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Cosmic Ray Modulation during the Solar Activity Growth Phase of Cycle 24

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Abstract—Recent years allowed us to study long-term variations in the cosmic ray (CR) intensity at an unusually deep solar activity (SA) minimum between cycles 23 and 24 and during the SA growth phase in cycle 24, which was the cycle when SA was the lowest for the epoch of regular ground-based CR observations since 1951. The intensity maximum, the value of which depends on the particle energy, was observed in CR variations during the period of an unusually prolonged SA minimum: the CR density during the aforementioned period (2009) is higher than this density at previous CR maxima in cycles 19–23 for low-energy particles (observed on spacecraft and in the stratosphere) and medium-energy particles (observed with neutron monitors). After 2009 CR modulation at the SA growth phase was much weaker over three years (2010–2012) than during the corresponding SA growth periods in the previous cycles. The possible causes of this anomaly in CR variations, which are related to the CR residual modulation value at a minimum between cycles 23 and 24 and to variations in SA characteristics during this period, were examined. The contribution of different solar magnetic field characteristics and indices, taking into account sporadic solar activity, has been estimated.

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1. INTRODUCTION

The 11- and 22-year cycles, which substantially differ from one another in phase, intensity, etc., are the main specific features of variations in solar magnetic fields. These variations create different CR variation types through the solar wind. As with the Sun, all cycles for CRs are different, and each cycle has its own specific features. This information is rather reliable, since long-term CR variations have been studied for a long time—since 1936, based on the data of ionization chambers, and since 1951, based on those of neutron monitors (NMs). The average CR modulation, i.e., the parameter that can characterize a cycle as a whole, pronouncedly varies from cycle to cycle (Gushchina et al., 2012). Cosmic ray variations within a cycle are even more individual. Cosmic ray variations and variations in the CR modulation parameters, determined based on SA observations, make it possible to compare cycles, to consider CR variation features during different CA cycle epochs, to reveal similarity and difference between cycles, and to try to determine the cause of differences between even and odd cycles.

In recent years, CR variations have differed from previous variations especially strongly. First, an unusually low SA minimum in 2007–2010 caused a record growth in the CR density. To all appearances, this density was never (during the period of regular observations) so close to the extraheliospheric level. Second, it is strange that CR modulation is unusually weak during the phases of growth and maximum of the current SA cycle (cycle 24).

The aim of the proposed work is to determine the specific features and compare the CR variations in recent years with the variations in cycles 19–23.

2. DATA

This study continues the series of previously presented works, e.g., (Belov et al., 2001, 2002, 2005; Gushchina et al., 2008), where long-term CR modulation was described using the multi-parametric model, including the SA characteristics linearly related to the CR variation amplitude. The CR intensity observations, global solar magnetic field characteristics, and data on solar activity are the initial data for modeling CR variations. The spectrum of the long-term CR variations for 1953–2012 was calculated using the previously proposed method (Belov et al., 1993). This method was used to determine the CR isotropic component based on all available data on the CR intensity, obtained by the ground NM network (~40 monitors) and when the stratosphere was sounded at three points (Stozhkov et al., 2007). Further analysis was performed using the monthly average variations in the intensity of CRs with 10 GV rigidity (A10 in percent relative to 2009), obtained from these data according to the above method: A10 is the amplitude of long-term galactic CR variations for particles with 10 GV rigidity, i.e., with an energy to which NMs are most sensitive.

Since CR variations observed near the Earth are the integral result of numerous solar phenomena, a reliable empirical model for describing CR variations should combine at least several solar indices. The selection of solar magnetic field parameters for empirical description of cycles in CRs is justified in (Belov et al., 2002, 2005; Gushchina et al., 2008).

The characteristic of polar solar magnetic fields *Hpol* (the field value and direction) and two characteristics of large-scale fields: the integral energy index (*Bss*) (the radial magnetic field component squared, averaged over a fixed-radius sphere, i.e., the solar wind source surface) and the heliospheric current sheet inclination (η) are used as indicators of global processes on the Sun. The monthly average values of these quantities were calculated on the solar wind source surface. The field characteristics are calculated based on direct observations at solar observatories, which were performed from May 1976 up to the present and were completed with indirect magnetic field observations before 1976 and processed using the methods presented in (Obridko and Shelting, 1999; Vanyarkha, 1995).

Different indices were used to take into account the effect of transient solar phenomena on CRs in the performed analysis. For this purpose, Belov et al. (2007) determined the index of solar flares (*xf*), which takes into account the X-ray flare power (≥M1 flares were selected). It was shown that the CR modulation model is specified (the short-period part of CR variations is presented in this model) if solar flare activity is additionally taken into account when the long-term variations in 1976–2012 are described. The introduction of the *Pi* index, which was determined with account the number of coronal mass ejections (CMEs) during a month and the average plasma velocity (Paouris et al., 2012), was the next step in adequately reflecting SA in the CR long-term variation model. The *Pi* index was calculated as follows: $Pi = a\,[Nc/Nc(\max) + b\,[Vp/Vp(\max)]$, where $a + b = 1$, a and $b > 0$; *Nc* is the number of CMEs during a month; *Vp* is the average CME velocity; and *Nc*(max) and *Vp*(max) are the maximal values of these parameters during the 1996–2012 period, for which the data on CME obtained on the SOHO spacecraft are available (http://cdaw.gsfc.nasa.gov/CME_list). The CR variations during the growth phase of cycles 23 and 24 are described much better if the *Pi* index is used to calculate the anticipated CR variations in 1996–2012. For the early period (before 1976, when it was impossible to calculate the CME and X-ray flare indices), the *Nssc* index (the number of geomagnetic storms with sudden commencement), which reflects solar wind disturbances propagating in the heliosphere, was used to reflect the effect of local solar fields in the CR modulation model (http://www.wdcb.ru/stp/data/sudden.com/).

Note that the above indices behave differently in solar cycles; this allows us to hope that a complete CR modulation pattern in SA cycles can be obtained if we construct the model using complementary indices (Fig. 1). We present here the anticipated and observed variations for a particle rigidity of 10 GV for cycles 19–24 and the contributions of variations in different indices to CR modulation. We constructed the CR modulation model using a multi-parametric regression analysis. This model rather adequately describes the general pattern of CR variations in 1957–2012 and has the following regression characteristics: the correlation coefficient is $\rho = 0.86$, and the rms deviation is $\sigma = 2.79\%$.

3. SOLAR ACTIVITY GROWTH PHASE IN CYCLE 24 AND CR MODULATION DURING THIS PERIOD

According to the data on the smoothed sunspot number and radioemission flux at a wavelength of 10.7 cm, the current solar cycle (cycle 24) had its first and, most probably, main maximum in February 2012. In April–May 2013, the Wolf number increased again, which possibly indicated that the second (low) peak in the development of the current solar cycle was formed. To all appearances, CR modulation in the considered cycle reached its maximum, but this maximum is near the minimal modulation level for other cycles (cycles 20 and 22) at the same solar magnetic field polarity and is very far from the maximal modulation level in any cycle. We compare the CR variations during the periods of growth and maximum of cycle 24 with the long-term variations in different epochs of cycles 19–23. Changes in the CR variation average value for each cycle, i.e., the value that can be considered as a characteristic of the CR cycle power, indicate that each cycle is individual. The deepest modulation ((Gushchina et al., 2012), Fig. 1) is observed (the average values of variation from one SA cycle minimum to the minimum of another cycle were obtained relative to 1976) in cycle 22 (–7.3%), CRs were least affected by modulation in cycle 20 (–3.1%), and modulation successively decreased in the remaining three odd cycles (–7.0, –6.3, and –4.6% in cycles 19, 21, and 23, respectively). Modulation was very insignificant, i.e., smaller than in the previous cycles, up to December 2012 in cycle 24.

Analysis of the observed cycle 24, which is the cycle with the lowest solar activity during the CR observation period, makes it possible to assume that a small modulation depth is explained by not only low SA and, correspondingly, the small values of modulating char-

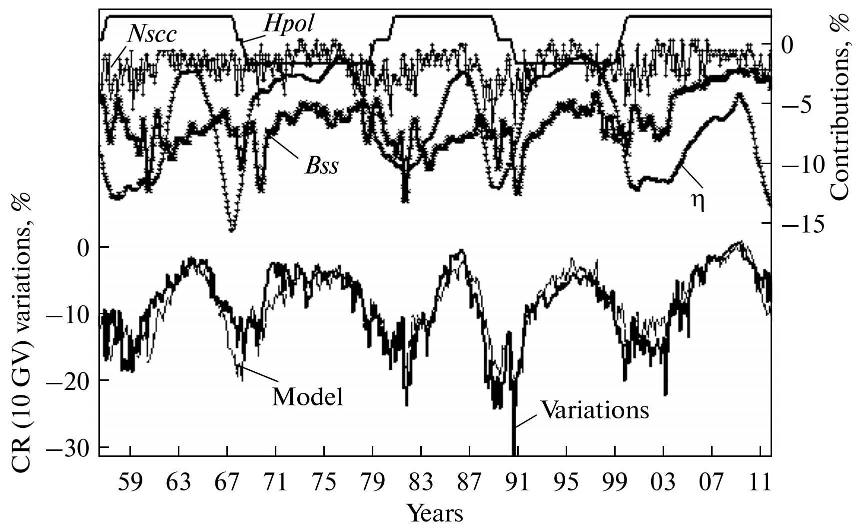

Fig. 1. Modulation of CRs in SA cycles 19–24. Bottom: the model and observations of CR variations (rigidity 10 GV); top: the contributions to modulation of *Hpol*, η, *Bss*, and *Nsss*, used to construct the model.

acteristics, but also by the lower effect of these characteristics on CRs.

The inclination of the heliospheric current sheet has been used as a main parameter in the CR modulation model for a rather long time (see e.g., (Belov, 2000)). Precisely inclination η best correlates with long-period CR variations. Inclination η is beyond competition and is irreplaceable when one SA index is considered. Specifically, inclination cannot be replaced by sunspot numbers but can be combined with the latter index. However, sunspot numbers are successfully replaced by other similar indices, e.g., by the mean solar magnetic field.

What do theorists think about it? First of all, we should not pursue an answer in the particle drift. A modulation drift theory is absent. Some available drift models cannot explain the main part of CR modulation. Drift certainly enters into any sufficiently developed modulation model as one of the charged particle transfer mechanisms. Many up-to-date modulation models (e.g., (Ferreira et al., 2003; Potgieter, 2013)) take into account the heliospheric current sheet inclination, which very substantially affects the modulation depth. The current sheet is not only the zone where drift is most effective but is also the largest magnetic inhomogeneity in the heliosphere, with which CRs interact. An increase in inclination not only increases a drift path but also creates magnetic inhomogeneities of a different type. This was adequately considered in the recent works (Krymsky et al., 2001, 2007).

A comparison of the observed and model CR density values (Fig. 1) indicates that the modulation depth in the last two years (beginning from 2010) would be larger if the index effectiveness remained unchanged. Figure 1 should be considered as follows. In 2010–1012 (cycle 24), the inclination of the current sheet was actually considerable, and its contribution would be larger than 10% if its relation to CR modulation remained as before (see Fig. 1). However, the model of a particular cycle 24 and Fig. 2 indicate that the contribution of the current sheet inclination was actually under 5% during this period. This indicates that the effect of the heliospheric current sheet inclination (η)—the main modulating index—on CR modulation changed (decreased).

In this work we found that the regression coefficient for the current sheet inclination is 0.05%/° in the model of cycle 24 (Figs. 2a and 2b). This is smaller than the coefficient during previous periods for other cycles by a factor of 2–3 (e.g., –0.16, –0.14, and –0.12%/° for cycles 20 and 22 and for the entire period from 1957 to 2012, respectively). Therefore, when describing modulation in our model, we can state that the changes in the structural characteristic of the solar magnetic field (namely, current sheet inclination η) from 11.5° at the beginning of the cycle (the CR minimum in October 2009) to >70° (from April 2012 to 2013) affected the CR intensity less effectively than in other cycles. The contribution of η variations to total modulation at the cycle 24 maximum is ~4.5%, which is twice as small as the contribution of the same variations in the previous even (20, 22; Figs. 3a and 3b) and odd (21, 23; Figs. 3c and 3d) cycles. When we modeled CR modulation during the SA growth phases in cycles 23 (1996–2001) and 24 (2009–2012), we used the *Pi* index as a parameter that reflects flare solar activity. In this case the modulation process is described with a higher statistical accuracy (e.g., the correlation coefficient is $\rho = 0.95$, and the rms deviation is $\sigma = 0.79\%$ for the SA growth phase in cycle 24).

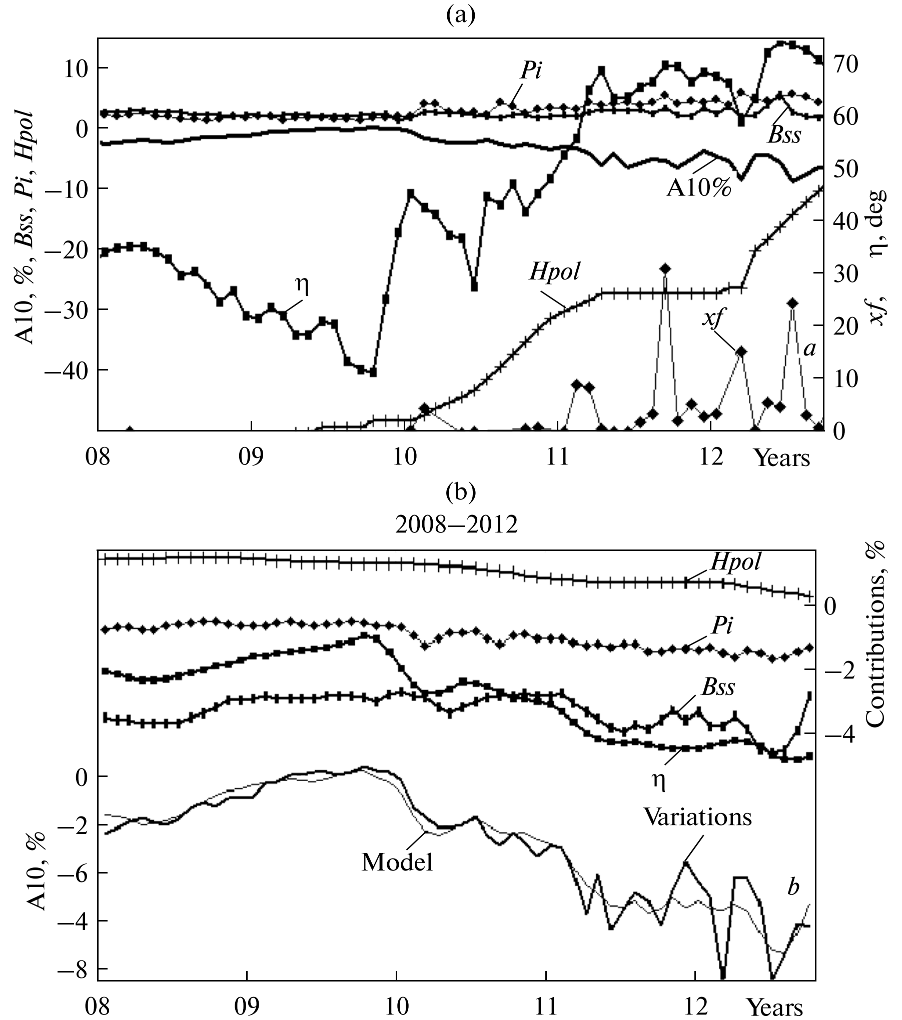

Fig. 2. (a) The A10 CR variation amplitude and the *Pi*, *Hpol*, η, *Bss*, and *xf* SA indices (in relative units) in 2008–2012; (b) the CR variations in 2008–2012. Bottom: the calculation and observations; top: the contributions of the above indices to modulation.

The effect of the large-scale solar magnetic field energy (expressed in terms of the *Bss* index) on CR during the considered SA growth period in cycle 24 is evidently lower (Figs. 2a and 2b) than such an effect during similar SA growth periods in the previous cycles. However, this is mainly caused by a decrease in the *Bss* value. Note that the effect of short-term local SA (characterized by the *xf*, *Pi*, and *Nssc* indices) to CR modulation is slightly larger than 1% in the current cycle and is 5–10% in other cycles (e.g., in cycles 21–23).

The obtained variations in the main modulating characteristics during the CR decline phase in cycle 24 and the role of these characteristics in CR variations result in the conclusion that the observed small modulation depth can be explained by not only small solar indices but also by other specific features in SA during this period or by the heliospheric state at the beginning of a new cycle.

4. RESIDUAL CR MODULATION AT SA MINIMUMS

Residual modulation for different intervals about the minimums of cycles 19–22 was determined in several works (Nagashima and Morishita, 1980; Garcia-Munoz et al., 1977; Sirotina, 1989). The last SA minimum and a record increase in the CR density near the Earth make it possible to determine residual modulation (δ_0). We determined the δ_0 value for individual periods with a duration of 8–10 years near the minimums of cycles 19–24. It was assumed that residual modulation is characterized by the free term in the regression equation. This parameter, which was obtained in our model for the period near the 1964 minimum, is $\delta_0 = 3.7 \pm 0.6\%$, which is close to the value determined in (Sirotina, 1989), where $\delta_0 = 3.6 \pm 0.5\%$. In the years near the 1976 minimum, residual modulation is $\delta_0 = 7.6 \pm 0.3\%$ in our calculations (in (Sirotina, 1989), $\delta_0 = 4.1 \pm 0.8\%$). We are more

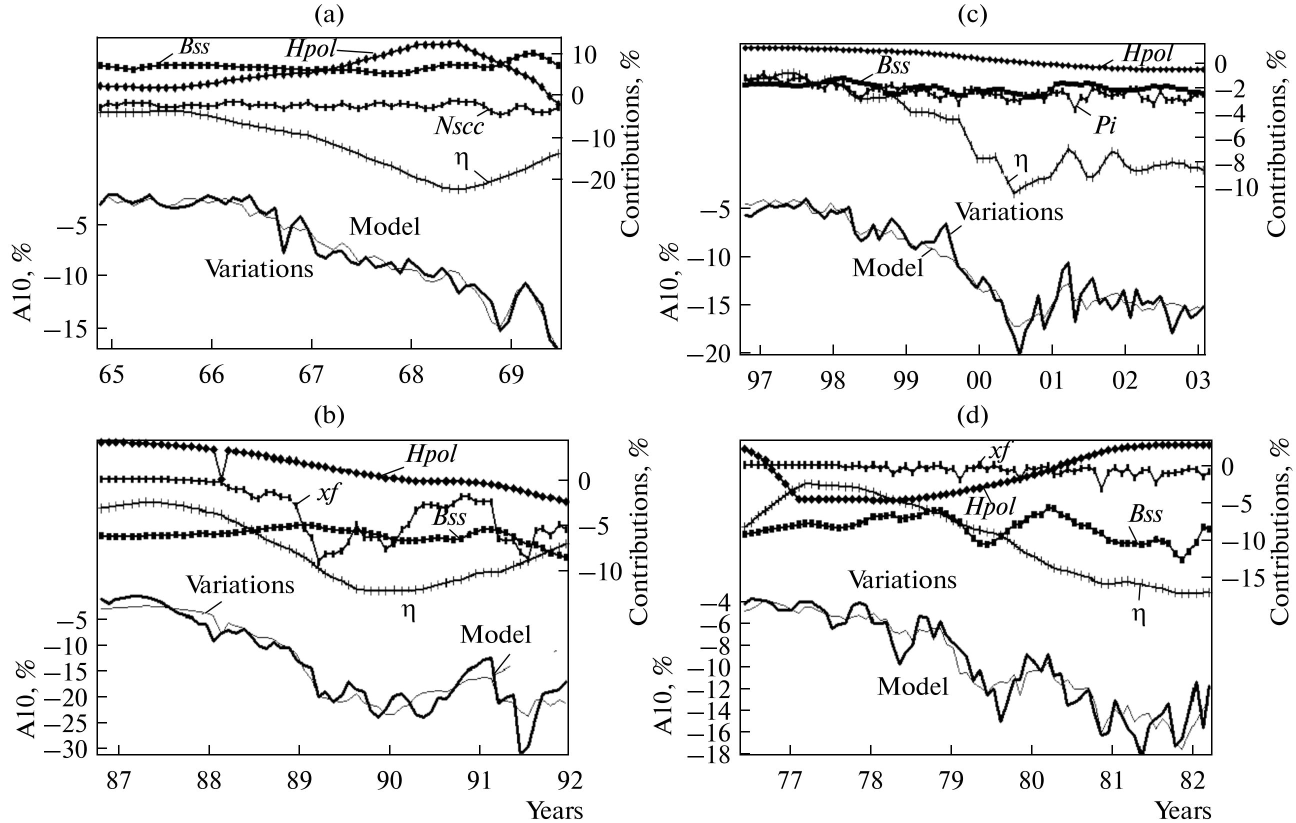

Fig. 3. The CR variations (the model and observations) during the SA growth phase in (a), (b) cycles 20 and 22 and (c), (d) cycles 21 and 23. The top plots of panels (a)–(d) show the contribution of different indices to modulation.

inclined to believe in a new result, noting that Garcia-Munoz et al. (1977) also wrote that modulation is significant at the 1976 minimum (unfortunately, they did not indicate the modulation value). According to our model, $\delta_0 = 9.8 \pm 0.3$ and $5.2 \pm 0.3\%$ for the 1986 and 1996 minimums, respectively. For the last minimum (of cycle 24), we found that $\delta_0 = 9.2 \pm 0.2\%$, which almost coincides with our result and the value obtained in (Nagashima and Morishita, 1980) for cycle 22 ($\delta_0 = 9.8 \pm 3.3\%$). Such considerable residual modulation during the period when CR density was anomalously high means that the heliosphere intensely affects comparatively high-energy CRs even when SA is very low. There is a strong possibility that residual modulation from not only the last but also previous cycles can be observed in the heliosphere at the current cycle minimum. We should state that our modulation description, performed based on the assumption that the CR intensity is linearly related to the SA characteristics, can differ from a true character of this relation. Finally, we should note that the residual modulation value should be affected by the polarity of the general solar magnetic field, but we have not yet obtained an evident dependence. These circumstances allow us to be skeptical about available definitions of the residual modulation value and make the obtained values rather conventional.

5. DISCUSSION OF RESULTS

Analyzing modulation during the SA growth phase and the maximum achieved in cycle 24, we arrive at the conclusion that insignificant modulation is most probably caused by anomalies that originated in the Sun and heliosphere. We can cite several SA observations that confirm such a conclusion. The magnetic flux values at the solar poles are lower than in the previous cycle by 40%, and the area of the polar coronal holes substantially decreased (Gibson et al., 2009). The heliophysicists determined (see, e.g., (Ishkov, 2013) and references therein) that the magnetic fields in the solar wind over the poles have generally decreased by a factor of approximately 3 during the last 30 years. A long interval with the smallest values from the beginning of observations (since 1947) was observed in the radioemission at a wavelength of 10.7 cm in 2008–2009. Sunspots were mostly absent in 2008–2009. Livingston and Penn (2009) indicated that the sunspot magnetic field strength has gradually decreased in recent times. If this result is confirmed, this can result in an absolutely new understanding of cyclic variations in SA (Obridko et al., 2012). In 2009 the average solar wind velocity was 365 km/s (as compared to 443 km/s during the entire long-term previous period of solar wind measurements); the IMF strength also extremely decreased: 3.94 nT in 2009 as compared to 6.47 nT in 1964–2008.

Some of the cited facts are evidently related to a decrease in one of the main modulating characteristics, which is used to construct the CR modulation model with the *Bss* index that gives information about the entire magnetic flux passing through the solar wind source surface.

Changes in the structural characteristic of the solar magnetic field (the current sheet inclination, η) during the indicated cycle phase do not differ in magnitude from η variations during the corresponding periods of other cycles. A small regression coefficient in the equation that is used in the multi-parametric model of the long-period CR variation means that the effect of this parameter and, correspondingly, the contribution of the variations in this main modulation index to CR modulation are decreased. It is still unclear what physical phenomena in the Sun and heliosphere are responsible for a similar anomaly.

At a SA minimum, magnetic fields usually disappear on small surface areas, and only the global magnetic field remains on the Sun (Obridko et al., 2012). Precisely this field becomes responsible for the origination of sunspots in a new cycle. This process was anomalous at a minimum between cycles 23 and 24. On the one hand, the magnetic field at the solar poles was much smaller than anticipated. According to the data of AMC ULISS, which passed over the solar poles, in 2008 the solar wind magnetic field and density became smaller by 35 and 20%, respectively. On the other hand, medium-scale equatorial structures disappeared less pronouncedly than was usually observed, as a result of which the minimum phase started later. A considerable value of CR residual modulation at the cycle 24 minimum and a decreased contribution of variations in the modulating parameter (the polar solar field, *Hpol*) may be related to the latter circumstances.

6. CONCLUSIONS

The current SA cycle (cycle 24) differs in the extremely weak CR modulation caused by anomalies that have recently originated in the Sun and heliosphere, namely, the weakening of solar magnetic fields. A similar conclusion is confirmed by several different SA observations during the period of activity growth in cycle 24.

In addition, it was revealed that the current sheet inclination affected CR modulation less intensely in 2009–2012. The inclination varies in the same range as during other cycles, but the effect of this influence is much lower.

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REFERENCES

Belov, A., Large-scale modulation: View from the Earth, *Space Sci. Rev.*, 2000, vol. 93, pp. 71–96.

Belov, A.V., Gushchina, R.T., and Sirotina, I.V., The spectrum of cosmic rays variations during 19–22 solar cycles, *Proc. 23rd ICRC*, 1993, vol. 3, pp. 605–609.

Belov, A.V., Shelting, B.D., Gushchina, R.T., et al., Global magnetic field of the Sun and long-term variations of galactic cosmic rays, *J. Atmos. Terr. Phys.*, 2001, vol. 63, pp. 1923–1929.

Belov, A.V., Gushchina, R.T., Obridko, V.N., Shelting, B.D., and Yanke, V.G., Connection of the long-term modulation of cosmic rays with the parameters of the global magnetic field of the Sun, *Geomagn. Aeron.*, 2002, vol. 42, pp. 639–700.

Belov, A.V., Gushchina, R.T., Obridko, V.N., et al., The relation of the global magnetic solar field indices and the solar wind characteristics with the long-term variations of galactic cosmic rays, *Proc. 29th ICRC*, 2005, vol. 2, pp. 235–239.

Belov, A.V., Gushchina, R.T., Obridko, V.N., Shelting, B.D., and Yanke, V.G., Simulation of the modulation of galactic cosmic rays during solar activity cycles 21–23, *Bull. Russ. Acad. Sci.: Phys.*, 2007, vol. 71, no. 7, pp. 974–976.

Ferreira, S.E.S., Potgieter, M.S., and Heber, B., Particle drift effects on cosmic ray modulation during solar maximum, *Adv. Space Res.*, 2003, vol. 32, pp. 645–650.

Garcia-Munoz, M., Mason, G.M., and Simpson, J.A., New aspects of the cosmic ray modulation in 1974–1975 near solar minimum, *Astrophys. J.*, 1977, vol. 213, no. 1, pp. 263–268.

Gibson, S.E., Kozyra, J.U., de Toma, G., Emery, B.A., Onsager, T., and Thompson, B.J., If the Sun is so quiet, why is the Earth ringing? A comparison of two solar minimum intervals, *J. Geophys. Res.*, 2009. vol. 114, p. A09105. doi 10.1029/2009JA014342

Gushchina, R.T., Belov, A.V., Obridko, V.N., and Shelting, B.D., Manifestations of cyclic variations in the solar magnetic field in long-term modulation of cosmic rays, *Geomagn. Aeron.*, 2008, vol. 48, pp. 571–577.

Gushchina, R.T., Belov, A.V., Obridko, V.N., and Shelting, B.D., Extrema of long-term modulation of the cosmic ray intensity in the last five solar cycles, *Geomagn. Aeron.*, 2012, vol. 52, pp. 438–444. doi 10.1134/S0016793212040068

Ishkov, V.N., The Sun near the solar cycle 24 maximum: The geoeffective flare phenomena, the evolution and the development forecast, *J. Phys.: Conf. Ser.*, 2013, vol. 409, p. 012167. doi 10.1088/1742-6596/409/1/012167

Krymsky, G.F., Krivoshapkin, P.A., Gerasimova, S.K., and Mamrukova, V.P., Heliospheric modulation of high-energy cosmic rays. I. Basic model of cosmic-ray modulation with solar cycle, *J. Exp. Theor. Phys.*, 2007, vol. 104, no. 2, pp. 189–195.

Krymsky, G.F., Krivoshapkin, P.A., Gerasimova, S.K., and Mamrukova, V.P., Heliospheric modulation of high-energy cosmic rays. II. Deformation of the neutral surface, *J. Exp. Theor. Phys.*, 2007, vol. 104, no. 2, pp. 196–200.

Krymsky, G.F., Krivoshapkin, P.A., Gerasimova, S.K., Grigor'ev, V.G., and Mamrukova, V.P., Neutral layer and particle drift in long-period CR variations, *Bull. Russ. Acad. Sci.: Phys.*, 2001, vol. 65, no. 3, pp. 353–356.

Livingston, W. and Penn, M., Are sunspots different during this solar minimum? *Trans., Am. Geophys. Union*, 2009, vol. 90, no. 30, pp. 257–264.

Nagashima, K. and Morishita, I., Long term modulation of cosmic rays and invferable electromagnetic state in solar modulating region, *Planet. Space Sci.,* 1980, vol. 28, no. 2, pp. 177–194.

Obridko, V.N. and Shelting, B.D., Structure of the heliospheric current sheet as considered over a long time interval (1915–1996), *Sol. Phys.*, 1999, vol. 184, no. 1, pp. 187–200.

Obridko, V.N., Nagovitsyn, Yu.A., and Georgieva, K., The unusual sunspot minimum: Challenge to the solar dynamo theory, *Asrtophys. Space Sci. Proc.*, 2012, vol. 30 P, pp. 1–17.

Paouris, E., Mavromichalaki, H., Belov, A., Gushchina, R., and Yanke, V., Galactic cosmic ray modulation and the last solar minimum, *Sol. Phys.*, 2012, vol. 280, no. (1), pp. 255–271.

Potgieter, M.S., Solar modulation of cosmic rays, *Living Rev. Sol. Phys.*, 2013, vol. 10, no. 3.

Sirotina, I.V., *Extended Abstract of Cand. Sci. Dissertation*, Moscow: Mosk. Gos. Univ., 1989.

Stozhkov, Yu.I., Svirzhevskii, N.S., and Bazilevskaya, G.A., Svirzhevskaya, A.K., Kvashnin A.N., Krainev M.B., Makhmutov V.S., and Klochkova T.I. Cosmic ray fluxes at an absorption curve maximum in the atmosphere and at the atmospheric boundary (1957–2007), *Preprint of Lebedev Physical Institute, Russian Academy of Sciences*, Moscow, 2007, p. 55.

Vanyarkha, N.Ya., Reconfiguration of the heliospheric current sheet based on geomagnetic data, *Geomagn. Aeron.*, 1995, vol. 35, no. 1, pp. 133–138.

http://cdaw.gsfc.nasa.gov/CME_list/

http://www.wdcb.ru/stp/data/sudden.com/

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