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ANNUAL VARIATIONS OF COSMIC RAYS AND INTENSITY VARIATIONS OF COSMIC RADIATION AS A FUNCTION OF EARTH'S HELIOLATITUDE

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SUMMARY

This paper presents the results of unambiguous investigation of annual variations of cosmic rays by going at length over the material of the world network of cosmic ray stations and aerological sounding with concomitant reference to data relative to other geophysical events for the year 1960.

Analysis of the curves obtained shows that there is in the hard component a wave with a 12-month period, which does not exist in the neutron component. This is evidence that a great contribution is made to the seasonal variation of the hard component the annual variation of atmosphere temperature.

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A large number of works were devoted to variations of secondary components of cosmic rays [1 - 10], in which it is mainly stressed that these variations have a meteorological nature. The difference obtained between the observed and the theoretically computed variation, that is, the annual wave, is referred to the inaccuracy of radiosonde data [1], or to the failure of temperature contribution above the 50 or 100 mb level [4]. Vallarta and Godart [10] proposed an explanation of the annual variation of cosmic rays, linked with the yearly variation of Earth's heliolatitude, by periodical distance variations between the Earth and the Sun, and Earth's axis inclination to the perpendicular to the ecliptic plane. However, the variation computed by these assumptions failed to coincide with the experimental data of [9]. E. S. Glokova [11] found from the material of the world network of cosmic ray stations for the period 1937-1946 the annual course of the intensity of μ-mesons which correlated well with the annual course of the C-index of magnetic activity, and had a universal character. Conclusion was derived in [11]on the extraatmospheric nature of annual variations.

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* GODOVYYE VARIATSII KOSMICHESKIKH LUCHEY I IZMENENIYE INTENSIVNOSTI KOSMICHESKOY RADIATSII V FUNKTSII GELIOSHIROTY ZEMLI

From the above considerations one may see that there is no single viewpoint in regard to annual variations of cosmic ray intensity. Obviously, an unambiguous answer to that question can only be found in the course of detailed investigation of the material of the world network of cosmic ray stations and by aerological sounding, involving at the same time the data relative to other geophysical events.

Such data for the year 1960 were utilized in the present work. The curves of the seasonal course of average monthly values of intensity of the hard and neutron components of cosmic rays are plotted in Figures 1 a and b, after corrections for the barometric effect and the secular course by the method of least squares [12]. Analysis of the curves shows that there is in the hard component a wave with a 12-month period, while no such wave exists in the neutron component. This speaks in favor of the fact that a large contribution to the seasonal variation of the hard component is made by the annual variation of atmosphere temperature.

Let us compute the expected seasonal variation $\delta N(h_0)/N(h_0)$ of the hard component, utilizing the radiosonde data $\delta T(h)$ to the 50 mb level by the integral method proposed in [13]:

$$\frac{\delta N(h_0)}{N(h_0)} = \int_0^{h_0} W(h)\,\delta T(h)\,dh,$$

where W(h) is the ensity of the temperature coefficient found in [13] theoretically. The results are plotted in Fig.1 a by dashed line. Subtracting from the observed seasonal variation of the hard component the expected wave, we shall obtain the residual annual variation which is shown in Fig.1 c. The annual wave can be traced in all stations, just as was done for the neutron component, and it has clearly expressed maxima near the equinoctial periods. The agreement of the annual course of the neutron component, which is nearly devoid of temperature effect, with the analogous course of the hard component of cosmic rays points to the extra-atmospheric origin of this variation. It is clear that it can not be ascribed to the inaccuracy of introduction of corrections for temperature effect [1].

Therefore, the results obtained point to the correctness of the theory of meteorological effects [13] and to the presence of a characteristic annual atmospheric wave in the intensity of cosmic rays with maxima in the equinox periods.

It is well known [14, 15] that the activity of magneto-ionospheric disturbances and polar aurorae also reveals clearly-expressed maxima in the periods of equinoxes. The annual course of the mean monthly values of the K_p-index of geomagnetic activity (Fig.1b) for the same period shows a good positive correlation with the annual course of cosmic ray intensity, corrected for the meteorological effects.

It is evident that the noted behavior of the combination of geophysical events in the course of the year may be treated from the standpoint of the relative position of the terrestrial equator and ecliptic planes. As a matter of fact, the active regions of the Sun are the sources of corpuscular streams, and they are forming mostly within the limits of 25° to the North and to the South of the solar equator, shifting toward the equator as solar activity drops.

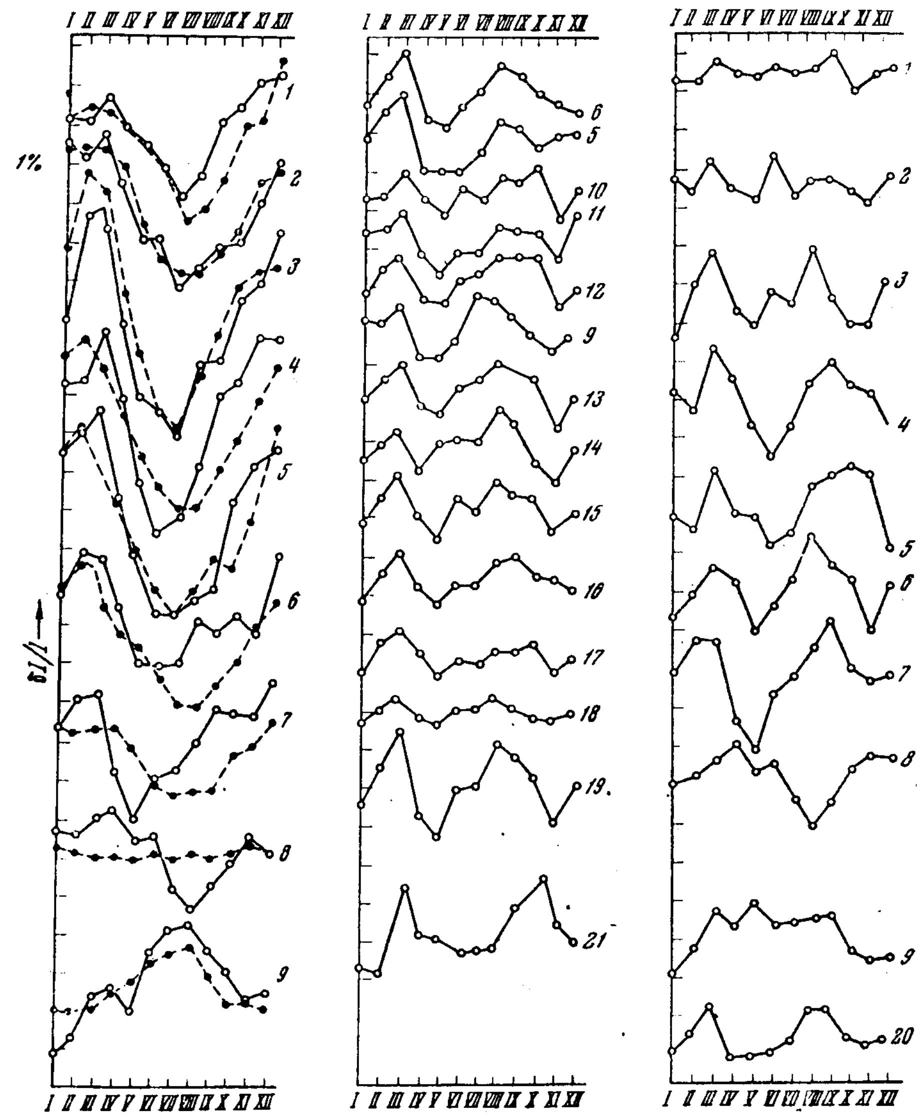

Fig.1. Seasonal course of cosmic ray intensity. a) hard component: solid line) the observed wave; dashed line) the expected wave; b) the neutron component corrected for the noncyclicity; c) residual annual wave of the hard component corrected for the noncyclicity. 1) Krasnaya Pakhra; 2) Tbilisi; 3) Hayes Island; 4) Ottawa; 5) Upsala; 6) Sulphur; 7) Prague; 8) Kampala; 9) Hobart; 10) Washington; 11) Nederhorst; 12) Climax; 13) Zugspitze; 14) Jungfrau-Joch; 15) Pic du Midi; 16) Rome; 17) Norikura; 18) Wankayo; 19) average neutron component for all stations; 20) average hard component for all stations; 21) Annual course of the K_p-index. - Denotations: where appropriate: a.s.k for stations 1, 2, meaning "shielded ionization chamber; k.t. for stations 3, 4, 6, 7, 8, 9, meaning "cubic telescope"; n. m. for stations 5, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18 meaning "neutron monitor. N.B.- These abbreviation are used in the original caption and they were deliberately omitted in this translated version.

If, starting from the assumption of corpuscular streams' radial propagation, we admit that the region of their propagation is limited in the plane perpendicular to the ecliptic plane, the observed geophysical events in equinoctial periods obtain quite a founded physical interpretation [14, 15].

In such a case the positive correlation of the annual course of the K_p-index of magnetic activity and of cosmic ray intensity could be explained in the light of representations on the influence of deformed Earth's magnetosphere on the intenisty of cosmic rays [16, 17]. However, the estimate made by us of the expected variations of neutron component intensity according to formulas of [18] on the variation of the horizontal component of the Earth's magnetic field at the equatorial station Kuiper (6.2°S), shows that the expected effect is no more than 0.2 percent. This effect is much less than the observed one, and it is not practically manifest in the obtained annual course of the intensity of cosmic rays.

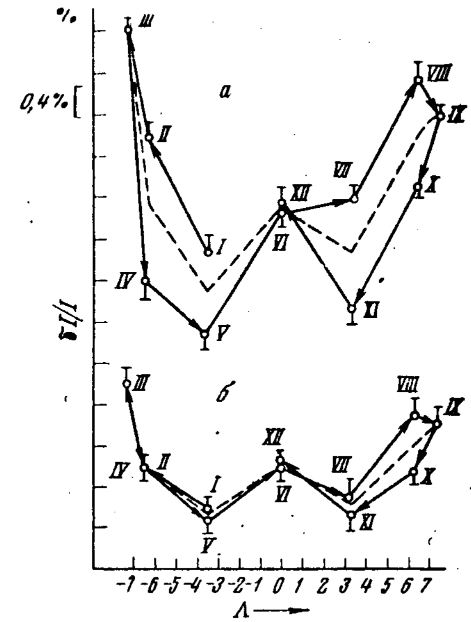

Fig.2. Dependence of cosmic ray intensity on the Earth's heliolatitude.
a) neutron component;
b) hard component.

The investigation of 11-year intensity variations of cosmic ray intensity [18, 19], and the measurements in space performed on the rocket Pioneer-V [20] speak in favor of the existance of a radial density gradient of cosmic rays in interplanetary space ($\lesssim$1%/0.1 a.u.). It is obvious that if the conditions of propagation and the emission frequency of corpuscular streams vary with the change of the angle with the solar equatorial plane, the position of the Earth, as the probe, registering cosmic rays, relative to the center of symmetry of these streams may contribute important data on the transverse gradient of cosmic ray density. In particular, the variation of the position of the Earth relative to solar equatorial plane in the presence of transverse intensity gradient must lead to a peculiar variation in time of cosmic rays on Earth.

The dependence of the intensity of neutron and hard components of cosmic rays on the Earth's heliolatitude in the course of the year 1960 is plotted in Fig.2, where the averaging accounted for the statistical weights for every station, the list of stations being that of the caption of Fig.1. The drawing shows that there is indeed a small transverse gradient of cosmic ray density in interplanetary space. The estimate of this gradient (in the direction perpendicular to the ecliptic plane) by the experimental data analyzed gives a value ∿ 1.3%/0.1 a.u. for the neutron component and ∿ 1.0%/ 0.1 a.u. for the hard component. This quantity is by one order smaller than the value of the gradient proposed in [21] for the explanation of the solar-daily variation of cosmic rays. (This shows that the mechanism considered in [21] for that purpose, is insufficient).

The singularity of intensity distribution on Earth as a function of heliolatitude points to the existence in interplanetary space of a region with minimum values of cosmic ray intensity. This region lies near the helioequatorial plane. The hysteresis phenomena observed on the same curves may be the consequence of a certain asymmetry in the disposition of active regions in the Sun in the course of the year; they may also be linked with the lag of intensity variations of cosmic rays relative to the variations of solar activity.

*** T H E E N D ***

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