

Spatial and temporal distribution of ^{222}Rn concentrations and its fluxes in the lower atmosphere over continental Russia

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INTRODUCTION

The fact that Radon-222 and its progenies can cause some negative effects on human health is well known. ^{222}Rn is also widely used for studying different atmospheric processes: determination of origin and motion paths of air masses (Prospero and Carlson, 1970; Wilkniss *et al.*, 1974) and of the vertical diffusion coefficient (Druilhet и Fontan, 1972), investigation of the lower atmosphere vertical stability (Guedalia *et al.*, 1980), estimation of greenhouse gases emissions (Martina Schmidt *et al.*, 1996; C.Duenas *et al.*, 1999; Sebastien Biraud *et al.*, 2000). ^{222}Rn concentration data are very useful for the analysis of different compounds accumulation in the lower atmosphere. Thus investigation of the spatial and temporal ^{222}Rn concentration variations and estimation of its fluxes into the atmosphere are important today.

Therefore we analyzed the ^{222}Rn concentration data in the atmospheric surface layer over the continental Russia from Moscow to Vladivostok cities. The data were obtained during five *TROICA (Transcontinental Observations Into the Chemistry of the Atmosphere)* expeditions of the railroad mobile laboratory along the Trans-Siberian railroad: *TROICA-5* (June-July 1999), *TROICA-7* (June-July 2001), *TROICA-8* (March-April 2004), *TROICA-9* (October 2005) and *TROICA-11* (July-August 2007). ^{222}Rn accumulation conditions in the atmospheric surface layer, spatial distribution and temporal variations of its surface concentrations along the Trans-Siberia railroad were investigated. Calculation of the ^{222}Rn accumulation layer depth and estimation of its emanation into the atmosphere during ground temperature inversions were made.

INSTRUMENTS AND METHODS

^{222}Rn concentration and the air temperature profile were measured continuously in the lower atmosphere (at a height of about 5 meters) during the mobile laboratory movement.

Radon-222 concentration data were obtained using the *Low Level Radon Daughter Monitor (LLRDM)* produced by Tracer Lab (Germany) and installed in the mobile railroad laboratory. The technique's procedure is pumping air through a quartz filter, where the ^{222}Rn daughters attached to aerosols are quantitatively collected. Using the Alpha spectrometry method the instrument measures and displays the potential alpha energy concentration (PAEC) in form of the Equilibrium Equivalent Radon Concentration (EEC) in Bq/m^3 , ^{222}Rn gas concentration estimated by the individual Radon-Daughter-Concentrations in Bq/m^3 and Equilibrium Factor (F). The measurement time is 10 minutes. The detection limit is 0.02- 100 Bq/m^3 with 30 % uncertainty.

To investigate the influence of the atmospheric temperature stratification on radon concentration variation in the lower atmosphere the air temperature profile was measured using the temperature profiler MTP-5 (ATTEX, Russia). It is a passive microwave sensor which allows determination of the air temperature profile from the ground up to 600 m with a vertical resolution being 50 m and a time resolution being 5 minutes. Accuracy is 0.2 - 0.5°C.

The MTP-5 mainly measures the thermal radiation of the atmosphere at the centre of the molecular oxygen absorption band (close to 60 GHz) at different angles. From the brightness temperature an inversion procedure (Kadygrov and Pick 1998) can be applied to obtain the temperature profile.

RESULTS AND CONCLUSIONS

The highest ^{222}Rn concentration values along the way from Moscow to Vladivostok were observed in the Amur Region (up to 70 Bq/m^3), in South Siberia: Baikal region (up to 60 Bq/m^3) and Transbaikalia (up to 50 Bq/m^3), in the Western Siberia regions from Novosibirsk to Krasnoyarsk and in Ural (up to 50 Bq/m^3). High ^{222}Rn concentrations are also noted in the regions located between Khabarovsk and Vladivostok (up to 45 Bq/m^3), Tyumen and Omsk (up to 40 Bq/m^3) and Kirov - Perm (up to 30 Bq/m^3) cities. The value of ^{222}Rn concentration being equal to $20\text{-}25 \text{ Bq/m}^3$ is observed near Nizhniy Novgorod. Fig.1 shows the spatial distribution of ^{222}Rn concentrations in the lower atmosphere from Moscow to Vladivostok according to the data of *TROICA- 8, 9 and 11* expeditions and altitude distribution along the Trans-Siberian railroad.

Distribution of ^{222}Rn concentrations observed from Moscow to Vladivostok is due to daily variations of ^{222}Rn concentration influenced by night temperature inversions. During the day when the atmosphere is unstable ^{222}Rn concentration in the surface atmosphere has minimum values ($2\text{-}5 \text{ Bq/m}^3$). To the end of the day air convections and mixing processes become weaker and temperature inversion builds up resulting in ^{222}Rn accumulation and its concentration rising with maximum concentration values being near sunrise (05:00 – 06:00). After sunrise the inversion is destroyed (09:00 – 10:00) and ^{222}Rn concentration decreases sharply up to minimum values. It was noted that there is a weak positive correlation between ^{222}Rn concentration and inversion size ($R = 0.36$) and a mean positive correlation between ^{222}Rn concentration and inversion depth ($R = 0.61$). The daily variation of ^{222}Rn concentration during summer days with temperature inversions and without them is shown in Fig. 2.

As it can be seen the highest ^{222}Rn concentration values are typical for the mountain and upland regions that can be explained by emanation of ^{222}Rn from fractures and cavities in rocks and in the regions influenced by local and remote anthropogenic radon sources (mines and open pits, barrows and tailings dumps of the mining industry).

The highest values of ^{222}Rn concentrations were observed in the period of the October expedition (monthly mean value is up to 13 Bq/m^3). It is likely to be due to larger total accumulation time of ^{222}Rn near the surface during night temperature inversions and smaller total precipitation period in October then in the other months (according to the data obtained). In March because of snow cover and frozen soil ^{222}Rn concentration values ($\sim 7 \text{ Bq/m}^3$) are lower than in summer months except June. It may be caused by snow thaw and soil defrosting in some investigated regions during the spring expedition that results in sharply rising of the mean ^{222}Rn concentration in March in comparison with the one in June (Fig. 3.).

Figure 1. Spatial distribution of ^{222}Rn concentrations in the lower atmosphere from Moscow to Vladivostok according to the data of TROICA- 8 (a), 11 (b) and 9 (c) expeditions, altitude distribution along the Trans-Siberia railroad (d).

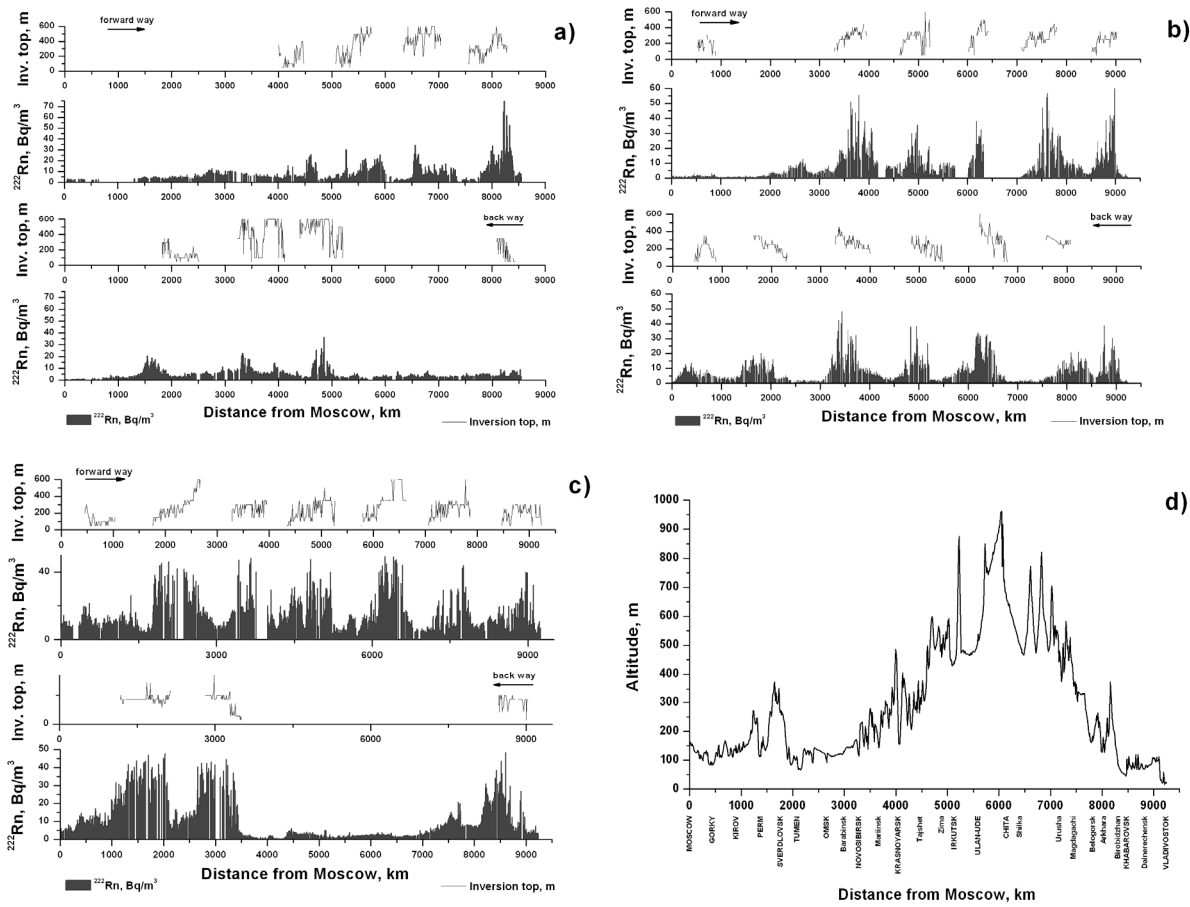


Figure 2. Daily variation of ^{222}Rn concentration during summer days with temperature inversions and without them.

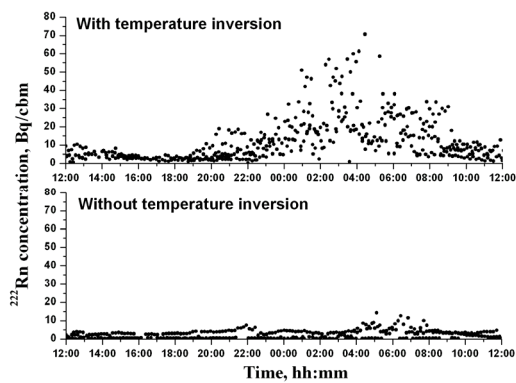
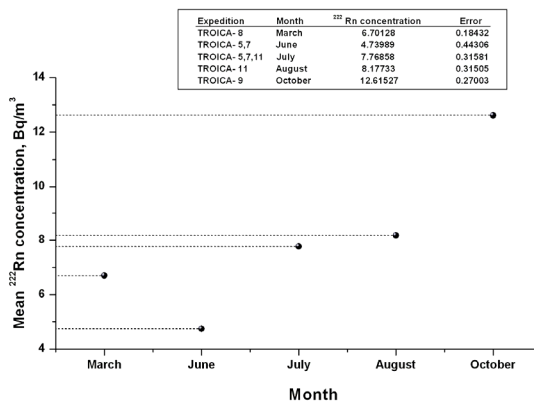


Figure 3. Monthly mean ^{222}Rn concentration variation.



Estimation of ^{222}Rn flux into the atmosphere according to the ^{222}Rn concentration data obtained during all expeditions was carried out. The ^{222}Rn flux was calculated from the observed concentration change over time and the average inversion top. The ^{222}Rn flux values obtained vary from Moscow to Vladivostok from 0.03 to 0.26 $\text{Bq/m}^2\text{s}$ with ^{222}Rn flux small increase from Moscow to South Siberia. The values may be overestimated because of our assumption that ^{222}Rn distributes to the inversion top varying from 50 to 600 meters according

to our data. There are considerations that ^{222}Rn accumulates only in the first 100 meters above the ground during temperature inversion (Servant, 1966; Kataoka et al., 1998). Taking this fact into account we estimated the accumulation layer depth using ^{222}Rn concentration data obtained and the generally assumed value of ^{222}Rn flux ($0.02 \text{ Bq/m}^2\text{s}$). The mean accumulation layer depth according to our calculations is about 62 ± 22 meters.

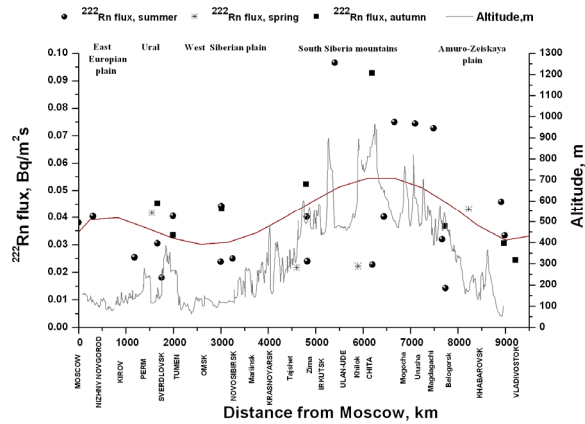


Figure 4. Distribution of ^{222}Rn flux from Moscow to Vladivostok.

Having accepted the mean ^{222}Rn accumulation layer depth to be 100 meters we estimated ^{222}Rn flux distribution from Moscow to Vladivostok. The obtained results vary from 0.014 to $0.225 \text{ Bq/m}^2\text{s}$ with the maximum values being in the mountain and upland regions (Fig.4).

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REFERENCES

- Kadygrov, E. N., Pick, D. R., 1998. The potential for temperature retrieval from an angularscanning single-channel microwave radiometer and some comparison with in situ observations. *Meteorological Application*, 5: 393-404.
- Servant, J., 1966, Temporal and spatial variations of the concentration of the short-lived decay products of radon in the lower atmosphere. *Tellus XVIII*, 2: 663-670.
- Kataoka, T. et al., 1998, Diurnal variation in radon concentration and mixing-layer depths. *Boundary-Layer Meteorology*, 89: 225-250.