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Study of Intense Geomagnetic Storms and associated Cosmic Ray Intensity Variation

Subhash C. Kaushik[a], A. K. Shrivastava[b] and Hari Mohan Rajput[b]

(a) Department of Physics, Government Autonomous PG College, Datia, M P 475 661, India
(b) School of Studies in Physics, Jiwaji University, Gwalior, M P 461 005, India
Presenter: H. M. Rajput(subash_kaushik@rediffmail.com), ind-kaushik-SC-abs1-sh34-oral

Shocks driven by energetic coronal mass ejections (CME's) and other interplanetary (IP) transients are mainly responsible for initiating large and intense geomagnetic storms. Observational results indicate that galactic cosmic rays (GCR) coming from deep surface interact with these abnormal solar and interplanetary conditions and suffer modulation effects. In this paper a systematic study has been performed to analyze the cosmic ray intensity variation during highly geoeffective conditions, referred by geomagnetic storms. These intense geomagnetic storms period have been categorized on the basis ofD_st index. Study reveals the significant decrease in the cosmic ray intensity following the similar pattern as the D_st index depicts. Analysis further indicates that magnitude of all the responses depend upon B_Z component of interplanetary magnetic field (IMF) being well correlated with solar maximum and minimum periods. Transient decrease in cosmic ray intensity with slow recovery is observed during the storm phase duration.

1. Introduction

Investigators have revealed that various activities taking place on Sun and other interplanetary proxies of coronal mass ejection's (CME's) lead to Cosmic ray (CR) modulations at neutron monitor energies. This heliospheric modulation process reflects the dominant role played by solar wind parameters (bulk speed and the IMF intensity). 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 etc [1] [2]. It is well known fact that solar wind velocity plays an important role to produce short- term as well as long- term modulation of cosmic rays and Forbush decreases (Fd's) are produced by perturbation in interplanetary conditions. These perturbations originate from shock waves, CME's, solar flares, high speed solar wind streams. As solar wind consists of various plasma and magnetic field characteristics, these plasma signatures in interplanetary medium produce disturbances in Earth's magnetic field whose intensity/ strength depending upon the nature of ejecta [3] [4] [5]. Interplanetary plasma data obtained from spacecraft's observations allowed rapid progress in relating cosmic rays variation with other solar and interplanetary characteristics. investigators have reported two possible sources responsible for the decrease from high speed -speed plasma streams observed in ecliptic plane. One kind of which is associated with ejection of solar flares in solar active region while another depends up on the coronal holes. Furthermore, flare generated streams and coronal -hole -associated streams have been defined [4] [6].

Geomagnetic storms are multifaceted phenomena originated at the Sun's atmosphere. These occur in interplanetary medium filled with solar wind i.e. the magnetosphere. The study of these worldwide disturbances of Earth's magnetic field are important in understanding the dynamics of solar -terrestrial environment and further more because they create electrical power network outrages, damage earth orbiting satellites or reducing their life time, disrupt the communication systems, satellite control systems, influence badly geophysical exploration programs, pose health hazards to air line passengers at higher altitudes and other research campaigns are highly influenced due to the occurrence of these terrestrial activities originated at the Sun's environment [2]. Present paper aims on the behavior of cosmic ray intensity during strong geomagnetic storms activity period. That is mainly concentrating on intense magnetic storms ($D_st \geq$ -150 nT), categorized on the basis of their intensity by D_st index.

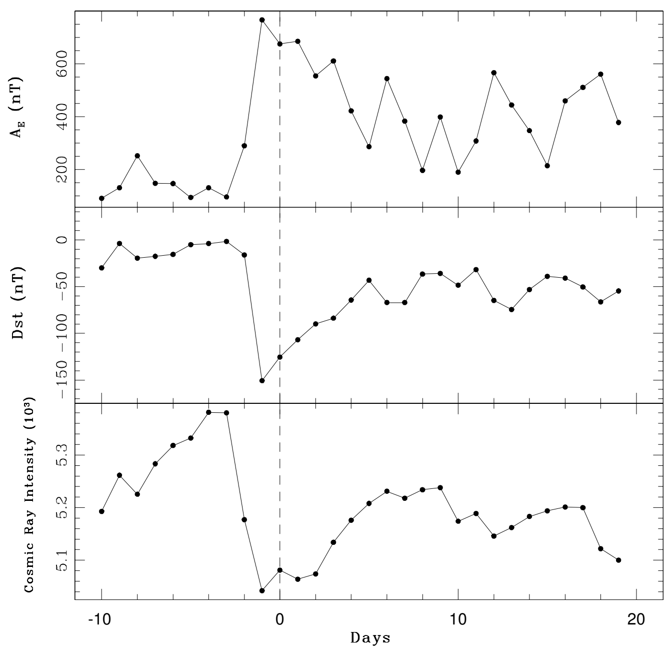

Figure 1. Plots depict cosmic ray intensity variation, Disturbance Storm Time index (D_st) and the Auroral electrojet (A_E) during the event period, on day to day basis. The occurrence of event is represented by O day on x-axis.

2. Data

We have analyzed the events represented by maximum D_st decrease. The study has been performed to analyze the cosmic ray intensity variation during this prescribed period 1979-2004. The neutron monitor data of three stations Oulu (Rc = 0.77 GV), Climax (Rc = 2.97 GV) and Huancayo (Rc = 13.01 GV) located at different latitudes have been used for this purpose. We have used hourly averaged IMF components and solar wind plasma data at 1 AU obtained from satellite observations provided by National Space Science Data Center (NSSDC) through its OMINIWEB (http://www.nssdc.gsfc.nasa/ominiweb.html) [7] [8]. Introduced in 1964, the ring current index Dst measures primarily the ring current magnetic field, using which one can investigate the low latitude effects. Here D_st is used as an indicator of geomagnetic activity to derive the possible relationship between cosmic rays intensity with geomagnetic activity [9].

3. Discussion

A geomagnetic storm is the response of the magnetosphere to the interplanetary phenomena arising as a sequence of activities taking place on the solar surface. The magnitude of these events further depends up on

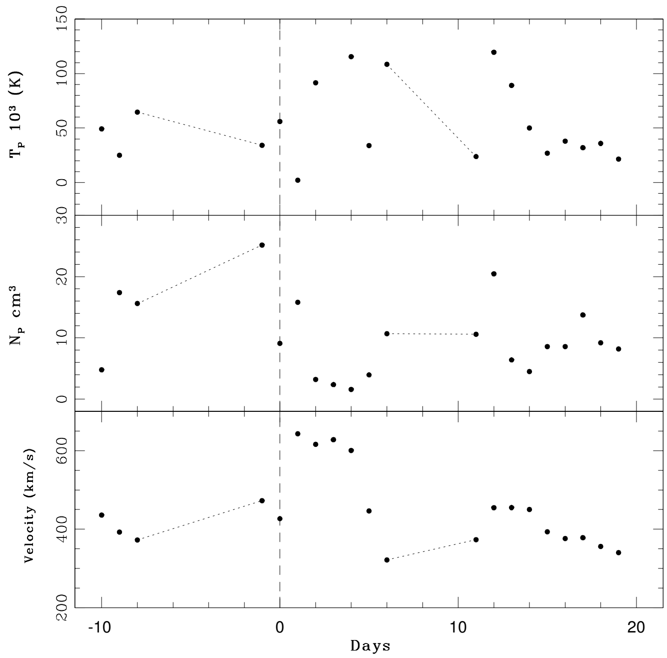

Figure 2. It represents solar wind parameters, lower panel depicts bulk speed, while ion density and ion temperature is shown in middle and upper panels respectively on day to day basis event day is represented by O on x-axis. Dotted lines represent the data gap.

the nature of ejecta and the possible interplanetary circumstances present at the time of occurrence. Investigators have observed a common association between solar and interplanetary events assumed as interplanetary CME's, co-rotating interaction regions (CIR's) [5] [9] [10]. As the aim of this study is to analyze the events which are highly geoeffective and than to find possible correlation between geomagnetic indices and cosmic ray intensity variation. To perform the study hourly averaged values of solar and geomagnetic indices is obtained from NSSDC [7] [8] [9]. The result are shown in figures 1 and 2. Cosmic ray intensity is shown in the lower panel of figure 1, while the geomagnetic indices D_st and A_E are shown in middle and upper panels. Figure 2 represents the bulk speed , ion density and ion temperature in respective panels. On comparing the averaged behaviour of parameters shown in figure 1, it is found that geomagnetic D_st index follows the same decrease pattern as that of cosmic ray particles. D_st index produce a significant decrease profile. As most of storms have been associated with coronal mass ejections. These events are large- scale structures and becomes highly geoeffective while travelling towards Earth. As in the case of Halo- CME's, they are supposed to play the key role in originating the geomagnetic activities in the magnetosphere. In the ejecta magnetic field varies very slowly and the magnetic field strength increases. At the same time plasma proton's temperature and thermal pressure decrease, while the solar wind speed also decreases as the ejecta passes through the interplanetary medium. In some cases the ejecta also present smooth rotation of magnetic field vector, resulting in to the interaction of this compressed plasma high speed flow with preceding slow solar wind. As a consequence the proton temperature, magnetic field strength increases while the solar wind speed rises [11] [12]. This is seen in figure 2 as immediately after the occurrence of event the bulk speed enhances. These compressed streams produce modulation effects in cosmic ray particles responsible for the significant decrease pattern as observed in figure 1. Observations indicate the strong association between super geomagnetic storms with CME's. Which is obvious as these solar events are large scale ejecta eruptions of solar wind plasma, that are further responsible for effectively modulating the cosmic ray intensity.

4. Conclusions

1. The occurrence of most of the events is dominant during the southward turning of B_Z component of IMF that leads to the significant decrease in D_st index as well as in the cosmic ray intensity.

2. Most of the events are associated with transient decreases in cosmic ray intensity, identified as Forbush decrease (Fd's).

3. Intense storms are having their well defined solar origin as during solar maximum the occurrence rate is 55% while it is only 45% during solar minimum phase of solar cycle.

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