# SOLAR WIND STREAMS AND THEIR IMPACT ON COSMIC RAY INTENSITY DECREASES IN YEAR 2003

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Long duration solar wind streams of very high velocity and long duration were observed during the year 2003, the declining phase of solar cycle 23. In this year large numbers of streams were found to be anomalous. Eleven events of high speed solar wind streams and associated cosmic ray intensity decreases (Fd) were observed in the year. During further analysis it was observed that during the event time period plasma density as well as the temperature increases. Moreover significant correlations between plasma density with plasma temperature and Dst with A*p* were observed. During the event time period, interplanetary magnetic field B is also found to increase along with the solar wind plasma speed.

## 1. INTRODUCTION

The short-term cosmic ray decreases are called Forbush Decreases (Forbush, 1937). Forbush decreases (Fd) are transient decreases in cosmic ray intensity generally having decrease in two steps or with an onset of sudden decrease associated with gradual recovery. Various investigators (Cane, 1995, Joselyn, 1986) have established that these decreases (Fd) are produced by perturbation in the interplanetary conditions and these perturbations originate from coronal mass ejections, solar flares and for shock wave and are generally associated with high-speed solar wind streams.

There are two types of Fds: (a) Non recurrent decreases: which are caused by interplanetary events related to solar flares and/or coronal mass ejections from the sun. These have sudden onset (in one or two steps) and reach their maximum depression in about day. (b) Recurrent decreases: which has a gradual onset and have symmetric profile; these tend to be associated with coronal hole associated high speed solar wind streams (Lockwood, 1971). Though geo-magnetic disturbances and Fds have a common origin in interplanetary space, the magnitudes of geomagnetic disturbance and Fds are not proportional to each other (*e.g.* Kane, 1977). Geomagnetic disturbance occur by the mechanism

(Dungey, 1961), where reconnection occurs at the day time magnetopause between the terrestrial magnetic field and the southward Bz component of the interplanetary field. When the field lines are swept back in the geomagnetic tail, a neutral point is formed through which the solar wind gets an entry into the magnetosphere. Low energy particles spiral around the stretched geomagnetic field lines and impinge on the terrestrial atmosphere in the Polar Regions, causing enhanced aurora. Higher energy particles rush towards the Earth but are diverted around the Earth in circular orbits in the equatorial plane, forming a ring current at several earth radii, which causes large geomagnetic field reductions. These reductions in the terrestrial magnetic field strength are measured by the Dst (disturbance storm time) index. It has been generally observed that with the increase of interplanetary magnetic field B (IMF) the solar wind plasma speed also increases.

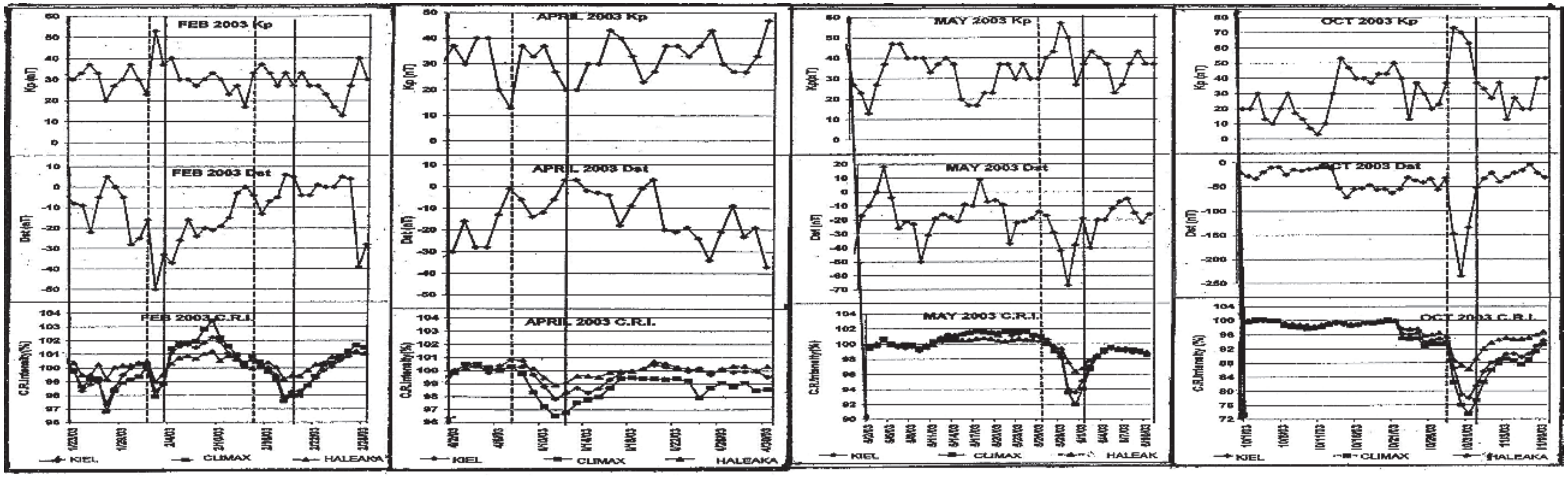
## 2. DATA AND METHOD OF ANALYSIS

Year 2003 is found to be anomalous because during the declining phase of solar activity (cycle 23) long duration solar wind streams with large value of geomagnetic disturbance Index A*p* are observed, there was a need to study the year 2003. In the present analysis, we start our examination by selecting all those days, which are associated with long duration high-speed solar wind streams and also the cosmic ray intensity for the same period. Out of such 11 events five events have been chosen for detailed studies. There five events started on ($2^{nd}$ Feb., $18^{th}$ Feb., 11 April, $8^{th}$ May, $31^{st}$ Oct. 2003). These events have associated significant cosmic ray decreases.

The cosmic ray decreases were identified from the hourly plots of cosmic ray intensity published by Nagoya University, Japan and by internet for the three neutron monitor stations, Kiel (2.29 Gev), Climax (3.0 Gev), Haleakala (13.3 Gev). The interplanetary magnetic field data, Dst, K*p*, solar wind plasma speed, plasma density, and plasma temperature data has also been obtained through National Space Science Data Center (NSDC). As and when necessary daily values have also been used.

## 3. RESULTS AND DISCUSSION

In the lower panel of Fig. 1 (a, b, c, d) daily values of cosmic ray intensity % deviation of three neutron monitor station have been plotted for five Fd events of February, April, May and October 2003. The middle and upper panel of Fig. 1 show the daily value of Dst and Kp for all the five events. One can see clearly from the Fig. 1 that in all the five events cosmic ray intensity is sharply decreasing and as well as recovery is also fast (within one or two days) except in



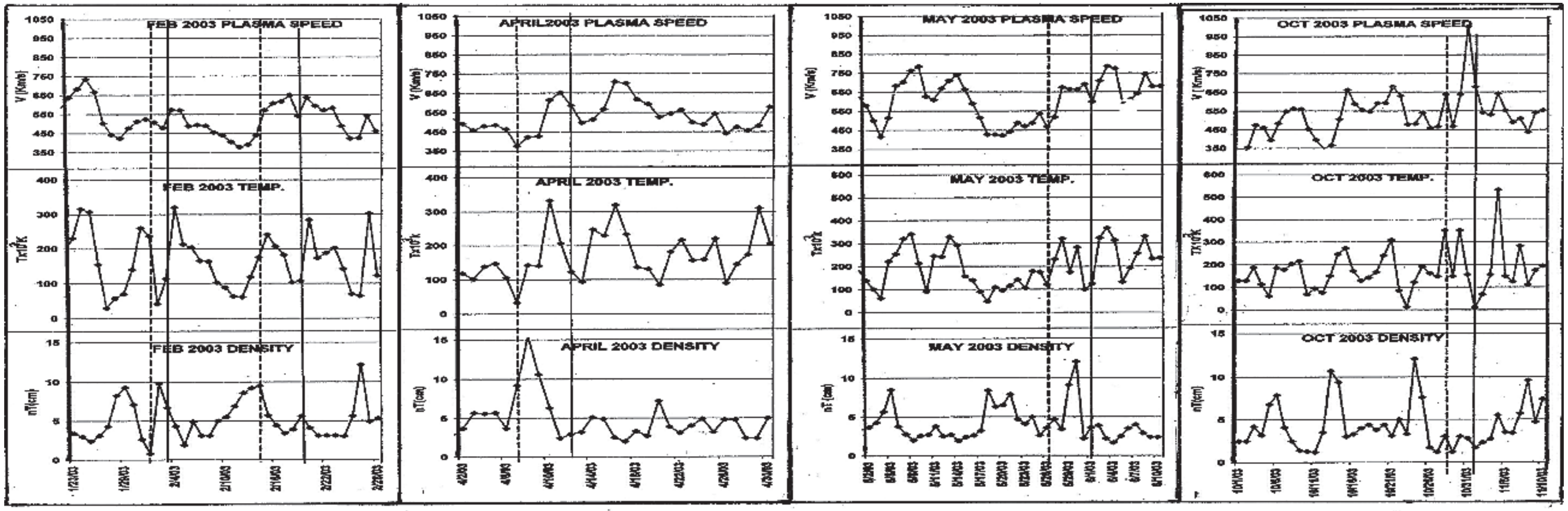

a) b) c) d)

Fig. 1 – Shows the daily values of K*p* (nT), Dst (nT) and C.R. (%) for a) 21 Jan. 2003 to 28 Feb. 2003, b) 2 April 2003 to 30 April 2003, c) 2 May 2003 to 10 June 2003, d) 1 Oct. 2003 to 10 Nov. 2003.

April, 2003. In all the five events, Dst, the disturbance storm time is decreasing on onset time of Fds, but the decrease is not of much magnitude (not greater than –70 nT) except in the event of October 2003, where Dst goes down upto –240 nT. Very surprisingly the Dst decrease during the events of 18$^{th}$ Feb. 2003 (Fd 6%) and in 11$^{th}$ April 2003 (Fd 4.5%) is very low (< 15 nT). Whereas, increasing trend in the K*p* index (maximum geomagnetic disturbance index) is also observed during the event time periods in almost all the events except in 18$^{th}$ Feb. 2003, where there is no increase observed. In October 2003, the K*p* index is found to have larger values in comparison to other four events. High speed solar wind streams have been observed during all the five event time period, with average velocity of 510 km/s, 588 km/s, 597 km/s, 561 km/s respectively, of duration 9 days (1 Feb – 9 Feb. 2003), 28 days (10 April – 07 May, 03) and 48 days (22 May, 03 – 08 July, 03) and 15 days (14 Oct. – 28 Oct. 2003). Lower panel of Fig. 2 (a, b, c) shows the plasma density for the five events from before and after ten days when the event has occurred, the middle and upper panel of Fig. 2 shows the plasma temperature and plasma speed for the same time periods.

It is clearly evident from the Fig. 2 that during the event time period the density and temperature increases except for the event of 16 Feb. 2003 where the density decreases and temperature is also decreasing, while the speed of solar wind velocity is much higher in almost all the events except in 18 Feb. event where no increase is seen. A good correlation is seen between temperature vs density during the event time period. It was noticed before that the relationship of cosmic ray decreases with Dst storm are poor (Cane 1996), whereas Dst having a good correlation with Bz. But here also during analysis we found a very good correlation between cosmic ray intensity decreases and Dst. In most of cases during the event time periods we found that B component of interplanetary parameter (IMF) is higher except for the events in 2$^{nd}$ Feb., 18$^{th}$ Feb. 2003 where no increasing pattern is observed, whereas Bx, By component did not show any trends having decreases in most of the cases, while Southward component Bz increases in one events and decreases in all other four events (Fig. 3). A very good correlation was observed between Dst and Kp during the event time period.

The heliospheric modulation process reflects the dominant role played by solar wind parameters which further play the key role in initiating the various space weather activities involving variety of phenomena, such as substorms, magnetic storms, acceleration of relativistic electrons (Ahluwalia, 2003; Feldstein, 1990). The Forbush decreases (Fds) are produced by perturbation in interplanetary conditions. These perturbations originate from CMEs, solar flares; high-speed solar wind streams investigators have reported two possible sources responsible for the decreases from high-speed plasma streams. One kind of which is associated with ejection of solar flares in solar active region while another depends upon the coronal holes (Shrivastava, 2003).




a) b) c) d)

Fig. 2 – Shows the daily values of plasma speed (Km/s), temp. ($T \times 10^3$ K) density (nT) for a) 21 Jan. 2003 to 28 Feb. 2003, b) 2 April 2003 to 30 April 2003, c) 2 May 2003 to 10 June 2003, d) 1 Oct. 2003 to 10 Nov. 2003.

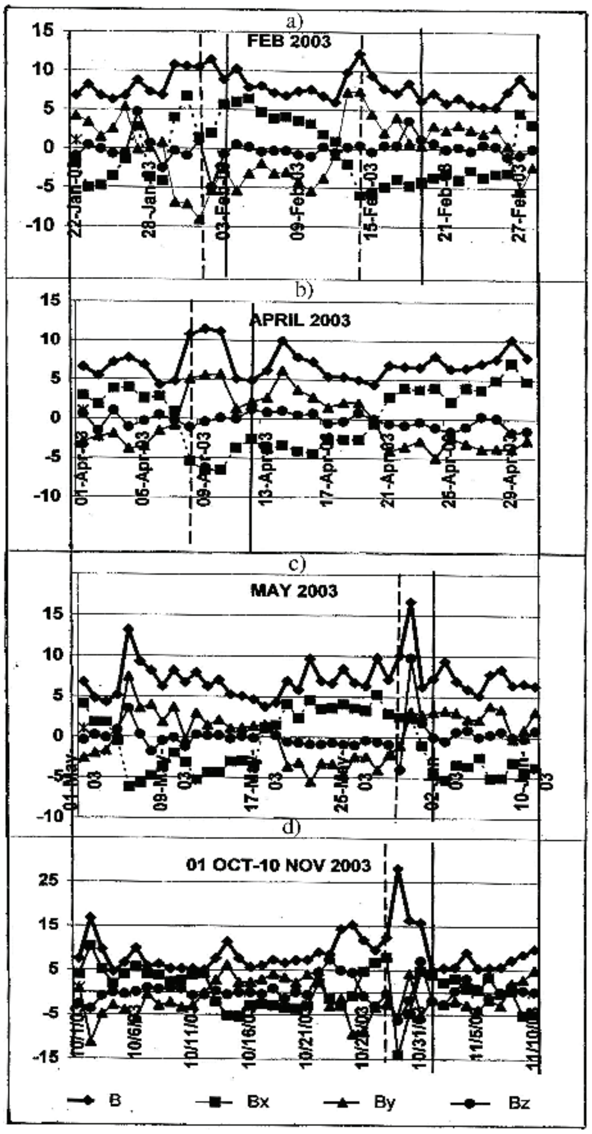



Fig. 3 – Shows the daily values of IMF component B, Bx, By, Bz (a) 21 Jan. 2003 to 28 Feb. 2003 (b) 2 April 2003 to 30 April 2003 (c) 2 May 2003 to 10 June 2003 (d) 1 Oct. 2003 to 10 Nov. 2003.

But finding the reasons here for the decreases in cosmic ray intensity and high speed solar wind streams during the event time period. We have gone through coronal holes structure and CME events occurring in the event time period. Surprising we observed that in February, April, May, 2003 events time period no major solar flares (> 10), no halo CME events were found though some of the coronal hole sectors were present during the event in May, 2003, CME occurred on 29 May at 1:29:12 and a coronal hole sector was also observed from 21–25, May. However, the decrease in cosmic ray intensity started before the CME event, but it may be thought that as the coronal hole sector was present from 25 of May 2003 the solar wind plasma speed started to increase and a high-speed solar wind stream was formed. In the October 2003 no major solar flares are observed but during the event time period two CMEs on 28 and 29 October 2003 were observed at time 11:30:05 and 20:54:05 respectively, no coronal hole sector was observed during the event time period. The reasons behind high speed solar wind stream and cosmic ray intensity decreases (Fds) during the events of May and October, 2003, may be the perturbations made by CMEs during the event time period. During the events of 18 February and 11 April, 2003, no major Dst storm was observed, neither the geomagnetic storm index was much higher, but the decrease in cosmic ray intensity of 6% (18 February, 2003) and 4.5% (11 April, 2003) was observed, the reasons behind these decreases (Fds) in February and April, 2003 is not yet understood and its a topic for the further investigation for the reasons behind the perturbation in interplanetary condition.

## 5. CONCLUSION

1. The year 2003 is anomalous, very large long duration high-speed solar winds streams were observed.

2. The long duration solar wind streams were found to be responsible for cosmic ray intensity decreases.

3. During cosmic ray decreases (Fds) solar wind plasma density and temperature's increasing trend was observed except for the event of 18$^{th}$ February 2003.

4. A good correlation between plasma temperature and density is observed.

5. A very good negative correlation between Dst and K*p* was observed during event time period.

6. During the event as interplanetary magnetic field B increases the solar wind plasma speed also increases.

5. The events (Fd) of 18 February is very peculiar, no solar flares, no CME and no higher value of interplanetary magnetic field B but decrease of 6% in cosmic ray intensity needs further investigation.

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