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Investigation of seasonal dynamics of *β*- and *γ*-radiation fields vertical profile in the surface atmospheric layer

K S Ryabkina[1], A G Kondratyeva[1], P M Nagorskiy[2], V S Yakovleva[1]
[1]National Research Tomsk Polytechnic University, 30 Lenin Ave., Tomsk, 634050, Russia
[2]Institute of Monitoring of Climatic and Ecological Systems Siberian Branch of the Russian Academy of Sciences (IMCES SB RAS), 10/3 Academichesky avenue, Tomsk, 634055, Russia

E-mail: vsyakovleva@tpu.ru

Abstract. This paper is devoted to the seasonal dynamics of β- and γ-radiation field vertical profile in the surface atmospheric layer study. The findings revealed the following: a) significant seasonal variation in vertical distribution characteristics fields β- and γ-radiation; b) reduced β-radiation flux density and γ-radiation dose with increasing height is maintained in the range of spring and fall, namely, starting with snow melt and finishing its setting; c) distortion vertical profile in the winter season, an inverse relationship β-flux density and dose rate of γ-radiation from the heights above the earth's surface was registered.

1. Introduction

Remarkable indicator properties of radionuclides and ionizing radiation are known and actively used since ancient times to obtain new knowledge of dynamic processes in the atmosphere and the lithosphere, as well as to forecast natural and man-made hazards. Models of gases and aerosols transport have been improving based on that knowledge.

Ionizing radiation (IR) and natural radioactivity are all-important in radioecology and radiobiology, radiological protection, construction and geophysics. Atmospheric field of IR are of particular interest in the areas of radioecology and radiobiology for evaluation small (background) doses of the population and environmental exposure. In this regard, research groups and governmental structures carry out radiation monitoring of the ground atmosphere.

Interpretation of the data derived from observations of the atmosphere ionizing radiation background is a complex task [1–5]. This task solution requires the use of IR transfer modeling results, as well as knowledge of atmospheric ionizing radiation sources function.

The scientific team [5] has developed a comprehensive approach to radiation monitoring. The study of the vertical profile of ionizing radiation field characteristics in the system soil-atmosphere is the main feature of this technology approach.

The aim of this study was to investigate the dynamics of the vertical profile of β- and γ-radiation fields in the surface layer of the atmosphere on the annual and above synoptic time scale.

2. Materials and Methods

Radiation monitoring is implemented since the end of 2008 in Tomsk Observatory of Radioactivity and Ionizing Radiation (TORIR). Its technology is constantly being improved. At present TORIR includes Dosimetry Laboratory (Bldg. 10, TPU) and two experimental platforms, which are located on the territory adjacent to the IMCES SB RAS building and its mezzanine. Radiation monitoring in the surface atmosphere includes synchronous continuous automated high sampling frequency (1–10 min.) measuring the characteristics of α-, β-, and γ- radiation fields. Radiation monitoring scheme is given in figure 1.

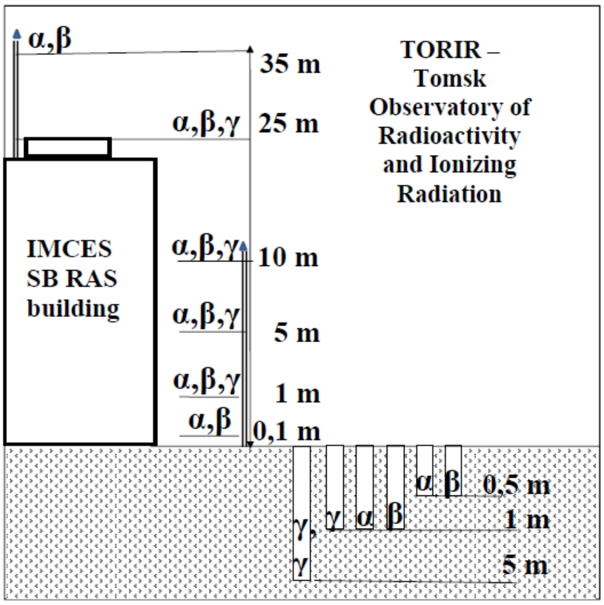

Figure 1. Radiation monitoring scheme

Instrumental equipment included: highly sensitive scintillation α-, β- and γ-radiation detectors, respectively, BDPA-01 BDPB-01, BDKG-03 (ATOMTEX, Republic of Belarus); gas-discharge γ-and β-radiation counters of STS-6 and SBM-19 types (RF); radon isotopes and their DPs radiometers RTM 2200 (SARAD, Germany), RRA-01-03 (RF), Ramon-01 (Kazakhstan); self-engineered devices for measurements of radon flux densities from the ground surface [5]. Ionizing radiation detectors or counters were installed in twos or in threes at series of heights as shown in figure 1.

BDPB-01 and BDPA-01 detectors were installed at heights of 10 cm, 1, 5, 10, 25 and 35 m to measure the flux densities α- and β-radiation in the surface atmosphere, and at depths 10, 20, 50 cm and 1 m – to measure soil radon concentration activity.

BDKG-03 detectors and STS-6, SBM-19 counters were installed at heights of 1, 5, 10 and 25 m to measure the flux density and ambient dose equivalent rate of γ-radiation in the surface atmosphere.

These detectors have been chosen based on the requirements of a wide range of operating conditions: temperatures range from - 30 to + 50 ° C and relative humidity – up to 98%.

Since the intensity of cosmic rays influences on the formation of the background ionizing radiation, the data of neutron monitor of Geophysical Observatory “Klyuchi” of Altay-Sayan Branch of Geophysical Survey SB RAS (Novosibirsk, RF) were used in this work. The data have been registered with 1 minute tact.

In order to determine the degree of external factors influence, the monitoring of meteorological (air temperature, pressure, air relative humidity, wind speed and direction, surface temperature and soil temperature at series of depths), actinometrical and atmospheric-electrical values was performed via automated information measuring system of IMCES. Incoming solar radiation is measured by pyranometer Kipp & Zonen CM-11 and the photometer NILU-UV-6T. The precipitation and snow thickness data were taken from http://rp5.ru/8218/ru.

3. Results and discussion

Analysis of radiation monitoring data revealed a strong seasonal variability of the vertical distribution β- fields and γ-radiation characteristics. An example of the dynamics of the vertical profile of β-radiation flux density and dose rate of γ-radiation is shown in figure 2. This figure also shows the dynamics of the neutron component of cosmic radiation (CR) and variations of the meteorological values. The data was smoothed rectangular filter duration of 10 days.

Since the beginning of April until October and November the vertical profiles of β-radiation flux density and the dose rate of γ-radiation agrees well with model representations [6]. The results of simulation [6] using the Monte Carlo method shows that the dependence of the dose rate of γ-radiation on the height above the Earth's surface is well described by an exponential law, and decreases with increasing altitude. The dependence of β-radiation from a height can be represented as a sum of two exponents [6].

The transition to the winter season is accompanied by a synchronous decrease in the γ-background at all altitudes. The β-background dynamics is substantially similar to, but with small differences. The appearance of snow cover leads to the following: a) first, β- and γ-background ceases to depend on the height; b) then, with increasing thickness snow cover, begins to grow with height. Should be noted, the appearance of snow cover leads to a change the sign of the vertical gradient of β- and γ-background. The above is illustrated in figure 2 as follows: a two-year dynamic of relationships of β-radiation flux density at altitudes of 25 m and 1 m (β(25m)/ β(1m)) and the dose rate of γ-radiation ((γ(25m) / γ(1m) is shown in the third top panel. These data directly point the existence of the annual cycle and a high consistency of year to year variations.

The variations β- and γ-background have weakly expressed maximum in the summer the annual cycle. For β-background the annual cycle changes from year to year, in contrast to the γ-background, for which there is a maximum in November and a minimum in February and March.

Between the height snow cover and atmospheric levels of β-, γ-background there is an obvious dependence. The increase in snow cover from 0.5 m to 1 m leads to the formation of "failure" in the annual cycle of β- and γ-background. This failure clearly expressed in figure 2. Since the "failure" depth (figures 2, 3) depends on the thickness of snow cover, then we construct the dependence of the level of atmospheric β-, γ-background from snow depth (figure 3). The same relationship is shown in figure 3 for the neutron component of the secondary cosmic radiation.

Straight lines in this figure are the regression lines. When carrying out the regression analysis data, satisfying the following conditions: a thickness of snow cover > 1 cm and an ambient temperature <-1 ^{o}C, were selected.

Comparing the regression analysis results (figure 3) and snow depth data has shown that in periods of the snow cover growth the levels of β-, γ-background decrease practically linearly and at the same time the dispersion of the experimental data is small.

The dispersion of levels β-, γ- background increases significantly during periods of stabilization of snow depth. If the change in depth of snow cover affects slightly on the level of variations of the neutron component of cosmic rays, the atmospheric pressure change leads to a consistent pressure and neutron component level change. This is due to the fact that the optical thickness of the atmosphere for primary cosmic radiation is much greater than 1 (figure 4, right panel).

The dependence of levels of β-, γ-background on the atmospheric pressure are much less expressed. It is caused by the fact that the pressure is at a maximum in the winter months of the annual cycle, when there is snow cover.

In the process of temperature change during the annual cycle the level of β- background practically unchanged, and the γ-background levels and CR grow poorly (figure 5). To analyze the levels of β-, γ-background and CR dependency on pressure and temperature (figures 4 and 5), all data in the annual cycle, and not only the data period of snow cover have been used as in figure 3.

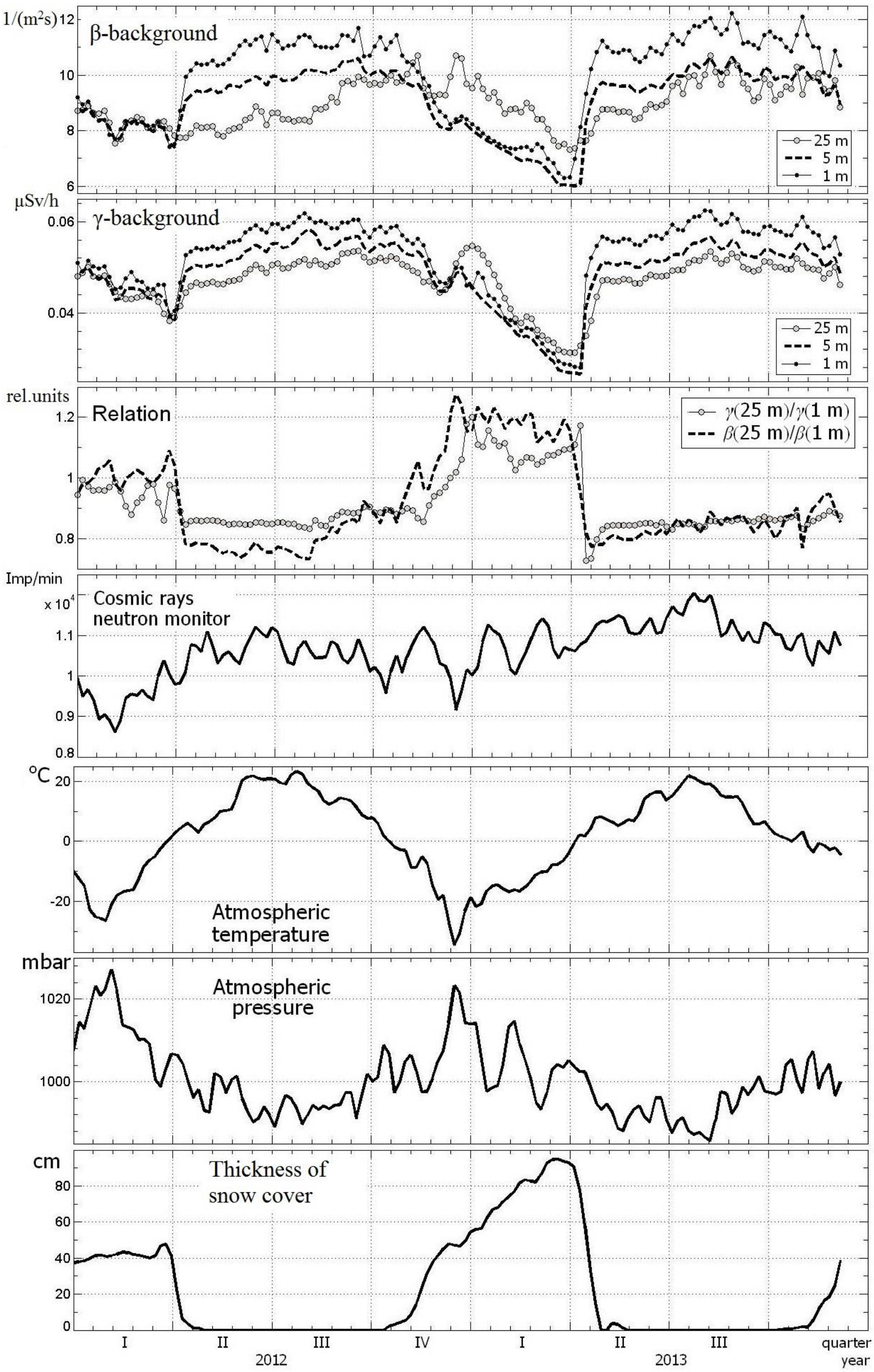

Figure 2. Dynamics of radiation and meteorological values

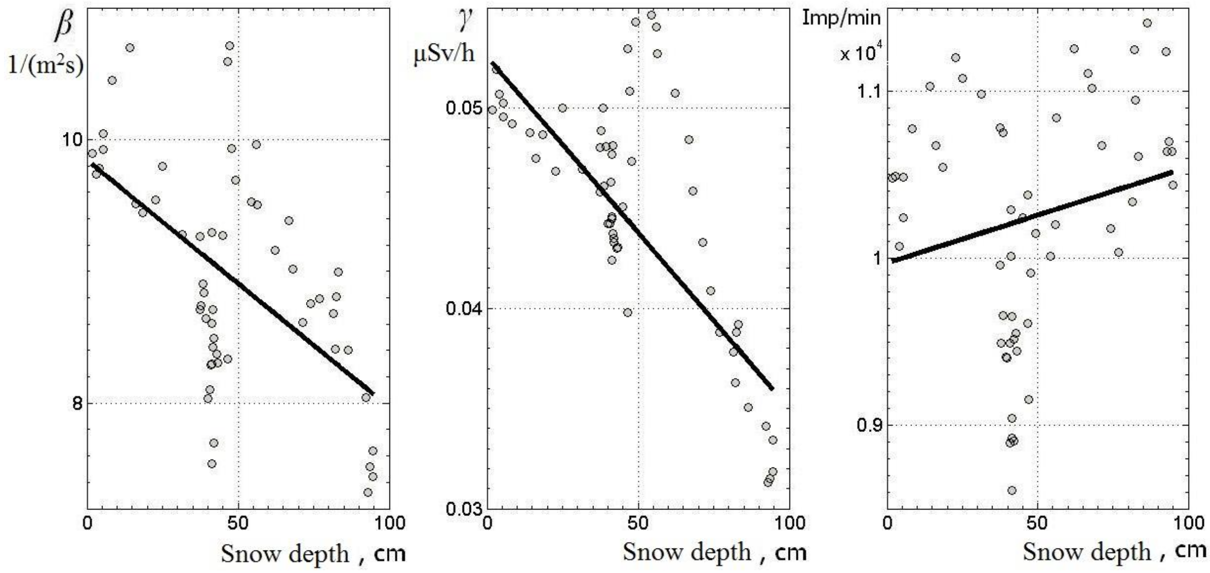

Figure 3. The level β-, γ- backgrounds and CR neutron component depending on the height of the snow cover (left - right)

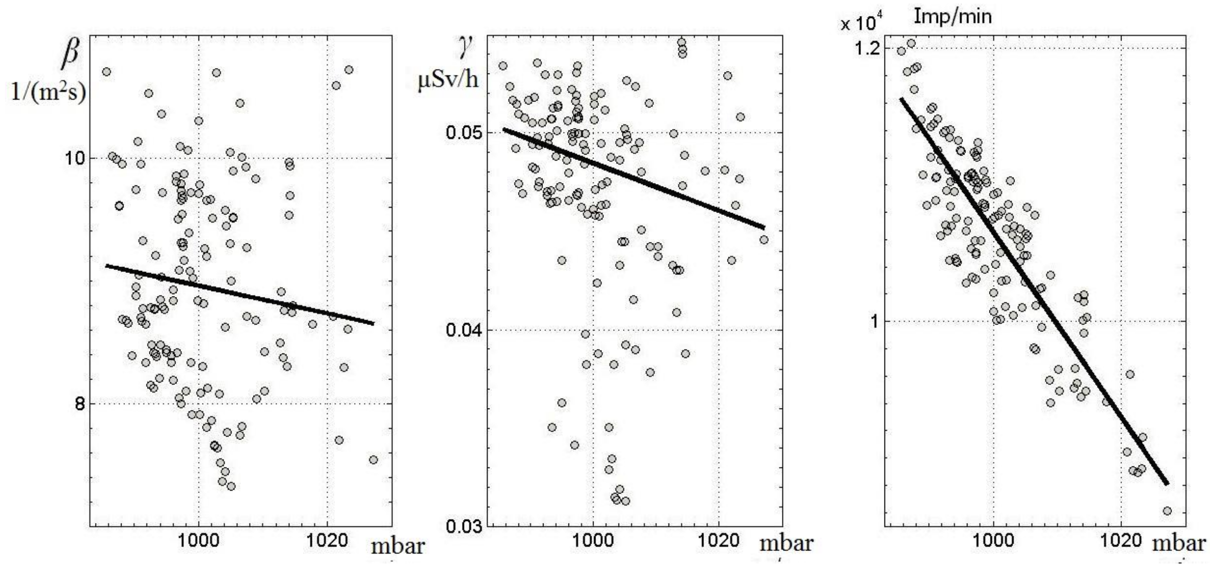

Figure 4. The level β-, γ- backgrounds and CR neutron component depending on the atmospheric pressure (left - right)

5. Conclusion

Analysis of the years' research results revealed a significant seasonal change vertical field profile β- and γ-radiation.

It was found that in the absence of snow cover there is a decrease of β-radiation flux density and γ-radiation dose rate occurring with increasing distance from the earth's surface.

It has been established that in the presence of snow and freezing temperatures in the winter, there is an inverse relationship, i.e., increase of β-radiation flux density and γ-radiation dose rate occurring with increasing distance from the earth's surface.

Furthermore, a linear dependence between snow depth and registered atmospheric β- and γ-background levels in periods of the snow cover growth was revealed.

It is shown that in Western Siberia the radiation dose of people who are outdoors in winter is reduced. This is pressing issue in terms of radiobiology.

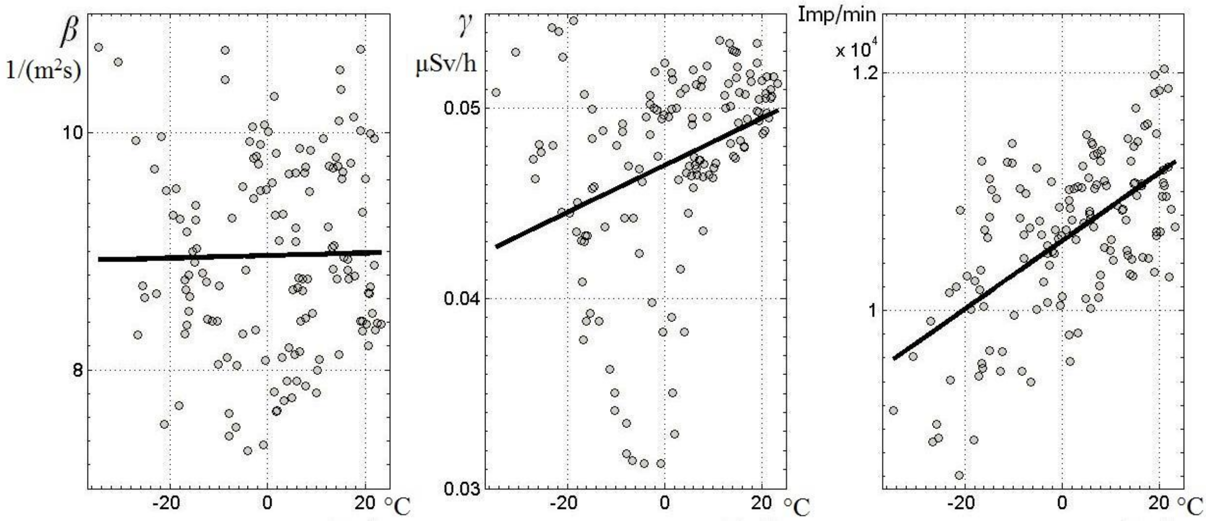

Figure 5. The level β-, γ- backgrounds and CR depending on the atmospheric temperature (left - right)

Acknowledgments

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References

[1] Mercier J F, Tracy B L, d'Amours, Chagnon R F, Hoffman I, Korpach E P, Johnson S and Ungar R K 2009 *Journal of Environmental Radioactivity* **100** 527-533

[2] Sobolev, A.I., Tikhomirov, V.A., Verbova, L.F., Mitronova, Yu.N., Zhunov, I.K., 2005 Fundamental research 6, 74-75

[3] Sedunova, Yu.S., 1991. Atmosphere. Handbook. Gidrometeoizdat, Leningrad, 511 p

[4] Burnett J L Croudace I W and Warwick P E 2010 *Journal of Radiological Protection* Volume 30 N.**3.** 525-**532**

[5] Yakovleva V S and Nagorsky P M 2015 *Bulletin of KRAUNTS. Physical and mathematical sciences* **1** 65

[6] Yakovleva V S, Karataev V D and Zukau V V 2011 *Bulletin of KRAUNTS. Physical and mathematical sciences* **1** 65