Authors' reply to CC1: 'Comment on egusphere-2023-2680' by Scott Chambers, posted on 28 Nov 2023

In the present document the authors of the manuscript "Full characterization and calibration of a transfer standard monitor for atmospheric radon and thoron measurements", currently under review for publication in Atmospheric Measurement Techniques, want to answer point by point, to the comment posted by Scott Chambers. Authors answers are here reported in blue colour.

First of all, authors want to thank Scott Chambers to actively participate into the discussion phase of this manuscript. In the following lines clarifications are presented for each Scott's comment:

CC1: Abstract

-For better transparency (considering readers who may not be familiar with ISO 11929-4), it would be good in the abstract to provide the reader with context for the claimed ARMON v2 detection limit of 0.132 Bq m^{-3} that would be directly comparable to other radon measurement systems. For example, some studies have shown the hourly measurement uncertainty of commercial AlphaGuard units at their nominal detection limit (of around 3 Bq m^{-3}) is 50 – 60%(in other cases the quoted uncertainty has been higher), and the radon concentration at which the 200 L ANSTO dual-flow-loop monitor has an hourly measurement error of 30% is around 0.14 – 0.16 Bq m^{-3} (Chambers et al. 2022; doi:10.5194/adgeo-57-63-2022).

It is important to take in mind that the current manuscript wants to presents the characterization and calibration of a new version of the ARMON monitor. The comparison of the ARMON with others radon and/or radon progeny monitors has been performed during a different activity of the project traceRadon, its results are currently under analysis and they are going to be presented in a further manuscript where the uncertainty budget of the all monitors will be performed for atmospheric hourly radon concentration measured at a typical ICOS station.

However, to help the reader with the context of the work and to avoid faulty comparisons, we think it is important to underline that:

i. in absence of thoron, the background of the ARMON is zero, so any count detected of ^{218}Po can be assigned to ^{222}Rn, and therefore the decision threshold is zero. In fact, it could be declared that the detection limit of the ARMON is 1 count per hour (0.048 Bq m^{-3}), but the authors have opted to use the ISO-11929 definition. In addition, in the presented analysis of the full ARMON measurement uncertainty, all the uncertainties, those of type A from the counting and those of type B coming from the different variables that may affect the measure, are taken in consideration which may intrinsically depend or not from the instrument.

ii. in the paper cited by Scott Chambers, where the new 200L ANSTO monitor was presented, the full uncertainty budget of the radon concentration measured with this instrument was not performed and declared as in the present ARMON manuscript. Therefore, uncertainty values for both monitors cannot be compared without a complete evaluation of all the uncertainties of the ANSTO (e.g. uncertainty introduced by the background variability of the monitor, the flow sample variability, the deconvolution calculation application, the T/P/RH sensors, etc.).

iii. in the paper by Radulescu et al., 2022 (https://doi.org/10.1016/j.nima.2021.165927) commercial radon monitors were compared only together with their statistical uncertainties.

Please take in mind again that the values reported are much bigger that 50-60% and, again, they do not represent the full uncertainty of the measurement.

- Based on the results of Figure 5a of this manuscript, the hourly ARMON v2 measurement uncertainty for ^{222}Rn in a dry, ^{220}Rn-free environment (i.e., best case scenario) at an ambient ^{222}Rn activity concentration of around 0.6 Bq m^{-3} is ≥ 30%. Guided by the shape of the curve in Figure 5a, the hourly measurement uncertainty at the claimed detection limit of 0.132 Bq m^{-3} would likely exceed 100%. Stating the hourly measurement uncertainty along with the claimed detection limit in the abstract would be a better guide for the reader.

Figure 5a represents the total uncertainty obtained by the ARMON during real field atmospheric measurements and WITHOUT using the thoron delay volume. This means that this curve does not represent the ARMON best scenario because the thoron contribution, and its influence on the radon concentration uncertainty, may be low here but it is not zero. Actually, using the thoron decay volume will improve the results (Figure 5b). For example, the uncertainty at 0.6 Bq m^{-3} is 28% (<30%), and 60% at the detection limit. We will clarify this point and add this value in the revised version of the manuscript.

-Furthermore, since the ARMON v2 is introduced here as being able to separately quantify radon (^{222}Rn) and thoron (^{220}Rn), it would be good to state in the abstract the expected detection limit and hourly measurement uncertainty both with, and without, the presence of ^{220}Rn in the sampled airstream (assuming a representative ^{220}Rn activity for the surface layer – such as the value quoted on Line 430).

Due to limitations in the number of words of the abstract it was not possible to include all results. However, we will try to rewrite it in the new version of the document to add this information too.

-Lastly, the suitable measurement range of the ARMON v2 is quoted to be 1 – 100 Bq m^{-3}, but the measurement uncertainty is given only for a concentration of > 5 Bq m^{-3}. Would it not make sense to quote the measurement uncertainty at 1 Bq m^{-3}? Or at least report this value also?

The full budget calculation was done for a typical inland atmospheric radon concentration value (5 Bq m^{-3}), however we will also add in the new version of the manuscript the range of variability of the radon uncertainty of the ARMON in the range between 1 and 100 Bq m^{-3}, which was the traceRadon project target.

CC1: Line 100

For completeness, the authors should also consider including the following paper in this summary: Wada, A., Murayama, S., Kondo, H.,Matsueda, H., Sawa, Y., and Tsuboi, K. (2010). Development of a compact and sensitive electrostatic Radon-222 measuring system for use in atmospheric observation. J. Meteorol. Soc. Jpn. 88, 123–134. doi: 10.2151/jmsj.2010-202.

Thank you Scott for the reference, we will add it at the corresponding line.

CC1: Section 2.4

Regarding the uncertainty and application of the STP correction for ARMON v2 measurements: according to Figure 1, the temperature measurements of the ARMON v2 are not made in the measurement sphere, but a long way downstream of the sphere and some other instruments. The location of the pressure measurements is not indicated in the figure, it would be good to see where they are made. Given the separation between the sensors and measurement volume, and the fact that the temperature sensor is in a separate, ventilated compartment of the ARMON's transport case, can the authors give any indication of the expected additional uncertainty in the derived STP correction parameter? At the moment, it seems that only the instrument manufacturer uncertainty values for temperature and pressure are being considered.

First of all, we want to clarify that the ARMON does not have a pressure meter and the STP correction is performed using the pressure value and uncertainty from the atmospheric station pressure meter where the instrument is running, as the air inside the sphere is at atmospheric pressure because it is an open circuit. Regarding the temperature meter, in stationary measurements we do not think it may differ from the temperature inside the sphere, as it is located in the same box. This was confirmed in the past with an old version of the ARMON which had the sensor inside the detection volume (Grossi et al., 2012, https://doi.org/10.1016/j.radmeas.2011.11.006). In any case, the sensitivity study shows us that even if there was a big error in the temperature measurement (e.g. 3 ºC), the uncertainty added would be below 1%, very low compared to the elements that have a greater contribution to the uncertainty of the system. We will add a sentence in the modified version of the document to explain this fact.

General: Consider revising the text for grammatical accuracy.

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Thank you again and yes, in the revised version of the manuscript we will carry on a deep grammar revision too.