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RELATIONSHIP BETWEEN GEOMAGNETIC STORM DEVELOPMENT AND THE SOLAR WIND PARAMETER β

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Abstract. We have analyzed the dynamics of solar wind and interplanetary magnetic field (IMF) parameters during the development of 933 isolated geomagnetic storms, observed over the period from 1964 to 2010. The analysis was carried out using the epoch superposition method at intervals of 48 hrs before and 168 hrs after the moment of *Dst* minimum. The geomagnetic storms were selected by the type of storm commencement (sudden or gradual) and by intensity (weak, moderate, and strong). The dynamics of the solar wind and IMF parameters was compared with that of the *Dst* index, which is an indicator of the development of geomagnetic storms. The largest number of storms in the solar activity cycle is shown to occur in the years of minimum average values (close in magnitude to 1) of the solar wind parameter β (β is the ratio of plasma pressure to magnetic pressure). We have revealed that the dynamics of the *Dst* index is similar to that of the β parameter. The duration of the storm recovery phase follows the characteristic recovery time of the β parameter. We have found out that during the storm main phase the β parameter is close to 1, which reflects the maximum turbulence of solar wind plasma fluctuations. In the recovery phase, β returns to background values β~2–3.5. We assume that the solar wind plasma turbulence, characterized by the β parameter, can play a significant role in the development of geomagnetic storms.

Keywords: geomagnetic storms, solar wind, interplanetary magnetic field, *Dst* index, β parameter, turbulence.

INTRODUCTION

The constant impact of solar wind (SW) and interplanetary magnetic field (IMF) variations on Earth's magnetosphere leads to geomagnetic disturbances, among which the most powerful are magnetic storms. Over the last decades, geomagnetic storms have been considered as one of the main factors of near-Earth space weather. Their sources are mainly solar disturbances (flares and Coronal Mass Ejections, CMEs) and Corotating Interaction Regions (CIRs) of high-speed SW plasma streams from coronal holes on the Sun and slow SW streams [Borovsky, Denton, 2006; Tsurutani et al., 2006; Guo et al., 2010]. By their nature, magnetic storms are very diverse; traditionally, they are divided into storms with sudden and gradual commencements [Akasofu, Chapman, 1975]. Storms of the former type have a pronounced sudden commencement (Storm Sudden Commencement, SSC), which manifests itself as a sharp jump in all magnetic field components almost simultaneously across the globe. CME-driven solar flares and magnetic clouds cause magnetic storms with sudden commencement [Guo et al., 2010]. Geomagnetic storms with gradual commencement feature a gradual increase in all magnetic field components, and their development is associated with both high-speed streams from coronal holes and compression areas of CIR [Tsurutani et al., 2006]. According to [Obridko et al., 2013], storms with sudden and gradual commencements form two independent populations. However, publications have recently appeared in which magnetospheric disturbances are selected according to the types of SW streams (drivers), e.g. [Ermolaev et al., 2007, 2010a; 2010b; Dremukhina et al., 2019]. Storms with sudden commencement are sometimes called CME storms; and those with gradual commencement, CIR storms.

Numerous publications deal with statistical and morphological patterns of geomagnetic storms, e.g. [Gonzalez et al., 1994; Loewe, Prölss, 1997; Vennerstroem, 2001; Hutchinson et al., 2011; Haines et al., 2019]. There is also an extensive literature on conditions on the Sun and in the interplanetary medium, which lead to the development of storms. Many works analyze heliospheric conditions favorable for the development of storms, using the epoch superposition method [Lyatsky, Tan, 2003; Zhang et al., 2006; Ermolaev et al., 2007, 2010a; Katus et al., 2015; Dremukhina et al., 2019]. The most frequently considered interplanetary medium parameters are the velocity V; the density N; the proton temperature T; the SW dynamic pressure $P_{\text{dyn}}=\rho V^2$ (ρ is the plasma density); the IMF B_x, B_y, B_z

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components; the modulus B; the E_y component of the SW electric field ($E_y = -V_x B_z$). Results of the statistical analysis show that the behavior of the parameters differ for different types of SW streams leading to the development of storms [Ermolaev et al., 2007, 2010a; Dremukhina et al., 2019].

Among the SW and IMF parameters under study, sharp fluctuations in P_{dyn} and a southward rotation of the vertical IMF component are considered as a trigger for the storm main phase. Gonzalez et al. [1994, 1999] note that the negative B_z component (B_z<0) is the main parameter responsible for the development of geomagnetic storms. Moreover, it controls the duration of the storm main phase and its intensity [Vichare et al., 2005]. The question of which parameter controls the duration of the storm recovery phase remains open.

Much less attention is paid to the discussion of the behavior of the SW parameter β during storm development (the β parameter is the ratio of thermal pressure to magnetic pressure: $\beta = NkT/(B^2/(8\pi))$. At the same time, the β parameter is used as one of the criteria for identifying SW streams of different types. For example, the large-scale solar wind structures CIR and CME, as drivers of storms, are characterized by β>1 and β<0.5 respectively [Ermolaev et al., 2009]. In one of the recent works [Yermolaev et al., 2021], the authors present the mean β parameter for various SW drivers. Furthermore, among other SW and IMF parameters studied by the the epoch superposition method, some works, such as [Ermolaev et al., 2007, 2010a], present the time variation of the β parameter during storms. It is observed that the β parameter dynamics during storms depends on the SW stream type. According to [Ermolaev et al., 2010a], 1–2 hrs before the onset of storms, β decreases for CME and magnetic clouds, and increases for CIR and sheath — the compression area ahead of the leading edge of a piston. This tendency in the behavior of β for these SW streams persists until *Dst* becomes minimum. For SW streams of other types, the β parameter dynamics remains unchanged as storms develop.

Meanwhile, our previous studies [Zotov, Klain, 2017; Zotov et al., 2018, 2019] have shown that this parameter plays a significant role in the magnetosphere dynamics, described by the A_p index. The A_p index is known to characterize the planetary geomagnetic disturbance. So, the observation of the periodic or chaotic mode in the A_p dynamics and hence in the magnetosphere dynamics during solar cycle depends greatly on the β parameter. At β values close to 1, the chaotic mode was observed in the magnetosphere; and at β>1, the periodic mode [Zotov et al., 2019]. The β parameter, which determines trigger modes in the magnetosphere dynamics [Zotov et al., 2019], characterizes the SW plasma turbulence [Borovsky, Funsten, 2003].

Since magnetosphere activity, along with planetary indices (K_p, A_p, etc.), is also quantitatively characterized by the *Dst* index, the question arises as to whether and how the β parameter affects the behavior of this index and hence geomagnetic storms. As is known, the *Dst* index is an indicator of geomagnetic disturbances in middle and equatorial latitudes and of the power of the ring current during geomagnetic storms. The *Dst* index is widely used to identify geomagnetic storms, assess their intensity, and classify them. According to minimum negative *Dst* values, storms are classified as weak, moderate, and strong [Gonzalez et al., 1994; Loewe, Prölss, 1997]. A number of works examine the relationship of *Dst* with SW and IMF plasma parameters [Burton et al., 1975; Wu, Lepping, 2002; Echer et al., 2008]. The research results have shown that during geomagnetic storms *Dst* exhibits the highest correlation with B_z and E_y. The latter clearly indicates that there is a relationship between *Dst* and these parameters. The correlation between *Dst* and other interplanetary medium parameters (V, P_{dyn}, N) is much weaker.The correlation between *Dst* and the β parameter is not discussed, although, as mentioned above, in some works, e.g. [Yermolaev et al., 2010b], the time profiles of *Dst* and β parameter are presented without examining their possible relationship. As a rule, in such studies, the β parameter is analyzed at relatively short time intervals (12 hrs before and 24 hrs after the onset of a storm), which do not allow tracing the β dynamics during the storm recovery phase. Besides, no specific analysis of simultaneous observations of *Dst* and β during a storm has been carried out. The possible influence of this parameter on the intensity or other characteristics of storms has also not been explored. In this context, it is of undoubted interest to study the possible relationship between the *Dst* dynamics and the β parameter.

In this paper, without selection by types of SW streams that cause geomagnetic storms, we try to figure out whether the β parameter has any effect on the dynamics of the development of storms of various intensities with sudden and gradual commencements. For this purpose, we perform a joint study of the dynamics of SW and IMF plasma parameters, in particular of the β parameter and the *Dst* index, during geomagnetic storms.

DATA

In this work, we use hourly average data on SW and IMF plasma parameters and the *Dst* index over the period from 1964 to 2010 from the OMNI database [https://spdf.gsfc.nasa.gov/pub/data/omni/low_res_omni]. The β parameter in OMNI is defined by the expression

$$\beta = \left(\frac{4.16T}{10^5} + 5.34\right)\frac{N_p}{B^2},$$

where T is the temperature; N_p is the proton density; B is the magnetic field. In addition, from OMNI we have taken annual average Wolf numbers and β parameter values over the period 1964–2020. Information on magnetic storms for the period 1964–2010 has been obtained from geomagnetic storm catalog 1 presented on the website of the World Data Center for Solar-Terrestrial Physics (Moscow) [http://www.wdcb.ru/stp/geomag/geomagnetic_storms.ru.html]. In addition, to estimate the annual number of storms we have used geomagnetic storm catalog 2 from the Kakioka Magnetic Observatory (Japan) [http://www.kakioka-jma.go.jp/obsdata/data-viewer] for 2011–2020. Both catalogs contain information about the type of storm commencement (sudden or gradual).

RESULTS

Before proceeding to the presentation of the main results, it is necessary to say about some observed regularities that have stimulated this study. It has long been known that solar activity and geomagnetic storms are closely related phenomena. Storms with both sudden and gradual commencements have an 11-year cycle and occur at different solar cycle phases. From 1964 to 2020, according to data from the two geomagnetic storm catalogs, there were 537 storms with sudden commencement and 1588 storms with gradual commencement.

We analyze variations in their number during a solar cycle.

Figure 1 illustrates variations, which occurred during several solar cycles (20–24), in annual average Wolf numbers (*a*) and in the annual number of geomagnetic storms (*c*) with sudden (red curve) and gradual (green curve) commencements. Figure 1 indicates that storms with sudden commencement are mainly observed during the growth and maximum phases of solar activity; and those with gradual commencement dominate during the decay phase. This regularity in observation of geomagnetic storms has previously been noted, e.g. [Obridko et al., 2013; Kurazhkovskaya, 2020]. This figure also shows the dynamics of annual average values of the SW parameter β (*b*). Comparing the dynamics of the number of storms and the parameter β in a solar cycle, it is easy to see that their maximum number generally falls within years of minimum β, regardless of the type of storms. During these years, β values are close to 1, i.e. in the SW plasma stream the mean thermal pressure turns out to be approximately equal to the magnetic one. This fact may indirectly point to the relationship between the occurrence of storms and the SW plasma parameter.

Another experimental fact pointing to the possible relationship between storms and the parameter β is the following. During geomagnetic storms, the typical *Dst* dynamics is its sharp decrease over a relatively short period of time (from 2 to 12–15 hrs) followed by a slow recovery (from 1 to 7–8 days) to the initial level. Figure 2 illustrates variations in the β parameter and the *Dst* index for two months (from May 1 to June 30, 2005), plotted using OMNI hourly average data. The original data was smoothed with a nine-point moving average. In this time interval, several isolated storms of various intensities with sudden and gradual commencements occurred. Near the onset of each storm, a sharp jump in the β parameter was observed, followed by its decrease, and practically each decrease in β to 1 or less than 1 coincided with a sharp decrease in *Dst* indicating the development of a geomagnetic storm. In other words, the *Dst* and β variations were roughly similar. Thus, the results presented in Figures 1 and 2 point to the fact that not only the number of observed magnetic storms, but also their development, is likely to be somehow related to the behavior of the β parameter.

Based on the above assumptions, we have carried out an in-depth study of the dynamics of SW and IMF parameters during geomagnetic storms. For 1964–2010 from catalog (1), we have selected 933 isolated geomagnetic storms for the analysis: 288 with sudden commencement and 645 with gradual commencement. The storms were considered isolated if the recovery phase of the previous storm did not entail the onset of the next storm. They were selected by the type of commencment in accordance with catalog 1, which contains this information. In addition to the most frequently analyzed interplanetary parameters listed in Introduction, we have examined the following parameters: the ratio of the density of alpha particles to the density of protons N_α/N_p, the parameter β, the Alfvén Mach number $M_a=VN^{1/2}/20B$.

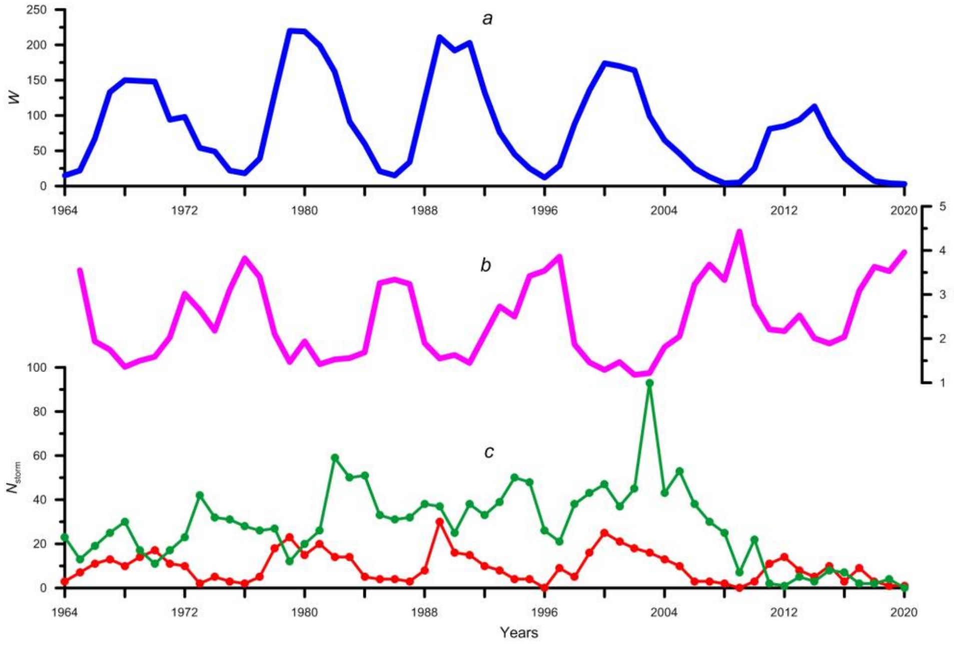

Figure 1. Variations in annual average Wolf numbers *W* (*a*), the β parameter of SW (*b*), and the annual number of geomagnetic storms N_{storm} (*c*) with sudden (red curve) and gradual (green curve) commencements in solar cycles 20–24

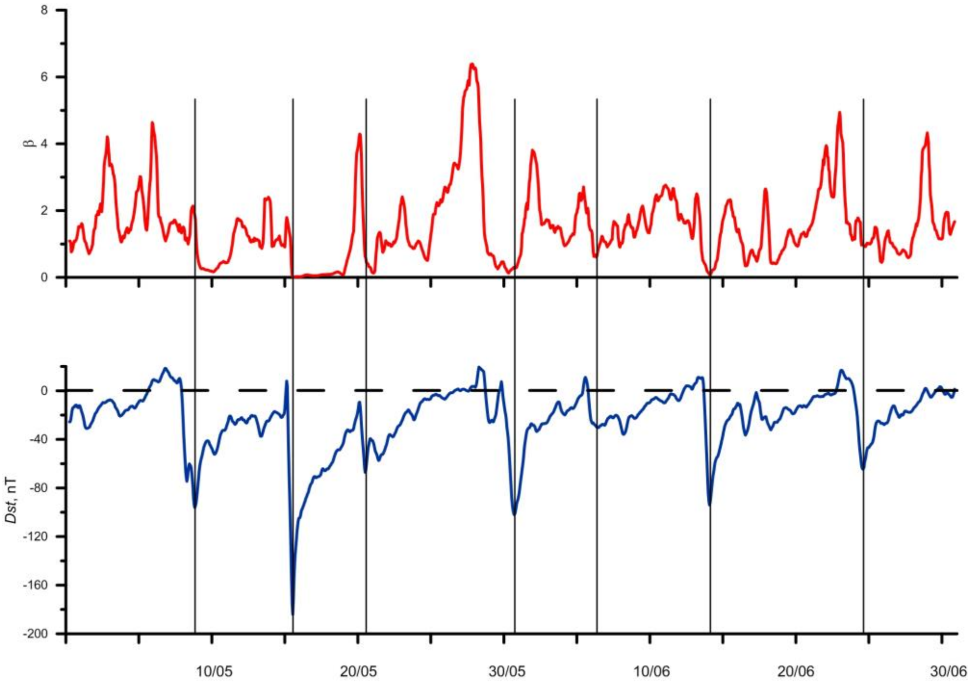

Figure 2. Variations in hourly average β and *Dst* over the period from May 1 to June 30, 2005. Vertical lines show minimum *Dst*

The interplanetary medium parameters were analyzed by the epoch superposition method. As a reference we have taken the moment of minimum *Dst* during each storm. According to the data obtained by Ermolaev et al. [2007], the duration of the main phases of isolated storms vary from 2 to 15 hrs with an average 7±4 hrs The behavior of the SW and IMF parameters was examined at the interval of 48 hrs before and 168 hrs after the minimum *Dst*. The choice of the 48 hr interval before the minimum *Dst* is justified by the possibility of analyzing the dynamics of the parameters both before the onset of a storm and after it, during the main phase. The duration of the storm recovery phase spans a longer period from 5 to 7 days. In this regard, the dynamics of the parameters was examined for 168 hrs after the minimum *Dst.* Compared to other researchers, we have analyzed data for longer time intervals (in general, the study covers an interval of 9 days). The geomagnetic storms were selected according to the type of storm commencement (sudden or gradual) and according to the intensity estimated by the *Dst* index.

The dynamics of all SW and IMF parameters during observation of storms with sudden and gradual commencements was compared with the *Dst* variation also obtained by the epoch superposition method. In general, the qualitative behavior of these parameters during storms with sudden and gradual commencements is confirmed by the results obtained by other researchers [Loewe, Prölss, 1997; Zhang et al., 2006], who took the minimum *Dst* as a reference. That is why, we do not analyze the dynamics of all parameters during storms, but, based on the purpose of this study, we compare the *Dst* index only with some of them.

Figure 3 depicts the averaged variations of the most geoeffective SW parameters, namely IMF B_z and the dynamic pressure P_{dyn}, as well as *Dst* and β during isolated storms with sudden (*a*) and gradual (*b*) commencements.

As expected, features of the dynamics of these parameters are identical for storms with sudden and gradual commencements. There are differences only in the peak values of B_z, P_{dyn}, and *Dst* in the storm main phase, which are quite natural. According to [Borovsky, Denton, 2006], storms with sudden commencement are generally more intense than those with gradual commencement.

The main peculiarity of the behavior of these parameters (Figure 3) is that IMF B_z and SW P_{dyn}, subject to sharp fluctuations near the onset of a storm, recover to background values rather quickly — within ~48 hrs after the onset of a storm. A similar trend is also noted in the behavior of the modulus *B*, the E_y component of the SW electric field, and other interplanetary parameters. Nonetheless, the storm recovery phase (*Dst*) lasts for up to 5–7 days. A similar recovery time is typical for the β parameter. Figure 3 indicates that characteristic recovery times of β are much longer than those of B_z and P_{dyn}. Note that in contrast to the dynamics of the interplanetary parameters (such as B_z, P_{dyn}, *B*, E_y), the variation in the parameter β during storms is similar to the typical *Dst* variation. The qualitative agreement of the dynamics of the β parameter with the *Dst* index is characteristic of storms with both sudden and gradual commencements. The behavior of the averaged values of the presented parameters (Figure 3) does not go beyond the confidence intervals, which indicates the statistical significance of the result. Is such regularity observed during storms of different intensity?

To answer this question, we divided storms with sudden and gradual commencements in terms of the minimum *Dst* in nanotesla into weak ($-50<Dst\leq-30$), moderate

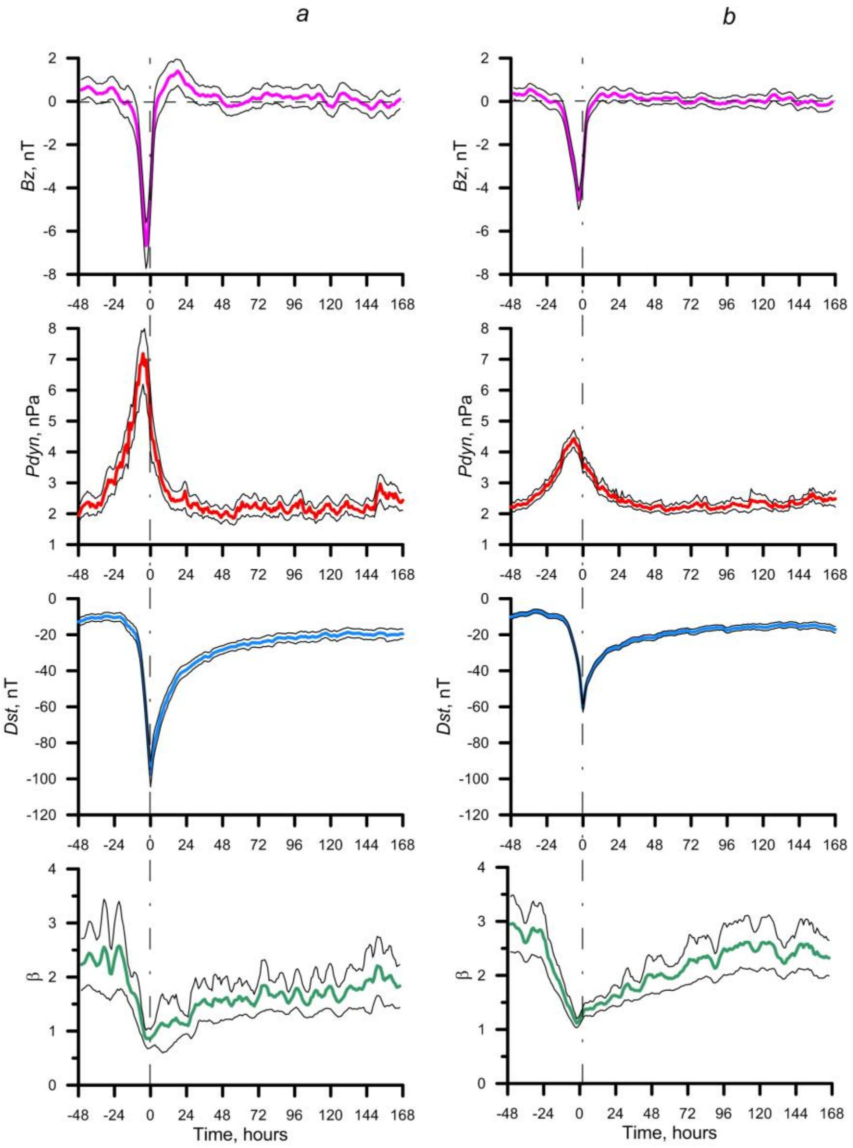

Figure 3. Averaged dynamics of the IMF B_z component, the SW dynamic pressure P_{dyn}, the *Dst* index, and the β parameter during isolated storms with sudden (*a*) and gradual (*b*) commencements. The confidence intervals corresponding to the probability of 0.95 are shown by black lines

(–100<*Dst*≤–50), and strong (*Dst*≤–100) according to the criterion from [Loewe, Prölss, 1997]. To increase statistics, we have combined strong and severe storms into one class. The number of the isolated storms under study is given in Table.

	Number of storms with sudden commencement	Number of storms with gradual commencement
Weak	50	278
Moderate	134	308
Strong	104	59

Next, we compare the dynamics of the *Dst* index and the β parameter during storms of different intensities with sudden and gradual commencements (Figure 4). The time of the minimum *Dst* index is seen to practically coincide with the time of the minimum β parameter. The behavior of the *Dst* index and the β parameter obtained by the the epoch superposition method is approximately similar for storms of various intensities. Estimated accuracies of the average values of the *Dst* index and the β parameter have shown that they do not go beyond the confidence intervals with a probability of 0.95, as well as the averaged data in Figure 3. The latter indicates the statistical significance of the result. The attained minimum *Dst* index (storm intensity) is in agreement with the β parameter: the smaller is β during the storm main phase, the more intense is the storm. For example, during the main phase of strong storms β<1; moderate storms, β~1; and weak ones, 1<β<2. This is typical of storms with both sudden and gradual commencements. In other words, the intensity of storms is to some extent determined by the β parameter.

A characteristic feature of the β parameter is that its value differs significantly during undisturbed periods and in different storm phases. Before the storm, β varies on average from 2 to 3.5; during the storm main phase,

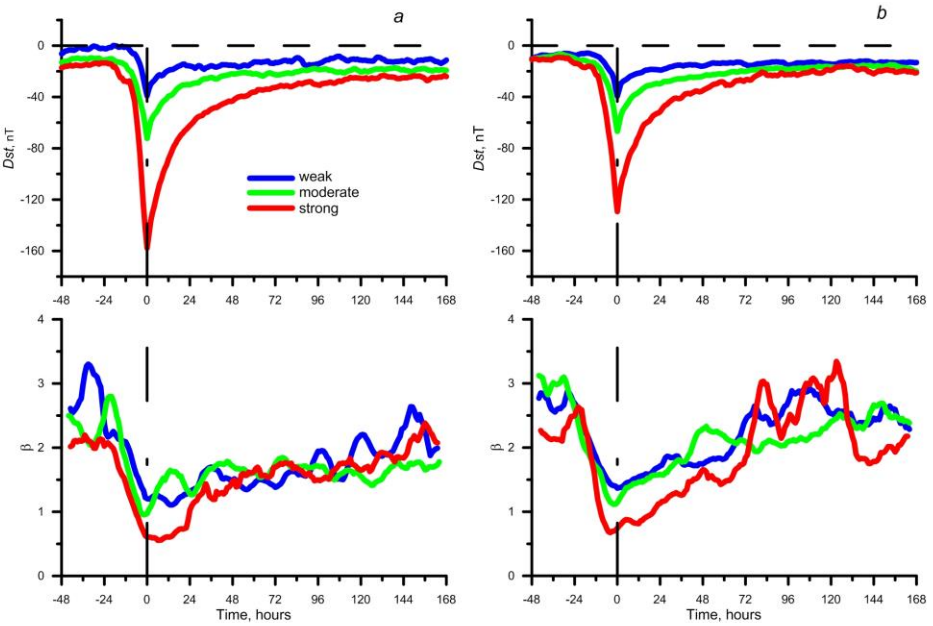

Figure 4. Dynamics of the *Dst* index and the β parameter during isolated storms of varying intensity with sudden (*a*) and gradual (*b*) commencements

its value becomes close to 1; in the recovery phase, β returns to background values ~2–3.5 (Figure 4). In Figure 4 are the same characteristic features of the storm recovery phase and the β dynamics for storms of different intensities as in Figure 3. Such behavior of the *Dst* index and the β parameter suggests that, regardless of the intensity of geomagnetic storms, the duration of the storm recovery phase is likely to be controlled by the behavior of the β parameter. It is possible that a shift in the balance of thermal and magnetic pressures determines the development of the storm main phase and subsequently of the recovery phase.

Evolution of the β parameter from the quiet period (before the development of storms) to the recovery phase is clearly seen in Figure 5, which shows β distributions before the onset (from –48 to –24 hrs), in the main phase (–24–0 hr), and in the recovery phase (0–168 h) of isolated storms with sudden (*a*) and gradual (*b*) commencements. The choice of duration of these time intervals is governed by the average statistical behavior of the *Dst* index (Figure 4). When constructing these distributions, we have restricted ourselves to the analysis of β in the range 0~4 since, according to [Veselovsky et al., 2010], this range contains approximately 90 % of all β parameter values observed. In addition, taking into account the results presented in Figures 1–4, our interest was in examining the behavior of β near β=1. Figure 5 clearly shows a change in the position of the maximum β parameter, with the β behavior being the same for storms with sudden and gradual commencements. Before the onset of a geomagnetic storm and during the recovery phase, the maximum observation frequency of β corresponds to β>1. In the main phase, the maximum number of observations of β falls on β<1 or close to 1. Thus, different geomagnetic storm phases differ in their associated β parameter.

DISCUSSION

The results of the study show that the plasma parameter β has an effect on the global disturbance of the magnetosphere, namely on the development of geomagnetic storms. In a solar cycle, the largest number of storms with both sudden and gradual commencements occurs in years when the mean β parameter is close to 1 (Figure 1). Dynamics of the *Dst* index, which is an indicator of geomagnetic storms, and the dynamics of the β parameters are almost identical (Figures 3, 4). The fact that the dynamics of the *Dst* index follows the behavior of the β parameter is reflected by the statistical dependence of the averaged *Dst* index on the mean β parameter (Figure 6) during 288 storms with sudden (*a*) and 645 storms with gradual (*b*) commencements. In both cases, averaging was carried out using accumulated hourly data from the onset of a storm for 168 hrs.

The intervals analyzed included the storm main and recovery phases. The experimental data is fairly well approximated by third-order orthogonal polynomials, as evidenced by the correlation coefficients for storms with sudden and gradual commencements (r=0.88 in both cases). This allows us to assume that there is a relationship between the *Dst* variation and the β parameter, regardless of the type of storm commencement. The qualitative behavior of the approximating polynomials is roughly the same for storms with sudden and gradual commencements. As the β parameter increases, the intensity of storms decreases. The difference between these dependences is that for storms with sudden commencement the highest intensity is observed at β<1; and for storms with gradual commencement, at β<1.25. When β>2, *Dst* almost stops to increase. The relationship between the *Dst* index and the β parameter is nonlinear (Figure 6).

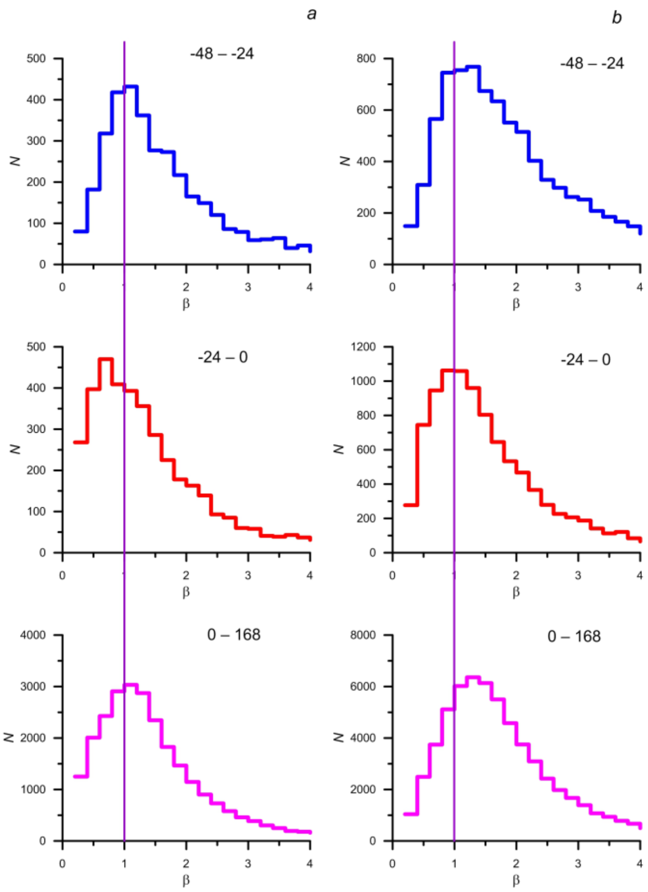

Figure 5. Distribution of the β parameter before the onset (–48 ÷ –24 hrs), during the main phase (–24 ÷0 hr), and during the recovery phase (0 ÷168 hrs) of isolated storms with sudden (*a*) and gradual (*b*) commencements. The vertical line is β =1

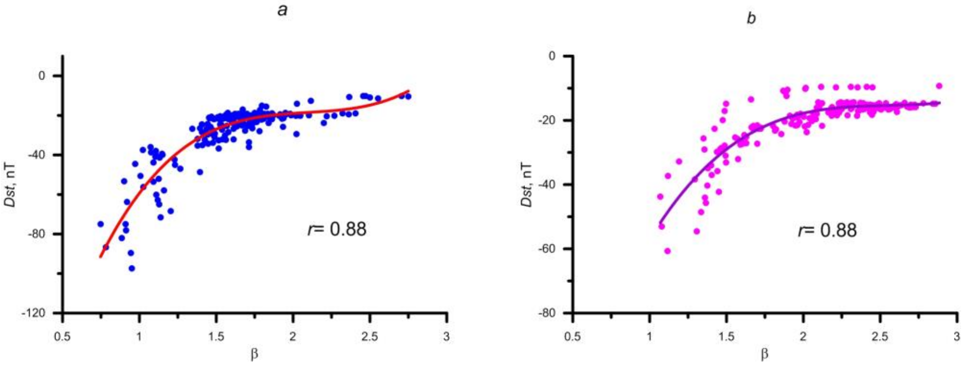

Figure 6. Relationship between the averaged *Dst* index and the average β parameter during storms with sudden (*a*) and gradual (*b*) commencements

Due to the fact that the most geoeffective parameters B_z and P_{dyn} (as well as other parameters) recover in a relatively short time, they cannot be responsible for the duration of the storm recovery phase. As inferred from our results, one of the factors determining the duration of the storm recovery phase may be the β parameter. From our point of view, β not only controls the duration of the recovery phase of storms with sudden and gradual commencements, but also is one of the important factors affecting their intensity (Figure 4). The smaller the value of β during the storm main phase, the greater the intensity of the storm. During the main phase, the β value is close to 1, regardless of the storm type. It is at β~1, according to [Chernyshov et al., 2014], that the level of turbulent space plasma fluctuations reaches its maximum. Wang et al. [2018], using satellite observations, have studied the relationship between the frequency of inflections in SW magnetic field power spectra and the β parameter. The inflection point frequency in the magnetic field power spectrum is an important characteristic of turbulence dissipation and is determined not only by the scale, but also by the amplitude of turbulent fluctuations. According to [Wang et al., 2018], the highest degree of turbulence in SW is achieved at 0.1<β<1.3, which does not contradict the numerical simulation results [Chernyshov et al., 2014]. Similar results have been obtained in [Šafránková et al., 2021], when examining the relationship between SW turbulence and the β value. The degree of turbulence of SW, magnetosheath, and magnetotail depends on the plasma parameter β [Borovsky, Funsten, 2003]. Thus, the β parameter may be a certain integral characteristic of interplanetary plasma turbulence, which has some effect on the development of geomagnetic storms. According to [Antonova, 2002; Borovsky, Funsten, 2003; D'Amicis et al., 2010], the interplanetary plasma turbulence also affects the efficiency of the SW-magnetosphere interaction, which produces geomagnetic disturbances.

It is traditionally believed that the dominant mechanism of the occurrence of geomagnetic disturbances is the reconnection of the interplanetary and geomagnetic fields at the appearance of an intense southward IMF component. In this case, large-scale electric fields appear which provide SW stream energy input into the magnetosphere. Pulinets et al. [2012] note that Earth's magnetosphere interacts directly not with SW plasma, but with magnetosheath plasma, whose characteristic feature is a high level of turbulence. It is the turbulent effects of the magnetosheath that largely determine the dynamics of processes at the magnetopause and the formation of large-scale magnetospheric convection. At the same time, the convection excitation mechanism considered in [Antonova, 2004] does not require penetration of the SW electric field into the magnetosphere due to large-scale reconnection. Thus, the role of the electric field (emerging during reorientation of B_z) in the processes of energy input into the magnetosphere during storms is not as unambiguous as it was thought to be. In our opinion, the β parameter can play the role similar to that of the large-scale electric field during storms, taking into account the fact that its dynamics practically coincides with the *Dst* variation and reflects the level of space plasma turbulence.

Our experimental data allows us to assume that geomagnetic storms reach their highest intensity at a very specific level of SW plasma turbulence. At β~1, a balance is established between thermal and magnetic pressures in the magnetosphere, which is a favorable condition for the formation of the storm main phase. When the thermal pressure begins to exceed the magnetic pressure, the magnetosphere becomes quiet. Without denying the role of B_z and its associated E_y, as well as other interplanetary medium parameters, we would like to draw attention to the possible influence of the β parameter on the development of geomagnetic storms. The probability that other key interplanetary medium parameters affect the duration of the geomagnetic storm recovery phase is significantly lower. Thus, our study has established new facts that should be taken into account when modeling the storm development (*Dst* variations) and interpreting it.

CONCLUSION

The joint analysis of the interplanetary parameters and the *Dst* index describing the development of geomagnetic storms has shown that the dynamics of the *Dst* index, regardless of the type of storm commencement and intensity, is similar to the dynamics of the β parameter. The largest number of storms in a solar cycle occurs in the years of minimum mean values of the β parameter (close to 1). The duration of the storm recovery phase follows the characteristic recovery time of the β parameter. The intensity of storms with sudden and gradual commencements is determined by the β parameter. We have found that during the storm main phase the β parameter is close to 1, which reflects the maximum level of SW plasma turbulent fluctuations. Before the onset of a storm and in the recovery phase, β varies from ~2 to 3.5. The SW plasma turbulence, characterized by the β parameter, can play a significant role in the development of geomagnetic storms.

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