LONG-PERIOD COSMIC RAY VARIATIONS AND THEIR ALTITUDE DEPENDENCE

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I. The study of long-period variations from the data of ground-based cosmic ray (CR) observations encounters great difficulties. In spite of a large value of an II-year variation, it is more difficult to obtain its spectrum than, say, the spectrum of a solar diurnal variation. Serious obstacles are caused by changes in individual detectors and in the whole world-wide network of CR detectors, by the absence of continuity and uniformity of data series, by various apparatus variations, etc. Therefore, in discrimination and investigation of long-period variations an important and determining point is preparation and preliminary analysis of data.

We have used average monthly data from 28 neutron monitors for the period from IO to 26 years. All the data were preliminarily verified. We made some corrections connected with the change in the efficiency of CR detector and with an incompleteness of some data series. Corrections due to temperature effect were made. We have assumed that the long-period variation δ_i of an individual monitor is caused by an isotropic variation and by first two zonal components of primary CR anisotropy, i.e.

$$\delta_i = a_0 C_0^i(\gamma) + a_1 C_{10}^i(\beta_1) + a_2 C_{20}^i(\beta_2) \qquad (I)$$

where a_0, a_I, a_2 and γ, β_1, β_2 are amplitudes (for a rigidity R= IO GV) and indices of power-law spectrum of the isotropic part and of the zonal components of the primary variation. We have used the acceptance coefficients C_0, C_{IO}, C_{20} calculated in refs. /I,2/ and in the present paper. In average annual data processing the amplitudes a_I and a_2 did not have a statistically significant difference from zero and variation in each station were determined only by the acceptance coefficient

$$C_0^i(\gamma) = 10^{\gamma} \int_g^{\infty} W(R,g,h) R^{-\gamma} dR, \qquad (2)$$

where g is a cutoff rigidity, h is hight, W(R.g,h) are the coupling coefficients of a given station.

In /3/ it is shown that if one uses the coupling coefficients of the neutron component calculated in /4/ and the approximation

$$W(R,g,h) = \alpha \varkappa \exp(-\alpha R^{-\varkappa}) R^{-\varkappa-1} / (1-\exp(-\alpha g^{-\varkappa})),$$

the coefficients α and $\varkappa$ will be linearly connected with the depth h in the atmosphere ($\alpha = \alpha_0 + \alpha_1 h$ and $æ = æ_0 + æ_1 h$ for h > 300 mb. For the minimal solar activity $\alpha_0 = 6.25 \pm 0.03$, $\alpha_1 = 0.70 \pm 0.04$, $æ_0 = 1.40 \pm 0.02$, $æ_1 = -0.56 \pm 0.02$.

Figure I presents the behaviour of the isotropic component a_0 of the primary variation of CR (for a rigidity of 5, IO and 20 GV) and the change in the intensity I_λ of the green coronal line during I957-I982. Note that the rigidity spectrum of the long-period CR variation is apparently "softer" in the years closest to the maxima of solar activity and "harder" near the minima. The CR modulation depth in a 20-th cycle is much smaller than in a I9-th or a 21-st cycle. This difference is especially large for hard particles. The Table presents the indices γ averaged for years of high solar activity. In the CR spectrum variations a 22-year repeatability is observed. It can possibly be explained by the difference in the level of solar activity in the maxima of three last cycles.

cycle	years	γ
I9	58-6I	$0.6 \pm 0.I$
20	68-7I	$I.2 \pm 0.I$
21	79-82	$0.7 \pm 0.I$

2. The use of acceptance coefficients is not the only way for obtaining the energy spectrum of CR variations from the data of ground-based recorders. The other methods require the knowledge of the altitude dependence of the variation δ of the studied component of secondary CR. It is convenient to characterize the altitude dependence by the quantity $\beta_\delta = \frac{1}{\delta}\frac{\partial\delta}{\partial h}$; it is natural to call this quantity a variational barometric coefficient. The quantity β_δ for the neutron component can be calculated with the use made of the above-mentioned data on the altitude dependence of coupling coefficients and the expression

$$\beta_\delta(g,h) = \left(\int_g^\infty \beta_W(R,g,h)W(R,g,h)\Delta(R)\,dR\right) \Big/ \int_g^\infty W(R,g,h)\Delta(R)\,dR \quad (3)$$

where $\beta_W = \frac{1}{W}\frac{\partial W}{\partial h}$ and $\Delta(R) = \frac{\Delta D}{D}(R)$ is the variation of the primary spectrum of CR. The dependence of β_δ on the cutoff rigidity g and on the variational spectral index γ is shown in Fig.2. The value of the coefficient β_δ can be an indication of the slope of the rigidity spectrum of secondary CR variation. Besides, the calculation of β_δ can be used for reduction of the variations observed at different altitudes to one barometric level and for calculation of variations of the total barometric coefficient for different neutron monitors. With the help of the same data on one can calculate also the partial barometric coefficient $\beta_m = \frac{1}{m}\frac{\partial m}{\partial h}$ (m = m(R,h) is the integral multiplicity of neutron component generation) since $\beta_m = \beta_W + \beta$ where β is the total barometric coefficient. The dependence of β_m on rigidity for h = 600 mb and IOOO mb is shown in Fig.3.

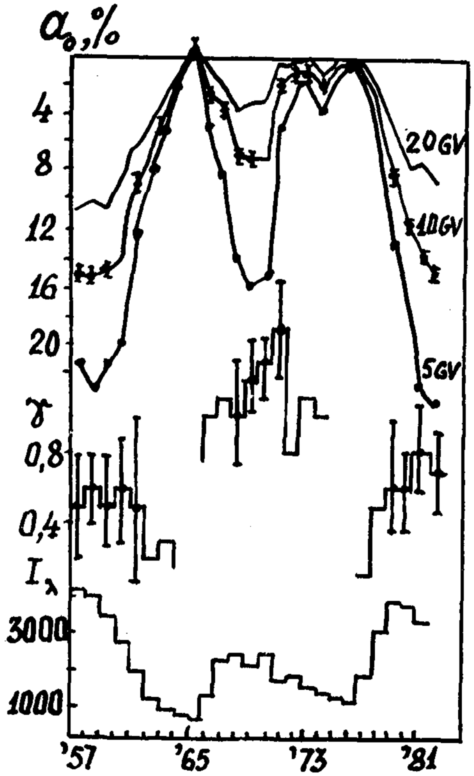

Fig. 1

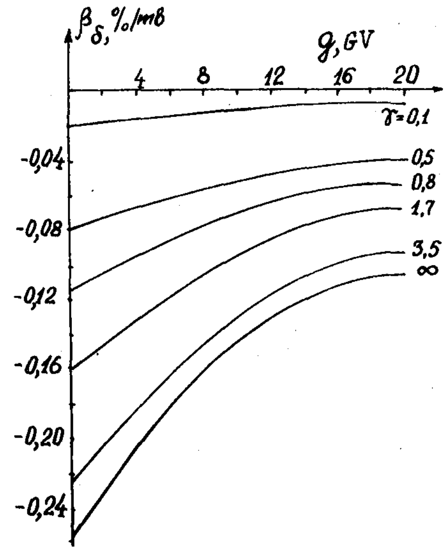

Fig. 2

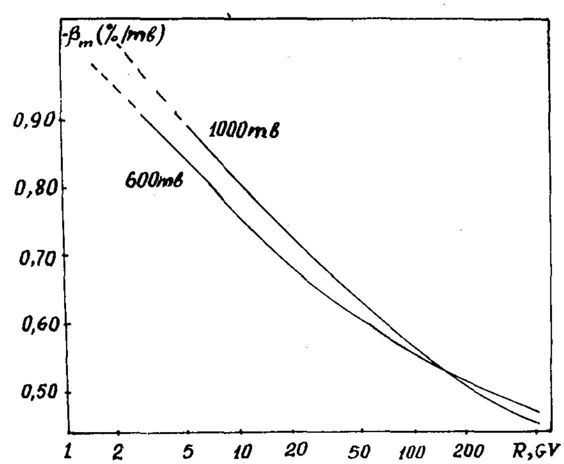

Fig. 3

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