Effects of fast and slow solar wind on the correlations between interplanetary medium and geomagnetic activity

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[1] The coupling between interplanetary parameters and geomagnetic activity has been investigated. In particular, the correlations between the interplanetary medium and the geomagnetic indices $K_p$ and $Dst$ have been calculated for different ranges of solar wind speed. The correlation coefficients obtained for data points corresponding to solar wind slower than 550 km/s are equal or slightly higher than the global correlations. The observations show generally lower correlation coefficients for solar wind speeds faster than 550 km/s. These results suggest that at high solar wind speeds the processes responsible for the energy transfer between the interplanetary medium and the magnetosphere saturate. In addition, the influence of internal magnetospheric plasma physics on the geomagnetic activity may be larger for the faster solar wind intervals. In the context of the deterministically chaotic approximations we discuss how the threshold at $\sim 550$ km/s might represent the break of the order in the interplanetary-geomagnetic coupling system, so that the linear correlations or the correlations with a relatively weak departure from linearity are significant mostly during the slower solar wind. 


1. Introduction

[2] The interaction between the interplanetary medium and the terrestrial magnetosphere is one of the most important subjects of study in the context of Sun-Earth relations. It is well accepted that energy and particles can enter the magnetosphere when reconnection occurs between the interplanetary magnetic field (IMF) and the geomagnetic field. The low-latitude dayside reconnection normally takes place during southward IMF and reconnection at the magnetospheric lobes and/or at the high latitudes can occur during northward IMF [e.g., Akasofu, 1981; Song and Russell, 1992]. Moreover, the magnetic shears at the bow-shock and magnetosheath can be associated with diffusion of particles [Phan et al., 1997] and waves [e.g., Yumoto and Saito, 1983] into the magnetosphere. In addition, the velocity shears at the magnetopause are commonly associated with the occurrence of the Kelvin-Helmholtz (K-H) instability, which is thought to allow the entry of energy and momentum to the magnetosphere in the form of plasma waves [e.g., Fujimoto and Terasawa, 1995]. In particular, during times of northward IMF, entry of mass from the interplanetary to the magnetospheric system is observed to be due to the K-H instability [Fairfield et al., 2000].

[3] The K-H instability has been invoked as the explanation for the significant correlations between the solar wind speed ($V_{sw}$) and the micropulsation power observed at ground-based observatories [e.g., Odera, 1986, and references therein]. However, further increases of solar wind speed above a threshold between 500 and 600 km/s do not provide any further increase in micropulsation power [Junginger and Baumjohann, 1988; Yedidia et al., 1991; Ballatore et al., 1996]. In the previous papers, this result was attributed to a possible saturation of the efficiency of energy transfer between velocity shears at the magnetopause.

[4] In the present paper, we verify the existence of a possible threshold in the solar wind speed, and we speculate about its interpretation in the context of the interplanetary-magnetospheric coupling.

2. Data Analysis and Experimental Observations

[5] The time interval under investigation is the period from January 1977 until December 2000. For this period the interplanetary data considered are the measurements of interplanetary magnetic field (IMF), solar wind speed ($V_{sw}$), and density ($n$) from the National Space Science Data Center (NSSDC) database. According to data availability, these measurements are from different satellites, mostly from IMP 8 before 1994 and from Wind since December 1994. Smaller amounts of data are from IMP 6,
IMP 7, ISEE 3, PROGNOZ 10, and ACE. The 1-hour resolution interplanetary data have been used to calculate three parameters: the electric merging field (indicated by $E_m$), the parameter $V_{sw} B_y$ (indicated by $V_{sw} B_y$) and energy coupling between the solar wind and the magnetosphere ($\varepsilon$) [Akasofu, 1981]. In particular, the electric merging field is defined:

$$E_m = V_{sw} B_y \sin^2(\varphi/2),$$

where $B_y$ is the projection of the IMF on the $Y$-$Z$ plane (in the GSM coordinate system) and $\varphi$ is the clock angle between $B_y$ and the $Z$ axis [e.g., Kan and Lee, 1979]. In the parameter $V_{sw} B_y$, $B_y$ defined as the component ($-B_z$) of the IMF during southward IMF, and it is zero during northward IMF ($V_{sw} B_y$ is considered only during southward IMF periods). The energy coupling, $\varepsilon$ is defined:

$$\varepsilon = V_{sw} B^2 \sin^4(\varphi/2),$$

where $B$ is the module of the IMF and $\varphi$ is the clock angle mentioned above [Akasofu, 1981].

These interplanetary parameters have been compared with the geomagnetic indices $Kp$ and $Dst$, respectively available at 3- and 1-hour resolution. However, the resolution considered in our case is 1 hour for both indices, by considering, for each one of the 3-hour intervals of the $Kp$, the same value repeated for each single hour.

A delay is introduced between the ground-based geomagnetic indices and the interplanetary data. This delay is set equal to 1 hour because this value optimizes the correlation between ground-based and interplanetary measurements in our data set. In addition, the approximation of a 1-hour delay is in agreement with previous estimations of average delays between satellites and ground-based measurements [e.g., Arnoldy, 1971; Ballatore et al., 2001].

The results that we obtain with this average delay are qualitatively similar to the results obtained with a slightly different delay or, in particular, to the results obtained with a more accurate calculation of the delays at specific times. For example, for Wind measurements during the year 1997 the propagation time has been approximated at each hour by taking into account the specific average solar wind speed and the Wind position in the interplanetary space with respect to the magnetospheric bow shock subsolar point. The results that we obtained for this test case are qualitatively similar to those using a 1-hour delay.

The linear correlation coefficient between the geomagnetic indices $Kp$ and $Dst$ has been calculated over 3-year periods from 1977 until 2000 and these are respectively 0.57, 0.59, 0.57, 0.58, 0.66, 0.65, 0.61, and 0.57. These coefficients have been re-calculated considering the data for all the 24 years together but separately for data points corresponding to different intervals of solar wind speed. In particular, the results obtained for $V_{sw} < 350$ km/s, $350 \leq V_{sw} < 450$ km/s, $450 \leq V_{sw} < 550$ km/s, and $V_{sw} \geq 550$ km/s are reported in the Figure 1. The correlation coefficients obtained during faster solar wind speeds are equal or higher than the coefficients obtained during the slower solar wind speeds. In addition, no time dependence for this result is shown.

In Figure 2 we show the linear correlation coefficients of $Kp$ and $Dst$ with the three interplanetary quantities considered, separately for data points binned by $V_{sw}$ ($< 350$, $350 \leq V_{sw} < 450$, $450 \leq V_{sw} < 550$ and $\geq 550$ km/s). In general, the data with faster solar wind speeds (in particular equal or faster than 550 km/s) are less correlated. In particular, considering two correlations with equal correlation coefficient value, the more significant is the one related to the larger number of data points. Therefore, in a condition of equal variability of the considered variables, the best correlations shown in Figure 2 are observed for $350 \leq V_{sw} < 450$ km/s and the worst are observed for $V_{sw} \geq 550$ km/s. The significance of the smaller interplanetary-geomagnetic
correlation for solar wind speeds equal or faster than 550 km/s is also indicated by the consistence of the results in the different panels. In addition, for purposes of direct comparison, we showed in Figure 3 the correlation coefficients between $Kp$ and $Dst$ for, exactly, the same data points considered in Figure 2. Results in Figure 3 indicate that the decrease of interplanetary-geomagnetic correlation is associated with an increase of the correlation between the geomagnetic activity indices.

[11] The study of the interplanetary-geomagnetic correlation versus years, similarly to Figure 1, indicates no solar cycle or other systematic time dependence. For example, we show the case for $Kp$ versus $E_m$ in Figure 4. The two cases of $V_{sw} \geq 550$ km/s for 1986–1988 and 1995–1997 can be considered statistically less significant due to the relatively smaller number of data point involved.

[12] The results obtained separately for IMF northward or southward are illustrated in Figure 5 (combining all the years of data together and for $n > 10$ cm$^{-3}$) for the two interplanetary parameters $E_m$ and $e$ and for the geomagnetic indices $Kp$ and $Dst$. As expected [e.g., Akasofu, 1981, and references therein], the coefficients are higher during southward IMF than during northward. In particular, an interesting result shown in Figure 5 is that the decrease of interplanetary-geomagnetic correlation at faster solar wind speeds is observed for both orientation of IMF, associated with an increase of the $Kp$ versus $Dst$ correlation. In addition, during the quietest conditions (northward IMF and $V_{sw} < 350$ km/s), the correspondence between $Kp$ and $Dst$ is about null, while each one of them separately can be

Figure 2. First-order correlation coefficients between the indicated parameters, separately for $V_{sw}$ in the intervals indicated on the $X$ axis. The data points considered correspond to interplanetary density $n > 10$ cm$^{-3}$. On the top of the left column the numbers of data points for each correlation are shown and these are the same for the panels in the first column on the right (for which no numbers on the top are specified). For the middle column, similarly, the numbers on the top specify the number of data points considered. In each panel, the horizontal dashed line indicates the total correlation coefficient for all the $V_{sw}$ values.

Figure 3. Correlation coefficients between $Kp$ and $Dst$ for the $V_{sw}$ intervals on the $X$ axis. The data points considered are the same as in Figure 2. The dashed line indicates the total correlation coefficient; the numbers at the top are the numbers of data points in each correlation.

Figure 4. Correlation coefficients between $Kp$ and $E_m$ for the interval of years indicated on the $X$ axis; each panel refers to the data corresponding to the $V_{sw}$ interval indicated. On the top of each panel the number of data points for each correlation is shown.
still correlated (statistical confidence level > 99.9%) to the interplanetary parameters.

[13] Nonlinear second- and third-order correlation coefficients have been calculated for \( K_p \) and \( Dst \) with the interplanetary quantities, still combining all the years of data together. In particular, these coefficients have also been calculated separately for data points binned by \( V_{sw} \) (the same \( V_{sw} \) intervals as above) and the results are reported in Table 1 for data points with solar wind density \( n > 10 \) cm\(^{-3}\). Similar to the linear case, the correlation coefficients for \( V_{sw} < 550 \) km/s are generally slightly higher than the correlations obtained for \( V_{sw} \geq 550 \) km/s. This is so both for the second- or the third-order correlations.

3. Discussion

[14] The interaction of the solar wind flow with the geomagnetic field lines at the magnetopause results in significant correlations between the solar wind speed and the geomagnetic variations observed on the ground [e.g., Odera, 1986, and references therein]. Since the geomagnetic indices are derived from the geomagnetic variations, the solar wind speed also correlates with these indices. In particular, in the years 1977–2000, the correlation coefficients between \( V_{sw} \) and the \( K_p \) index is \( \sim 0.50 \) and between \( V_{sw} \) and \( Dst \) is slightly smaller. These correlations sharply decrease when they are calculated separately for data points corresponding to specific ranges of \( V_{sw} \). This result is expected due to the basic procedure used for the calculation of correlation coefficients and it is attributed to the decrease of the variability of \( V_{sw} \) in each subcorrelation interval.

[15] Differently, we can meaningful calculate the correlations between \( K_p \) and \( Dst \) in different ranges of \( V_{sw} \). Recall that these two indices are derived from ground-based stations located at different latitudes, with \( Dst \) related to the equatorward locations (with respect to the geomagnetic coordinate system) while \( K_p \) is related to intermediate latitudes. The number of stations contributing to \( K_p \) is 13, while only four stations are considered for \( Dst \). Therefore \( K_p \) is considered a geomagnetic indicator at a more average planetary level, while \( Dst \) (as an index of the equatorial ring current) is more strictly related to the development of geomagnetic storms. The results shown in Figure 1 demonstrate that the global correlations between \( Dst \) and \( K_p \) for higher solar wind speeds are generally more significant than the correlations observed for the slower speeds. This result shows that the different latitude (i.e., magnetospheric-ionospheric) regions are related to each other better during the faster solar wind. If we recalculate the correlations between \( K_p \) and \( Dst \), combining all data together and taking solar wind density \( n > 10 \) cm\(^{-3}\) (and considering just the data point for which the interplanetary data are also available), we can directly compare the results with the interplanetary-geomagnetic correlation discussed in the following. This case is shown in Figure 3, where a clear increase of correlation is evident for the increase of \( V_{sw} \).

[16] On the contrary, considering the correlations between the geomagnetic indices and the interplanetary medium (Figure 2), the correlation coefficients for \( V_{sw} \geq 550 \) km/s

| Table 1. Correlations at the Second and Third Order Between the Interplanetary Parameters and the Geomagnetic Indices \( K_p \) and \( Dst \) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| \( K_p = aX^2 + bX + c \) | \( K_p = aX^3 + bX^2 + cX + d \) |
| \( X = E_m \) | \( X = V_{sw}Bs \) | \( X = \varepsilon \) |
| \( V_{sw} < 350 \) | \( N = 14004 \) | \( N = 7014 \) | \( N = 14004 \) |
| \( \rho = 0.64 \) | \( \rho = 0.65 \) | \( \rho = 0.62 \) |
| \( 350 \leq V_{sw} < 450 \) | \( N = 17372 \) | \( N = 8552 \) | \( N = 17372 \) |
| \( \rho = 0.67 \) | \( \rho = 0.68 \) | \( \rho = 0.64 \) |
| \( 450 \leq V_{sw} < 550 \) | \( N = 4030 \) | \( N = 2046 \) | \( N = 4030 \) |
| \( \rho = 0.66 \) | \( \rho = 0.66 \) | \( \rho = 0.62 \) |
| \( V_{sw} \geq 550 \) | \( N = 1244 \) | \( N = 629 \) | \( N = 1244 \) |
| \( \rho = 0.53 \) | \( \rho = 0.60 \) | \( \rho = 0.53 \) |
| \( Dst = aX^2 + bX + c \) |
| \( X = E_m \) | \( X = V_{sw}Bs \) | \( X = \varepsilon \) |
| \( V_{sw} < 350 \) | \( N = 14004 \) | \( N = 7014 \) | \( N = 14004 \) |
| \( \rho = 0.53 \) | \( \rho = 0.57 \) | \( \rho = 0.52 \) |
| \( 350 \leq V_{sw} < 450 \) | \( N = 17372 \) | \( N = 8552 \) | \( N = 17372 \) |
| \( \rho = 0.56 \) | \( \rho = 0.61 \) | \( \rho = 0.56 \) |
| \( 450 \leq V_{sw} < 550 \) | \( N = 4030 \) | \( N = 2046 \) | \( N = 4030 \) |
| \( \rho = 0.56 \) | \( \rho = 0.60 \) | \( \rho = 0.56 \) |
| \( V_{sw} \geq 550 \) | \( N = 1244 \) | \( N = 629 \) | \( N = 1244 \) |
| \( \rho = 0.53 \) | \( \rho = 0.57 \) | \( \rho = 0.52 \) |

\( N \) is the number of data points, and \( \rho \) is the correlation coefficient. \( V_{sw} \) in km/s.

**Figure 5.** Correlation coefficients between the indicated parameters for the intervals of \( V_{sw} \) indicated on the \( X \) axis. Results are shown separately for IMF (top) \( B_z > 0 \) and (bottom) \( B_z < 0 \). The numbers on the top of the central panels are the number of data points in each correlation. These numbers are the same in each panel of the same line.
are consistently slightly lower than the ones for slower speeds, indicating a smaller correlation at these times.

[17] Previous studies demonstrated the existence of an extreme variability in the interplanetary data measured by different satellites [Russell et al., 1980; Crooker et al., 1982]. However, rather little control on this variability could be attributed to the solar wind speed, at least in the range 300–500 km/s [Crooker et al., 1982]. Most recent works on this subject have shown that the correlations among interplanetary measurements from different spacecrafts are 50% higher for density \( n > 10 \text{ cm}^{-3} \) than for density \( n < 4 \text{ cm}^{-3} \) [Paularena et al., 1999, and references therein].

[18] This justifies our exclusion of data points with ion density \( n > 10 \text{ cm}^{-3} \) for the interplanetary-geomagnetic correlations. In particular, rather similar results are obtained for \( n < 4 \text{ cm}^{-3} \), while, considering all \( n \) values, a slight decrease of the correlations for solar wind 350–450 km/s and a slight increase for \( v_{sw} \geq 550 \text{ km/s} \) may be observed at times. In particular, if we consider only the Wind satellite data, for all \( n \) values together, over the years 1995–2000, we obtain that the decrease of interplanetary-geomagnetic correlation at high speeds is much more evident than in Figure 2 (for \( v_{sw} \geq 550 \text{ km/s} \) the correlation coefficient is generally <0.4). Differently, considering the only data from IMP 8, for all \( n \) values and during the same period, the high-speed correlation is slightly higher than in Figure 2. This indicates the importance of selecting the highest solar wind density data in order to obtain a better reliability of the upstream parameters [Paularena et al., 1999, and references therein].

[19] However, the solar wind density and speed are not just independent, but they correlate with correlation coefficients of the order of about −0.45 in our data set: the higher \( v_{sw} \) is statistically associated to a smaller density. Therefore an increase of interplanetary-geomagnetic correlations can be expected during slower solar wind associated with a higher reliability of upstream measurements. This is one more reason for restricting the variability of \( n (n > 10 \text{ cm}^{-3}) \) when studying the effects of \( v_{sw} \).

[20] It is important to stress that since most high-speed solar wind intervals are low density, the condition \( n > 10 \text{ cm}^{-3} \) is affecting the sector \( v_{sw} > 550 \text{ km/s} \) more significantly than the rest of the \( v_{sw} \) intervals. This might indicate that the smaller interplanetary-geomagnetic correlation is just related to the occurrence of interplanetary structures of both high speed and density. In fact, the presence of high density associated with high speed can be related to the ejections of solar coronal mass (coronal mass ejections (CMEs)) or to the compression of the slow solar wind streams reached by faster streams in the interplanetary space (corotating interactions regions (CIRs)) [e.g., Kivelson and Russell, 1997, and references therein]. The implication of the decrease of interplanetary-geomagnetic correlation for \( v_{sw} \geq 550 \text{ km/s} \) is not specifically related to the CME or CIR events is proved by the fact that a similar decrease is not found for intervals of higher solar wind pressure \( (n v_{sw}) \).

[21] In addition, in respect to spatial scale sizes of interplanetary medium variability [Crooker et al., 1982] or IMF orientation [Russell et al., 1980; Crooker et al., 1982], we do not find a clear association between the satellite location and the observed decrease of correlation for \( v_{sw} > 550 \text{ km/s} \).

[22] Results reported in Figure 2 combine together all data from the all years 1977 until 2000. However, considering each year or groups of years separately (an example is given in Figure 4), we see no systematic solar cycle effects.

[23] The interplanetary quantities considered are \( E_{sw}, v_{sw}B_{z} \), and \( \epsilon \) because these parameters give the best correlations between the interplanetary medium and the magnetosphere, as expected from previous studies [Akasofu, 1981; McPherron, 1997a, and references therein]. However, we obtained similar results considering other interplanetary parameters (for example, IMF \( B_{z} \), or \( v_{sw}B_{z} \)).

[24] The results above, related to the first order approximation, indicate that the mechanism responsible of the energy transfer between the interplanetary medium and the magnetosphere is different for \( v_{sw} \) faster or slower than a certain threshold between 500 and 600 km/s. This could be related to the saturation of the energy transfer processes that are active during the quieter conditions.

[25] As suggested by previous studies on micropulsations (see the introduction), the saturation of the K-H instability process is also expected to occur at \( \sim 500–600 \text{ km/s} \). We find that a decrease of linear correlation values at 500–600 km/s also occurs in the \( E_{m} \), the \( \epsilon \) and the \( v_{sw}B_{z} \) correlations; these quantities are typically considered as indicators of the reconnection rate between the IMF and the magnetosphere [Akasofu, 1981, and references therein]. The entry of energy and plasma to the magnetosphere through reconnection is somehow seen as an alternative process with respect to the K-H instability. In fact, the former is considered to be mostly active during southward IMF, and the latter is usually invoked for IMF-magnetosphere coupling during northward IMF [Fairfield et al., 2000, and references therein]. In particular, \( v_{sw}B_{z} \) takes into account only reconnection for negative IMF \( B_{z} \), while \( E_{sw} \) is a more general parameter including also the effects of lobe reconnection during positive IMF \( B_{z} \).

[26] Figure 5 shows the correlation coefficients versus \( v_{sw} \) considering separately the periods of northward and southward IMF: the change of the correlations as a function of \( v_{sw} \) is similar in the two cases considered and in agreement with results shown in Figure 2 and 3. Our results suggest that similar to the K-H instability, the ground-based effects of the merging between the IMF and the magnetosphere undergo a kind of saturation at \( v_{sw} \sim 550 \text{ km/s} \).

[27] A difference might be expected for the results related to higher-order correlations, e.g., these correlations could be definitely smaller for \( v_{sw} < 550 \text{ km/s} \) than for the global case, or for \( v_{sw} > 550 \text{ km/s} \) they could be higher than for \( v_{sw} < 550 \text{ km/s} \). In fact, the correlations between interplanetary quantities and geomagnetic indices are not expected to be only linear. One known explanation of the possible origin of the non-linear relationship between \( Dst \) and \( \epsilon \) was given by Akasofu [1981], who invoked the fact that a more intense ring current tends to form at a closer distance to Earth. The correlation function estimated in that case was a second order polynomial function in the independent variable \( \log(\epsilon) \) [Akasofu, 1981].

[28] Therefore, in our case it is of interest to verify what happens by considering a departure from linearity. So we have calculated higher-order correlations up to the fifth order. We report in Table 1 results up to the third order:
for orders higher than this, no more increase in the significance of the correlations was observed.

[29] We also have considered a second order polynomial function in the variable \( \log\langle e \rangle \). Use of this variable does not improve our results.

[30] Table 1 confirms the observations derived from the first-order approximation: the correlation coefficients for data corresponding to \( V_{sw} < 550 \text{ km/s} \) are slightly higher than the for data with \( V_{sw} \geq 550 \text{ km/s} \). Therefore, similar to the linear case, the fast solar wind may be associated to a decrease of the correlations.

[31] This result confirms the different nature of the interaction between the interplanetary medium and the geomagnetic indices when the solar wind flow is faster or slower than \( \sim 500 \text{–} 600 \text{ km/s} \).

[32] If we take into account the fact that the interplanetary medium affects the geomagnetic activity less during the faster solar wind, we may deduce that the causes of the observed geomagnetic activity are inside the magnetosphere itself at these times. This is also in agreement with the higher correlation between \( Kp \) and \( Dst \) at these times (see Figure 3).

[33] By analyzing some specific fast solar wind intervals we noted some occurrences of geomagnetic substorms at these times, with specific high correlation between \( Kp \) and \( Dst \) and small interplanetary-geomagnetic correlations.

[34] The mechanism producing the substorms is related to the continuous presence of the magnetospheric-ionospheric convection system that transports magnetic plasma flow from the dayside toward the geomagnetic tail. In this sense the substorms can be seen as a way to return the plasma energy and flow toward the dayside, as determined by the reconnection in the magnetotail [e.g., McPherron, 1997b, and references therein]. The primer of the tail reconnection is related to the fact that the electric fields between the plasma layers in the tail become so thin that the conductivity (generally infinite in these plasmas) becomes finite and plasma can move. This primer is due to the energy stored in the magnetosphere and/or to the geometry of interactions between the solar wind flow and the magnetosphere. The initial phase of the substorms (or of the storms, seen as larger substorm events) is impulsive as soon as the critical energy parameters are reached [e.g., McPherron, 1997b, and references therein].

[35] In the terms above, during the occurrence of the substorms (and we mean in particular during their initial phase), the geomagnetic activity is determined by processes related to the magnetospheric plasma and is not directly related to the interplanetary medium, although its primer is determined by the interplanetary medium.

[36] It is worth to specify that the results obtained for \( Kp \) and \( Dst \) in Figure 2 are similar also for the geomagnetic index \( AE \) (the standard \( AE \) is considered until 1988, after 1988 the provisional \( AE \) is considered, in agreement with public \( AE \) availability). This result is expected in association with the positive correlation between \( AE \) and \( V_{sw} \) (with correlation coefficients of the order of 0.5 in our data set). Since an increase of \( AE \) indicates an increase of substorm activity, during faster solar wind a larger substorm occurrence rate is expected in the \( AE \) values which may produce the decrease of the \( V_{sw} \) versus \( AE \) correlation.

[37] In we consider \( Kp \) and \( Dst \), the statistical significance of their correlation with \( V_{sw} \) is not so directly implying a higher substorm occurrence during the faster solar wind. However, we recall that one of the causes of substorm occurrence is solar wind structures faster than the average solar wind speed (\( \sim 400 \text{ km/s} \)). For example, fast CMEs are known to produce preceding shocks and compressed solar wind and IMF, and these elements are generally associated with the onset of geomagnetic storms [e.g., Tsurutani et al., 1990a; Gonzalez et al., 1994, and references therein].

[38] Although this observation, the decrease of interplanetary-geomagnetic correlation at \( V_{sw} \sim 550 \text{ km/s} \) cannot be due to the substorms and storms occurrence solely. In fact, if we exclude the data corresponding to the substorm intervals (with \( AE > 500 \text{ nT} \) in particular), the results shown in Figures 2 and 3 are still qualitatively observed in our data set. This result is in agreement with the previous finding relating solar wind speed to the low-frequency geomagnetic pulsation power. In particular, in the work of Ballatore et al. [1996] the SSC (sudden storm commencement) events were excluded from the data set considered. In addition, the ground-based data considered by Yedidia et al. [1991] were from only the dayside 0600–1800 LT interval and from a station located at middle latitude, so that the effects of both substorms and storms are expected to be excluded.

[39] In these studies the storms and substorms were excluded because, during these events, there is less order in the magnetosphere, so that linear correlations or correlations with a weak departure from linearity may fail in predictions. In particular, the magnetospheric system is not just random, but it seems deterministically chaotic so that, given the initial state, its evolution may be predicted [e.g., Baker et al., 1990; Tsurutani et al., 1990b]. In this context, our results can be interpreted as the fact that a general break of the magnetospheric order can occur, independent of the substorm or storm occurrence, in association with the increase of the solar wind speed above a certain threshold between 500 and 600 km/s.

4. Conclusions

[40] The relationship between the interplanetary medium and the geomagnetic activity is found to be different during periods of solar wind faster or slower than a threshold speed of about 550 km/s. We suggest that the processes responsible for the coupling between the interplanetary medium and the magnetosphere are different during different regimes of solar wind speed.

[41] In particular during the faster solar wind the correlation coefficients between the interplanetary quantities and the geomagnetic indices are smaller. On the contrary, for the same faster solar wind data, the coefficient of the correlation of one geomagnetic index with the other is higher. These results show that the geomagnetic variations at different latitudes of the terrestrial system are very well correlated, in particular during fast solar wind speed. This may suggest that the geomagnetic activity observed during the faster solar wind conditions can be more directly related to plasma processes inside the magnetosphere than to the interplanetary parameters.
[42] In the context of the treatment of the magnetosphere as a deterministically chaotic system, our results are interpreted in the sense that an order in the interplanetary-magnetosphere coupling is significant only until a certain threshold of solar wind speed, i.e., ~550 km/s. Above this speed, the correlations between interplanetary parameters and the geomagnetic activity are expected to be lower, both in linear and in higher-order approximations.

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