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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Estimation of nocturnal ^{222}Rn soil fluxes over Russia from TROICA measurements" *by* E. V. Berezina et al.

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The authors thank the anonymous referee #1 for the constructive comments and corrections. They helped us to improve our paper.

Page 4670, line 8: Estimates of radon-222 flux densities with the same instrument and approach over a large area provides very useful insights into its variation over space and time. I have no doubts about the reliability of relative differences reported. These are interesting and well worth being published.

Reply: Thank you for the positive assessment of our study.

Page 4670, line 11: The absolute values are very high, compared to the well doc-

umented global average of around 1 atom cm-2 s-1. Winter time measurements of radon-222 in the marine boundary layer off the West coast of Japan, for example (Williams et al. (2009) Tellus, 61B, 732-746), suggest an about three times smaller flux density (0.014 Bq m-2 s-1, or 0.7 atom m-2 s-1) for the area corresponding to the eastern half of the domain covered in the present paper.

Reply: The enhanced rates of surface radon emissions obtained in present study compared to some baseline global average radon flux value, on our opinion, should not be a cause of confusion as they relate completely to continental crust in the regions of high tectonic activity (Eastern Siberia) and orogenic belts. Therefore, the obtained high values reflect the overall geological settings in the area crossed by the Trans-Siberian Railroad. In fact, the estimated 222Rn flux of 14.1 mBq m−2 s−1 (1σ-range: 18 mBq m−2 s−1) for the lower latitude band (Williams et al., 2009) is 3–5 times lower compared to the range of 30 – 90 mBq m−2 s−1 proposed in present study (Table 6). The generic feature of any atmospheric concentration measurements, however, is that any time- and space-averaged techniques produce generally smaller concentration values, so the observed disagreement can be explained by essentially different techniques employed in (Williams et al., 2009) and in our study. The first is based upon the concept of 'budget equation' which utilizes some poorly defined parameters relevant to atmospheric mixing and advection, whereas in our study we operate with in-situ measurements in highly specific meteorological conditions (surface inversions) which are characterized, however, by purely constrained turbulent mixing rates. We circumvent the problem of depicting turbulent vertical mixing by considering a wide range of plausible turbulent mixing rates, so the proposed confidence interval on final estimates of 222Rn fluxes is seemed to constrain well the final estimates. Undoubtedly, the effect of seasonal soil thawing and seasonal variations in 222Rn soil fluxes must contribute to the observed differences in estimated 222Rn fluxes as well.

Page 4671, line 8: Nocturnal near surface gradients in atmospheric radon concentrations can be extremely steep in the lowest 50 m (see for example Fig. 3 in Servant

(1966) Tellus, 18, 663-671). The lower tens of meters may even retain most of the radon emitted during a night (see for example Lehmann et al. (2001) Radiochimica Acta, 89, 839-843; Xia et al. (2011) Boundary-Layer Meteorology, 138, 163-170). Therefore, an estimate of radon flux density, based on concentration measurements at 4 m height, depends very much on the accurate representation of the concentration profile within the first tens of meters above ground. The 50 m vertical resolution of the temperature profiler used in the present study did not allow to resolve this critical section of the nocturnal inversion. An extrapolation of the vertical diffusivity profile from greater heights to the near-surface layer may therefore have led to an over-estimation of radon flux densities.

Reply: According to Cohen et al. (1972): J. Geophys. Res. 77 (15), 2654-2668, Ta-Yung Li (1974): Boundary-Layer Meteorology 7, 185-198, Beck and Gogolak (1979): J. Geophys. Res. 84 (C6), 3139-3148, radon concentration decreases from the surface up to the heights above 50 meters during stable atmospheric stratification. In our inverse procedure, we circumvent multiple uncertainties owing to the observation technique and environmental settings by prescribing a wide range of diffusivity rates, which are expected to cover the whole range of uncertainties connected to the atmospheric dispersal process. We used the vertical diffusivity profiles from 1 meter above ground given by Jacobi and Andre (1963): J. Geophys. Res., 68, 3799–3814 (their curves WNW and IWN on Fig.1) and widely used in the relevant studies on 222Rn distribution (for example in Beck and Gogolak, 1979; Moses et al., 1960). We agree with the referee on the important role of vertical mixing regime within the first meters above the surface, but one should take into account that the 222Rn measurements were performed from the moving railway carriage that inevitably resulted in highly disturbed near-surface originally calm air. Then, the measured 222Rn concentrations should be considered as representative for some height-average quantities in the layer from the ground up to $\sim$ 4 m a.g.l., which are used as a lower boundary condition for the diffusion equation relevant for the heights from 4 m to the upper boundary H (see Eqs. (2, 3)).

Page 4671, line 19: A few other studies with similarly high radon flux densities directly measured in different parts of Russia are cited in support of the estimates derived in the present study. Most of them are in conference proceedings to which I do not have access, so I can not assess how reliable these data may be. One study cited in support, the radioactivity report of the county of Perm, is available online, but information on radon flux density is limited to one average number in a table (Table 17.8) with no information at all on materials and methods used to derive it. That Kirichenko (1970) is cited in support of the high values found, is surprising and not appropriate. The values he derived for larger areas are all < 1 atom cm-2 s-1. As summarised by Turekian et al. (Ann. Rev. Earth Planet. Sci. 1977, 5, 227-255), Kirichenko's regional estimates range from 0.18 to 0.88 atom cm-2 s-1, with an average of 0.52 atom cm-2 s-1 (or 0.011 Bq m-2 s-1), so 3 to 8 times smaller than the regional weighed mean flux density estimates presented here.

Reply: You are right. Unfortunately, there is a lack of direct radon flux measurements reported for Russian regions. Therefore, we tried to find any data published to compare with our estimations. The reference to Kirichenko (1970) is presented inaccurate and corrected (Correction: "Kirichenko [1970] reported 222Rn flux in the South Ural region from summer studies to be 0.01 Bq m-2 s-1 which is lower than our estimations, 0.03 – 0.07 Bq m-2 s-1.").

Page 4672, line 3: Please provide more information on the radon detector used in this study. In a phone call with someone at Tracer Lab, I have learned that the instrument was a specially made some time ago for low level detection of radon-222. Since there is no documentation available to the interested reader (or reviewer), please put more effort in describing the technical details (flow rates, calibration, ect.).

Reply: Agreed. We will provide more information about the instrument in the final version of our paper (see section 2.1. 222Rn measurement technique).

Minor issues: Page 4672, line 9: Page 14548, line 24: What do you mean with "anthropogenic origin" of radon? Uranium mine tailings?

Reply: We mean mining operation as well as mine tailings.

Page 4672, line 11: Page 14548, lines 9-10: Calling measurements of radon and temperature an experiment is not appropriate from my point of view. An experiment is a procedure in which a hypothesis is tested, which is not the case here. Observations were made along several journeys. Therefore, the terms 'expedition' or 'campaign' would be more appropriate.

Reply: Agreed. It will be corrected in the final version of the paper.

Page 4672, line 16: The use of English language could be improved in many instances. Long-winded sentences (e.g. Page 14558, lines 24-28) should be rephrased to form two or more shorter ones. Reply: Agreed.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 14545, 2013.