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Cosmic Ray Variations in October, 2012

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Using ground-based observations of cosmic rays (CRs) from the neutron monitor stations of the worldwide network, and the spectrographic global survey method, we have examined variations in the rigidity spectrum and anisotropy of galactic CRs in October 2012. Also, the paper demonstrates relative changes in CR intensity with R=4 GV in the geocentric solar ecliptic system for different time points of the time interval in question

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1. Introduction

In October 2012, the overall level of solar activity was low. Before 9 October, the relative number of sunspots remained at low level, then, it was medium till the end of the month [8]. In general, the solar flare activity in October was low and very low, medium — on 8, 9, 10 October, high — on 20, 22 and 23 October. On 8.10.12, a M 2.3 flare occurred, on 21.10 — a M 1.3 flare from the active region (AR) 1598 was registered, on 22.10 — a M 5.0 from the AR 1598, onset at 21.38 UT, maximum at 21.58 UT. The second strong solar flare in 2012 on the Sun was registered on 23 October 2012, a X1.8 flare from AR 1598, onset at 06.13 UT, maximum at 06.17 UT. On some days of the month, no flares of C class or higher were observed on the Sun. Two coronal holes produced high-speed fluxes with the result that considerable geomagnetic disturbances were detected in the near-Earth space. Two magnetic storms occurred at the Earth's midlatitudes, and the disturbed geomagnetic conditions remained for four days. In October 2012, the maximum interplanetary magnetic field (IMF) modulus was ~20 nT, the solar wind (SW) velocity ~600 km/s, and Dst = –130 nT. In October 2012, the amplitudes of cosmic ray (CR) modulation were ~ –6,5% at polar stations, ~ –4% at midlatitudes, and ~ –3% at the low latitude stations.

1.1Data and method

For our calculations, we used data from the neutron monitor stations of the worldwide network worldwide network of cosmic ray stations equipped with neutron monitors (42 CR stations), averaged over 1-hour intervals and corrected for pressure. Modulation amplitudes Amplitudes of CR modulation were measured relative to the background level of 05 October 2012. For analysis, we used the method of spectrographic global survey (SGS) [4, 5] developed in ISTP SB RAS. The SGS method allows investigating variations in the rigidity spectrum, anisotropy and changes in geomagnetic cutoff rigidities (GCR) for each observation hour, using data of ground-based observations of cosmic rays.

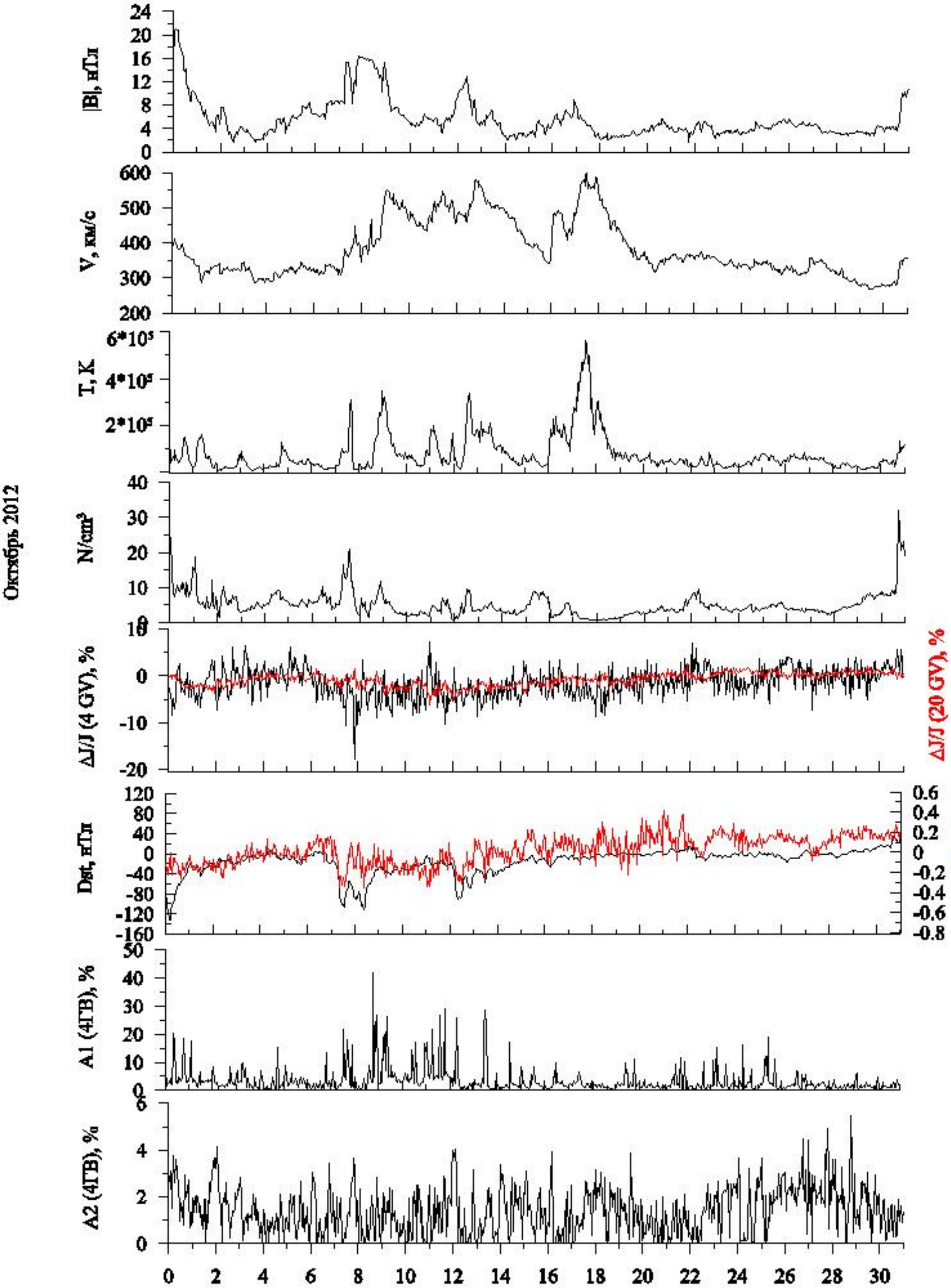

Fig.1 IMF modulus, SW velocity, SW temperature, SW density, time profiles of variations in global CR intensity with rigidity 4 (black line) and 20 GV (red line), changes of geomagnetic cutoff rigidity ΔRc at

the point with threshold rigidity Rc=4 GV (red line) together with the Dst-index (black line), amplitudes of the first A_1 and second A_2 spherical harmonics of the CR pitch-angle anisotropy for particles with R=4 GV.

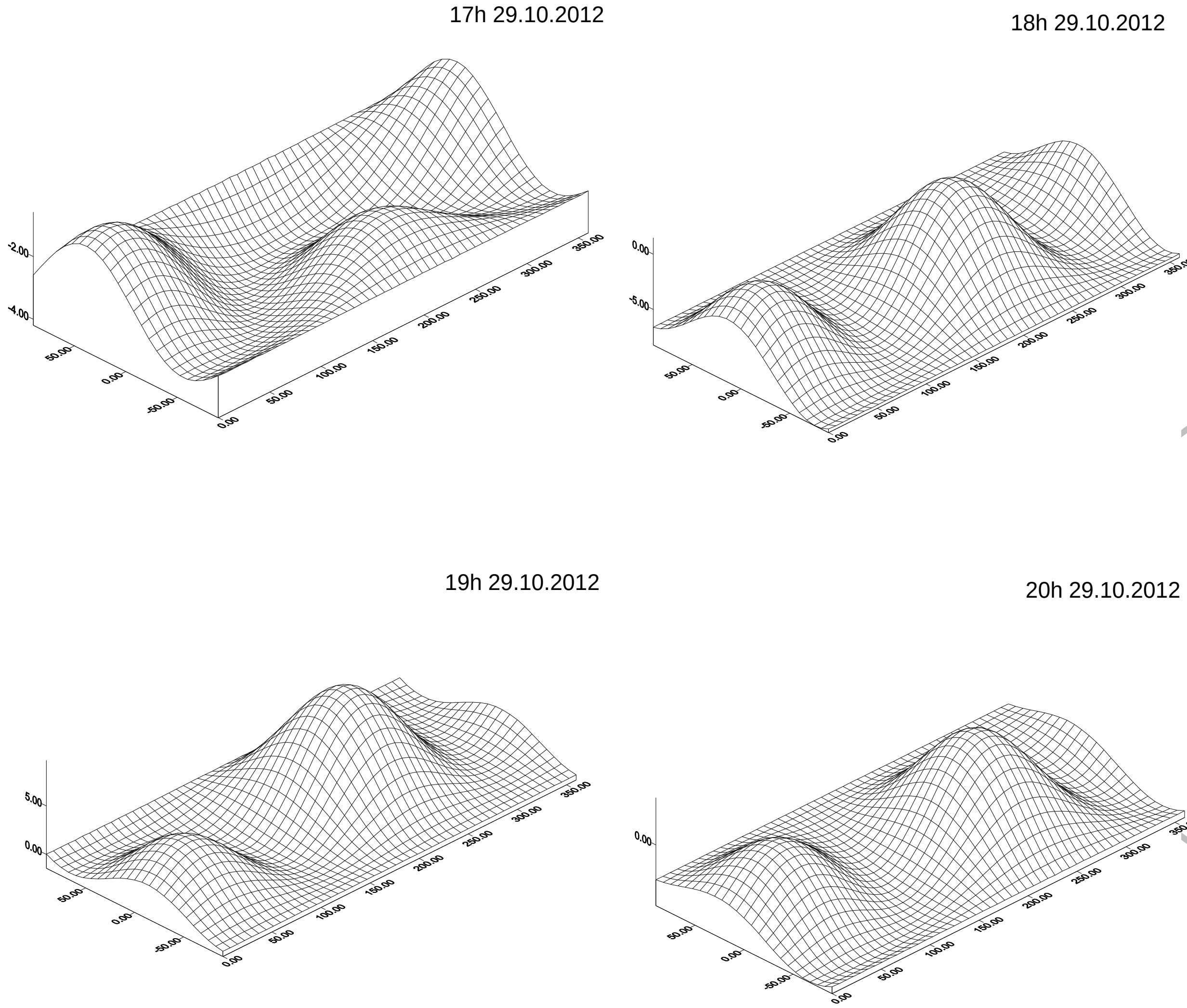

Fig.2 Relative changes in CR intensity with R=4 GV in the Geocentric Solar Ecliptic coordinate system for different time points on 29 October 2012.

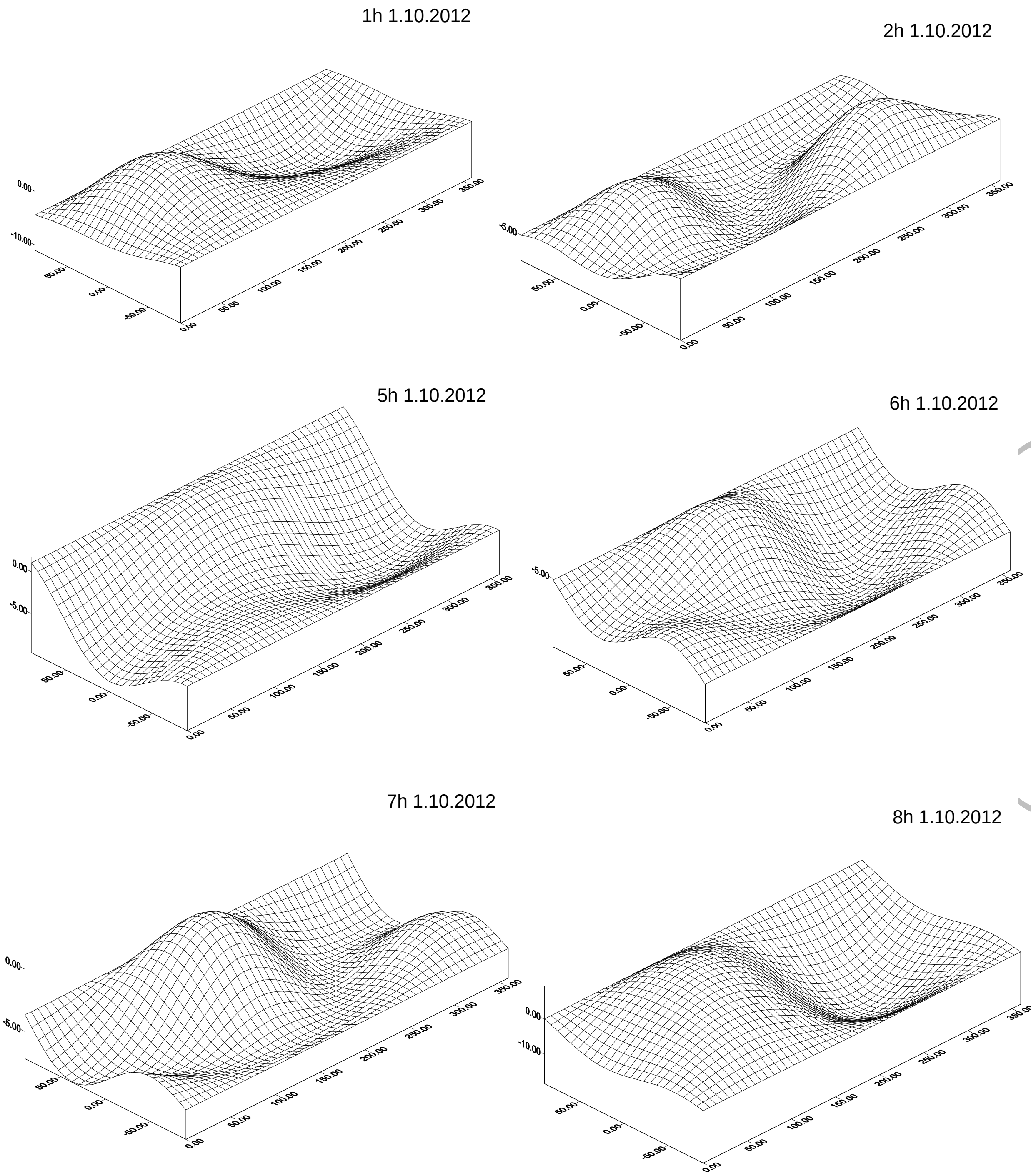

Fig.3 Relative changes in CR intensity c R=4 GV in the Geocentric Solar Ecliptic coordinate system for different time points on 1 October 2012.

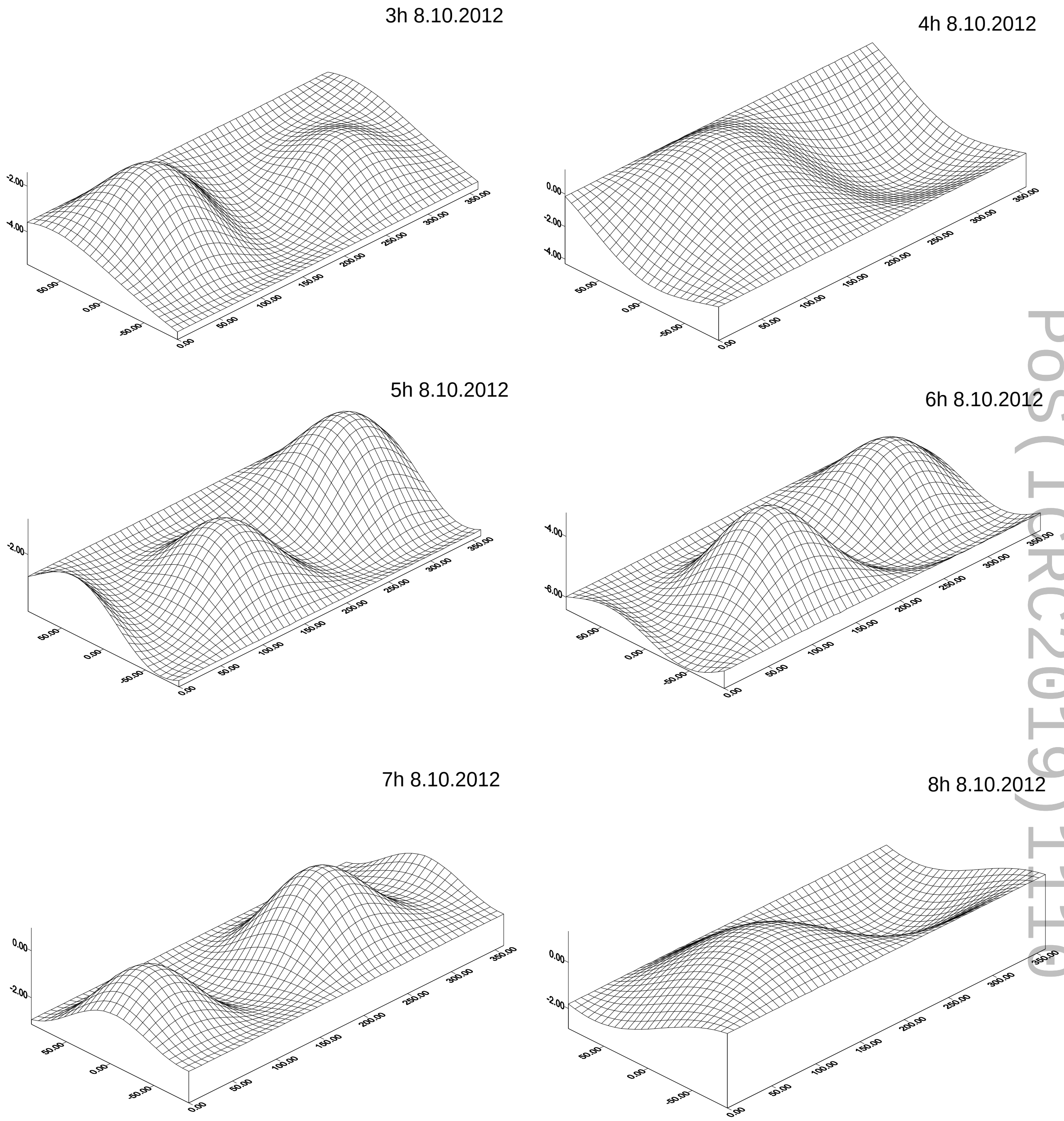

Fig.4 Relative changes in CR intensity c R=4 GV in the Geocentric Solar Ecliptic coordinate system for different time points on 8 October 2012.

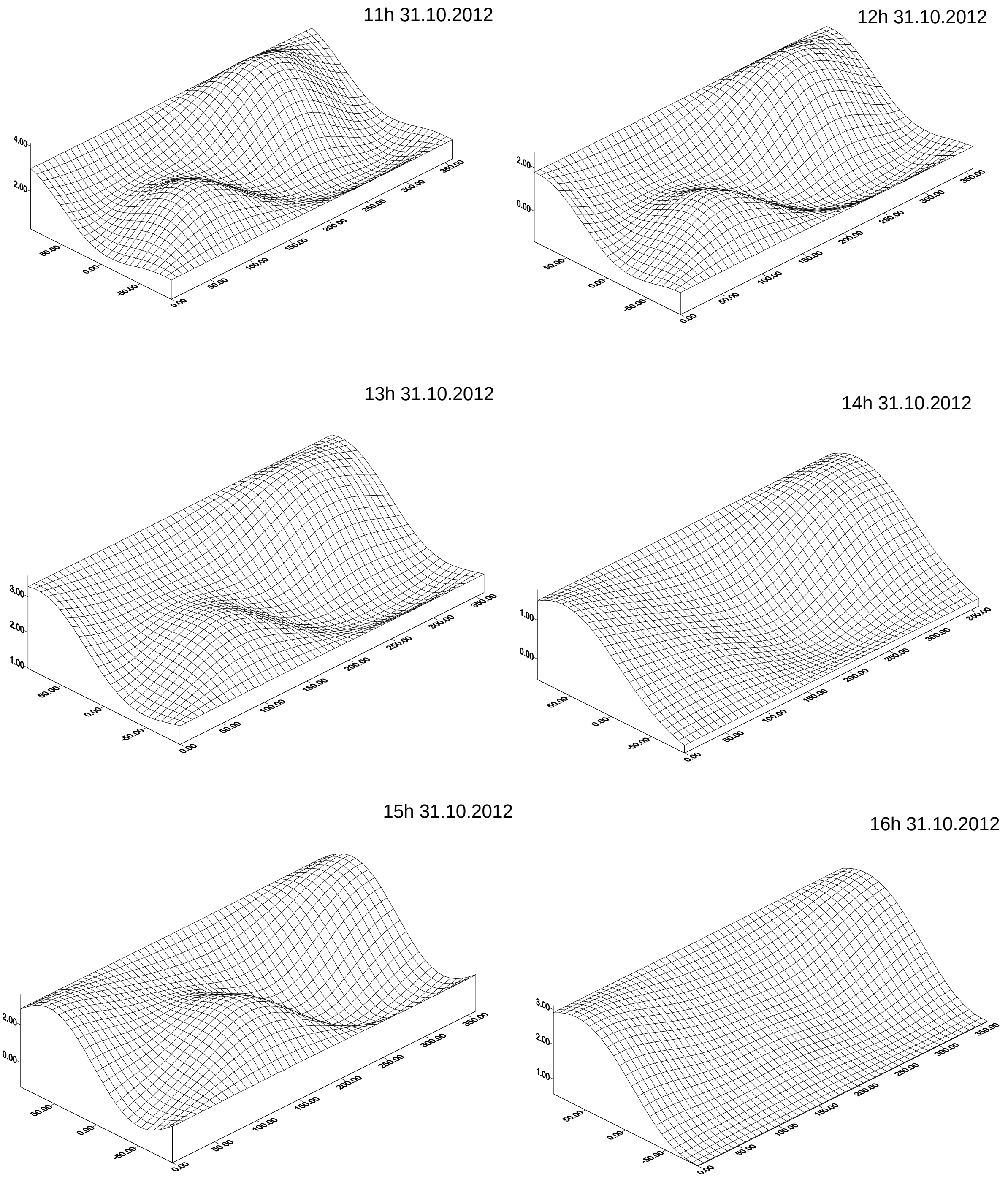

Fig.5 Relative changes in CR intensity c R=4 GV in the Geocentric Solar Ecliptic coordinate system for different time points on 31 October 2012.

1.2 Results

In Figure 1, top-to-bottom you can find data of direct measurements in the interplanetary space of the following parameters: IMF modulus, SW velocity, SW temperature, SW density, time profiles of variations in global CR intensity with rigidity 4 (black line) and 20 GV (red line), changes of geomagnetic cutoff rigidity ΔRc at the point with threshold rigidity Rc=4 GV (red line) together with the Dst-index (black line), amplitudes of the first A_1 and second A_2 spherical harmonics of the CR pitch-angle anisotropy for particles with R=4 GV in October 2012. In Figures 2–5, equilines show relative changes in CR intensity with rigidity R=4 GV in the Geocentric Solar Ecliptic coordinate system geocentric solar ecliptic system for different time points on 29, 1, 8, 31 October 2012. Along the X-axis, there are values of the longitude angle ψ; along the Y-axis — of the latitude angle λ. Numerals on equilines are amplitudes of particle intensity variations as a percentage of the background level.

Following Figure 1, in October 2012 the maximum modulation amplitude was: ~ –18% for particles with rigidity R=4 GV, and ~ –6% for particles with rigidity R=20 GV. Detected in October 2012, the amplitudes of modulus of the first harmonic of anisotropy A_1 reached ~ 25–45% for particles with R=4 GV, amplitudes of A_2 second harmonic — ~ 6,0% for particles with rigidity R=4 GV. A magnetic storm was observed on 01.10 (Dst ~ –130 nT). The Forbush effects detected on 08.10. and 31.10 were related to the interplanetary shock wave and SSCs (sudden commencements of geomagnetic storms) [6]. Commencements of Forbush effects on 02.10, 5–7.10, 09.10, 11.10, 17.10, and 27.10 occurred without shock waves and SSCs. Coefficients of correlation between ΔRc and Dst-index during geomagnetic storms are: 0,82 for 01.10; 0,61 for 07.10; 0,84 for 08–09.10. The ΔRc time profile shows a close correlation with the Dst-index time profile during Forbush decreases, since they represent the same phenomenon — amplification of the magnetospheric ring current. The maximum amplitudes of the second A_2 harmonic for particles with R=4 GV were on 29.10 and amounted ~5,0–5,5%. Figure 2 shows that the increased CR intensity was detected from ψ ~20°, 205°, λ = ~35°, ~–50° (17 UT), ψ ~35°, 210°, λ = ~10°, ~ –7° (18 UT), ψ ~ 40°, 220°, λ = ~ –5°, ~ 5° (19 UT), ψ ~50°, 230°, λ = ~15°, ~ –5° (20 UT). CR intensity from these directions was ~8 % higher than the minimum observed intensity. On 1.10 (Figure 3), the increased CR intensity was observed from ψ ~70°, 215°, λ = ~40°, ~–50° (2 UT), ψ ~150°, 250°, λ = ~50°, ~–10° (6 UT), ψ ~150°, 330°, λ = ~350°, ~–50° (7 UT). On 8.10 (Figure 4), the increased CR intensity was detected from ψ ~80°, 275°, λ = ~25°, ~–10° (3 UT), ψ ~120°, 310°, λ = ~–10°, ~25° (5 UT), ψ ~120°, 290°, λ = ~–20°, ~20° (6 UT), ψ ~40°, 230°, λ = ~0°, ~–5° (7 UT). On 31.10 (Figure 5) — from ψ ~80°, 250°, λ = ~–30°, ~50° (11 UT), ψ~ 90°, 275°, λ = ~–30 °, ~60° (12 UT), ψ~ 100°, 290°, λ = ~–25 °, ~60° (13 UT), ψ ~140°, 350°, λ = ~–20°, ~60° (15 UT). CR intensity from these directions was ~3–8 % higher than the lowest observed intensity. The presence of high amplitude bidirectional anisotropy in particle angular distribution attests occurrence of a magnetic trap-like IMF structure related to the Sun [7].

1.3 Conclusions

From the analysis, we can conclude that the maximum amplitudes of the first harmonic of anisotropy A_1 were observed on 9.10 (~ 45 %). The modulus amplitudes of anisotropy A_1 first harmonic seen in October 2012 reached ~ 25–45% for particles with R=4 GV. The maximum modulus amplitude was ~ –18% for particles with R=4 GV, and ~ –6% for those with R=20 GV.

The occurrence of high amplitude bidirectional anisotropy in the particle angular distribution (amplitudes of A_2 second harmonic ~ 5–5,5% for particles with R=4 GV) is caused by the fact, that during some periods of 2012, the Earth was inside a Sun-related magnetic trap-like IMF loop structure that deformed the background magnetic field.

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