VARIATIONS OF RIGIDITY SPECTRUM AND ANISOTROPY OF COSMIC RAYS IN AUGUST 2005

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Using the method of spectrographic global survey, variations of galactic cosmic ray (CR) rigidity spectrum and anisotropy (August 2005) were studied with the data from ground-based observations of CR at the worldwide network of stations.

A high degree of anisotropy was revealed (~30-70% and ~5-7% for the first and second spherical harmonics, respectively) for particles with rigidity of 4 GV at the moments of maximum cosmic-ray modulation.

The high degree of anisotropy (including the bidirectional one in the CR angular distribution) and their phases' variability evidence, firstly, ejection of magnetic clouds and loop-like IMF structures by coronal mass ejections and, secondly, a high degree of the IMF regularity in these structures.

INTRODUCTION

In order to solve problems related to the space weather monitoring with the use of data from ground-based observations of cosmic rays (CR) at the worldwide network of stations, the following conditions are necessary: continuous recording of intensity of different CR components at the existing worldwide network of stations and application of special data-processing techniques allowing usage of this network as a integrated multi-channel device.

The period under consideration is characterized by the following features: presence of some high-speed fluxes with solar wind (SW) velocities up to ~700 km/s in interplanetary space; increase in modulus of the interplanetary magnetic field (IMF) up to ~45 nT; large amplitudes of CR modulations (~6-8% at polar and mid-latitude stations) involving geomagnetic disturbances with Dst lower than -200 nT.

DATA AND METHOD

Data from the worldwide network of neutron monitors, corrected for pressure and averaged over one-hour intervals, were used for analysis. Modulation amplitudes were reckoned from the quiet level of 2 April 2005. Data from 44 neutron monitors were used.

The analysis was made using the spectrographic global survey method (SGS) [1, 2]. The method allows us to study variations of the rigidity spectrum and CR anisotropy as well as changes in the GCR planetary system for each observation hour.

Distribution of amplitudes of secondary CR variations over the world is described by the following system of nonlinear algebraic equations:

$$\frac{\Delta I_c^i}{I_c^i}(h_l) = -\Delta R_c W^i(R_c, h_l)\left(1 + \frac{\Delta J}{J}(R_c)\right) + \\ + \int_{R_c}^{\infty} \left\{ \sum_{k=1}^{3} a_{ok} R^{-k} + \sum_{n=1}^{2} \sum_{k=1}^{2} \left[\left(c_{nk} R^{-k} \right) P_n(\mu) \right] + \sum_{k=1}^{2} \left(d_{1k} R^{-k} \right) P_1(\mu) \right\} dR \ ,$$

where $\frac{\Delta I_c^i}{I_c^i}(h_l)$ are the amplitudes of variations of the type-i secondary particle flux (relative to some background level I_c^i) observed at the geographical point c, at the level h_l in the Earth's atmosphere; R_c is the effective GCR; $W^i(R_c, h_l)$ is the coupling function between primary and secondary CR variations, $P_n(\mu)$ is the Legendre polynomial, μ is the pitch-angle cosine of particle, $\psi_c(R)$, $\lambda_c(R)$ are the asymptotic angles of arrival of particles to the given point.

Rigidity spectra of the isotropic component and anisotropy are approximated by inverse power series of particle rigidity.

Dependence of ΔR_c on threshold rigidity is approximated by the expression $\Delta R_c(R_c) = \left(b_1 R_c + b_2 R_c^2\right)e^{-\sqrt{R_c}}$.

As CR stations are non-uniformly distributed all over the world, we did not take account of the longitude effect of changes in cosmic-ray GCR when performing calculations.

RESULTS AND CONCLUSIONS

Fig. 1 presents data on direct measurements of the IMF modulus (a) and SW velocity (b) in space. The panel (c) demonstrates time profiles of variations of the CR global intensity with the rigidity of 4 (red line) and 10 GV (blue line). Panels (d, e) present modulus of the first spherical harmonics and amplitude of the second harmonics, respectively. The lower panel (f) shows GCR variations ΔR at Rc=4 GV (red line) and the Dst-index (blue line).

The maximum modulation amplitude for particles with R = 4 GV was observed on 24 August (about -25%); that for particles with R=10 GV was observed on 25 August (-10 %). On 24 August (12:00-13:00 UT), the index of variation spectrum (γ) for rigidity values higher than ~3-4 GV was ~ -1.4; later on, this index was -1.1-1.2. The anisotropy amplitudes A_1 and A_2 for particles R=4 GV observed during the maximum modulation period on 24 August were ~ 45% and ~ (4-5) %, respectively. The maximum amplitude of the first spherical harmonics for particles with R = 4 GV (A_1~70%) was observed on 25 August at 22:00 UT.

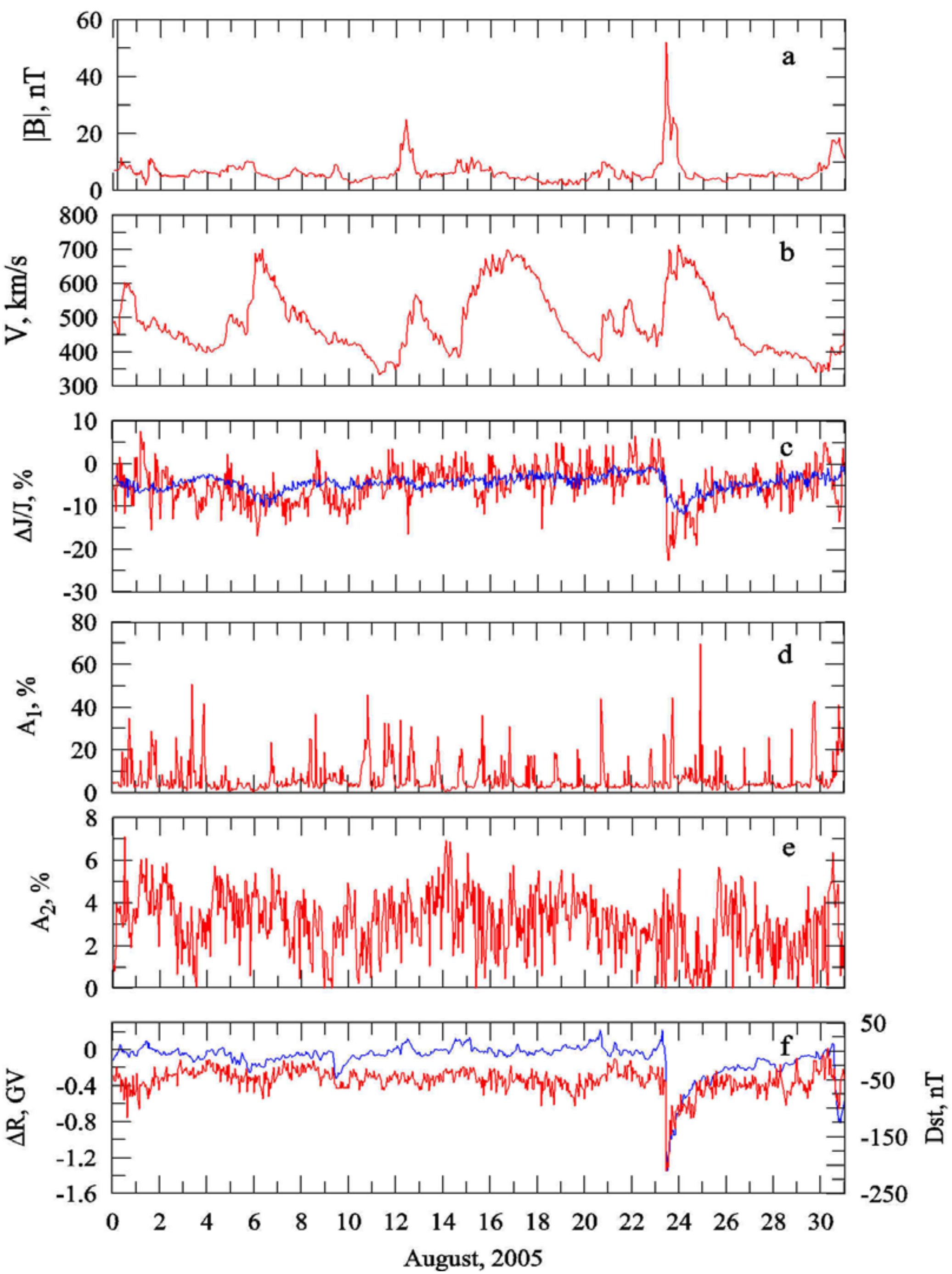

Fig. 1. T*he picture depicts the time dependence of selected parameters: a – values of the IMF modulus; b – the SW velocity; c – variations of the CR global intensity with R = 4 (red line) and 10 GV (blue line); d – amplitudes of modulus of the first spherical harmonics* A_1 *for particles with R = 4 ГВ; e – amplitude of the second harmonics* A_2 *for particles with R=4 GV; f – variations of the geomagnetic cutoff rigidity at Rc=4 GV (red line) and Dst-index (blue line).*

Isolines at Fig. 2 demonstrate relative changes in the CR intensity with R=4 GV in the geocentric solar ecliptic coordinate system for different instants of time. Values of the longitudinal angle ψ are plotted along the X-axis; those of the latitudinal angle λ are plotted along the Y-axis. Numerals on the isolines indicate values of amplitudes of particle intensity variations in percentage terms relative to the background level. Signs "+" denote direction of the IMF vector at the instants of time under consideration.

Referring to Fig. 2, the first harmonics dominated during the Forbush effect on 24 August (16:00, 17:00 UT) and 25 August (22:00 UT). The CR intensity was reduced by ~30%, ~40%, and ~50 %, respectively, from the direction ψ~270°, λ~10 °(relative to the Earth-Sun line). Contribution of bidirectional anisotropy with higher CR intensity from the direction perpendicular to IMF was observed on 24 August (24:00 UT) and 26 August (16:00 UT). The CR bidirectional anisotropy with rigidity R=4 GV was also observed on 31 August (10:00 UT). On 31 August (19:00 and 21:00 UT), the first harmonics of the CR anisotropy dominated. Note that the lower CR intensity with rigidity R=4 GV was observed in the direction $\psi \sim 80°$, $\lambda = \sim -10°$ at 19:00 UT; in two hours (at 21:00 UT), it was observed in the opposite direction.

The observed high degree of anisotropy (including the bidirectional one in the CR angular distribution) and variability of their phases evidence, firstly, ejection of magnetic clouds and loop-like IMF structures by coronal mass ejections and, secondly, a high degree of IMF regularity in these structures [3].

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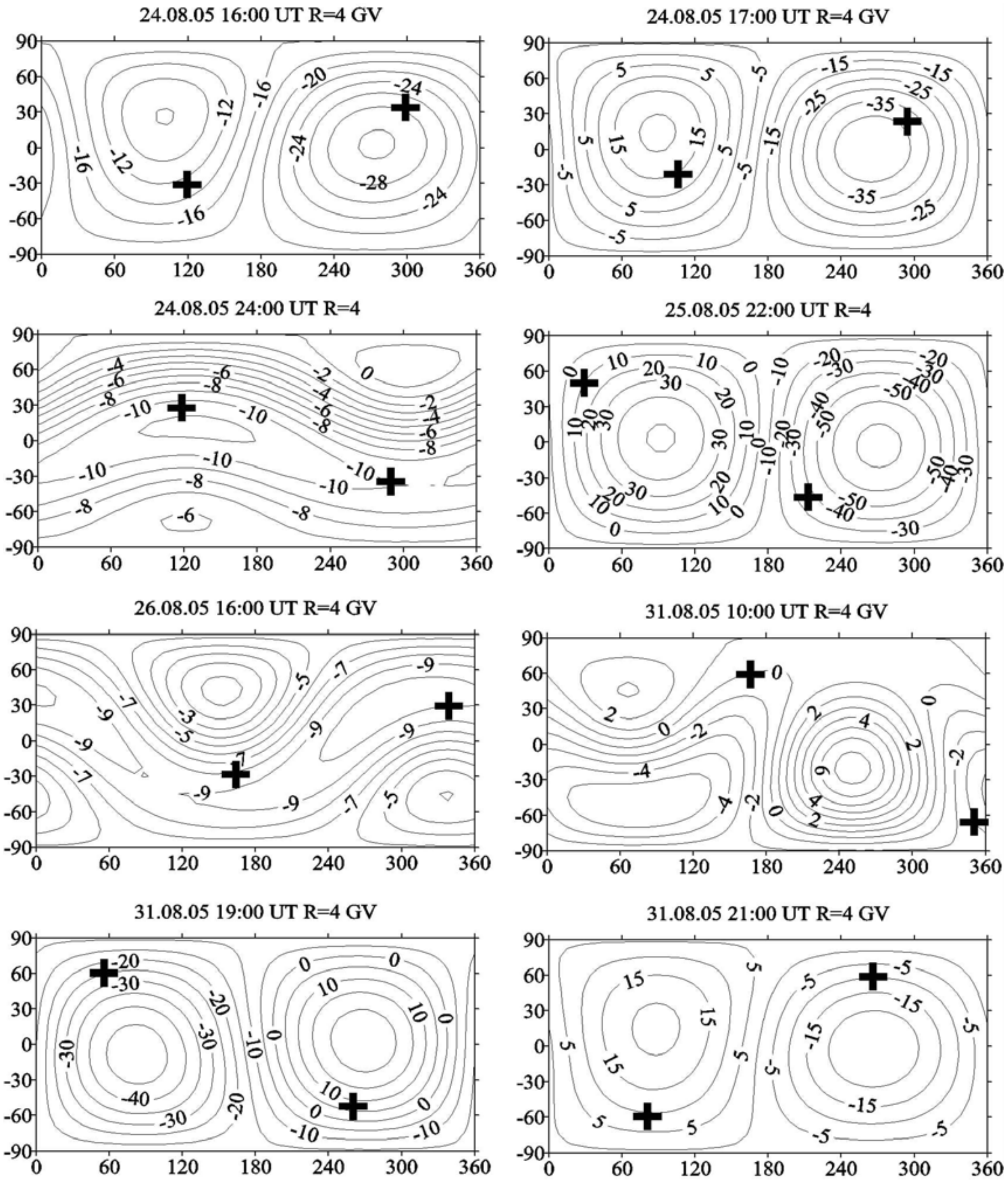

Fig. 2. *Relative changes in the CR intensity with R = 4 GV, depending on asymptotic directions in the geocentric solar ecliptic coordinate system for different instants of time.*

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