We thank the reviewer for the comments and insights. Our responses are in blue text. The line and page numbers in our responses refer to those in the revised manuscript with track changes.

As far as I am aware of, this study presents the most comprehensive piece of work to date using 222Rn to evaluate atmospheric transport and mixing on a global scale. It includes the assessment of four 222Rn emission scenarios, a CTM driven by two meteorological data sets, and the comparison of simulations with practically all atmospheric222Rn observations currently available, including vertical profiles. The clear structure of the paper, its great readability and meaningful displays make it a pleasure to read. It leaves no open question to me. There is very little that I can suggest to further improve it.

Minor comments

Differences between simulated and observed atmospheric concentrations occur for various reasons. One is the bias in measurement techniques, especially the underestimation of 222Rn concentrations derived from 222Rn progeny measurements near the surface (< 100 m above ground; cf. Grossi et al., 2020). Further, 222Rn concentration gradients within the first few metres above ground can be steep (e.g. Chambers et al., 2011). Several of the atmospheric observations in China were done between 1 and 1.5 m above ground (Jin et al., 1998, cited in Zhang et al, 2011, cited in the present study), which might explain some of the difference between simulation and observation for those sites. Are those sites represented in Figure 6 e-h by points indicating simulated values more than a factor of two smaller than observed values (or, better, observed values exceeding simulated values by more than a factor of two)?

The comparisons between observations and model results for Asian sites (Fig. 6e-h) suggest that surface ^{222}Rn concentrations were underestimated by at least a factor of two in the model for a few sites. As the reviewer pointed out, the measurements have been taken very close to the surface. According to Figure 1 in Chambers at al. (2011), ^{222}Rn concentrations measured close to surface can be significantly higher than those at 50m between 8pm until 9am, and are possibly higher than the average taken from the model bottom-layer gridbox (~100m high). On the other hand, there are possible low biases in the measurements due to measurement techniques. Such low biases may partially compensate for the underestimate due to the steep concentration gradients near the surface. Considering these rationales, we have added the following discussion in Line 16 on Page 16:

"The observations in China were taken between 1m and 1.5m above ground according to Jin et al. (1998). The model surface layer concentrations usually represent the averages in the model bottom layer (~100m high), and thus may be literally lower than the observations due to the steep concentration gradients near the surface, especially during nighttime (Chambers et al., 2011). On the other hand, there are possible low biases in the ^{222}Rn concentrations derived from ^{222}Rn progeny measurements (Schmithüsen et al., 2017; Grossi et al., 2020), lessening the above model underestimate due to large near-surface vertical gradients. These biases differ on a case-by-case basis and are difficult to quantify."

Figure 6, y-axis label in the second row (Panel e) is "Observed ..." Should this not be "Simulated ...", as in the other rows?

Thanks for catching this typo. Now corrected.

Page 19, lines 7 and 8: "The seasonality in surface 222Rn concentrations is mainly affected by three factors: (1) the surface 222Rn emission flux rate determined by radium content and soil conditions; ..." This sentence is subject to eventual misinterpretation, in the way that radium content may be misunderstood as being seasonally variable. I would suggest to change the sentence to something like: "The seasonality in surface 222Rn concentrations is mainly affected by three factors: (1) seasonality in surface 222Rn emission flux rate resulting from seasonal changes in soil moisture, diffusivity, depth of the water table, snow and ice cover; ..."

Thanks for the suggestion. We have revised the sentence to:

"The seasonality in surface ^{222}Rn concentrations is mainly affected by three factors: (1) the variability in ^{222}Rn emission flux rate due to seasonal changes in soil moisture, diffusivity, depth of the water table, and snow and ice coverage; ..."

Page 24, lines 1 and 2: Some 222Rn flux measurements from Antarctic soil are reported in Envangelista and Pereira (2002). As mentioned in the text, there are vast regions without atmospheric 222Rn observations. Perhaps suggest, where from a modeller's perspective it would be desirable to see an atmospheric 222Rn detector established. Personally, I would very much like to see that happen at the tall tower (300 m) at Zotino (60 N 90 E), in the middle of Siberia (http://www.zottoproject.org/index.php/Main/Home).

We thank the reviewer for pointing us to this ^{222}Rn flux measurement work in the Antarctic. The work provides valuable measurement of ^{222}Rn fluxes during the summer of 1998/1999 at the Admiralty Bay area of King George Island, Antarctic Peninsula (62°S, 58°W). Reported fluxes ranged between 0.21×10^{-2} atom cm^{-2} s^{-1} and 28×10^{-2} atom cm^{-2} s^{-1}. We have added the following discussion in the text:

"Evangelista and Pereira (2002) reported summertime ^{222}Rn fluxes ranging between 0.21×10^{-2} atom cm^{-2} s^{-1} and 28×10^{-2} atom cm^{-2} s^{-1} during the summer of 1998/1999 at the Admiralty Bay area of King George Island, Antarctic Peninsula (62°S, 58°W). The work also suggested such low fluxes could not explain ^{222}Rn concentration surges in the atmosphere. The sparse measurements at the edge of the Antarctic are not adequate for inferring emission fluxes over the remote continent."

Regarding the desire for more observations, we have made a few statements in section 3.2 to suggest more measurements in Asia, North America, and Antarctic. Measurements in the middle Siberia would be very valuable because they may help quantify ^{222}Rn emissions and surface concentrations in the northern Asia.

References

Chambers et al. (2011) Separating remote fetch and local mixing influences on vertical radon measurements in the lower atmosphere. https://doi.org/10.1111/j.1600- 0889.2011.00565.x

Grossi et al. (2020) Intercomparison study of atmospheric 222Rn and 222Rn progeny monitors. https://doi.org/10.5194/amt-13-2241-2020

Evangelista and Pereira (2002) Radon flux at King George Island, Antarctic Peninsula. https://doi.org/10.1016/S0265-931X(01)00137-0