layer over land. Given that the focus of the manuscript is on radon observations at ICOS stations, I would encourage the authors to focus more on just discussing radon's suitability and usefulness as a tracer of transport and mixing (including model validation).

I think it would be pertinent to mention in the abstract the intended provision of a RH flagged/corrected 11-year radon dataset from the 8 ICOS stations investigated in this paper.

Is it possible, perhaps in the methods section, to provide an approximate detection limit for the HRM under ideal conditions? (>90m agl, <98% humidity, no line loss correction required).

Specific

L24: Consider saying "half-life" rather than "half-life time" (throughout the manuscript)

L25: Vertical radon gradients that occur in the atmosphere related to radon's half-life are typically between the atmospheric boundary layer (ABL) and the free troposphere. This characteristic is not important in the context of this study (since everything is occurring within the ABL – or at least beneath the synoptic inversion). Vertical gradients that occur within the ABL are typically related to mixing, alone. Most important here is that (i) radon's half-life (3.8 d) is short compared with synoptic time scales (~4-12 d), so it doesn't accumulate in the atmosphere on greater than synoptic timescales, but (ii) radon's half-life is long compared with mixing timescales in the ABL (~ 1 hour), such that it can roughly be considered a conservative tracer for boundary layer mixing and transport studies.

L32: "Owing to its applicability as **an** atmospheric transport tracer, ^{222}Rn observations are recommended as **a** supplementary ..."

L42: Isn't there also a HRM operating at the Amazon Tall Tower Observatory? Or has this now stopped?

L47: Related to the Jacobi and Andre (1963) reference, consider mentioning the dependence of radioactive equilibrium on height **and** stability here. The authors make this point later (see line 98). Depending on how well the stability dependence is understood, this may be a subject for future investigation given that some of the German ICOS station observations are made at heights within the stable nocturnal boundary layer (based on the diurnal cycles; Figure 6).

L104-105 (and L124): At the time of the mentioned ICPs, there was no traceable method to calibrate 1500L ANSTO radon detectors. Only field calibration (on the sample air flow) was possible, leading to uncertainties in *absolute* calibration of order 4-8% associated with necessary assumptions (Chambers et al 2022; Kikaj et al 2025). So, adjusting to an ANSTO detector-based scale could have been problematic. *Relative* radon concentration changes reported by ANSTO 1500L detectors however are very reliable. Importantly, since the 19ENV01 *traceRadon* Project (Röttger et al. 2021) this calibration uncertainty can be removed with the use of Calibration Transfer Standard Devices (Chambers et al. 2022; Röttger et al. 2025).

L184: "... transport **away** from the ^{222}Rn source ..."

L187-189: "... south-north gradient of the ^{222}Rn ~~flux~~ concentration is ..."

While the spatial variability of the radon flux is certainly one driver of observed radon concentrations, air mass time in contact with land *en route* to a site (which changes on synoptic and seasonal timescales), also has a strong influence (since the radon half-life is 3.8 days, on synoptic timescales the air mass can have a strong radon "memory" of surface types it has passed over). See also **L193-194**.

L203-205: In winter and early spring, if sites are prone to snow cover or frequent cloud cover, then there is usually much less contrast between daytime and nighttime mixing depths, so diurnal amplitudes of trace gas concentrations can be much smaller.

L215-217: It is worth considering here that the strongest (stable nocturnal) inversion conditions occur when there is strong surface cooling. If measuring within the stable nocturnal boundary layer (though mainly if closer to the surface), it may not be uncommon to reach values of quite high relative humidity. I doubt that for the measurements in this study (>90m agl) even if they are within the SNBL (as indicated by diel radon cycles in the warmer months) that high RH values would be common.

References

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