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Connection of the Long-Term Modulation of Cosmic Rays with the Parameters of the Global Magnetic Field of the Sun

A. V. Belov, R. T. Gushchina, V. N. Obridko, B. D. Shelting, and V. G. Yanke

Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation, Russian Academy of Sciences, Troitsk, Moscow oblast, 142090 Russia

rgus@izmizan.troitsk.ru

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Abstract—The connection of long-term variations of galactic cosmic rays (CR) with the characteristics of the global solar magnetic field and with the solar wind parameters is considered. This paper continues our study of long-term CR variations, in which solar–heliospheric parameters are used for a description of the observed CR modulation in various solar cycles. A distinctive feature of this paper is that it is based on characteristics of the global solar magnetic field, determined on the solar-wind source surface. The set of such characteristics includes the tilt of the heliospheric current sheet and the mean intensity of the solar magnetic field and its polarity. Both the direct effect of the polarity of the global solar magnetic field on CR and the effect of the polarity on CR modulation, connected with the change in the tilt of the current sheet, are taken into account. For the period for which direct observations of the solar magnetic field are lacking, the characteristics of the global solar field have been reconstructed from observations of filaments in the H_α line. Thus it was possible to extend the time interval of the CR model simulation to as far as 1953. As a result, a semiempirical model of modulation has been constructed. This model adequately describes the behavior of CR with a rigidity of 10 GV during a long period covering three solar cycles.

1. INTRODUCTION

The long-term variations of galactic CR have been compared with the behavior of different solar activity indices and heliospheric parameters many times. The magnetic-field parameters of the Sun, calculated for the solar-wind source surface [Hoeksema and Sherrer, 1986], take a special place in this series. The magnetic field on the source surface determines the structure and properties of the heliomagnetosphere. Therefore, it should be more closely connected with CR modulation than other solar characteristics (such as sunspot numbers or coronal emission intensity). Mikhailutsa [1990] and Nagashima *et al.* [1991] successfully used the amplitudes of the magnetic-field spherical harmonics on the source surface to model the long-term CR modulation. The tilt of the heliospheric current sheet is determined precisely on the source surface. The strong connection of this parameter with the CR behavior in the last two decades has been justified theoretically [Jokipii and Thomas, 1981] and confirmed multiple times by experimental data, e.g., Smith and Thomas [1986], Webber *et al.* [1990], Belov *et al.* [1995, 1999a], Bazilevskaya and Svirzhevskaya [1998], Krymsky *et al.* [2001].

Now it is becoming more and more obvious that particular characteristics of CR modulation cannot be explained without using the tilt of the heliospheric current sheet and other magnetic-field characteristics on the source surface. This approach would have been even more successful if there were no time limitations. The magnetic-field characteristics have been calculated for the source surface only since 1976, and all the above-mentioned works are limited to rather narrow time intervals and refer to the last solar cycles. In recent years, hope has appeared that these limitations could be overcome. Obridko and Shelting [1999] have developed a technique permitting the reconstruction of the field on the source surface from optical observations of solar filaments in the H_α line, and the magnetic-field characteristics on the source surface have been determined for a long time interval, completely overlapping the period of CR observations. In the earlier studies of CR modulation, an alternative technique of recovering the heliospheric current-sheet tilt from the data of geomagnetic observations [Vanyarkha, 1995] was used, but it is inapplicable during periods of high solar activity.

The purpose of this paper is to use for modeling of long-term CR variations the magnetic-field characteristics on the source surface, including those obtained from indirect optical data.

2. INPUT DATA

To analyze the connection of long-term CR variations with variations in the characteristics of solar magnetism, we used δ, the amplitude of the density variations of particles with a rigidity of 10 GV (lower curve in Fig. 1). The rigidity spectrum of CR variations for each month was obtained from the data of neutron monitors of the entire global network of CR stations, ioniza-

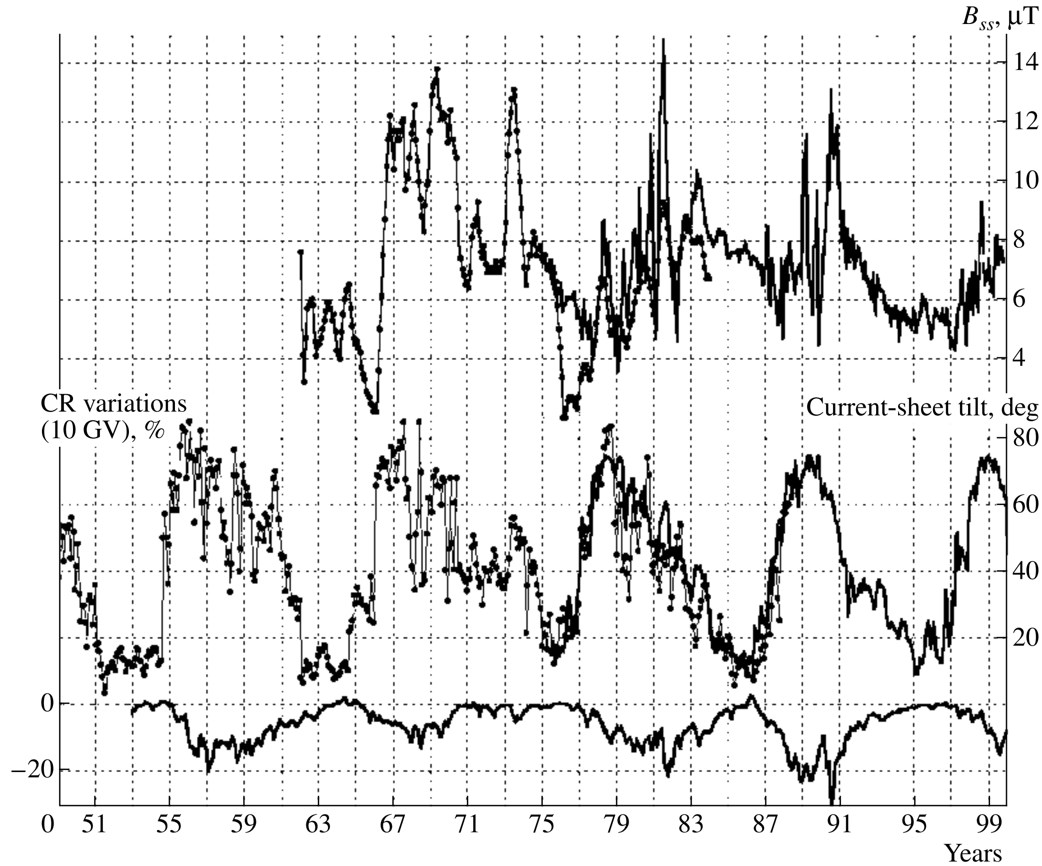

Fig. 1. Long-term variations of the mean magnetic intensity of the Sun on the source surface B_{ss}, obtained from Stanford magnetic measurements [Hoeksema, 2000] (solid curve); calculations of Obridko and Shelting [1999], based on the Kitt Peak and Mount Wilson observations (dots on the upper curve). The tilt angle η_m of the heliospheric current sheet found from the magnetic measurements of Hoeksema [2000] (solid curve) and the tilt η_{H_α} found from optical observations in the H_α line [Obridko and Shelting, 1999] (dots on the central curve). Amplitude of variations of CR with a rigidity of 10 GV (lower curve).

tion-chamber data, stratospheric-sounding data, and the results of the IMP-8 observations of CR with energies above 106 MeV using the technique proposed in the paper of Belov *et al.* [1993] and in references therein. Below, we will consecutively consider three models of modulation (two auxiliary models and the main one). All three models use the tilt angle η of the heliospheric current sheet. In the first (elementary) model, the heliospheric current-sheet tilt is the unique parameter. In the second (two-parameter) model, it is unified with the intensity B_{ss} of the radial magnetic-field component, averaged over the entire source surface. In the third, main model (in addition to changes in η and B_{ss}), we used changes in the polarity p of the global solar magnetic field and in the heliospheric parameter BV, the product of the interplanetary-magnetic-field (IMF) intensity and velocity of the solar wind (SW). The justification for using these parameters for modeling long-term CR variations and the results of the application of this approach to the description of variations in 1977–1999 were given by Belov *et al.* [2001]. The characteristics of the solar magnetic field were obtained by the technique developed by Obridko and Shelting [1999] and were specially improved for the present problem. They have been calculated for the source surface using magnetic and optical observations. The time boundaries of the global solar field inversion were obtained from various data on the photosphere and on the solar-wind source surface.

3. CR MODULATION AND THE TILT OF THE HELIOSPHERIC CURRENT SHEET

Figure 1 shows the behavior of the tilt angle η_m of the heliospheric current sheet obtained from the data of magnetic observations [Hoeksema, 2000]. It also shows the heliospheric current-sheet tilt angle η_{H_α} calculated from the optical data [Obridko and Shelting, 1999]. The close similarity of the changes of η_m and η_{H_α} in 1976–1989, when these two time series overlap, is readily visible (the correlation coefficient is 0.89). Earlier, Belov *et al.* [1995] found a rather strong connection between the heliospheric current-sheet tilt and long-term CR

Parameters of the regression between δ and η

Interval	a, %	b, %	τ_u, months	ρ	σ, %
July 1953–June 1959	2.7 ± 0.2	−0.24 ± 0.01	26	0.93	2.26
Feb. 1961–Jan. 1970	2.2 ± 0.1	−0.16 ± 0.01	23	0.92	1.32
May 1973–May 1980	4.3 ± 0.2	−0.15 ± 0.02	4	0.88	1.51
Sept. 1981–Sept. 1991	4.6 ± 0.2	−0.33 ± 0.01	5	0.95	2.23
Mar. 1992–Dec. 1999	4.0 ± 0.1	−0.20 ± 0.01	25	0.93	1.04

behavior during the periods of identical polarity of the global solar magnetic field. To test whether this connection exists in broader time intervals, we used a sequence of data on η, combined from η_{H_α} (since 1950 up to April 1976) and from η_m since May 1976. Using linear regression analysis, we found periods approximately coinciding with the periods of identical heliomagnetospheric polarity, when the following relationship fit the CR variations fairly well:

$$\delta(t) = a + \frac{b}{\tau_u + 1}\sum_{\tau = 0}^{\tau_u} \eta(t - \tau), \qquad (1)$$

where τ is the delay time between changes on the Sun and in CR. Here, we have taken into account the fact that the CR modulation is determined by events on the Sun in the current month ($\tau = 0$) and in the near past, beginning from the moment $t - \tau_u$. For each period, the least-squares method determined three parameters, a, b, and maximum delay τ_u. They are listed in the table together with correlation coefficients ρ and standard rms deviations σ. In the last two periods, we used only the values of η_m; in the first two, only η_{H_α}; whereas in the third period (1973–1980), the data were mixed. At present, the analysis of the connection of CR variations with changes in the heliospheric current-sheet tilt could be extended to five halfperiods of the solar magnetic cycle, covering in total 47 years. We see a good agreement of the behavior of the current sheet and CR for almost all this time, except for relatively short interruptions during and immediately after the field reversal. In all the selected periods, the correlation coefficient was in the range of 0.88–0.95, and the rms deviation was smaller than 2.3%. Taking into account the simplified character of the applied model (1) and using only one solar–heliospheric parameter, we must consider such agreement as quite satisfactory.

The connection of CR modulation with the heliospheric current-sheet tilt has recently become universally recognized. The moment has come when the connection of reconfigurations of the heliospheric current sheet and long-term CR behavior does not require any more evidence, but it still requires convincing explanations [Belov, 2000]. The mechanism of this connection is not yet quite understood; most likely, it is more complex than its descriptions given in the first theoretical studies [Jokipii and Thomas, 1981; Kota and Jokipii, 1983]. Here, we should take into account several circumstances. The fact that the neutral current sheet favors CR transport in the radial direction and, for a considerable tilt angle, also in the latitudinal direction is only one of these circumstances and is not necessarily the most important one.

Now, after measurements of the SW characteristics in a broad range of heliolatitudes, nobody doubts that, during most of the solar cycle, SW is divided into three different zones: low-latitude, where the SW velocity is 300–450 km/s, and northern and southern high-latitude zones, where the SW velocity is 700–800 km/s. The size of the low-latitude SW region, which has a lower average wind velocity and a more efficient interaction between streams with different velocities, is probably connected with the heliospheric current-sheet tilt. It can be supposed (see, e.g., Svirzhevskaya *et al.* [2001]) that this low-latitude part of the solar wind has a large modulation capacity with respect to CR.

Phenomena that are even more important for the CR modulation take place at the boundaries of the zones. This boundary is clearly pronounced, and at it everything is observed that should be observed when a fast stream flows onto a slow one (a couple of shock waves, an increase in the density of the medium and of the interplanetary-magnetic-field intensity, etc.). Two such interface zones (in the northern and southern hemisphere) extend from a heliodistance of 1–2 AU to the limits of the Solar System and represent the main structural features of the heliosphere. Recently, evidence (e.g., Richardson *et al.* [1999]) that the shape of these boundaries varies together with the shape of the heliospheric current sheet has appeared. This means that in the solar minimum, when the heliospheric current sheet is almost flat, the fast and slow SWs interact weakly. The greater the heliospheric current-sheet tilt, the more intense is this interaction, the more extended, broad, and powerful are the regions of the streams' interaction, and the greater is their modulation capacity. The last circumstance was noted by Krymsky *et al.* [2001]. According to their calculations, the enhanced magnetic fields of the interaction regions can create all the actually observed CR modulation, and the changes in these regions, connected with reconfigurations of the heliospheric current sheet, are can explain the main part of long-term CR variations and their connection with solar cycles.

Finally, speaking about the role of the tilt in creating the observed long-term run of the CR intensity, we should also say that coronal mass ejections occur preferentially near the current sheet.

Let us consider the value of the obtained delay time τ_u (see table): for some intervals, it exceeds two years. We can suppose that the solar wind crossing the interface shock wave (it takes about one year to reach it) does not lose its capacity to modulate CR. The CR modulation region can have a large size, and the delay time for them can basically be much longer than 12 months [Kalinin and Krainev, 1990; McCracken and McDonald, 2001]. The delays listed in the table represent a description of the obtained regression connections. They cannot be recommended for an estimate of the sizes of the heliosphere or modulation region. In this part of the paper we do not attempt to present a complete model of CR modulation. Here we have shown that the correlation between the heliospheric current-sheet tilt and CR behavior has existed not only during the last decades, and it can be revealed using not only direct magnetic observations but also indirect optical data. Thus, the heliospheric current-sheet tilt obtained from indirect optical data can replace the generally used tilt obtained from magnetic measurements. To what extent is such a replacement valid? In the last intervals, the results look more convincing, and this is most likely not accidental. We have analyzed separately, but in the same way, the interval ranging from April 1981 through December 1989, when the data on the heliospheric current sheet tilt, obtained by different methods, overlap. For η_m, the coefficient of correlation ρ with the CR variations was 0.93 with $\sigma = 2.37$, whereas for η_{H_α} we obtained the following values: $\rho = 0.89$ and $\sigma = 2.93$. The difference definitely favors η_m, although using optical observations also yields satisfactory results. On the basis of the evidence obtained, we can assert that optical observations are capable of giving a sufficiently successful and justified replacement to the data on the heliospheric current sheet tilt, and they can be recommended for the periods when there are no direct magnetic observations.

The obtained results confirm that the sufficiently high correlation of the long-term CR variations is observed both for the negative (the 1960s and 1980s) and for the positive polarity of the global solar magnetic field [Belov *et al.*, 1995]. Beginning from the 20th solar cycle, we see a clear alternation of large (for the negative polarity) and small regression coefficients. At a transition to the negative polarity, the value of factor b increases more than twofold. The interval of the 1950s was not complete, and at this time the data used were the least reliable. In the 1950s there were no satellite or stratospheric observations, and before 1957 only a few neutron monitors had been operating. Because of this, the accuracy of the rigidity spectrum of CR variations in these early years could not be sufficiently high. The quality of the optical solar data in the 1950s and 1960s was lower than during the subsequent years. This period apparently requires an additional analysis based on a revision of the experimental data.

4. A MODEL WITH TWO INDICES AND CR MODULATION AT HIGH SOLAR ACTIVITY

The description we have obtained for the observed CR variations is rather crude and approximate. This could not be otherwise. The CR modulation is a complicated phenomenon, occurring throughout the heliosphere and depending on many factors. None of them, not even the best solar index, can alone explain the CR variations. Belov *et al.* [1999a] proposed a multiparameter description of the long-term CR variations and showed that for such a description, it is very efficient to use, together with the heliospheric current-sheet tilt, the variation of the interplanetary-magnetic-field intensity. It is even easier to justify the IMF-intensity effect on the CR modulation theoretically than the effect of the heliospheric current-sheet tilt, and these two parameters indeed supplement each other successfully. The point can also be that the heliospheric current-sheet tilt gives information about the structure of the heliomagnetosphere, and the IMF intensity quantitatively characterizes its capacity to affect CR. However, when using the IMF data, there is always at least one doubt: whether the presently available near-Earth IMF measurements can characterize the magnetic field variations in the entire heliosphere, where the CR modulation takes place, well enough. Therefore, it is desirable to find another parameter that also supplements the heliospheric current-sheet tilt well but, in contrast to the IMF intensity, is more global. Such a solar index could be the magnetic field of the Sun as a star, but it is probably more logical to search for this parameter on the source surface, where the tilt angle of the heliospheric current sheet is determined. As such a characteristic we considered [Belov *et al.*, 1993] the radial component B_r of the magnetic field averaged over the entire source surface: $B_{ss} = \sqrt{\langle B_r^2 \rangle}$. The choice of this quantity is connected with the results obtained in the solar magnetism studies of recent years. Since the magnetic field on the source surface is primarily determined by the dipole component of the solar magnetic field, this quantity behaves similarly to the dipole moment in the expansion of the magnetic field on the source surface (see Fig. 5 in Wang *et al.* [2000]). To explain the anomalous CR variations in 1982, Nagashima *et al.* [1991] and Bazilevskaya *et al.* [1990] invoked the dipole field of the Sun. Proceeding from the conclusions of Wang *et al.* [2000], we can suppose that the exotic CR variations of 1991 may be explained in a similar way. On the other hand, the B_{ss} variations should be similar to the magnetic-flux variations, whose importance is the main

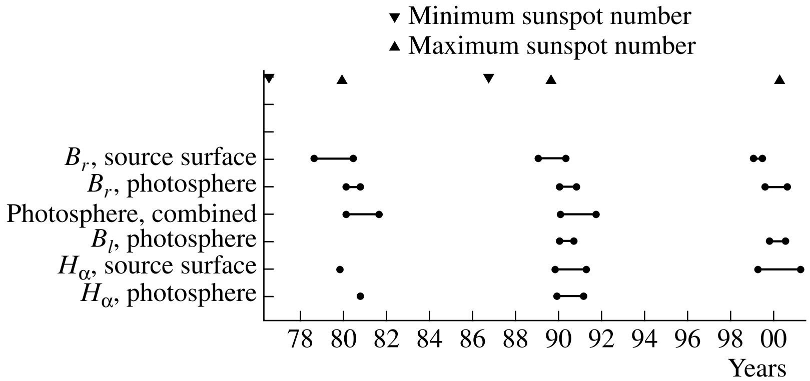

Fig. 2. Polarity-reversal periods, obtained from various data on the photosphere and source surface of the solar wind [Obridko and Shelting, 2001]. B_r and B_l are the magnetic-field components (radial and line-of-sight).

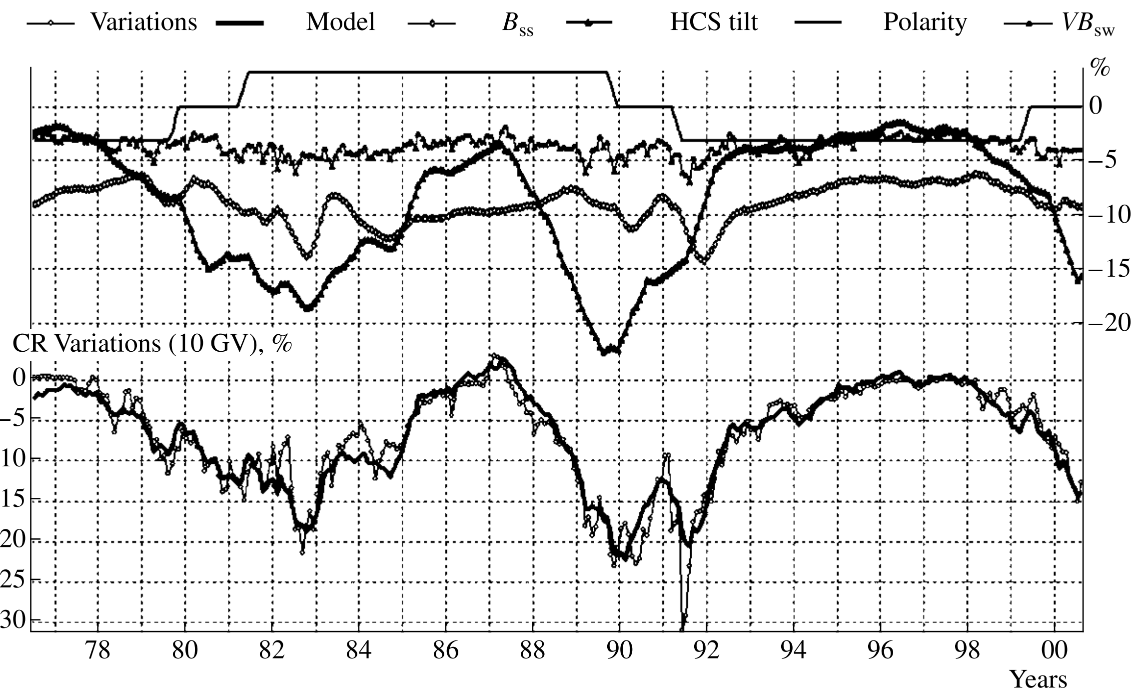

Fig. 3. Observed and model monthly average CR variations in 1976–2000 (bottom graph). Top graph: contributions to the calculated variation from the changes in B_{ss}, η, p, and parameter $|B_{IMF}|V_{sw}$.

conclusion of Cane *et al.* [1999]. Figure 1 shows the long-term variations in B_{ss}, determined from magnetic measurements for 1963–2000. The data were obtained from the observations of the solar magnetic field at the Mount Wilson, Kitt Peak, and Stanford observatories and have been processed by the method similar to that of Hoeksema and Sherrer [1986]. The calculation method was described by Obridko and Shelting [1999] and references therein; for this work, it has been slightly improved as compared to the B_{ss} calculations reported by Belov *et al.* [2001]. Now we must modify relationship (1) as follows:

$$\delta(t) = a + \frac{b_\eta}{\tau_{u\eta}+1}\sum_{\tau=0}^{t_{u\eta}}\eta(t-\tau) + \frac{b_B}{\tau_{uB}+1}\sum_{\tau=0}^{t_{uB}}B_{ss}(t-\tau). \quad (2)$$

For the interval of October 1981 – August 1990, approximately coinciding with the period of negative polarity of the global solar magnetic field, the least-square fit yields the following parameters: $a = 8.1 \pm 1.4$,

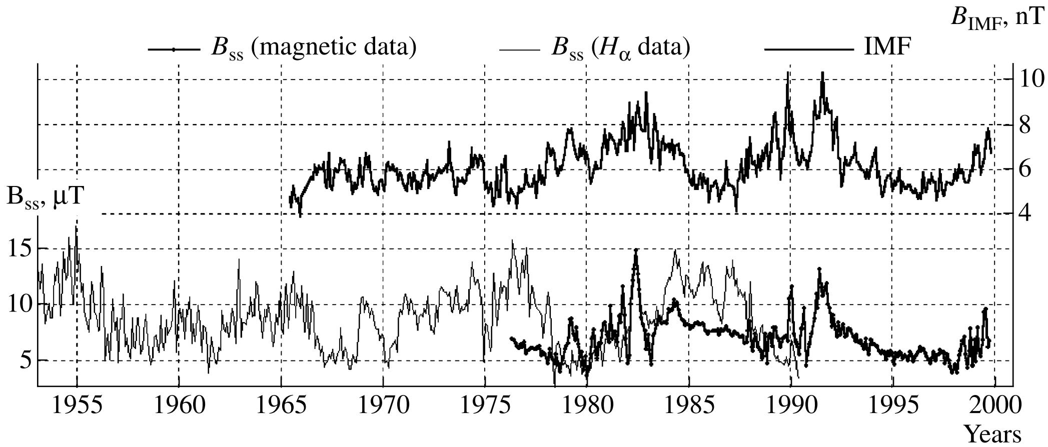

Fig. 4. Long-period variations of the mean magnetic field on the source surface, obtained from magnetic measurements $(B_{ss})_{\rm m}$ (thick curve) and optical observations in the H_α line $(B_{ss})_{H_\alpha}$ (thin curve). Top: variations of the monthly average intensity of the interplanetary magnetic field $B_{\rm IMF}$, measured near the Earth (the OMNI Data).

$b_\eta = -0.33 \pm 0.01$%/deg, $b_B = -1.1 \pm 0.2$%/nT, $\tau_{u\eta}$ = 4 months, τ_{uB} = 8 months. With these parameters, very good agreement of the observed and calculated CR variations is achieved (the correlation coefficient is 0.96). Such an agreement cannot be called crude. In this case, our model describes sufficiently well not only the general run of the CR variations, but also numerous details. The agreement for such a simplified model is surprising. It describes the CR variations in such a complicated interval better than models with a much greater number of parameters, proposed by Nagashima *et al.* [1991] and Belov *et al.* [1999a]. We should note that the B_{ss} variations taken alone correlate with CR variations very poorly. However, combining this index with the heliospheric current-sheet tilt paradoxically changes its capabilities. In combination with the η variations, the B_{ss} variations not only participate in the control of the CR variations but play a leading role in this process (at least in the 1980s). Applying model (2) to other intervals also yielded good results, including the years close to the solar maxima, which are the most difficult periods for modeling CR modulation. The proposed model describes them better than other models do, but it is still far from being perfect.

5. A MULTIPARAMETER MODEL OF CR MODULATION

In the two previous sections, we discussed modeling of the CR modulation using one or two solar-activity indices. Such models are suitable for separate time intervals with the same sign of the global solar magnetic field. The complete model suitable for longer time intervals (preferably, for any arbitrary period) should include a greater number of parameters and, necessarily, information on the changes of the global solar field polarity. Below, we will consider CR modulation for the entire interval of July 1976–August 2000, in which a uniform series of the magnetic-field characteristics on the source surface, obtained from magnetic and optical observations, is available. This interval includes three field reversals. The effect of the heliomagnetic polarity on CR was described by means of auxiliary function $p_S(\tau)$, taking values +1 and –1 for the positive and negative polarities, respectively, and 0 during the reversal. In addition to this, using another function $p_F(\tau)$, obtained from photospheric observations, we described the effect of the change in the heliospheric current-sheet tilt on CR depending on the polarity of the large-scale solar field. One of the particulars of the definition of these auxiliary functions is that the inversion intervals are now determined from different solar observations and they differ substantially from each other. To understand how CR respond to the solar field inversion, we had to perform modeling for various time boundaries of these intervals, obtained from various experimental observations (Fig. 2). We used optical and magnetic data for determination of the polarity on the photosphere and on the source surface and observational data on the line-of-sight polar field and field determined in the radial direction. The calculations of Obridko and Shelting [2001] showed that the magnetic field on the source surface changes its sign earlier than on the photosphere. It turns out that CR behavior correlates better with the reversal of the polarity of magnetic fields on the source surface than on the photosphere. The best results have been obtained using the polarity of magnetic fields obtained from the H_α observations on the source surface, $-p_{H\alpha ss}$, namely, for the following inversion boundaries: September 1979–March 1981, October 1989–March 1991, and April 1999.

In the proposed model, the long-term SW variations are described by parameter $|B_{\rm IMF}|V_{\rm sw}$, which is a product of the IMF-intensity module and SW velocity. The variation model, supplemented as stated above, is

$$\delta(t) = a + \frac{b_\eta}{\tau_{u\eta}+1}\sum_{\tau=0}^{\tau_{u\eta}}(1 + b_{\eta p}p_F(t-\tau))\eta(t-\tau)$$

$$+ \frac{b_B}{\tau_{uB}+1}\sum_{\tau=0}^{\tau_{uB}}B_{ss}(t-\tau) + \frac{b_p}{\tau_{up}+1}\sum_{\tau=0}^{\tau_{up}}p_S(t-\tau) \qquad (3)$$

$$+ \frac{b_{BV}}{\tau_{uBV}+1}\sum_{\tau=0}^{\tau_{uBV}}(BV)(t-\tau).$$

This description differs from the model proposed earlier by Belov *et al.* [1999a] in the fact that here, B_{ss} replaces the IMF module. Figure 3 demonstrates the good agreement (the correlation coefficient is 0.95) between the observed and calculated variations, both as a whole and in many details. These calculations correspond to the following values of the parameters: a = 14.9 ± 0.1, b_η= –0.224 ± 0.009%/deg, $b_{\eta p}$ = –0.49 ± 0.05, b_B = –1.27 ± 0.15%/nT, b_p = –3.2 ± 0.6%, b_{BV} = –2.6 ± 0.8%, $\tau_{u\eta}$ = τ_{uB} = 7 months, τ_{up} = 2 months, τ_{uBV} = 0. The magnetic-field characteristics on the source surface (the structural one is the heliospheric current-sheet tilt and the quantitative one is the mean field B_{ss}) supplement each other in the description of the CR variations: the changes in the heliospheric current-sheet tilt control the long-term part of the variations, whereas the short-period variations are connected with the behavior of B_{ss}. Accordingly, the heliospheric current-sheet tilt plays the main role during low and moderate solar activity and gives a place to B_{ss} near solar maxima. The SW characteristics found near the Earth (the BV parameter) contribute to the shortest-period part of the CR modulation with a zero delay of the modulation (τ_{uBV} = 0). The effect of local SW parameters in our model is minor. In contrast, the polarity effect is very important. During periods of negative polarity ($qA < 0$), the CR density increases by ~3%, and for ($qA > 0$), it decreases by the same amount. This effect agrees by its sign with the drift model, and by its magnitude it corresponds to the potential difference between the low-latitude part of the heliomagnetosphere and its polar part [Jokipii and Levy, 1979].

A comparison of the obtained results with the earlier ones from Belov *et al.* [1999b] demonstrates that replacing the IMF module with B_{ss} is not only possible but even improves the quality of the model during high solar activity. From general considerations, it is clear that the interplanetary magnetic field must be connected to the field on the source surface. However, in fact the connection between B_{ss} and the IMF module measured near the Earth (Fig. 4) is not so strong (the correlation coefficient is 0.52 for the interval of May 1976–October 1999). Therefore, the correlation between B_{IMF} and B_{ss} found in the modulation models should not be considered as a trivial fact.

At present, it is accepted that during high solar activity, magnetosheaths expanding in the solar wind are of primary importance for CR modulation [Svirzhevskaya *et al.*, 2001; Burlaga *et al.*, 1993]. We are not inclined to consider that the revealed strong correlation between the magnetic field on the source surface and the CR modulation is at odds with the generally accepted concept. It is clear that the connection of solar fields with interplanetary fields in general and with large solar-wind disturbances in particular is still insufficiently studied, and the major link of this connection should be searched for precisely on the source surface. We have attempted to extend the same approach to an earlier period, using $(B_{ss})_{H_\alpha}$, the magnetic field averaged over the source surface, calculated from indirect optical data. However, we could not find any obvious connection between the behavior of this quantity and the CR modulation. The point is that physically, $(B_{ss})_m$ and $(B_{ss})_{H_\alpha}$ (Fig. 4) differ substantially. Local components of the solar magnetic field and its sectorial structure largely contribute to $(B_{ss})_m$, whereas $(B_{ss})_{H_\alpha}$ is almost entirely determined by the global field and its zonal components [Obridko and Shelting, 1999]. Figure 4 shows that, some features being similar (for example, in 1982), the long-term behavior of $(B_{ss})_m$ and $(B_{ss})_{H_\alpha}$ differs substantially. It seems that the obtained negative result allows us to draw an important conclusion. Local solar magnetic fields not only reach the source surface but also play an important role in the formation of the heliomagnetosphere and in the global modulation of cosmic rays.

6. CONCLUSION

We can use the tilt angle of the heliospheric current sheet from optical data in studies of CR modulation. The good correlation of long-period CR variations with changes in the heliospheric current-sheet tilt exists during all intervals of identical heliomagnetospheric polarity since 1953 (i.e., throughout the time of ground-based CR observations with neutron monitors).

When modeling long-term CR modulation, it is necessary to take into account both the direct action of the polarity of the global magnetic field of the Sun on CR and the indirect effect of the polarity on CR modulation connected with changing tilt angle of the current sheet. It is shown that the CR behavior correlates better with the change in the polarity of magnetic fields obtained from the H_α observations on the source surface than with the field inversion on the photosphere.

The local component of the solar magnetic field and its sectorial structure participate in the formation of the heliomagnetosphere and play an important role in CR modulation.

Combining the global solar magnetic-field parameters determined for the source surface allows us to create a model of the modulation that describes the long-period CR variations over the last 25 years well.

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