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# Heliospheric observations during October-November 2003

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## Abstract

The period of October-November 2003, though in the declining phase of the solar activity, but have been the period of most powerful solar flares (up to a class of X28). In fact three flares in this period are classified as the most powerful flare recorded since 1976. The analyses of terrestrial effects of this very intense solar activity have been carried out. There are most severe geomagnetic storms due to the interaction of dense and fast solar wind observed in this period. These storms are not found to be associated with the negative z-component (Bz) of the Interplanetary Magnetic Field. In fact when Bz is negative, geomagnetic index Kp is mostly low. The large positive Bz values are correlated with enhanced geomagnetic activity. The Kp is found to be strongly related to solar wind pressure and not with the direction and the magnitude of IMF. In this paper these investigations will be presented and compared with other periods of strong geomagnetic activity.

## 1. Introduction

The solar flares are explosions on the Sun that happens when energy stored in twisted magnetic fields (usually above sunspots) is suddenly released. Flares produce a burst of radiation across the electromagnetic spectrum, from radio waves to x-rays and gamma-rays. Solar flares are classified according to their x-ray brightness in the wavelength range 1 to 8 Angstroms. There are 3 categories: X-class flares are big; they are major events that can trigger planet-wide radio blackouts and long-lasting radiation storms. M-class flares are medium-sized; they generally cause brief radio blackouts that affect Earth's Polar Regions. Minor radiation storms sometimes follow an M-class flare. Compared to X- and M-class events, C-class flares are small with few noticeable consequences here on Earth. Most of the flares initiate large coronal mass ejection (CME). When a CME hits the magnetosphere, it can compress the magnetosphere and unleash a geomagnetic storm. The period of October–November 2003 (Halloween events), “NASA, Solar System Exploration: News and Events, July 8, 2004, News Archive, Space Storm Tracking” mentioned that the effects on Earth were severe enough to cause the rerouting of aircraft, affect satellite operations, and precipitate a power failure in Malmoe, Sweden. Long-distance radio communications were disrupted because of the effects on the ionosphere, and northern lights (aurora borealis) were seen as far south as Florida. The International Space Station astronauts curtailed some of their activities and took shelter in the Russian- supplied Service Module several times during the storm. Thus the solar activity of this period has a very special interest to the scientific community and became a target for detailed and intensive investigations. Snyder et al. (1963) showed a possible link between interplanetary solar wind speed V and geomagnetic index Kp, such a relationship has been examined by many workers and found to be rather loose. He the observation of solar X-ray flares during this period are presented. The relation of solar wind parameters with geomagnetic activity is also reported.

## 2. Most intense Solar X-ray flares

The flares on Sun are usually some what related to the area of solar flare, Fig. 1 shows the variation of all solar flares (S Flares) during the year 2003 with the Sunspot Area. The sunspot area in the month of October 2003 was the highest, however, there peaks of sunspot area in almost every solar rotation period (~27 days).

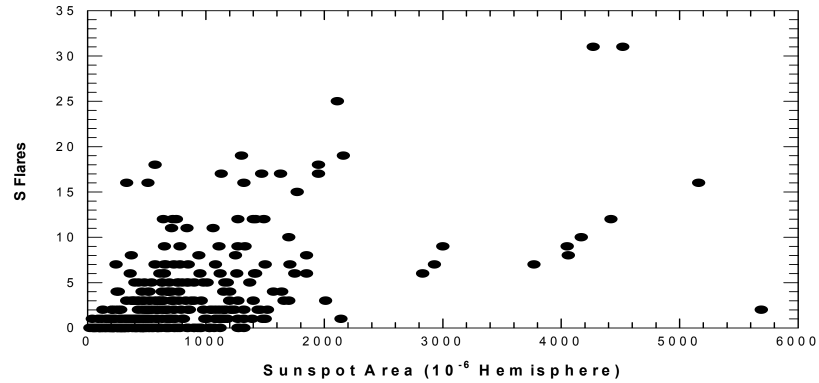


**Fig.1** Variation of Solar Flares with the sunspot area

During October – November 2003, three solar active regions produced a series of eruptions. These eruptions were extreme in terms of their origin and terrestrial consequence (Gopalswamy et al. 2005). Kane (2005) remarked that the largest Dst value was −589 nT on 13 March 1989 with V only ~550–800 km/s. The next largest Dst values were near −400 nT, but their V values were vastly different (Halloween events, 29 October 2003, Dst −401 nT, V ~ 2000 km/s and 20 November 2003, Dst −472 nT, V ~ 700 km/s). Fig.2 shows the solar X-ray observations of GOES satellite during the period of October-November 2003, clearly the Sun was most active and violent. This period had a large number of solar flares, three flares on October 28, 29 and November 4 were of class X17.2, X10 and X28 respectively. The X28 was the largest solar X-ray flare observed and recorded so far, all the three of these flares are one among the 14 most powerful flares observed in last three decades. Bhardwaj et al. 2005, reported that during Nov. 26–29, 2003 XMM-Newton observed soft (0.2–2 keV) X-ray emission from Jupiter for 69 hours. The simultaneous light curves of Jovian and solar X-rays show similar day-to-day variability. A large solar X-ray flare occurring on the Jupiter-facing side of the Sun was found to have a corresponding feature in the Jovian X rays. Thus X-ray emission from Jovian low-latitudes appears to be solar X rays scattered from the planet's upper atmosphere. This scattering would be significant only during strong solar X-ray

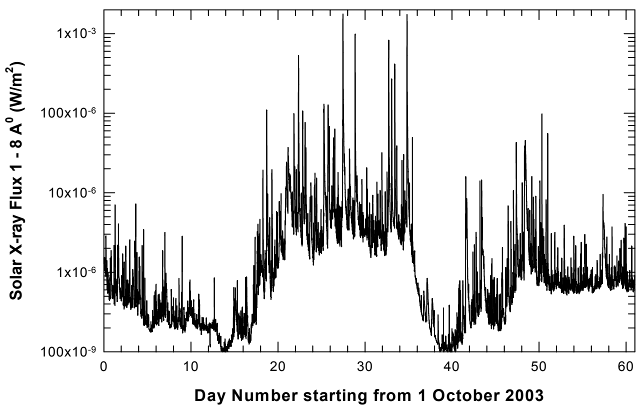


**Fig. 2** Solar X-ray flaring activity during October – November 2003

like the ones during this very active period of the solar eruptions. More observations of this type would firmly establish this. This indicates the period of October – November 2003 was the most violent period of cycle 23. The geomagnetic influence of the solar wind will be discussed in the next section.

## 3. Geomagnetic influence

Geomagnetic activity is caused by the transfer of momentum and energy from the solar wind to the magnetosphere. The geomagnetic activity is measured by the several indices e.g. Kp, Ap, Dst etc., here, Kp and Dst are used as the indicators. The interplanetary magnetic field (IMF) has three components. Of these the southward component of IMF termed as negative Bz, is considered the most important condition for the transfer of solar wind momentum and energy to the magnetosphere. When Bz is negative, the magnetospheric fields on the dayside are oppositely directed and facilitate reconnection of the two magnetic fields. The reconnection produces forces that transport magnetic flux into the polar caps (Lindsay et al., 1995). High solar wind enhances the interaction by increasing the flux of energy transported into magnetosphere. About 1 hour after the southward turning of the IMF, reconnection begins in the magneto tail. If the IMF remains southward (-Bz) for several hours, the associated steady duskward convection electric field energizes the ring current, thereby producing a geomagnetic storm (indicated by high values of Ap and Kp and also by the decrease in Dst (i.e. Dst becoming highly negative). When Bz turns northward, reconnection ceases, ring current decays and the magnetosphere returns to quiet state (Burton et al., 1975). The dependence of Bz and Dst index during October – November 2003 is shown in Fig. 3. Fig.3 clearly shows that except for a single event in which Dst is ~ - 400, all the other Dst values are higher than -200 for all the – Bz values. Whereas there are several points of Dst lesser than -200 for positive Bz, even the most negative value of Dst ` -461 nT is for Bz positive. Geomagnetic storms can occur due to several interplanetary features, including magnetic clouds, but it is only when the magnetic field of the interplanetary feature engulfing the Earth has a strong southward component (Wang et al. 2003). The interplanetary causes of geomagnetic storms have been extensively studied (Tsurutani et al. 1992 and references therein). The Earth-directed solar wind speed and southward component of interplanetary magnetic fields are of most importance in enhancing geomagnetic disturbances.

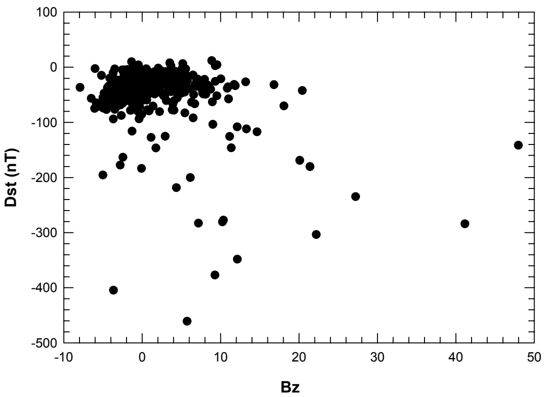

Fig.3 Dependence of Dst on Bz

at 5.7. This shows that southward turning or remaining has very little or no strong relation with the geomagnetic activity. Gonzalez et al., 2004, reported a poor relationship between V and Dst however, estimate of V could certainly be useful to estimate the time when the storm would hit the Earth but remembering that 15% of the halo CMEs may miss the Earth. To ascertain the dependence of geomagnetic indices on the parameters of solar wind and interplanetary medium during October – November 2003 events several combinations were tried. The most promising candidate is found in the form of solar wind RAM pressure. Figs. 4 and 5 show this dependence on Dst and Kp. Snyder et al. 1963, showed a possible link between interplanetary solar wind speed V and geomagnetic index Kp, such a relationship has been examined by many workers and found to be rather loose. In Fig.5 we best fit line is shown which indicate that most of the observations of October – November 2003 indicate linear relationship of Kp and solar wind pressure (nPa). Further, a ten fold increase in solar wind pressure increases Kp by 7.

## 4. Conclusions

The study of heliospheric observations of the most energetic solar event of cycle 23 presents

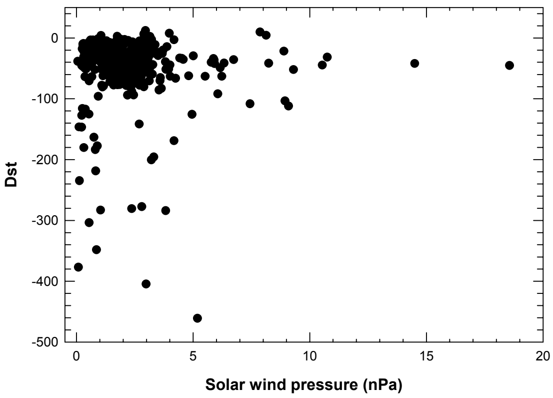

**Fig.4** Dependence of Dst on solar wind pressure

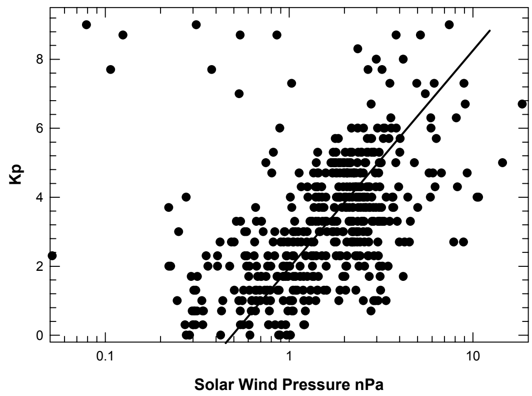

**Fig.5** Dependence of Kp on solar wind pressure

a very peculiar situation in which there are very strong or the strongest X-ray flares. In this period Bz is mostly positive. Even when Bz was negative all indices indicate no significant geomagnetic activity. Most of the geomagnetic storm activity was associated to positive Bz which contrary to the common belief. Thus either this period had some thing special which need to be understood or Bz is not an essential requirement for strong geomagnetic storms and sub-storms. In this case solar wind pressure seems to dominate as that showed an almost linear relationship with Kp. A ten fold increase in solar wind pressure increases Kp value by 7. More studies with other strong solar events are necessary to ascertain these findings.

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**References:**

[1] Bhardwaj, A., G. Branduardi-Raymont, R. F. Elsner, G. R. Gladstone, G. Ramsay, P. Rodriguez, R. Soria, J. H. Waite Jr., and T. E. Cravens, Solar control on Jupiter's equatorial X–ray emissions: 26–29 November 2003 XMM–Newton observation, *Geophys. Res. Lett.*, *32*, L03S08, 2005.

[2] Burton, R. K., R. L. McPherron and C. T. Russell, An impirical relationship between interplanetary conditions and Dst, J. Geophys. Res., 80, 5725, 1975.

[3] Gonzalez et al. 2004.

[4] Gopalswamy, N., L. Barbieri, G. Lu, S. P. Plunkett, and R. M. Skoug, Introduction to the special section: Violent Sun-Earth connection events of October–November 2003, Geophys. Res. Lett., 32, L03S01, 2005

[5] Kane, R. P. , How good is the relationship of solar and interplanetary plasma parameters with geomagnetic storms?, J. Geophys. Res., 110, A02213, 2005.

[6] Lindsay, G. M. Russell C. T. and J. G. Luhmann, Coronal mass ejection and stream interaction region characteristics and their potential geomagnetic effectiveness, J. Geophys. Res. 100, 16999, 1995.

[7] Snyder, C. W., M. Neugebauer, and U. R. Rao, The solar wind velocity and its correlation with cosmic ray variations and with solar and geomagnetic activity, J. Geophys. Res., 68, 6361, 1963.

[8] Tsurutani, B. T., W. D. Gonzalez, F. Tang, and Y. T. Lee, Great magnetic storms, Geophys. Res. Lett., 19, 73, 1992.

[9] Wang, Y., C. L. Shen, S. Wang, and P. Z. Ye (2003), An empirical formula relating the geomagnetic storm's intensity to the interplanetary parameters: $-VB_z$ (average) and $\Delta t$, Geophys. Res. Lett., 30(20), 2039,