Radiation Aspects Of Cosmic Ray In The Earth Atmosphere For Different Periods Of The Solar Activity

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In the paper the results of investigation of radiational situation in the space near the Earth at the different altitudes of the Earth atmosphere and at the ground level in dependence on geocoordinates and solar activity during 1957 - 1997 are presented. Radiation is due to the Galactic Cosmic Rays flux for different periods of the Solar activity. The radiation near ground level of the Earth for the last 500 years was calculated also using the data of the radioactive carbon ^{14}C intensity investigations.

Introduction

Now different components of the primary cosmic rays on a lage scales of cosmos, in the cosmic space near the Earth and on the boundary of the Earth's atmosphere have studied [1-3]. There are the results of measurements and theoretical calculations of the energy spectra, the angular distribution of different components of the secondary cosmic rays from ground level of the Earth up to the atmospheric boundary, and also the fluxes of direct and reverse albedo on the atmosphere boundary [4-8]. Total radiational doses at different levels of the Earth atmosphere and in the cosmic space near the Earth were calculated on the base of data of primary and secondary Galactic and solar radiation. It is shown that the maximum doses of radiation are at the altitudes of 16-19 km from the ground level of the Earth (60÷50 g/cm^2). Secondary cosmic emission maximum is at these altitudes as a function of geolatitude. It is also emphasized that when appring to as for aviation at altitudes more than 12 km flight during the 6-7 and more hours is undesirable [9-10].

It is necessary to point out that the contribution of the nuclei with $Z>2$ at energies E<1 GeV into the secondary fluxes of the different components of CR is small. Therefore it is possible that the nuclei with relatively are not taken into consideration $Z>2$ and $E>10^9$ eV as a rule when determining the doses what, it seems to us, is unjustified [9, 11, 12].

Equivalent dose rate is calculated in the case of biological object radiation. Its spectral composition is known from the formula:

$$P_i(x,R) = \sum_i \iint D_i(E) N_i [E,\Omega,x] dE d\Omega \quad (1)$$

where $D_i(E)$ - is conventional specific equivalent dose Zv/cm^2/particle ; E - is the energy of i-sort particle radiation; N(E,Ω) - is the differential density of this radiation flux at depth x. We noted $m(E,x,E',\theta)dE'd\Omega$ - to be the number of i-sort secondary particles with energies $(E',E'+dE')$ in angle dΩ at depth x, produced by a primary particle with energy E and isotropicaly falled on the atmosphere boundary. Then the intensity of i-sort particles is written down in the form:

$$N_i^R(E,x,\theta) = \sum_i N_i(E') m_i(E',x,E,\theta) dE' \quad (2)$$

In the case the equivalent dose rate

$$P_i(x,R)=\sum_i \int_{E_m}^{\infty}\int_{\Omega}^{\infty} N_i(E,x,\theta)D_i(E)dEd\Omega=\sum_i \int_{E_m}^{\infty} D_i(E)\int_{\Omega} d\Omega\int_{R}^{\infty} N_0(E')m(E',x,E,\theta)dE'dE=$$

$$=\sum_i \int_{R}^{\infty} N_0(E')\left\{\int_{\Omega} d\Omega\int_{E_m}^{\infty} D_i(E)m(E',x,E,\theta)dE\right\}dE'=\sum_i \int_{R}^{\infty} N_0(E')d\Omega\Re(E',x)dE'$$

where $\Re_i(E',x)=\int_{\Omega} d\Omega\int_{E_m} D_i(E)m(E',x,E,\theta)dE$ - is integral of the equivalent dose rate from the incident particle with energy E.

It is noted that the dose rate may be calculated also from:

$$P_i(x,R)=\sum_i \int_{E_R}^{\infty} N_0(E')\Re(E',x)dE' \qquad (4)$$

where E_R - is the correspondent to the cut off rigidity energy R.
For the simplicity one can introduce the transition coefficient for dose rate:

$$W_p(R,\rangle\varepsilon,x)=P_i(x,R)/N_0(0,\rangle\varepsilon_m) \qquad (5)$$

where the numerator is given by (1) and denumerator - is the primary spectrum at the pole from single particle.
The coefficient (5) has dimension and it is the standartized rate of equivalent dose.
The CR spectrum for the Earth's orbit have been taken for the calculations in the form:

$$N(\varepsilon)=1{,}32\cdot 10^4\,\varepsilon^{-2{,}65}\left(1-\frac{0{,}6}{\sqrt{E}}\right)\cdot\exp-\int_{r}^{r_0}\frac{U}{\chi}dr \qquad (6)$$

where E- is the total energy, U - the solar wind velocity, χ - the diffusion coefficient, r_0 - width of the modulation region.

The calculations shows that the modulation coefficient $K=\int_{r}^{r_0}\frac{U}{\chi}dr$ varies from the minima to the maxima of solar activity in range 0,3÷2,5.

Results

The calculated doses of irradiation by GCR at different altitudes of the Earth's atmosphere and their change in time presented below.

Figure 1. shows the doses, calculated on the basis of the experimental data of measurements total ionization component of cosmic radiation connected with the different Earth atmospheric levels, for the solar activity minimum -fig.1.a. and for solar activity maximum - fig.1.b. and also for 4 stations of the Earth with geomagnetic cut off rigidity 6,61 GV (Almaty, $\lambda=43^0$ N, $\varphi\approx 76^0$E), 2,39 GV (Moscow, $\lambda\approx 55^0$ N, $\varphi\approx 37^0$E), 0,5 GV (Murmansk, $\lambda\approx 69^0$ N, $\varphi\approx 33^0$E), 0,03 GV (Mirny, Antarctida, $\lambda\approx -66^0$ S, $\varphi\approx 93^0$E). From fig.1. we can make a conclusion that the maximum of radiation is on 16-19 km height (at the altitude of cruiser flight of supersound planes), also we can notice, that the radiation over Almaty is almost twice less because of the high geomagnetic cut off rigidity, then in high latitude stations. We can stress that CIC CR includes p, $e^{\pm}$, $\mu^{\pm}$,γ, $\pi^{\pm}$ and doesn't include neutrons, which make a large contribution to the radiation doses.

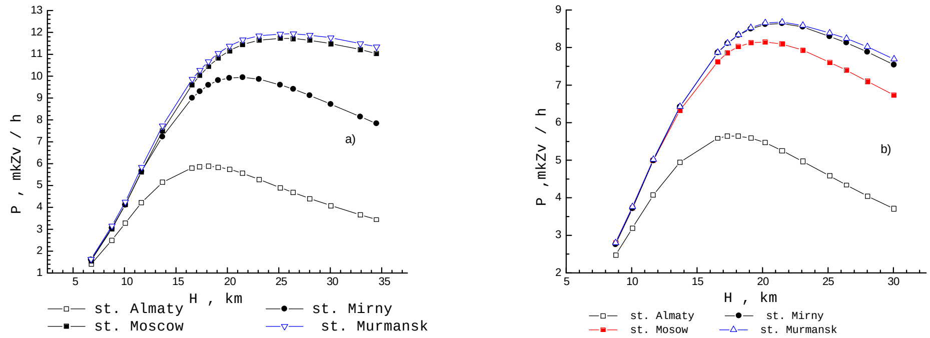

Figure 1. The doses of total ionization component at the different Earth atmospheric levels.

a) for the solar activity minimum
b) for the solar activity maximum.

Time modifications of the radiation doses on the different Earth atmospheric heights are shown in fig.2. From fig.2. we can make a conclusion, that in the solar activity minimums in high latitude stations the radiation doses on heights more than 12 km are 1,5 times more. This fact is also observed at middle latitude stations (Moscow), the difference between the radiation doses at minima and maxima equals to 35%, and in Almaty equals to 20%.

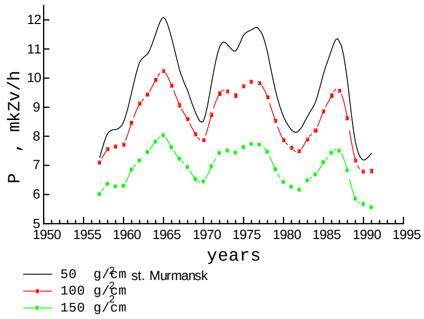

Figure.2. Time changes of the radiation doses at the different Earth atmospheric levels.

In fig. 3 the variations of radiocarbon ^{14}C and radiational doses within period 1000 to 1990 are shown. Calculations of radiational doses were carried out on the base of radiation intensity data through radioactive carbon ^{14}C [13-14]. It seenos from fig. 3, that the variation of ^{14}C for more than 900 years have got two visible peaks in the minimum of Maunder minimum (1645-1715) of the Solar activity and in period after on 1950, when a number of nuclear weapon tests were made at the Earth's atmosphere. Fig. 3 also presents two maxima of the radiational doses at the same time as in the fig. 3.

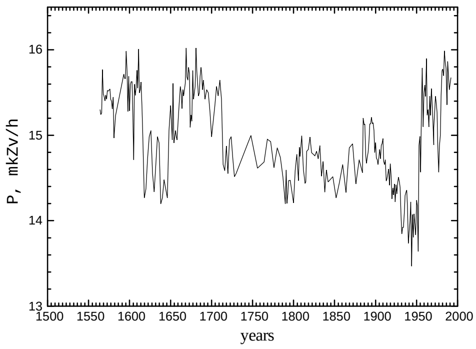

Figure 3. Radiation doses of C^{14} at the different period.

Thus the radiation dose variations for a long period in the Earth atmosphere are caused by natural and quaternary influences. In conclusion, using the obtained results of the work we can make the next conclusions:

-the radiation doses are several times more than background doses (at the expense of GCR on the Earth surface) at the altitudes of the maximum of the second cosmic radiation of the Earth atmosphere - 16-19 km.

-in high geomagnetic latitudes the radiation doses also exceed background doses in several times.

-during the nuclear tests in the Earth's atmosphere the radioactive clouds at latitudes ~12-13 km which go ground the Earth two or three times were created.

-it seems to us that these couds make a certain contribution to the ecological situation in the Earth atmosphere and on the surface.

From the above mentioned we can make a conclusion that aviation shouldn't flight at the altitudes more than 12 km, especially in high latitude and in the Solar activity minimum.

After a powerful Solar flash of a high degree within 10-15 minutes protons of high energy over 10 MeV reach the Earth [15-17]. They create a threat of radiation in stratosphere at the height of 10 km.

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