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A comparative study of Forbush decrease events of February and August, 1999

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Abstract : Forbush decrease in cosmic ray intensity shows a sudden decrease in count rates of neutrons followed by a slow recovery, typically lasting for several days. Two such Forbush decrease events noted first in August 19 to 29, 1999 and another in February 15 to 23, 1999 occurred during a high solar activity period in 1999. It is noteworthy that both the events were accompanied with several intense solar flares and geomagnetic stroms. In this paper, we made a comparative analysis of the characteristics and production mechanisms of the events. Further, we have found out a significant correlation between cosmic ray intensity variation and geomagnetic activity index *Dst*. Decrease in *Dst* values shows a similar pattern of cosmic ray decreases, indicating a strong relationship between the two. Results of analysis also suggest a strong relationship between geomagnetic activity and cosmic ray intensity variation on short-term basis.

Keywords Forbush decrease, solar flares, magnetic stroms

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1. Introduction

Transient and rapid decrease in cosmic ray intensity followed by a slow recovery is called as a Forbush decrease event in cosmic ray intensity. The various cosmic ray researchers established that these Forbush decreases are produced by perturbation in interplanetary condition and that these perturbations originate either from solar flares or from magnetic field structures associated with interplanetary solar wind streams [1,2]. The perturbation could be produced from shock waves, coronal mass ejection and flare generated high solar wind streams [3,4]. In 1975, Barouch and Burlaga [5] have reported that the high magnetic field regions in the interplanetary space are associated with Forbush decrease. Further, thay have demonstrated that these cosmic ray decreases are not related to the turbulent or random motions in the field, while only the regions of high field strength in interplanetary space are found responsible for causing Forbush decreases. These regions consist of magnetic blobes and magnetic clouds ejected from active solar regions. In the environment of shocks, high speed streams are simply tangential discontinuities [5].

Iucci *et al* [6] investigated the idea of spiral cone like region which extends along the interplanetary magnetic field. Further, they have shown that in a two-step decrease, the first step is symmetric and is due to shock passage, whereas the second step is strongly asymmetric and is due to the entire magnetic field and with a loop like field configuration.

They have also determined the separate configuration of shock front and the magnetic perturbation during the period of Forbush decrease. In this study, we have compared the characteristic of Forbush decrease events of August 19 to 29, 1999 and February 15 to 23, 1999.

2. Data analysis

We have identified these two events of Forbush decreases from the hourly plots of two neutron monitors Kiel and Climax. Daily mean values of cosmic rays have been used in this analysis from these two stations situated at two

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different locations (Table 1). We have used the *Ap/Dst* indices for geomagnetic activity and sun spot numbers/solar flares are taken as reliable solar parameters of solar activity.

Table 1. Location of neutron monitors.

S No	Station name	Geographical Latitude (degree)	Geographical Longitude (degree)	Cut-off rigidity GV
1	Calgary	51 08 N	245 91 W	1 09
2	Goose Bay	53.27 N	60 40 W	0.69
3	Climax	39 37 N	106 18 W	2.97
4	Moscow	55.47 N	37 32 E	2 41
5	Kiel	54.3 N	10 1 E	2.23

Cosmic rays, geomagnetic and solar activity data for the period of February, 1999 have been taken from prompt report of Solar geophysical data book [7]. All these data sets for August, 1999 event have been taken from the prompt report of Solar geophysical data book [8].

3. Results and discussion

Figure 1(a) displays the daily average cosmic ray intensity from 1 August to 9 September, 1999, as recorded by Kiel and Climax ground based neutron monitors. Middle and upper panels of Figure 1(a) show the daily values of cosmic ray intensity for Kiel and Climax station respectively, and lower panel of Figure 1 shows the ratio of Kiel and Climax

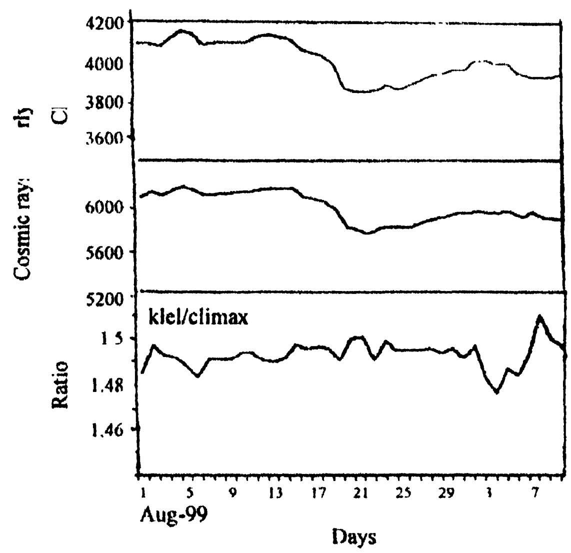

Figure 1(a). Shows the daily average counts of Kiel and Climax neutron monitors for August, 1999. Ratio of Kiel and Climax neutron counts are also plotted in lower panel of figure.

daily counts of neutron monitor data. Similarly, Figure 1(b) shows the similar plots for the period of February 7 to 28, 1999. We can observe significant cosmic ray decrease in both the plots. Only differences are noticed in the ratio of Kiel and Climax data.

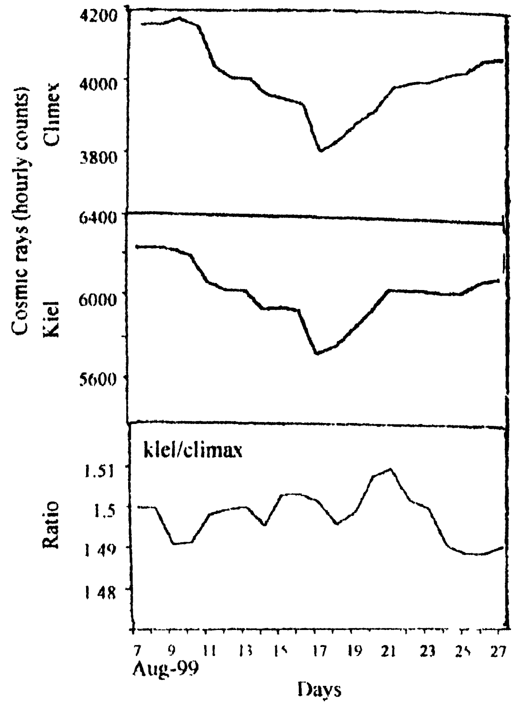

Figure 1(b). Shows the daily average counts of Kiel and Climax neutron monitors for February, 1999 Ratio of the daily average counts at Kiel and Climax is also plotted in lower panel.

We have plotted the daily values cosmic ray intensity of Kiel and Climax neutron alongwith the ratio of Kiel and Climax count rates. Decreases in cosmic ray intensity are well depicted in middle and upper panel of the figure. Ratios of Kiel and Climax cosmic ray intensity are shown in the upper pannel of the figure. During the period of February, 1999 event, the ratio of Kiel and Climax neutrons vary by more than 30%. On the other hand, variation in ratio is nearly constant during the period of August, 1999 event. These results indicate that the cosmic ray particles get into modulated in different way in different interplanetary conditions. The ratio of cosmic ray counts of Kiel/Climax neutron get into modulated due to the larger influence of interplanetary shock waves during the period of February, 1999. The shock shields more cosmic ray particles in high longitude of western zone that low longitude of eastern zone of the earth.

Figure 2(a) shows the Forbush decrease event of August, 1999. Onset time of this event is in early hours August, 1999 and it remains low during four to five days. Recovery period of this Forbush decrease event is five days. The Figure shows cosmic ray intensity plot for several neutron monitor stations situated at, Calgary, Goosebay, Moscow, Climax, Kiel, Beijing and Haleakala covering a wide range of cut-off rigidity. Daily values of *Dst* index are plotted in upper panel of Figure 2(a) for the event of August 1999. Several intense solar flares are observed during the event period. Solar flares of 17th August which occurred in NOAA region of 8668 seems to be more powerful in producing decrease in cosmic ray intensity. Further, solar flare events of 19, 20 and 21st August in same NOAA region are also supported to enhance the decrease in cosmic ray intensity.

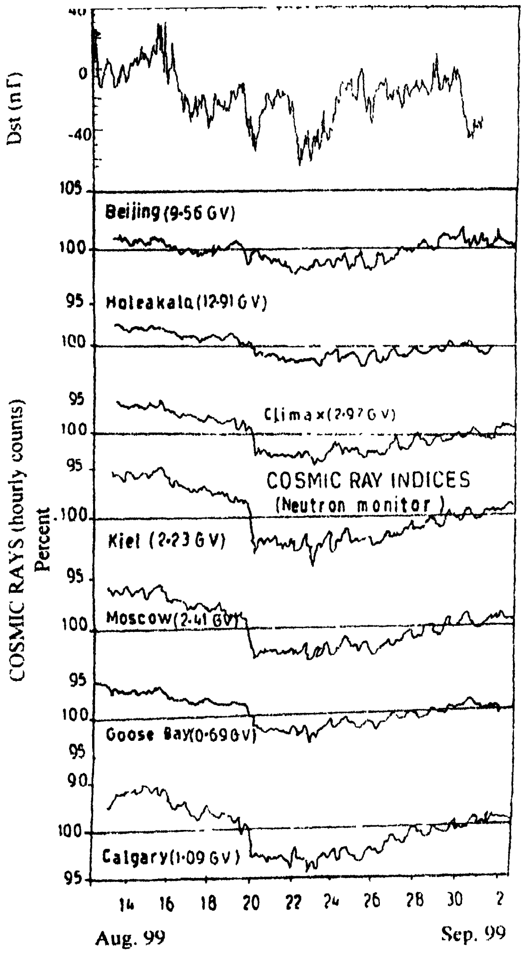

Figure 2(a). Shows the plots for hourly values of cosmic rays for several neutron monitors for August, 1999 Forbush decrease event. *Dst* values are plotted in upper panel.

Major solar flare events of August 20 and 21 are responsible for the maximum decrease on August 23. A series of geomagnetic events occurring on August 16, 17, 18 and 22 provided a possible solar terrestrial relationship during the period of Forbush decrease.

Similarly Figure 2(b) shows the plot of Forbush decrease event of same neutron monitor stations for the period of February 15 to 23, 1999. The values of *Dst* index for the period of February 1999 are also plotted in the Figure. Significant variations in *Dst* values were noticed during the period of the events. Onset time of this event was February 17 and it remained low during two days. Recovery period of this event was four days. We noticed two major solar flares on February 15 and 16 on Noaa region of 8462 which might have affected large decrease in cosmic ray intensity. We have also noted geomagnetic storms on 17 and 18 February, which incidentally coincides with the maximum decrease of cosmic ray intensity.

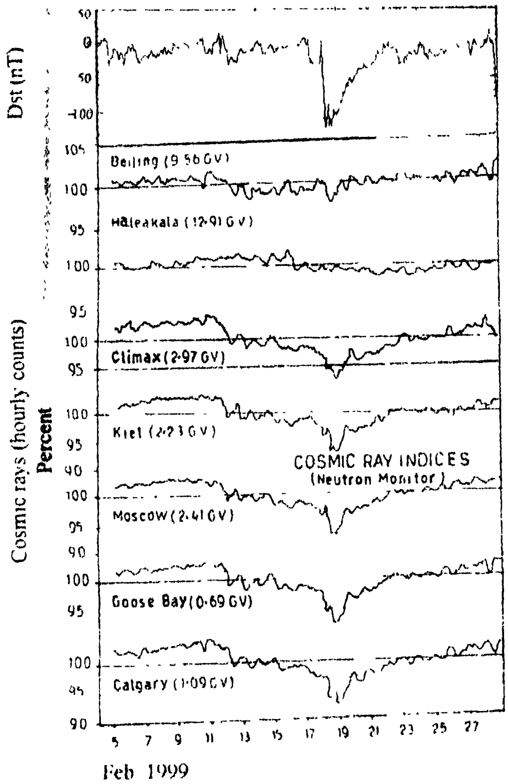

Figure 2(b). Shows the plots for cosmic ray intensity variation for several neutron monitors for February, 1999 *Dst* values are also plotted in upper panel

Further, we have plotted the daily values of Sunspot number (*Rz*) and *Ap* index for both the events as depicted in the Figure 3(a) for August 1999 and 3(b) for February, 1999 respectively. Low *Rz* values and high *Ap* values were seen during the period of Forbush decrease event of August 1999 and similar by high *Ap* values were observed during

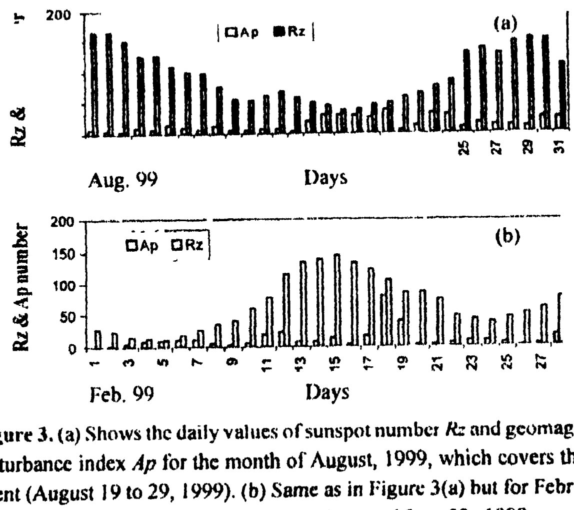

Figure 3. (a) Shows the daily values of sunspot number *Rz* and geomagnetic disturbance index *Ap* for the month of August, 1999, which covers the *Fd* event (August 19 to 29, 1999). (b) Same as in Figure 3(a) but for February, 1999, which covers the *Fd* event of February 15 to 23, 1999.

the event period of February, 1999. However, high sunspot numbers were also observed during this event period. In this way, we observed a difference in variation of sunspot numbers during these two events. We also observed a significant pre-increase in *Rz* values.

Conditions of interplanetary medium play an important role in energy transmission from solar wind to magnetosphere which significantly modulated cosmic ray particles. Forbush decrease events as we observed during August and February, 1999, are examples of such events. To draw a possible relationship between cosmic ray decrease and interplanetary features, we have plotted the daily values of solar wind velocity (SWV), solar magnetic field (SMF) and interplanetary magnetic field *B* (*nT*) as shown in Figure 4(a) and 4(b) for August and February events respectively.

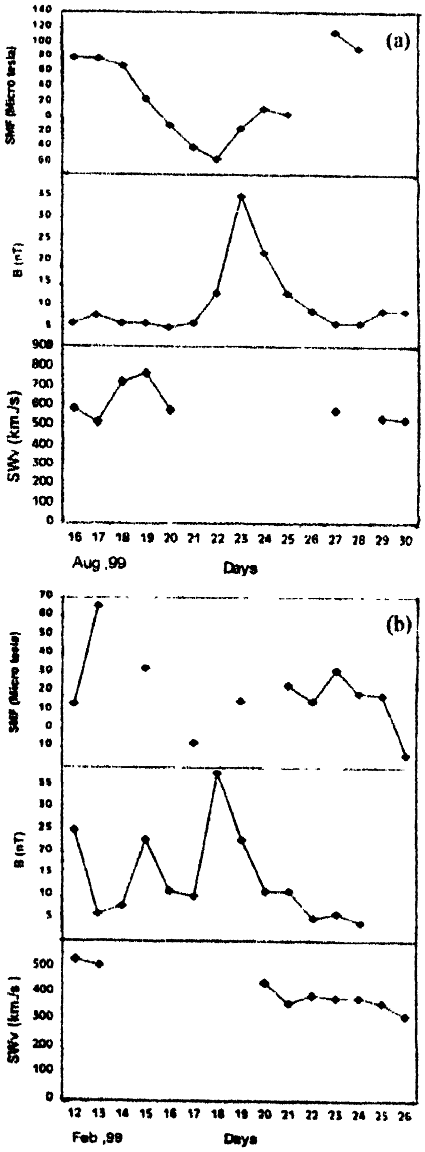

Figure 4. **(a) Shows the daily values of solar wind velocity, solar magnetic field and interplanetary magnetic field for August, 1999. (b) Same as in Figure 4(a) bur for February, 1999.**

Here, *B* (*nT*) shows the total magnetic field values of interplanetary medium, which were monitored by IMP-8 space craft in GSE co-ordinates. Solar wind velocity are also monitored by the detector on board of IMP-8 space craft. Solar magnetic field values were different from these two interplanetary features and magnetic field on solar disc. It is seen from the Figure 4(a) that solar magnetic field is lower during event periods.

Simultaneously, we have observed high solar wind speed and *B* (*nT*) period to event periods. Occurrence of several intense solar flare along with flare generated solar wind streams are expected to causes of Forbush decrease event of August, 1999. Similarly, we have plotted daily values of all these parameters in Figure 4(b) for the February, 1999 event Higher values of *B* (*nT*) coincide with the event period and lower solar magnetic field strengths also are seen for event February, 1999 event. Solar wind velocity data were not available during event period to draw any meaningful conclusions. Hence, we infer the similar interplanetary conditions for both the events. However, variation in cosmic ray intensity of event periods, depend on the larger/smaller disturbances in interplanetary condition. High speed solar wind streams particularly generated by solar flare, are found to be more responsible factors in producing transient decreases in cosmic rays. Most dominatent and important features in interplanetary medium are with solar wind plasma streams (high speeds), which produce large decrease in cosmic ray intensity. The decrease in cosmic ray intensity is expected due to the shielding of cosmic ray particles by the shock fronts produced by flare generated high speed solar wind stream. This result is consistent with previous results reported by Shrivastava and Shukla [4] in 1994 They observed that the flare generated high speed solar wind streams are more effective in modulating the cosmic ray intensity.

It is clear from the figures that the cosmic ray intensity decreases with the decrease of *Dst* values. Variational profiles of *Dst* index for these two event periods vary according to variational profiles of Forbush decrease events. A large and narrow decrease in *Dst* index during the period of February 15 to 23 coincides with the main phase of Forbush decrease event of February, 1999. Similarly, we also observed a significant decrease in *Dst* index which coincides with decreases of cosmic ray intensity for entire period of Forbush decrease event August, 1999. In both the events, we have observed significant decreases in cosmic ray intensity as well as geomagnetic Dst index during the main phase and recovery phase of storm.

The relationships between the solar flare and cosmic ray intensity decrease observed during these two events were similar to that found in previous investigation [9]. The solar flare effect has the north south asymmetry. The flare located in northern hemisphere can cause longer disturbance in cosmic ray intensity than in southern hemisphere.

One sudden storm commencement (SSC) was observed on February 17, 1999 in association with the Forbush decrease event of Frbruary, 1999. As we known SSC is a signature of arrival of shock waves. Therefore, it can be inferred that shock waves also play an important role in producing large cosmic ray decreases.

Significant fluctuations were seen in geomagnetic *Dst* index during both the periods of Forbush decrease. The values of *Dst* index show significant transient decrease in similar pattern as that of Forbush decrease. The geomagnetic distrubance index *Dst* recorded at low latitude which comes from the outward blowing zonal current system called the ring current. The *Dst* index gives the average depression of horizontal component in unit of *nT*, which is proportional to the total kinetic energy of symmetrically distributed particles injected and trapped in the Van Allen belt. It is assumed that the massive compression of the magnetosphere and enormous intensification of the large scale magnetosphere current system reflected in *Dst* lead to a significant geomagnetic effect on cosmic ray measurement near the earth.

It is known that coronal mass ejections (CMEs) events are generally associated with solar flares. CMEs have considerable importance towards our understanding of the heliospheric disturbances because of the open out and expand amout of mass and energy injected into interplanetary medium. In a number of recent studies CMEs are investigated as geomagnetic and cosmic ray disturbances [10]. We have noticed a number of CMEs events during both August and February events of Forbush decreases. We observed two CME events on 17 and 22 August. Similarly, we observed a series of CME events on 12, 13, 14, 20 and 21 February. Now, we can say that the CMEs are also one of the factors in producing short-term decreases on short-term basis.

4. Conclusions

From the comparative analysis of these two Forbush decrease events of August and Frbruary, 1999, it can be concluded that these events were found very much influenced by the magnetic field of the earth. Both the events were found to be associated with geomagnetic storms. Their main phases also coincide with maximum decrease in *Dst* values. This leads to confirm the ring current effect on cosmic ray intensity modulation. We can distinguish these events only on the basis of Sudden Storm Commencements (SSCs). Occurrence of SSC event on 17th February 1999, clearly exhibits the effects of interplanetary shock waves on cosmic ray intensity which shows a step like decrease in shorter time scale. However, effects of intense solar flare on cosmic ray decrease are significantly seen in both these events. It is found that the CMEs are also one of the factors in interplanetary medium to produce geomagnetic disturbances and depression in cosmic ray intensity. However, occurrence of large number of CMEs during February, 1999 produce larger decrease in comparison to Forbush decrease event of August, 1999, where we observed less number of CMEs.

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References

[1] E N Parker *Interplanetary Dynamical Processes* (New York : Interscience, John Viley and Sons) (1963)

[2] A Kadokura and A Nishida *J Geophys Res* **91** 13 (1986)

[3] H V Cane and I G Richardson *J Geophys Res* **100** 1755 (1995)

[4] P K Shrivastava and R P Shukla *Solar Physics* **154** 177 (1994)

[5] E Barouch and L F Burlaga *J. Geophys Res* **80** 449 (1975)

[6] N Iucci, M Parisi, C Signorini and G Vello Rest *Nuov Cim* **7C** (1984)

[7] *Solar Geophysical Data* (Prompt Report Compiled by NGDC, Boulder, Colorado) **Vol. 653** Part I p114 (1999)

[8] *Solar Geophysical Data* (Prompt Report Compiled by NGDC, Boulder, Calorado) **Vol. 663** Part I p121 (1999)

[9] Xue Shunshong and Ye Zhonghei *Proc 21-st Intl Cosmic Ray Conf* (Adeliad, Australia) **Vol. 6** p 241 (1990)

[10] P K Shrivastava *Proc 27-th Intl. Cosmic Ray Conf* (Germany Hamburg) **Vol. SH 9** p 3481 (2001)