COSMIC RADIATION ANNUAL VARIATION

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Abstract

CR annual variation have been studied using data of CR stratospheric registration, world-wide network of NM stations and primary CR registration by IMP-8 spacecraft over a long period of time. Numerical selective filter with influence function developed by authors was used to make calculations. It was obtained that the variation phase falls mainly on winter months, however, it shifts to summer months in SA minimums. The phase shift to summer is not observed for high energies. It was also found that the variation energy spectrum becomes more rigid by energy increase and in SA minimums. CR density latitudinal gradients were calculated using annual variation data.

1. Introduction

The question about contribution of different factors in dependence on electromagnetic conditions in heliomagnitoshpere (level of SA),polarity of general solar magnetic field (GSMF) et al. in origin of annual variation is still open to a marked degree. The investigations are carry out, mainly, separately for different components of SR, i.e. for different energy intervals. In this work the unique data base of CR registration on IMP-8, on different deeps in Earth atmosphere by balloon, on groundbase with help of world-wide network of NM, and also the data of SA and interplanetary magnetic field were used. The use of this data allow to extend covered energies range essentially, investigate the dependence of different characteristics of annual variation from changes in solar activity, interplanetary magnetic field, and more certainly speak about presence or absence those or either effects in annual variation.

2. CR annual variation amplitude-phase and energy characteristics

Numerical selective filter with improved influence function developed by the authors was used for annual variation distinguish from CR registration data.

The analysis of obtained results shows that CR annual changes accord-

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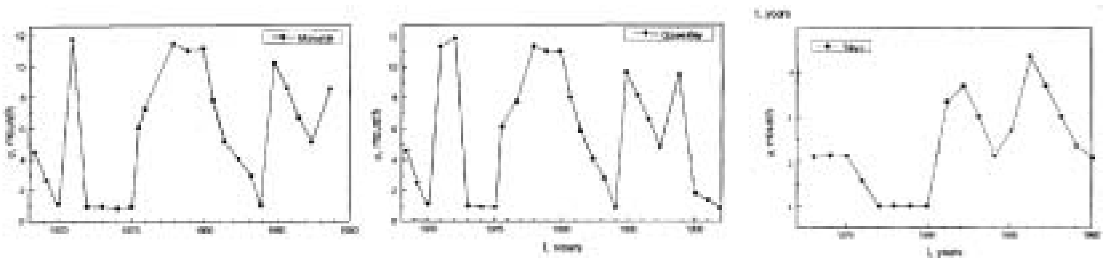

Fig. 1. The phase of CR annual variation according to data of different NM station.

ing to data of high latitudinal NM station of northern and southern hemispheres occurs in phase (fig. 1). Taking into account that the data are corrected for pressure, i.e. barometrical effect is excluded, and geomagnetic cutoff rigidity is almost constant for high latitudinal stations, the conclusion that origin of annual variation distinguished by these data is not atmospheric and it is caused by heliomagnetospheric modulation could be made.

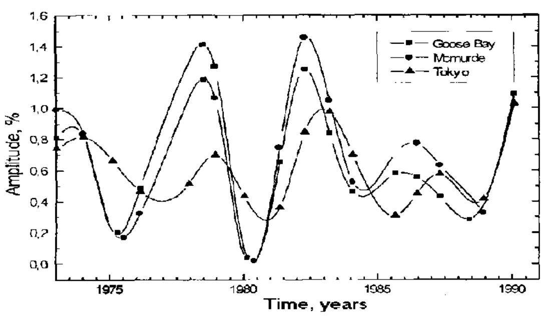

Fig. 2. The amplitude of CR annual variation according to data of different NM station.

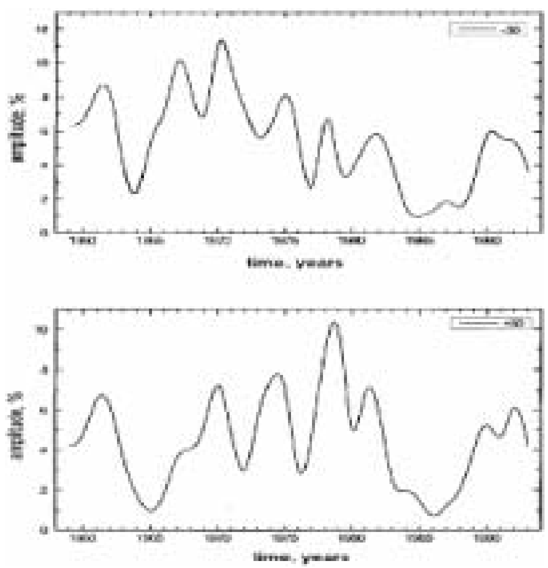

Fig. 3. The amplitude of SA annual wave according to data of green coronal intensity for heliolatitudes $0^0 \div \pm 30^0$.

On fig. 2 and 3 one can see that although correlation between SA and CR annual variation amplitude change in time takes place and it is not strong, i.e. it is not possible to explain the annual wave in CR only by annual change of SA . It is also seen from fig.1 that the annual variation phase falls mainly on winter months.However, the phase shifts to summer months when the solar activity is minimal. Perhaps, it shows that in periods of the solar activity minimums the cosmic radiation density latitudinal gradients are small and in this case the annual variation is mainly caused by the positive radial gradients presence in heliomagnetosphere and the Earth being more distant from the Sun in summer. Really, almost for all neutron monitors stations the variation amplitude is about 0,2 % in 1976 (fig.2) which is in accord with the amplitude expected because of radial gradients (for radial gradients value of a few %/a.u. [5]). It is interesting that also takes place in 1980-1981 years and besides, the variation amplitude is also small in this period (as in SA minimums). It is necessary to note that the phase shift to summer is not observed by low latitudinal stations that is for high energies.

The variation energy spectrum was studied using the Earth's atmosphere and magnetosphere as a spectrometer of particles according to their energies. The results of this research are presented in fig. 4. On this figure the dependence of annual variation amplitude on energy obtained on the base of data of IMP-8 (E 100 MeV), stratospheric measurements (E 8-15 GeV), neutron monitors (E 20-40GeV), muon telescopes [6] (E 80 GeV), ionizing camera (E 100 GeV) is shown.

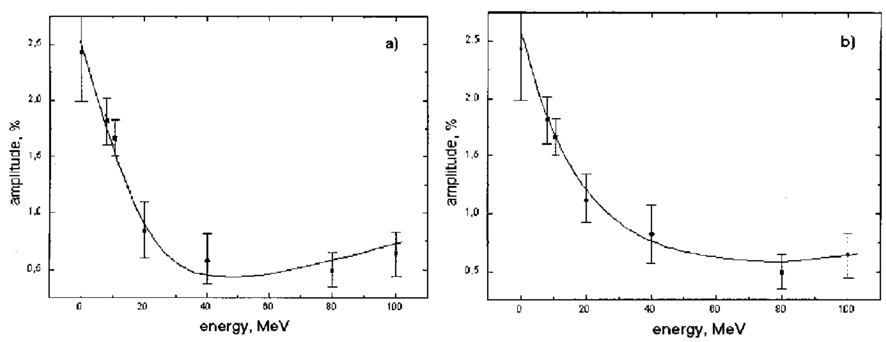

Fig. 4. The energy spectrum of CR annual variation.

It is seen that: 1) the annual variation energy spectrum becomes more rigid with the energy increase (the variation amplitude decreases with energy growth down to E 20 GeV and is almost independent of the energy if the latter is higher than 20 Gev, 2) the energy spectrum is more rigid in periods of the solar activity minimum than it is in maximal solar activity periods. It confirms that different modulation mechanisms are prevalent within different energy ranges and during different periods of solar cycle. If within the low energy range the diffusion-convection mechanisms are determining then in range of energies higher than 30 GeV the drift effects are prevalent. More rigid variation energy spectrum in minimums of SA shows that drifts make a greater contribution in CR modulation in these periods in compare with maximal SA periods. It can be explained by more regular IMF in periods of SA minimums.

3. Gradients of cosmic ray density

Investigation of annual CR variations allows to obtain data of latitudinal and radial gradients of CR density. Assuming that annual wave in CR is caused by the change of radial distance from Earth to Sun only and taking into account that gradients of CR density are usually calculated in % /a.u. for radial gradient it can be wrote:

$$\delta_r 2ae = \frac{\Delta n}{n} \tag{1}$$

where δ_r - radial gradient of CR density, $\frac{\Delta n}{n}$ - change of CR intensity in % during the year, a - big semi-axis of Earth orbit, e - eccentricity of Earth orbit. If annual variation is caused with the latitudinal gradient of CR density only, then

$$\delta_\perp = \frac{\Delta n}{n} \frac{1}{atg(\Delta\lambda)} \tag{2}$$

where $\delta_\perp$ - latitudinal gradient of CR density, $\Delta\lambda$ - change of Earth heliolatitude during the year. Taking into account the little of eccentricity of earth orbit and the value of radial gradient is a few %/a.u. [5], we obtain that contribution of radial gradient for annual wave is about 0,2 % and it is small in compare of contribution of latitudinal gradient. Thus, using the data of annual variation amplitude one can calculate the latitudinal gradient of CR density in accuracy 1%.

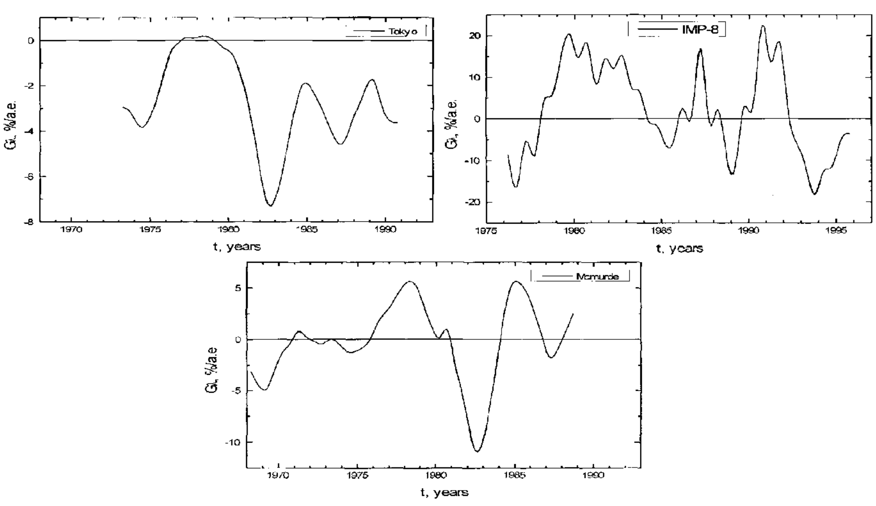

Fig. 5. CR density latitudinal gradients.

In fig 5 latitudinal gradient calculated on (3.2) are presented. In the diffusion-convection modulation theory without an account of drift effects the correlation of the latitudinal gradient change with the N-S asymmetry of SA

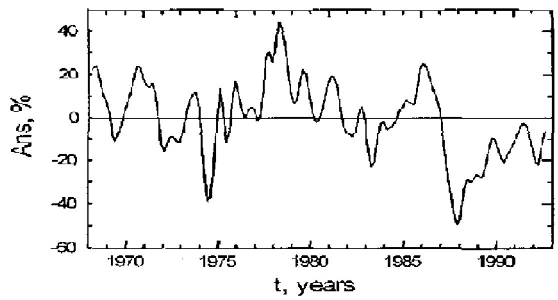

Fig. 6. SA NS-asymmetry according to data of green coronal line intensity.

change must be observed: the growth of latitudinal gradients of module with increase of SA must be occur and on the contrary. The comparison of fig.5 and fig.6 (where the change of N-S asymmetry of SA is shown) demonstrates that this correlation takes place for latitudinal gradients, calculated on data IMP-8 (low energy) and NM McMurdo, although in some periods it is violated, but according to the data of NM Tokyo (high energy) the correlation was not observed. Thus, we can conclude that the effects of CR drift in IMF carries out the determined contribution in a forming of latitudinal gradients of CR density especially in range of high energy (more than 30 GeV).

4. References

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