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Forbush Effects with a Sudden and Gradual Onset

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Abstract—For a comprehensive study of the Forbush effects and their relation to solar and geomagnetic activity, a database of transient phenomena in cosmic rays and the interplanetary medium has been created, which is continuously updated with data on new events. Based on these data, we study the dependence of the Forbush effects on various internal and external parameters, as well as select different groups of events. In this paper, we consider recurrent (caused by high-speed solar wind streams from coronal holes) and sporadic (associated with coronal mass ejections) events. We investigate groups of events with a sudden and gradual onset. We show that the resulting dependencies of the Forbush effects (on the parameters of interplanetary disturbances, geomagnetic activity indices, etc.) are substantially different for the above-mentioned groups. Most likely, these differences are caused by different sources of solar wind disturbances.

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1. INTRODUCTION

A Forbush effect (FE), or a Forbush decrease (FD), is a change in the density and anisotropy of cosmic rays (CRs) in large-scale disturbances of the solar wind (SW). This effect was discovered by S. Forbush in 1937 (Forbush, 1937) and has been much addressed in literature: for example, in the books by L. Dorman (Dorman, 1963, 1974) and in (Lockwood, 1971; Iucci et al., 1979, 1986; Cane, 1993, 2000; Richardson and Cane, 2005; Belov and Ivanov, 1997; Belov et al., 1997; Belov, 2009).

There are two main types of disturbances of the interplanetary medium: sporadic and recurrent (Lockwood, 1971; Sapa, 2000; Belov, 2009; Richardson and Sapa, 2010). The former are conditioned by coronal mass ejections (CMEs), and latter are high-speed plasma flows (HPFs) from coronal holes, rotating with the Sun. Both types of interplanetary disturbances can cause a response in CR variations (as well as in the magnetosphere and ionosphere of the Earth). However, the mechanism of additional modulation of CRs in these types of SW disturbances is different (Parker, 1963; Lockwood, 1971; Belov, 2000). The FE characteristics of these two types differ too. However, it is difficult to obtain quantitative data on the differences of these characteristics, because the source of a specific event and its type are not always known. Moreover, many events have a mixed nature and can be created by both CMEs and coronal holes (Ivanov, 1996).

Since it is difficult to perform a direct statistical comparative analysis of the two FE types, one has to seek indirect approaches. For example, one can divide events by specific features of their onset: events caused by the arrival of an interplanetary shock wave to the Earth are placed into one group and events without a shock wave are placed into another group; this was first suggested as far back as by Kitamura (Kitamura, 1954). Of course, we do not imply that this division is fully consistent with the division by solar sources. Shock waves near the Earth are sometimes also observed on the fronts of high-speed streams from coronal holes. On the other hand, many interplanetary disturbances produced by CMEs, i.e., by ICMEs (especially, weak ones) arrive without a shock wave. Still, it can be stated that shock waves are more typical of events caused by CMEs and are not typical of events associated with coronal holes.

In this work, we perform a statistical analysis of a large amount of data to study the relations of various FE characteristics between themselves and with environmental parameters. The analysis was performed for two different groups bringing together events with an onset at the arrival of an interplanetary shock wave to the Earth (S group) and events with a gradual onset that were accompanied by neither a storm with a sudden commencement (SSC) nor a shock wave (NS group).

2. DATA AND METHODS

Variations in the CR density and anisotropy were combined with solar, interplanetary, and geomagnetic characteristics into a special-purpose database of interplanetary disturbances and FEs at the Pushkov Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation, Russian Academy of Sciences (Belov et al., 1999, 2001). Cosmic rays are represented by global survey data from the entire global network of neutron monitors (GSM) for a rigidity of 10 GV and the solar wind data were taken from the OMNI database (http://omniweb.gsfc.nasa.gov). The database includes a large number of different characteristics for ~6000 FEs covering more than fifty years of observations (1957–2010).

Figure 1 shows some FE characteristics: A_F is the magnitude of FEs (the maximum variation in the CR density for 10 GW); Δ_{min} is the maximal hourly decrease in the CR density during this event (i.e., the maximum decrement); t_{min} is the full time of the main phase of the FE, i.e., the time elapsed between the onset of the event (in this case, coinciding with SSC) and the time of the maximum decrease in the CR density.

This database not only contains data on various characteristics of FEs and interplanetary disturbances, but is also a convenient tool for their processing. It allows one to select different sets of events to determine the relationships between different parameters, representing the requested information in both numerical and graphical forms, which have been used to obtain the results of this work.

Unfortunately, not all events collected in the database are equally suitable for statistical analysis. For example, if two or more solar wind disturbances follow one another without a sufficient break, the first FE does not have enough time to evolve, while the second FE evolves under the action of two, rather than one, disturbances. To avoid such interferences, we considered those events, the onset of which was separated from adjacent FDs by at least 60 h. In this case, since the effect of small decreases is usually small, we only selected events that were preceded by FDs not exceeding 1.5%. The remaining events were divided into two groups: group S (with interplanetary shock waves) and group NS (without shock waves). Sudden onset of magnetic storms was used as the most convenient indicator of interplanetary shock waves (ftp://ftp.ngdc.noaa.gov/stp/solar_data/sudden_commencements/). The S group did not include weakly-expressed and unreliably selected events from sudden starts (those that were not attributed to class A by any magnetic observatory) (Mayaud and Romana, 1977). In some cases, the S group includes events without SSC but with reports of shock waves observed by the ACE (http://www.swpc.noaa.gov/ace/), Wind (http://lepmfi.gsfc.nasa.gov/mfi/mag_cloud_pub1.html), and Soho (http://lascowww.nrl.navy.mil/) satellites. The S group includes a total of 536 events, and the NS group includes 2432 events.

3. RESULTS AND DISCUSSION

As noted above, using the database of interplanetary disturbances and FEs, one can obtain information on different parameters in the selected groups. The table shows the average, maximum, and minimum values of the FE parameters of interplanetary disturbances for the S and NS groups:

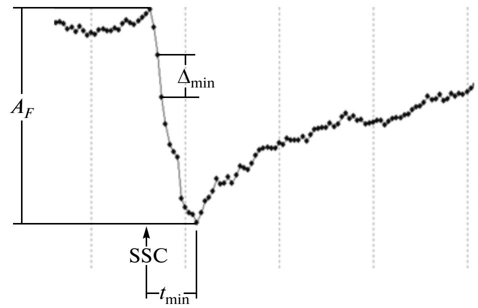

Fig. 1. Typical behavior of the CR density in a Forbush effect.

A_F is the FE magnitude; Axy_{max} and Az are the maximum values of the anisotropy components in the plane of the Earth's equator and along the axis of the Earth's rotation, respectively; Δ_{min} is the maximum hourly decrease in the CR density; Kp_{max}, Ap_{max}, and Dst_{min} are the maximum values of the geomagnetic activity indices in a given disturbance; B_{max} is the maximum value of the IMF strength; V_{max} is the maximum solar wind velocity; V_mB_m is a parameter characterizing solar wind disturbances and normalized as

$$V_mB_m = \frac{V_{max}}{V_0}\frac{B_{max}}{B_0}, \quad (1)$$

where V_0 and B_0 are parameters of the undisturbed interplanetary medium (usually, V_0 = 400 km/s and B_0 = 5 nT); $t(V_{max})$, $t(B_{max})$, $t(Axy_{max})$, and $t(\Delta_{min})$ are the times from the onset of a disturbance to the maximum value of the solar wind velocity, IMF strength, anisotropy component Axy, and hourly decrease in density Δ_{min}, respectively; R_B is the maximum rigidity of particles capable of reflecting the magnetic field of the interplanetary disturbance (see explanations below); t_{min} is the time from the onset of the event to the CR density minimum; and A_F/B_{max} is the ratio of the FE magnitude to the maximum value of the IMF strength. Analyzing the table, one can note that the values of most parameters in different groups differ significantly: for example, the average magnitude of FEs in the S group is almost twice higher than that in the NS group (2.27 ± 0.08 and 1.12 ± 0.01%, respectively). The fact that events commencing with the arrival of interplanetary shock waves are characterized by a considerably higher FE magnitude than in the group without shock waves confirms the distribution of FE magnitudes (Fig. 2).

It can be seen in Fig. 2 that the maximum number of events in the NS group is smaller and shifted leftward (towards the domain of lower FE amplitudes) relative to the maximum of the S group. The number of FEs with $A_F < 1\%$ turns out to be 1218 (almost half

Characteristics of Forbush effects for the S and NS groups

Characteristic	S-group				NS-group			
	Average values	Max maximum	Min minimum	Number of events	Average values	Max maximum	Min minimum	Number of events
A_F, %	2.56 ± 0.10	20.40	0.30	536	1.15 ± 0.02	11.00	0.10	2432
Axy_{max}, %	1.73 ± 0.04	9.67	0.32	536	1.22 ± 0.01	4.85	0.13	2432
Az, %	1.98 ± 0.04	10.18	0.53	536	1.40 ± 0.01	5.60	0.54	2429
D_{min}, %	–0.61 ± 0.02	–0.13	–5.15	536	–0.32 ± 0.00	–0.09	–3.67	2432
Kp_{max}	5.41 ± 0.06	9.00	2.00	536	4.18 ± 0.02	8.67	1.00	2432
Ap_{max}, 2 nT	74.46 ± 2.65	400.00	7.00	536	36.09 ± 0.55	300.00	4.00	2432
Dst_{min}, nT	–66.9 ± 2.3	4.0	–330.0	514	–35.5 ± 0.5	9.0	–327.0	2345
B_{max}, nT	16.69 ± 0.39	65.60	4.90	361	10.81 ± 0.09	33.20	4.10	1748
V_{max}, km s	559.9 ± 6.3	950.0	337.0	354	523.4 ± 2.8	874.0	296.0	1725
$V_m B_m$	4.91 ± 0.17	23.91	1.24	324	2.90 ± 0.03	11.14	0.76	1618
$t(V_{max})$, h	24.30 ± 1.10	71.00	–12.00	354	25.88 ± 0.55	80.00	–13.00	1725
$t(B_{max})$, h	10.33 ± 0.71	76.00	–13.00	361	17.92 ± 0.46	75.00	–13.00	1748
$t(Axy_{max})$, h	18.87 ± 0.84	71.00	–13.00	536	25.46 ± 0.48	71.00	–13.00	2432
R_B, GB	39.35 ± 3.48	266.77	0.00	189	9.91 ± 0.60	172.46	0.00	1211
t_{min}, h	20.86 ± 0.71	126.00	–13.00	536	22.48 ± 0.50	116.00	–13.00	2264
$t(D_{min})$, h	11.95 ± 0.59	62.00	–17.00	536	18.79 ± 0.39	93.00	–31.00	2264
A_F/B_m, %/nT	0.159 ± 0.007	1.26	0.02	344	0.109 ± 0.001	0.60	0.02	1634

of all events) for the NS group and only 88 (around one-sixth of all events) for the S group. For events with $A_F < 2\%$, the number of events turns out to be 2172 (almost 90% of the total number) for the NS group and 297 (~55%) for the S group. Analyzing the upper part of the distribution with large FE magnitudes in Fig. 2, one can see a strong quantitative prevalence of the S group in this area. The number of FEs with $A_F > 6\%$ constitutes almost 1/400 of the total number of events for the NS group and 1/12 for the S group; i.e., events with larger magnitudes mainly belong to the S group. The maximum FE magnitudes for the S and NS groups are 20.4 and 11.0%, respectively. Here, it should be noted that many events that exceed these values by magnitude (mainly belonging to the S group) have been eliminated in view of the above considerations and the prevalence of the S group among large FEs is in fact even more obvious. Moreover, a more detailed examination of individual events indicates that all large FEs are fully or partially associated with CMEs.

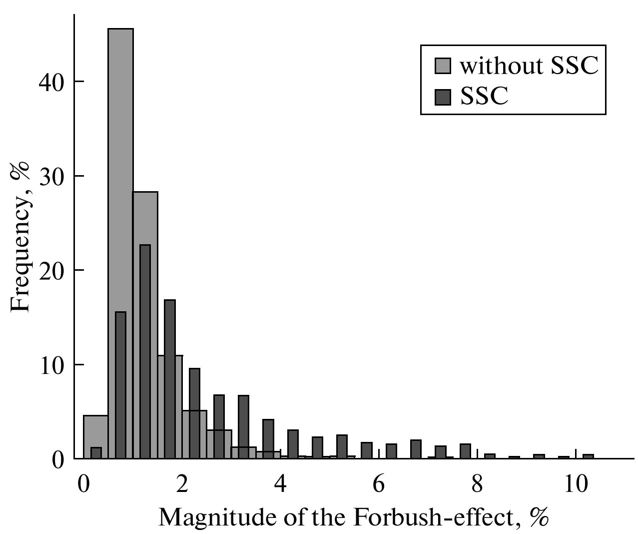

Fig. 2. Distribution of Forbush effect magnitudes for groups of events with SSC and without SSC.

It may seem that the differences between the S and NS groups are only in the strength of solar and interplanetary events and they are different samples of one and the same distribution. It is clear that more powerful solar wind disturbances, whether ICMEs or high-speed streams (HSSs) from coronal holes, more often create shock waves and have a stronger influence on CRs. However, we attempt to show that the groups differ not only quantitatively, but also qualitatively, and that these groups represent different distributions, rather than two different samples of one distribution. One of the objectives of this work is to determine the characteristics and properties of these groups, as well as their similarities and differences, and find out how different characteristics of events are associated in these groups.

The times necessary to reach a minimum in the CR density (t_{min}) are close enough in the two groups (20.9 ± 0.7 h (S) and 22.5 ± 0.5 h (NS)); however, the majority of other parameters differ significantly (for example, the anisotropy of galactic cosmic rays). For the maximum of the equatorial component of anisotropy Axy_{max}, we have 1.73 ± 0.04 (S) and 1.22 ± 0.01% (NS).

The differences in the FE magnitudes of the two groups become clear if we compare the parameters of the corresponding B_{max}, V_{max}, V_mB_m, and R_B interplanetary disturbances. These are all larger in the S group both in terms of average and maximum values. For example, the average V_mB_m parameter differs ~1.7 times (4.91 ± 0.17 and 2.90 ± 0.03). However, the largest differences are obtained for the R_B parameter—the estimate for the maximum rigidity of particles capable of reflecting the strengthening of the magnetic field in a given interplanetary disturbance (Dorman, 1963; Belov and Ivanov, 1997). We calculated this value for each event with sufficiently complete measurement data on the solar wind as follows:

$$R_B = \sum_{t=t_0}^{t_{min}} (B(t) - B_0)V(t), \quad (2)$$

where $B(t)$ and $V(t)$ are the IMF strength and solar wind velocity, respectively; B_0 is the constant value of strength up to which the field can be considered as undisturbed (here, $B_0 = 7$ nT); and the summation is conducted by the hour from the FD onset (t_0) to the hour of the minimum CR density (t_{min}).

The average R_B values for the two groups differ by a factor of ~4 (39.4 ± 3.5 (S) and 9.9 ± 0.6 (NS)). Naturally, the more pronounced interplanetary disturbances in the S group produce larger FEs. The same is also true for concurrent disturbances in the Earth's magnetic field. For example, the average values of the *Ap* indices for the S and NS groups are equal to 72.3 (which corresponds to a moderate magnetic storm) and 34.4 (a minor magnetic storm), respectively.

By analyzing only the average values for the selected groups, it is difficult to characterize the difference between them and find out whether this difference is only quantitative or one can speak about a difference in the mechanisms of additional CR modulation. These questions could rather be answered by comparing different parameters. Figure 3 shows the correlation between the IMF B_{max} maximum and the V_{max} solar wind velocity maximum for each event. From general considerations, it is clear that they should correlate with one another. As in the case of coronal holes, for CMEs we also have that the higher the rate of the disturbed solar wind stream, the stronger it contracts the interplanetary matter and the IMF. In addition, for large CMEs, the correlation between the CME rate and the strength of the ejected magnetic

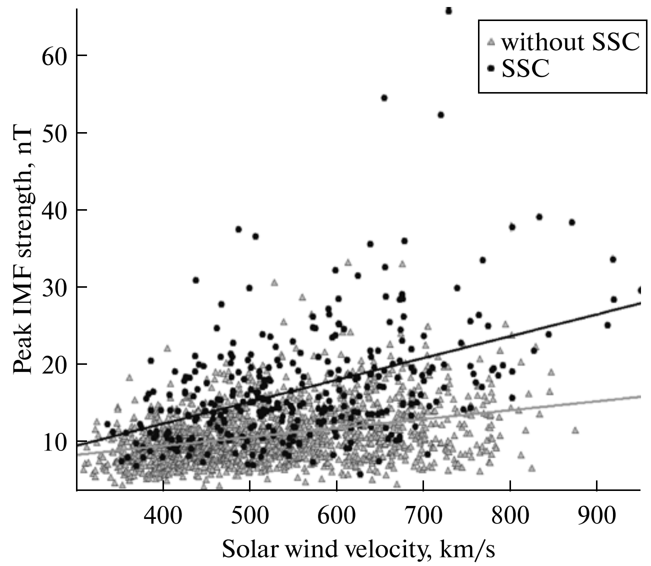

Fig. 3. Dependence of the IMF on the solar wind velocity for each FE in the S and NS groups of events.

field can be assumed to be in the solar source of the CME. On the other hand, it is obvious that velocity is not the only parameter governing the solar wind disturbance (particularly, the efficiency of its interaction with the environment). This interaction is significantly affected by the rate of the background solar wind, the heliospheric current sheet, earlier created interplanetary disturbances, etc. It is important that in many ejections (ICMEs), the maximum IMF strength is frequently observed in the magnetic cloud (Burlaga et al., 1982) without any direct connection with the wind velocity (for example, larger values of B_{max} can be seen in slow fiber emissions). In view of this, we should not be surprised that there is a correlation between V_{max} and B_{max} for the S and NS groups, but the correlation coefficients are small (0.46 and 0.32, respectively).

Figure 3 may give an impression that the events in the S group have approximately the same range of velocities as the events in the NS group, but this is not quite true: by various reasons (the incomplete data on the solar wind and imposition of multiple events are disregarded in our conditions), a part of events with high velocities were not included in the sample. For example, all events with a V_{max} value higher than 1000 km/s are related to CMEs and usually begin with a SSC (i.e., must belong to the S group), but they were not included in this sample. It should also be emphasized that the CME rate can reach several thousand kilometers per second at the Sun, while the rate of plasma flows from coronal holes is much smaller: even in the largest polar coronal holes, the rate is no more than 900 km/s according to the Ulysses mission (McComas et al., 2001).

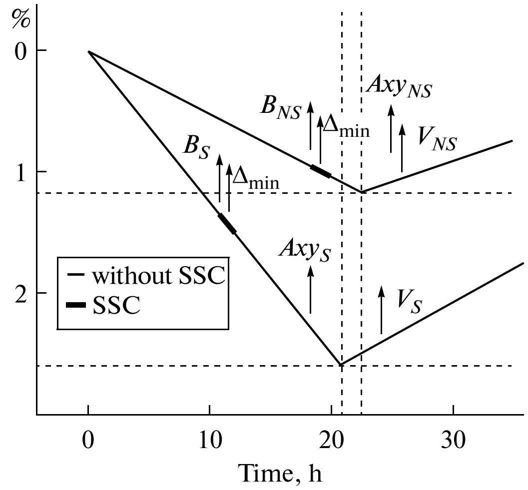

Fig. 4. Schematic of mean Forbush decreases in the S and NS groups corresponding to the table.

It can be seen in Fig. 3 that the interplanetary disturbances in the S group are stronger than in the NS group. The weakest (i.e., the slowest and with the weakest IMF) disturbances are in the NS group, while the strongest (fast and with higher B_{max} values) ones, on the contrary, belong to the S group. At the same rates, the IMF magnitude is rather considerably different and the regression line for the S group is much higher than that for the NS group. This means that the S group at the same rates contains stronger disturbances in the interplanetary space (greater enhancement of the magnetic field) than the group without shock waves. Thus, conditions for deeper modulation of galactic cosmic rays are created.

The cloud of points in the S group is not only located above the NS cloud, but is also deployed in a different way; i.e., the regression lines differ by both position and slope. Let us quantitatively compare the regression parameters $B_{max} = a + bV_{max}$. We have $b = b_S = 0.027 \pm 0.003$ for the S group and $b = b_{NS} = 0.011 \pm 0.001$ for the NS group. It is seen that there is a sufficiently large and statistically significant difference between the b coefficients. When increasing the maximum velocity by 100 km/s, the maximum IMF strength increased on average by 2.7 nT in the S group and by only 1.1 nT in the NS group. Thus, growth in velocity leads to an increased difference between the B_{max} values. The fact that the interplanetary disturbances of the two groups have different mechanisms is also confirmed by the difference in the times of the $t(V_{max})$ solar wind velocity maxima and the $t(B_{max})$ IMF strength (see table). For the NS group, the maxima are reached later (Fig. 4) and the difference for $t(B_{max})$ is particularly large. The velocity maximum lags behind the IMF maximum by 14 ± 1 h in the S group and by only 8 ± 1 h in the NS group. We see that the two groups differ both quantitatively and qualitatively; hence, they are two different distributions rather than two parts of one and the same distribution. One can expect that the mechanisms of additional CR modulation in these groups are different. A confirmation of this fact can be found in the table showing the differences in the average values of the A_F/B_{max} ratio (0.159 ± 0.007 and 0.109 ± 0.001), which suggest that an increase in the IMF strength up to the same values leads to a substantially greater modulation in the S group.

The specific features of CR modulation in different groups of events can be inferred from the relation between the FE magnitude and different parameters: both external (the interplanetary medium parameters) and internal (characteristics of FEs themselves). One of these internal parameters, in addition to the FE magnitude, is the Δ_{min} parameter (Fig. 4), showing the maximum decrease (in percentage points per hour) in the CR density for the given event.

Δ_{min} is a part of FDs, and it is no surprise that there is a good correlation (with the coefficient $\rho = -0.79$) between Δ_{min} and A_F in the S group. For the NS group, this correlation is smaller ($\rho = -0.57$), but also sufficiently obvious. This particularly makes it possible to estimate the maximum of the FE magnitude even in the CR intensity decay phase; in this case, the estimates will be different for the two groups. For example, if Δ_{min} constitutes 2%, the FE magnitude can be expected (in accordance with the linear regression data in Fig. 5) to be ~7.3% for the events in the S group and ~6.1% for those in the NS group. There are also differences in the temporal evolution of FEs in different groups (see Fig. 4 and the table). The CR decrease in the S group proceeds faster, and its minimum (which is deeper) is reached slightly earlier than in the NS group. The $t(\Delta_{min})$ times differ more strictly than t_{min}. The FD minimum in the S group is on average reached in 8.9 ± 0.9 h after $t(\Delta_{min})$, while the time difference in the NS group is much smaller (-3.7 ± 0.7 h). In addition to the differences, one should also note the important similarity between the two groups: in both groups, the highest decrease in density ($t(\Delta_{min})$) is observed immediately after the maximum IMF strength ($t(B_{max})$).

A part of the internal parameters of FEs describes the anisotropy of cosmic rays. Figure 6 shows variations in density A_F as a function of the magnitude of the equatorial Axy_{max} component of anisotropy of galactic cosmic rays.

In this case, the regression lines for the two groups are almost identical. However, this does not mean that the CR anisotropy in different groups behaves similarly. Rather, it is different, but the identification of these differences requires a more detailed analysis and more subtle methods. This assumption is confirmed by a comparison between the times at which the maximum Axy_{max} values are reached in the two groups (see

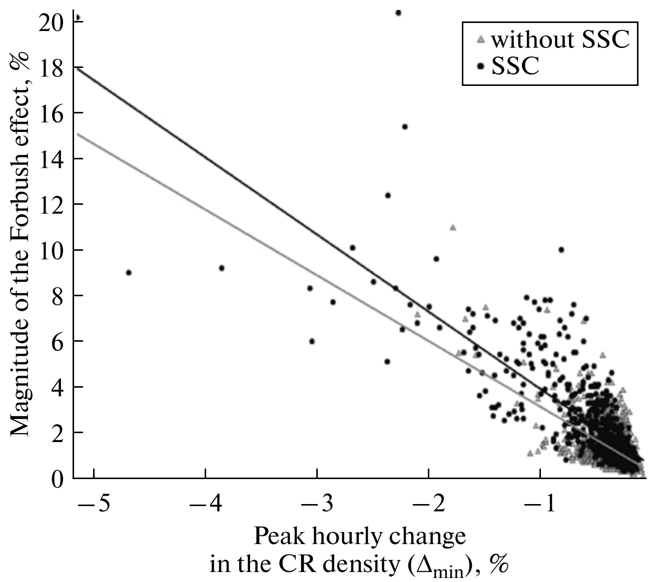

Fig. 5. Dependence of thr FE magnitude on the peak hourly decrease in density.

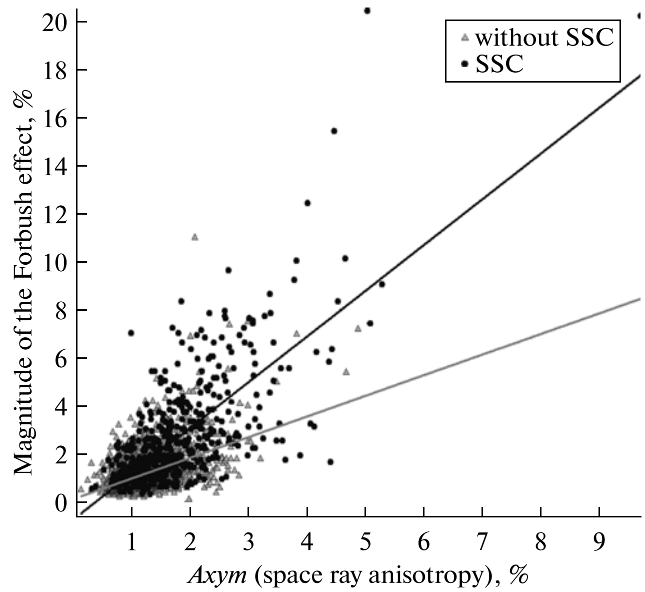

Fig. 6. Dependence of the FE magnitude on galactic CR anisotropy for the S and NS groups.

table and Fig. 4). We have $t(Axy_{max}) = 18.9 \pm 0.8$ h for the S group and $t(Axy_{max}) = 25.5 \pm 0.5$ h for the NS group; the maximum level of anisotropy is observed before the FD decrease in one group and after it in the other one. It is easy to find other differences in the manifestations of anisotropy, and we plan to discuss them in another paper.

Next, we consider the dependence of the FE magnitude on external parameters. As a parameter well characterizing disturbances in the solar wind, we take V_mB_m (Belov et al., 2001). Figure 7 shows the behavior of the FE amplitude (A_F) depending on the value of this parameter. One can see a significant difference between the groups: the events in the S group are more disturbed. These events are generally characterized by larger velocities and IMF strengths. The number of events in the S and NS groups for $V_mB_m > 8$ is 35 events (~1/15) in the S group and 14 events (~1/174) in the NS group. For $V_mB_m > 15$, there are no events at all in the NS group and there are 7 events (~1/77) in the S group. We see again that the S group is characterized by stronger interplanetary disturbances. It is equally important that the relationship between A_F and V_mB_m is different (the linear regression coefficient $b_S = 0.46 \pm 0.03$ in the S group and $b_{NS} = 0.21 \pm 0.01$ in the NS group). We see that for the same disturbance of the interplanetary medium, the events in the S group are accompanied by an FE with a larger magnitude than the events in the NS group. For example, if the V_mB_m solar wind disturbance parameter is equal to 10, the average FE magnitude for events in the S group is ≈4.9% and ~2.6% for events in the NS group, which is almost twice smaller. This difference in efficiency suggests that if the V_mB_m value is the same, interplanetary disturbances of different groups differ in something else, such as their size or structure, and this allows us to assume that different groups have different dominant sources of solar wind disturbances.

Similar differences between the groups were detected when other characteristics of solar wind disturbances (such as B_{max} or R_B) were used instead of V_mB_m. In this case too, disturbances of the S group are

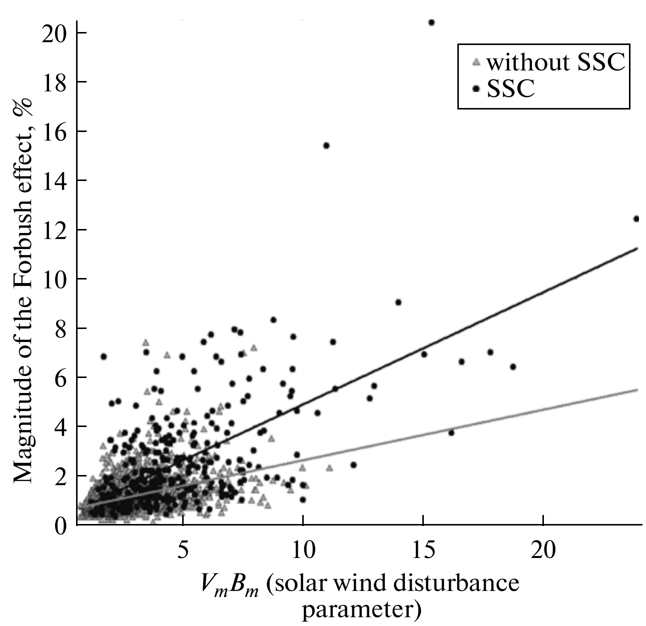

Fig. 7. Dependence of the FE magnitude on the V_mB_m solar wind disturbance parameter.

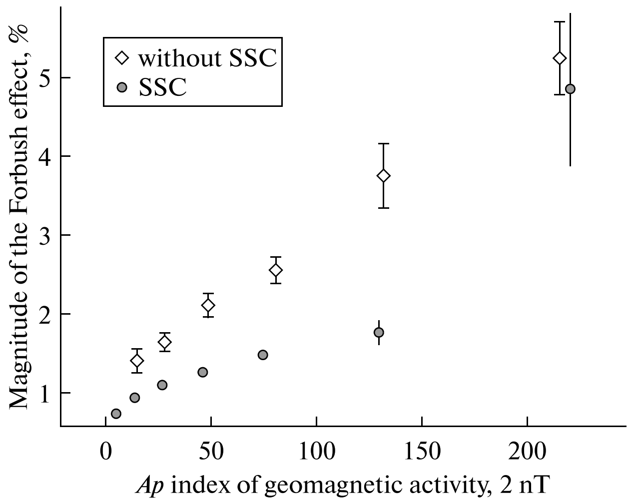

Fig. 8. Dependence of the FE magnitude on the *Ap* index of geomagnetic activity.

significantly more effective in modulating cosmic rays in comparison with those of the NS group.

Thus, interplanetary disturbances not only have different structures, but also modulate CRs in different ways. We can assume that the two groups have different dominant mechanisms of CR modulation and link the S group predominantly with CMEs and the NS group with high-speed streams of solar wind from coronal holes. Of course, we only speak about some predominance, and both mechanisms act in both groups. We should make another reservation. Strictly speaking, these conclusions are only valid for special samples which are free of overlapping and close-in-time events. Most likely, the number of CME-induced events excluded by us was higher, and this could affect the results.

Figure 8 shows the dependence of FEs on the *Ap* index of geomagnetic activity for the selected groups. All events are divided by geomagnetic activity levels, depending on the maximum *Kp* index (Kp_{max}). The cases with $Kp_{max} < 2$ are attributed to the quiet level, and those with $2_0 \leq Kp_{max} \leq 3_+$ are referred to the weakly disturbed level. The cases $Kp_{max} = 4_-$, 4_0, and 4_+ refer to the disturbed level, and higher values of Kp_{max} refer to geomagnetic storms of varying strength (http://www.swpc.noaa.gov/NOAAscales/index.html#GeomagneticStorms).

It can be seen that strong geomagnetic storms can be found in both S and NS groups; however, under the same geomagnetic activity, the FE magnitude in the S group is much higher than in the NS group. One could say that the interplanetary disturbances of the S group more effectively modulate cosmic rays and less effectively disturb the Earth's magnetosphere. However, we know that the most severe geomagnetic storms are usually those with a sudden onset. In our sample, there are only two extremely long storms ($Kp_{max} = 9_0$) and they belong to the S group.

It is evident that the S group is also prevalent for other classes of strong storms. Therefore, it will be more precise to state that the interplanetary disturbances in the NS group are sufficiently effective in creating geomagnetic activity and less effective in modulating cosmic rays. Sometimes, after a gradual onset, there can evolve a very strong geomagnetic storm. In these cases, a very large FD is also possible, but less probable.

4. MAIN CONCLUSIONS

Our database of FEs and interplanetary disturbances is sufficiently large and representative to provide a comparative statistical analysis of different types of events.

Events with a sudden onset (S group) and with a gradual onset (NS group) differ significantly from one another. The S group turns out to involve on average more powerful events. The interplanetary disturbances of the two groups also differ in structure.

Interplanetary disturbances related to the S group more effectively modulate cosmic rays and create large FDs in comparison with disturbances of the NS group with similar characteristics.

The same levels of geomagnetic activity in the NS group correspond to FDs of a lower magnitude than in the S group.

Our results testify that the selected groups have different dominant mechanisms of modulation of galactic cosmic rays. The events in the S group are more conditioned by CMEs, while a significant fraction of the events in the NS group is associated with HPFs from coronal holes.

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