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Relationship between Interplanetary (IP) Parameters and Geomagnetic Indices during IP Shock Events of 2005

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Abstract. In the present study, we investigate the possible relationship of IP parameters of solar wind and interplanetary magnetic field with ground-based geomagnetic indices. To carry out the study, we take all the IP shock events listed by Proton Monitor onboard Solar and Heliospheric Observatory (SOHO) during 2005, and plot the time variations of all the IP parameters and geomagnetic parameters (±5 days), centered at the shock arrival time. Next, we obtain scatter plots of absolute values of solar wind parameters such as Vsw, Nsw and Interplanetary Magnetic Field (IMF) components Bx, By, Bz and total B with the values of geomagnetic parameters such as Dst, Kp indices, dayside Magnetopause (MP) distance and Cosmic-Ray Neutron Monitor count (CRNM). The scatter plots show that before the IP shock, the pattern is random with no clear relationship. Following the shock, a clear pattern emerges with a type of relationship being seen – clear for SHARP shocks and less clear for DIFFUSE shocks. A total of 10 shock events for 2005 have been studied. Typical examples of this behaviour are the shock events of January 21, 2005 and May 15, 2005.

Our study suggests a definite correlation between changes in the solar wind and interplanetary magnetic field parameters and ground-based geomagnetic response. We are trying to obtain quantitative relationships between these for shock events of 2005.

Key words. IP parameters—IP shocks—solar–terrestrial relationship.

1. Introduction

Magnetic field and particle emissions from the Sun are mainly responsible for changes in the electromagnetic and energetic particle environment of earth. An active Sun spews out concentrated particle and field energy into interplanetary space (IP), and manifestations of these have been studied by many researchers (to mention a few, Cargill 2000; Lepping *et al.* 1990; Gopalswamy *et al.* 2004; Bothmer & Schwenn 1998). Propagation of these emissions through IP space and their entry into earth's

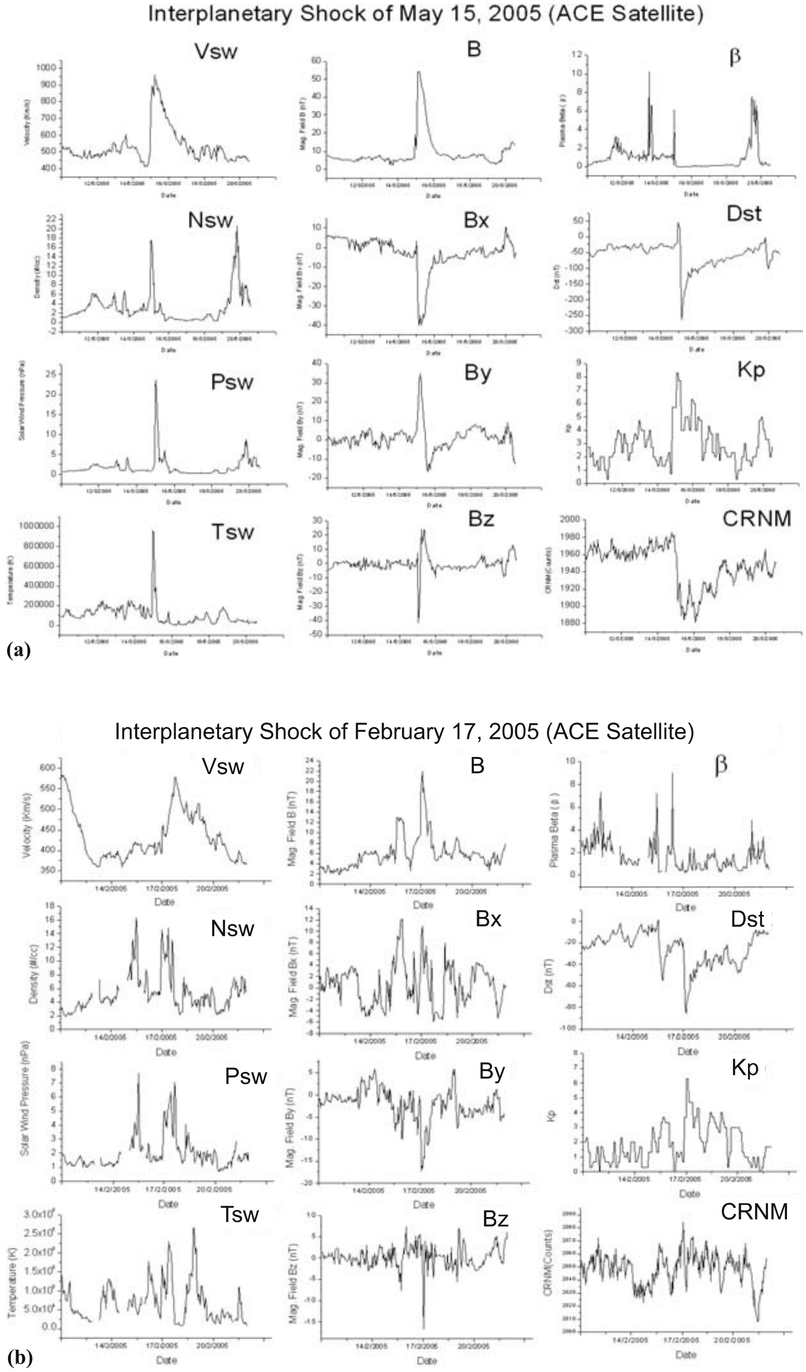
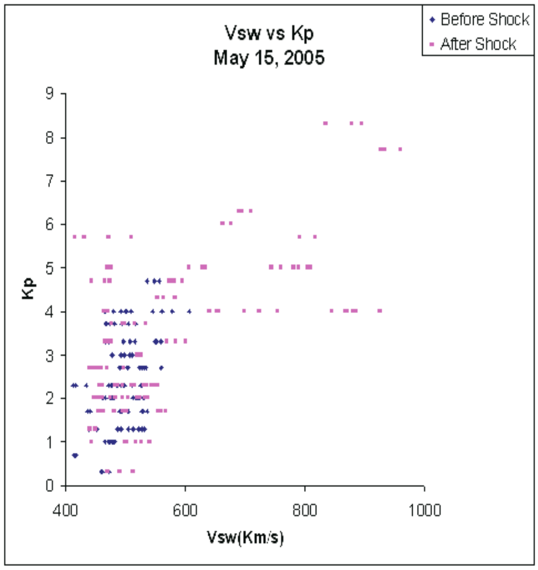


Figure 1. **(a)** Comparison of solar wind and IMF parameters for 'sharp' shock event of 15 May, 2005, and **(b)** 'diffuse' shock event of 17 February 2005. Note the sharp rapid rise and clean drop in these parameters for 'sharp' shock as compared to the gradual rise and oscillating variations in the parameters for 'diffuse' shock. Note that the β factor and the geomagnetic parameters Dst, Kp and CRNM (Cosmic Ray Neutron Monitor) also reflect the 'sharp' and 'diffuse' characteristics seen in causative solar wind and IMF parameters.



(a)

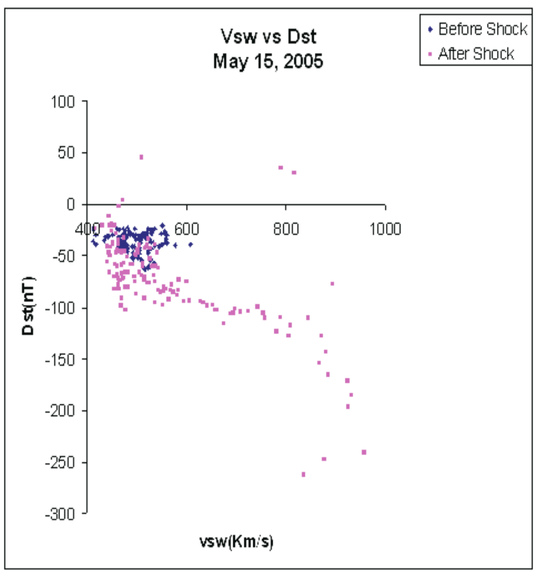
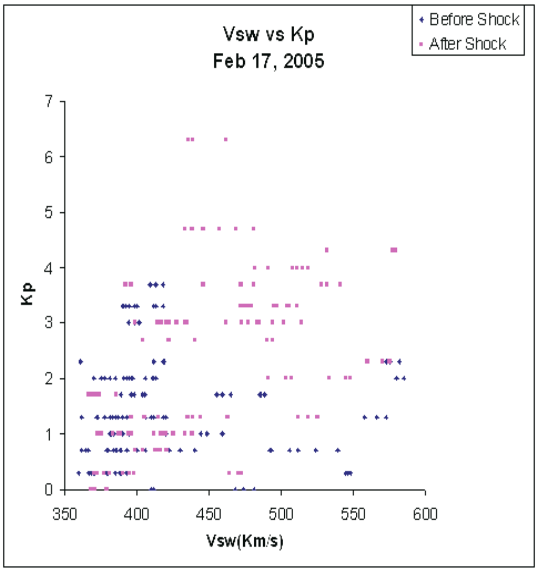


Figure 2(a). Scatter plots of Vsw *vs*. hourly values of the geomagnetic indices Kp and Dst for ±5 days around the day of sharp shock (15 May 2005). Note the clustering of points before the shock; after the shock a linear-to-curvilinear relationship is seen for both Kp and Dst.

environment results in various space weather changes, including the phenomenon of the geomagnetic storm and its manifestations (Chapman 1936). Since the 1960s, orbiting and geostationary satellites have made it possible to study the linkage between solar emissions, their manifestations in IP space, and geomagnetic storm phenomena (cf. amongst others Adachi *et al.* 2006; Oh and Yu 2004; Maltsev & Rezhenov 2003; Murayama 1982).



(b)

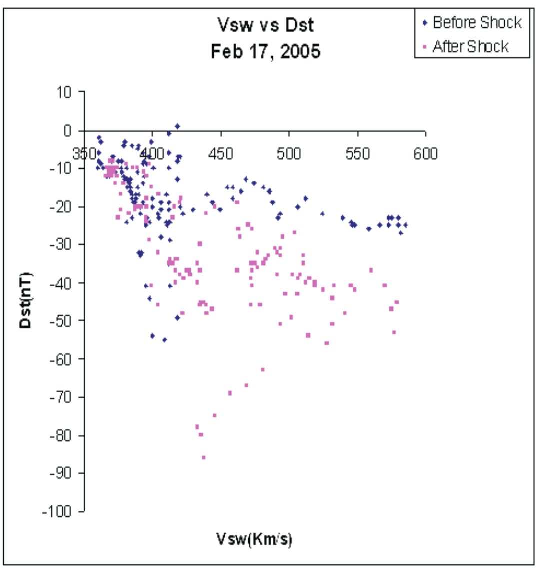
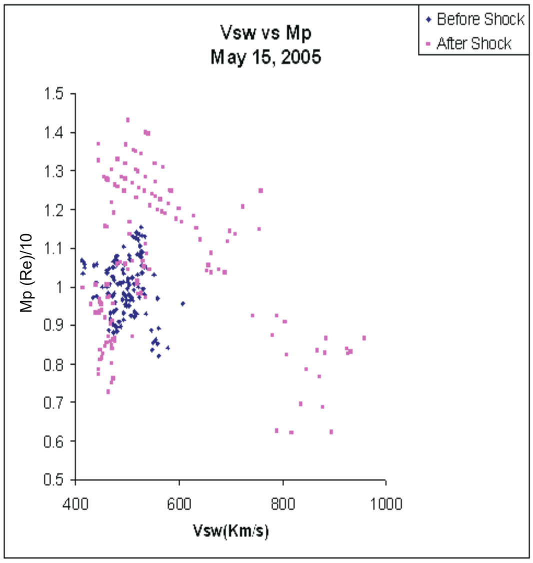


Figure 2(b). Same as for 2(a), but the day is one of a 'diffuse' shock (17 February 2005). Note the considerable scatter in relationship between Vsw and Dst and Kp before and after the shock in contrast to 'sharp' shock case of Fig. 2(a).

2. Data presentation

For the present work we have studied 19 IP shocks in 2005. In this work, we are studying IP parameters (i.e., solar wind velocity (Vsw), solar wind ion density (Nsw), solar wind dynamic pressure (P_{dsw}), total interplanetary magnetic field B along with its



(a)

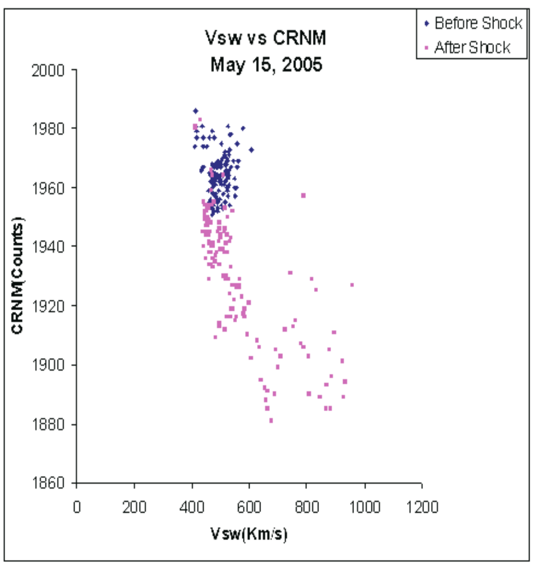
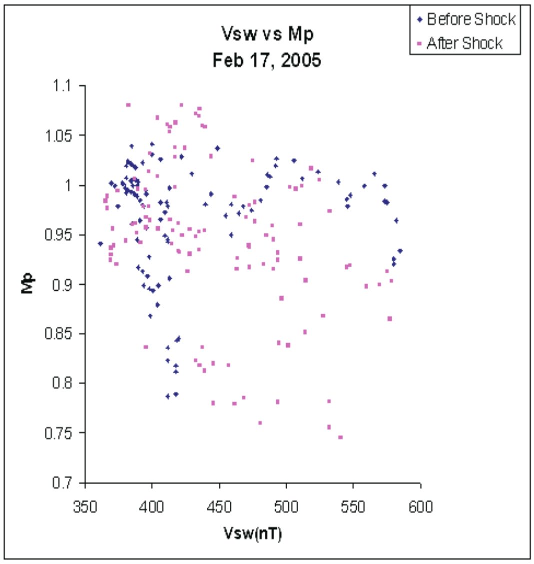


Figure 3(a). Scatter plots of Vsw *versus* hourly values of CRNM and Mp (the Magnetopause distance from centre of the earth) before and after the sharp shock (15 May 2005). Note the clustering of points before the shock. After the shock onset, the Mp moves earthwards as Vsw increases. Similarly, CRNM values decrease rapidly with increasing Vsw, showing the presence of Forbush-type decrease in cosmic ray protons.

north-south component, Bz, dayside magnetopause distance (MP) and the geomagnetic indices (i.e., Dst, Kp and CRNM count). The data are taken from ACE, OMNI and SOHO satellites. All the data are hourly averaged. The absolute values of all the



(b)

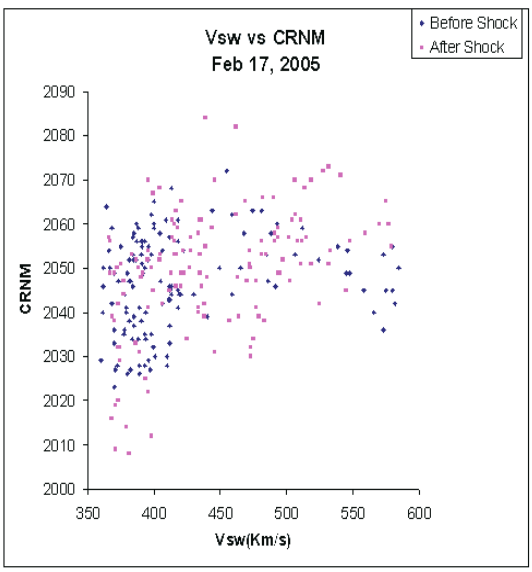
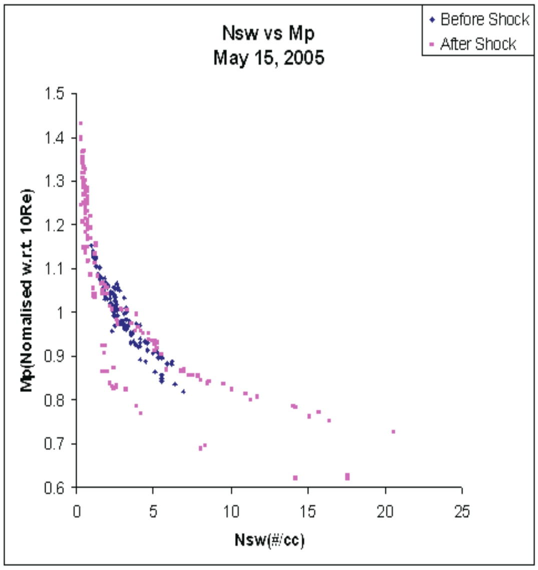


Figure 3(b). Same as for Fig. 3(a), but results are for diffuse shock day 17 February 2005. In this case scatter of Kp values both before and after the shock is considerable for both CRNM and MP showing no clear trend as was seen in Fig. 3(a). In the case of Mp, there is more scatter before the shock onset; after the shock, despite scatter of points, the trend of Fig. 3(a) for MP to decrease with increasing Vsw is seen.

parameters are taken for comparison except for dayside magnetopause distance. In case of magnetopause distance, the values are normalized with respect to $10\,R_E$. CRNM counts are taken from Beijing station (www.spidr.ngdc.noaa.gov). The values are taken



(a)

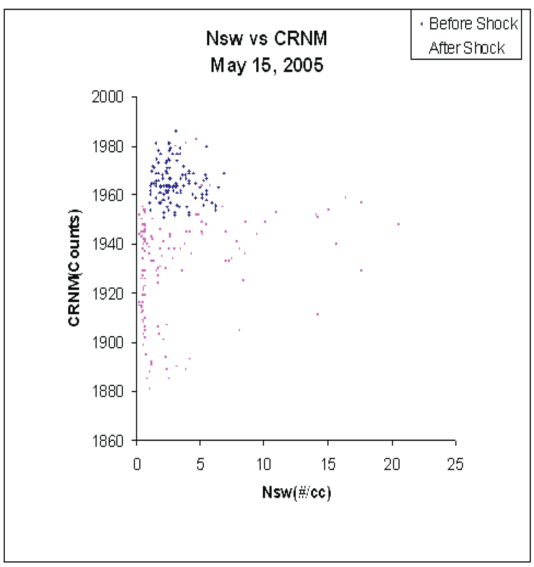
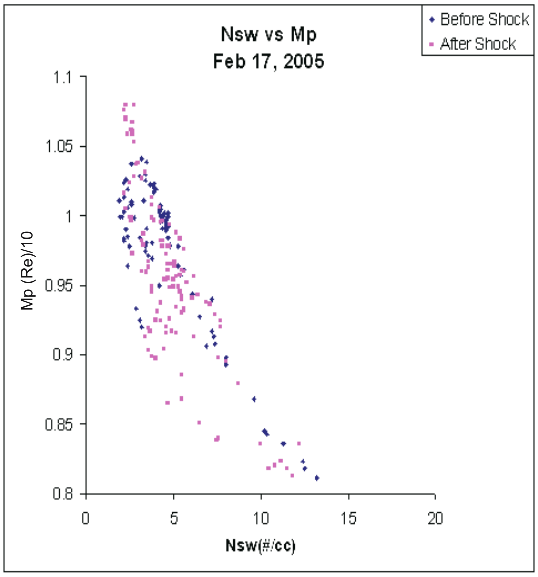


Figure 4(a). Scatter plots of Nsw *vs.* MP (magnetopause distance from earth) and CRNM (count at Beijing, China) for the sharp shock event of 15 May 2005. Note how the MP moves rapidly after the shock towards earth, first very rapidly with increasing Nsw, then more gradually, i.e., an exponential decrease to values of MP as low as 6Re. The CRNM plot shows that Nsw is not a controlling parameter, as there is no relationship between the two parameters. (MP distance is computed from the balance between the plasma pressure of the solar wind and the magnetic pressure of the geomagnetic field. The y-axis shows the MP distance normalized w.r.t the normal distance 10 Re).



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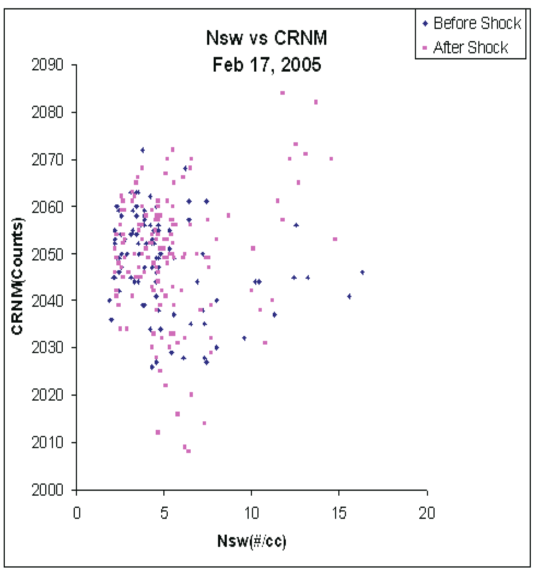

Figure 4(b). Same as Fig. 4(a), but for the diffuse shock event of 17 February 2005. Note that in this case unlike for Fig. 4(a), the normalized MP ratio is not less than 0.8, and the relationship to Nsw is an almost linear one, both before the shock and after the shock. Clearly Nsw is a major parameter in controlling MP. As in the case of Fig. 4(a), the CRNM count shows no relationship with Nsw, thereby ruling it out completely as a controlling parameter.

for ±5 days from zero time, i.e., the time of IP shock. But due to brevity of space, we are discussing only two cases (one sharp shock type and another diffused shock type event) are discussed in the present paper.

3. Conclusions

- There are definite relationships between the changes in the solar wind/IMF parameters, and the ground-based geomagnetic indices Kp, Dst, CRNM count, and the distance of the dayside magnetopause (MP), notably so after the onset of an IP shock. There is generally clutter of relationship points before the shock.
- These relationships differ for shock events of the sharp type and the diffuse type.
- Solar wind speed Vsw is clearly related to the Kp and Dst indices, and to MP and the CRNM count.
- Solar wind density Nsw clearly controls MP distance, marginally controls Kp and Dst, but does not control CRNM.
- Total B (IMF) is related to changes in Kp and Dst, and clearly controls both MP and CRNM.
- Rapid oscillations in Bz (+ve to −ve and *vice versa*) are well-related to increases in Kp, decreases in Dst, and to decrease in the MP distance and the CRNM count.
- Sunward-directed Bx (+ve) shows association with increased Kp, decreased Dst, and decrease in MP distance and CRNM.
- Downward-directed By (−ve) seems to increase Kp and Dst, but does not show clear relationship with the MP distance and CRNM count.
- Approximately 20 shock events of the year 2005 have been studied, of which the 15 May (sharp shock), and 17 February (diffuse shock) are two representative examples. Through averaging procedures on the 20 shock events, we are establishing quantitative relationships between the changes in the geomagnetic parameters, and the solar wind and IMF parameters. Such quantitative relationships will be invaluable for modelling studies, and for space weather predictions.

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