

THE INFLUENCE OF THE EXTREME SOLAR WIND PARAMETER VALUES ON THE EARTH'S MAGNETOSPHERE DISTURBANCES

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Abstract. We have analyzed the solar wind parameter data set from 1964 till 1998, presented in the OMNIWEB database. The parameters, corresponding to the magnetosphere nose point location at $R_{SS} < 6.6 R_E$ or at $R_{SS} > 16 R_E$, were selected as extreme ones. The distance to the nose point was calculated using previously developed models, based on the total data- base on the magnetosphere size and shape. Extreme parameter distribution is defined depending on the solar activity cycle phase. During the analyzed period there were 830 events with extremely small calculated size of the magnetosphere and 148 events with extremely large size. However during 1983-1996 the large magnetosphere size was not observed.

Introduction

Statistical analysis of different solar wind parameters during 1964-1997 was made by Dmitriev et al. (2000). The solar wind (SW) density N , velocity V , temperature T and interplanetary magnetic field (IMF) value B were analyzed. The probability distribution for the different values of the solar wind dynamics pressure $P_d = N \cdot V^2$ and IMF B_z -component in the solar-magnetospheric coordinate system was analyzed by Kuznetsov et al. (1998). The most probable values of the SW parameters are the following: $N \sim 8 \text{ cm}^{-3}$, $V \sim 450 \text{ km/s}$, $T \sim 5 \cdot 10^4 \text{ K}$, $B \sim 7 \text{ nT}$, $B_z \sim 0$, $P_d \sim 2 \text{ nPa}$, and a quiet magnetosphere corresponds to these values. The geomagnetic disturbances increase, when V increases.

At $B_z > 0$ the principal parameter, which controls the magnetosphere size and the distance to the magnetopause sub-solar (nose) point R_{SS} , is the SW dynamics pressure P_d . Furthermore B_z with southward direction ($B_z < 0$) influences geomagnetic disturbances.

The geomagnetic field B_E near R_{SS} is equal to the doubled dipole field and the dynamic balance between P_d and $B_E^2 / (8\pi)$ determines the R_{SS} position. If $B_z < -10 \text{ nT}$, the calculated B_E value is practically equal to the dipole one and R_{SS} is less than R_{SS} at $B_z > 0$. Geomagnetic disturbance increases when $B_z < -5 \text{ nT}$ and P_d increases. The strong increase of magnetosphere size during the decrease of N on May 11, 1999 was observed by Le et al. (2000).

Experimental data

We analyzed all the solar wind data from 1964 till 1998, presented in the OMNIWEB database. The hourly average data were used. The R_{SS} values

measured in Earth's radii R_E were calculated in the following way (Kuznetsov and Yushkov, 2000):

$$R_{SS} = \frac{8.51}{p^{0.19}} + \frac{3.45}{p^{0.22}} \exp\left(-\frac{(|B_z| - B_z)^2}{200 p^{0.15}}\right)$$

Similar results can be received, using other approximations (Shue et al., 1997, Kuznetsov et al., 1998). We calculated R_{SS} and

$$(V^2/V_A)^2 = M^2 = 4\pi N m_p V^2 / B^2.$$

Here m_p is the proton mass, V_A is the Alfvén velocity, M is the Alfvén's Mach number. We also analyzed Kp and Dst . Data with $R_{SS} < 6.6 R_E$ and $> 16 R_E$ were selected, they correspond to the events with 9-fold P_d increase or decrease in comparison with the most probable value $P_d = 2 \text{ nPa}$ of $B_z < 0$. R_{SS} can be less $6.6 R_E$ for small P_d if B_z is less than -10 nT .

Analysis results

The calculated value of R_{SS} was less than $6.6 R_E$ during 1966-1998 in 835 points. We observed during this time 191 events when P was $> 17 \text{ nPa}$. R_{SS} was greater than $16 R_E$ in 147 points during 1967-1981 and in 1998. We assume that the background current in the IMP-8 plasma detector increased in 1981-1982 and therefore low plasma density could not be measured during 1982-1997. We compared the probability distribution of the SW density during 1978-1980 and 1989-1991. These distributions are identical for $N > 2 \text{ cm}^{-3}$. Density values $N < 1 \text{ cm}^{-3}$ were not available during 1989-1991.

We shall compare concrete events with small and large R_{SS} . Different parameters characterizing the interplanetary medium (V , N , $|B|$, B_z , T , $M2$, P_d , J_{cr}) and magnetosphere (R_{SS} , Dst , Kp) for 3-5 July, 1979 (185th DOY) are presented in Fig. 1. J_{cr} is the flux of protons with energy $> 1 \text{ MeV}$. V , N and $M2$ are shown in the first (bottom) panel. $|B|$, T and J_{cr} are shown in the second panel. R_{SS} , P_d and B_z are presented in the third panel and Dst , Kp are presented in the fourth (top) panel. The low value of P_d was observed in the time interval 06-22 UT July, 4 between vertical lines 1 and 3 and was connected with low value of N . V decreased only in the middle of this interval (vertical line 2) and was not accompanied by P_d changing. $|B|$ increased in line 1 from 7 to 11 nT. J_{cr} had little value between 1 and 4 lines. T changed without any connection with low P_d . B_z was near 0 during the event. Kp decreased to ~ 0 in line 1 and increased in line 4. The small Dst decrease in line 1 connected with the fact that $Dst \sim 0$ corresponds to $R_{SS} \sim 10 R_E$. In other events the P_d decrease can be connected with V decreasing.

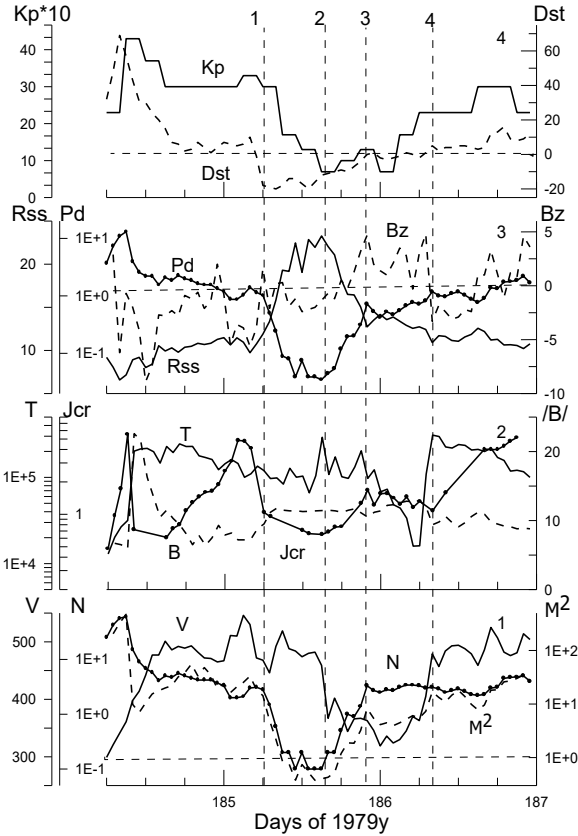


Fig. 1. The event of 3-5 July, 1979

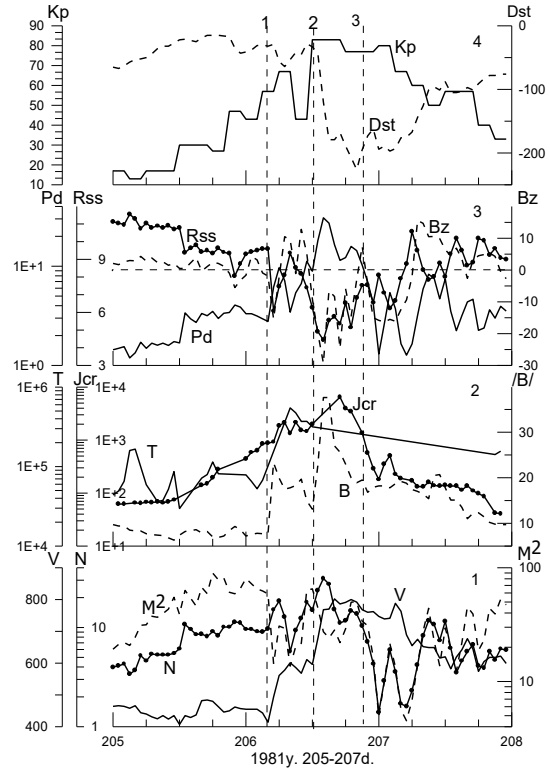


Fig. 2. The event of 24-26 July 1981

In Fig. 2 we present data for 24-26 July 1981(206th DOY). Positions of differ parameters in the panels correspond to Fig. 1. The time range of high P_d was 4-21 UT July, 25 between vertical lines 1 and 3. Its increasing was caused by V and accompanied by $|B|$ increasing. The jump of V , $|B|$ and negative B_z was observed at 12 UT of July, 25 (line 2). The development of magnetic storm began at this time. The R_{SS} value decreased to $\sim 4.4 R_E$ due to the influence of P_d and B_z .

We assume that similar events are connected with CME. We noticed attention that $R_{SS} < 6.6 R_E$ was often observed during magnetic storms. Therefore we analyzed the probability of magnetic storm observation. We assumed that the duration of the storm main phase was equal to 10 h. The following correlation between the solar Wolf number (W_S), the probability of magnetic storms (st) and the probability of extreme R_{SS} values was obtained:

$$P_0(st) = 8.6 \cdot 10^{-4} W_S^{0.61} \quad (r = 0.65)$$

$$P_0(R_{SS} < 6.6) = 1.44 \cdot 10^{-4} W_S^{0.86} \quad (r = 0.72)$$

$$P_0(R_{SS} > 16) = 1.0 \cdot 10^{-5} W_S^{1.05} \quad (r = 0.49),$$

(1967-1980yy)

Here r is the correlation coefficient, $P_0(st) = 10 N_{st}$

$/N_0$, N_0 is the full number of hours in a year.

We also analyzed how points with $R_{SS} < 6.6 R_E$ and $R_{SS} > 16 R_E$ were grouped in events. There are 48 events with $R_{SS} > 16 R_E$. Single hour events constitute more than 50%, events with duration > 10 h add up to $\sim 20\%$. All the points with $R_{SS} < 6.6 R_E$ correspond to 357 events, and single hour events also constitute more than 50 %. The event distribution versus duration can be approximated as $P_0(R_{SS} < 6.6) \sim \exp(-t/\tau_0)$, here t is the event duration, $\tau_0 \sim 2$ hours. More than 50% of events with $R_{SS} < 6.6 R_E$ were associated with magnetic storms, but for one-hour events this fraction corresponds to about 1/3. Events with $R_{SS} > 16 R_E$ were observed only during the quiet conditions.

The SW parameters as well as geomagnetic disturbance ones are presented in Fig. 3 and 4 depending on P_d for extreme R_{SS} values.

For $R_{SS} > 16 R_E$ the P_d value is mainly determined by the N value, not V . The V values change little and $V < 200$ km/s values are most probably conditioned by detector errors. The most probable $|B|$ value is 9 nT at

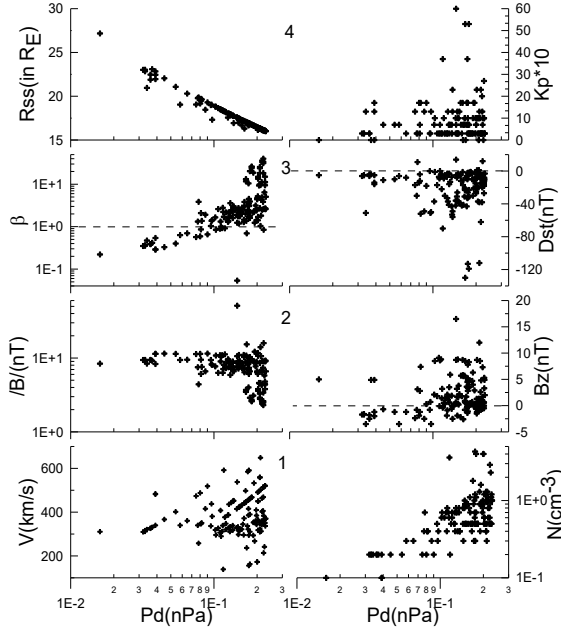


Fig. 3. The solar wind parameters and geomagnetic indices at $R_{SS} > 16 R_E$.

$P_d < 0.16$ nPa, and B_z changes from -4 nT to $10 \div 17$ nT. The dependence of M^2 on P_d is interesting. For P_d decreases the M^2 value decreases, and SW becomes sub-Alfven's at $P_d < 0.1$ nPa. This means that the SW magnetic pressure exceeds its dynamic one at $R_{SS} > 20 R_E$. Under these conditions the Earth's magnetosphere becomes closed and the sub-cusp point shifts to the pole. The β value increases drastically at $P_d > 0.2$ nPa.

At $R_{SS} < 6.6 R_E$ the connection between P_d and V is weak. There is no connection between P_d and N . The IMF value is more than its average one. The B_z distribution is wider than for small P_d . The M_A^2 value changes from ~ 10 to ~ 1000 without connection with P_d . $P_d > 17$ nPa were observed mainly when D_{st} was < -100 nT.

Conclusions

We analyzed those events when the calculated distance to the magnetopause sub-solar point R_{SS} was $< 6.6 R_E$ or $> 16 R_E$. This corresponds to 9-fold P_d change in comparison with the most probable value at $B_z > 0$. The observation probability for both event kinds increases during the solar activity maximum. The absence of low pressure events during 1982-97 can most probably be explained by methodical reasons.

The events with $R_{SS} > 16 R_E$ are characterized by P_d decrease due to decrease of N . The V value changes from 300 to 600 km/s and the value of B is about 10 nT, $B_z \approx 0$. At $P_d < 0.05$ nPa ($R_{SS} > 20 R_E$) the SW magnetic pressure becomes equal to P_d . Since V under these conditions is less than the Alfven velocity, the shock wave has to disappear. The magnetosphere becomes closed and the sub-cusp point shifts to the pole. The magnetotail plasma sheet

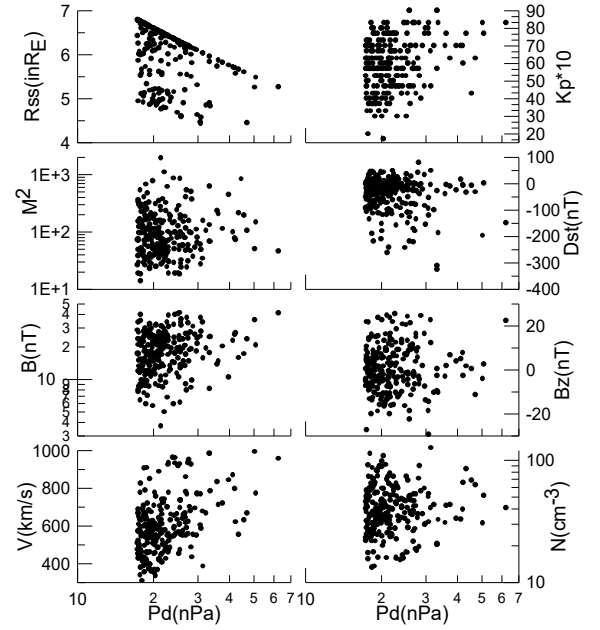


Fig. 4. The solar wind parameters and geomagnetic indices at $R_{SS} < 6.6 R_E$ for $P_d > 17$ nPa.

has the possibility to disappear. These events are possibly connected with a quiet prominence ejection into the interplanetary medium.

The events with $R_{SS} < 6.6 R_E$ are most probably connected with coronal mass ejection. Absence of the connection between P_d and N as well as V points to this fact. These events are well correlated with geomagnetic storms.

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