Proceedings of the 30th International Cosmic Ray Conference
Rogelio Caballero, Juan Carlos D'Olivo, Gustavo Medina-Tanco,
Lukas Nellen, Federico A. Sánchez, José F. Valdés-Galicia (eds.)
Universidad Nacional Autónoma de México,
Mexico City, Mexico, 2008
Vol. 1 (SH), pages 307–310

ID 194

30TH INTERNATIONAL COSMIC RAY CONFERENCE

Mérida, México

Study of two major Forbush decrease events of 2005

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Abstract: Two major Forbush Decrease (FD) events were recorded – one on 15th May and other on 9th November 2005, of magnitudes 18 % and 12 % respectively. We have taken the data for cosmic ray intensity from Neutron Monitor stations at Oulu and Mawson, Antarctica. In the present paper an analysis of the relation of FDs to the sources and different parameters of the interplanetary medium and geospace is studied. The data corresponding to Sun Spot Numbers, Solar Wind Velocity, Dst index and Ap index have been taken along with the variation in the Cosmic Ray Intensity to find a correlation between CRI and above parameters. Results indicate that there is a strong relationship of FDs with solar activities which further influence Earth environment. The main cause for such large decrease should be intense solar flares followed by coronal mass ejections.

Introduction

Forbush Decreases is a transient and rapid decrease in galactic cosmic ray intensity (GCR) followed by slow recovery, which is observed at 1AU near Earth regions. It is a complex phenomenon, which may incorporate cosmic ray variations of interplanetary, geomagnetic and solar origin. The reduction is from about 3-20% and occurs over a timescale of several hours to a few days since their discovery [1] they have been extensively studied and many associated features have been clarified. Nevertheless, this subject is not only unexhausted but on the contrary it becomes more and more interesting [2].

A deficit of GCR is mainly due to a coronal mass ejection associated with big solar flares as reported by several scientists [3] It is caused by the passage of condensed and irregular magnetized shock with a velocity of ~ 1000 kms^{-1} and the magnetic shield effect after the passage [4] driven by the CME. It has to be affected by a size, a velocity and strength of irregular magnetic field of CME and associated shock wave. It is also assumed that the solar wind is responsible for convecting the CME material to the Earth. Therefore the flight time for the CME ejecta is connected to the solar wind [5]. Hence the propagation of ejecta (magnetic clouds) in the solar wind should be studied to understand the mechanisms of Forbush decreases properly.

The magnetic field near the Earth was found to be increased at the time of Forbush decreases [6] due to the impact of CME and very often FD appears simultaneously with a geomagnetic storm, which connects FD and magnetic disturbances on Earth. In the last few years number of solid evidences have appeared indicating geomagnetic storms of scales G5 (Kp=9), G4 (Kp=8) and G3 (Kp=7) are dangerous for people technology and health [7]. As Forbush Decrease events data can be used in forecasting such dangerous geomagnetic storms, it is essential to analyze the background of large decrease in cosmic rays regarding solar and geomagnetic activities. A number of extreme events have taken place in a time period very close to the minimum of the 23rd cycle of solar activity [8], [9], [10] and solar flare and coronal mass ejection produced large variations in cosmic ray intensity. Lot of attempts [11] has been made to explore the relation between these phenomena and their impact on cosmic rays. In the present paper we have selected two major FD events of 2005 – one of 15th May and another of 9th November and the CR variations for both events are studied in reference to solar as well as geomagnetic parameters.

Specifically a large FD (~18%) detected by neutron monitors all over the world on 15th May 2005 was a peculiar event in response to intense solar flare associated with CME. The effect of various solar parameters and their correlation with the large FD of 15th May 2005 is analyzed in this paper. Since the event was accompanied by major geomagnetic storm also we tried to find its correlation with the geomagnetic parameters in terms of geomagnetic index Dst. The data for solar wind velocity and sun spot numbers (SSN) have been taken from website of Solar Geophysical data center and plots of their averaged values for the month of May 2005 are compared with the variation in cosmic ray intensity taken from Moscow neutron monitor station.

The second event i.e. of 9th November was also large (~12%) observed by neutron monitors station at Mawson, Antarctica. Though it is not observed at other stations but it is found to be connected with solar flare and CME. The geomagnetic storm observed on 12th November supports the relation of FD with magnetic field disturbances on Earth.

From all available data an effort has been made to acknowledge all possible causes that can lead to above kind of events. Proposed study could be of great scientific interest because of some uncommon features observed in both the events

Data and analysis

During the mid of May 2005, extreme solar and interplanetary events were recorded. The sun was rather active with 221 solar flares in May 2005 visible in figure 1. On May 13th there was huge flare on the sun, which emitted from NOAA active region 10759. (N12, E12)The start time was 1631 UT and end time was 1946 UT (total duration 95 min) with optical importance 2B. Just half an hour later a full halo CME was visible in SOHO image at 1712UT. It advanced in the direction of Earth at linear speed of 1689 km/sec. When the shock wave hit earth's atmosphere, the proton flux peaked the electron flux and of course the magnetic field of earth became highly distorted.

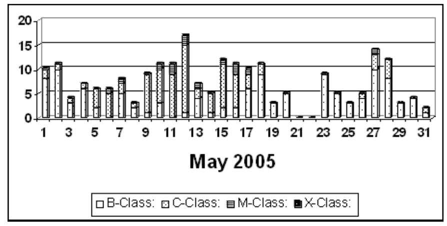

Figure 1: Summary of solar flares in May 2005

As a result an intense geomagnetic storm was observed on May 15, 2005 with maximum valve of Kp index equal to 9. The disturbance during storm time index (Dst) was also suddenly increased (-113 nT) indicating high geomagnetic activity during event time (fig.2).

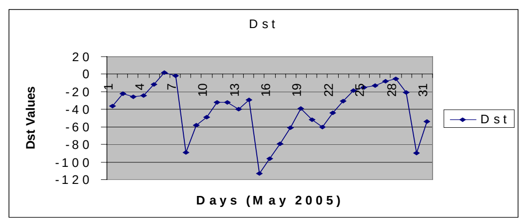

Figure 2: Daily Averaged Dst Index for May2005

The magnetic fields entrapped in and around CME exert a shielding effect on the galactic cosmic radiation causing a sudden reduction in the count rate from the neutron monitors called Forbush Decease that is very much clear from the figure 3, the daily variation in CRI for the month of May 2005.

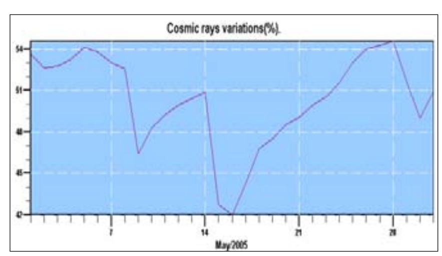

Figure 3: Cosmic Ray Intensity variation in May 2005

The onset time of this FD was 7.00 UT with a recovery time of about 12 days Its magnitude as recorded by Oulu NM station was ~18 % which is one of an extreme events of its kind. The daily averaged solar wind velocity also shows an increase before the FD event (Fig 4). The raw mean values of Sun Spot Number as per Solar bulletin, May 2005 was maximum (=77), on May 11th 2005. Figure 5 shows that the sudden ionospheric disturbance report (SID) approached 60 events which is reported to be one of the highest number. Thus May 2005 turned out to be a fairly active month for interplanetary and geomagnetic disturbances.

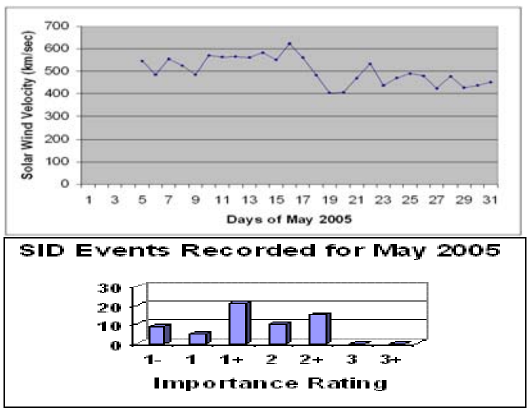

Figure 4. & 5: Daily averaged solar wind velocity & Total SID events for May2005 respectively.

Now we come to the other event of major Forbush Decrease that occurred on 9th November 2005. The data for FD is provided by neutron monitor located at Mawson, Antarctica. It has no geomagnetic (lower) cutoff energy and thus provides the most sensitive indication of cosmic radiation of any sensor located on the Earth's surface. It recorded an FD of 12 % with onset time of 0600 UT (Fig 6).

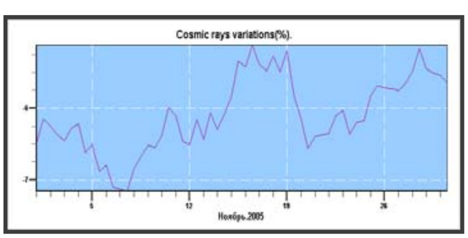

Figure 6: Cosmic Ray Variation in November 2005

The month November 2005 was having fairly a large number of X ray solar flares of B class originated from NOAA 10819 and 10820 regions. (about 20 flares in four days i.e. 5-8th November 2005). There were two big flares recorded on 7th November described as in table 1.

Table 1.Description of solar flares on 7 Nov.2005

Day	Start Time	End Time	Location	Region	Imp.
7.11.05	2052	2107	S16 W55	10820	B 4.3
7.11.05	2229	2237	S10 W78	10879	B 3.4

A partial halo solar CME was observed from SOHO/LASCO images on 7th November 2005 at 23:06:05 with linear speed of 335 km/sec. A magnetic storm was reported on 12th November with Kp index as 6. The Dst valves and SSN along with Ap index for this month have been plotted (fig 7).

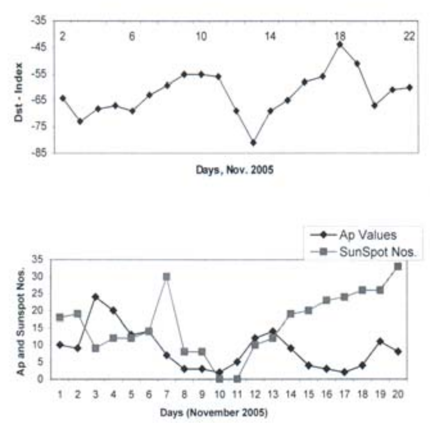

Figure 7: Dst Index, Ap Index and Sun Spot Numbers for the month of November 2005

The Dst index is representation of the magnetic effect at low latitude. It got disturbed showing large increase on 12th and 13th November that coincides with the main phase of FD. The geomagnetic index Ap index was also found to be decreased during the event period. The rise in SSN earlier the onset of FD reveals that it should have some connection with the occurrence solar flares which further affected cosmic ray intensity.

Discussion

The various data related to FD event of 15th May 2005 clearly indicate that highly energetic solar eruptions were produced on the Sun from 1st to 13th May 2005. This interval had everything: very large sunspot regions, intense solar flares, CME, particle events, and geomagnetic disturbances. A wide range of effects was felt around the world due to this remarkable solar activity. The inspection of CRI data revealed a strong Forbush Decrease registered by several worldwide neutron monitors. The coronal mass ejection initiated by this flare was emitted at a very high speed and directed towards the Earth. It passed the Earth in 33 hours resulting in major FD. During this period complex plasma and magnetic disturbances were formed s a result of gushing solar wind, which caused increased geomagnetic Dst index indicating a large geomagnetic storm.

The second event i.e. FD of 9th November 2005 also had high solar activities not as intense as that of 15th May 2005. There was a solar flare, coronal mass ejection, rise in solar wind velocity causing increased Dst index and decreased cosmic ray intensity. The CME observed on 7th November associated with solar flare formed shock wave which moved towards Earth creating condition of Forbush decrease on 9th November 2005.By the end of this period, geomagnetic conditions were unsettled that are confirmed by Dst index values appeared in the graph. Indeed the major geomagnetic storm took place (Kp=6) on 12th November, should be related to the CME and couple of two major solar flares occurred on 7th November.

Results

We presented experimental evidence of recording two major Forbush Decrease events as a result of high activity on the Sun and in the heliosphere that took place in the months of May and November 2005. Heightened solar activities created, disturbed situation in the interplanetary space that reflected in CR behavior on the background of geomagnetic storms. Above study supports the fact that the solar flares observed in the eastern or central region of the solar disk exhibits a higher probability to cause larger FDs compared to those observed in the western region of the solar disk [12]. FDs are rather variable in their manifestation reflecting the various conditions on the Sun and in the interplanetary medium Every FD is heliospheric phenomenon which starts at the Sun and may be over in the outer heliosphere. But our observations of the FD are essentially limited. We see always only a small part of a large-scale phenomenon. The same FD may be observed simultaneously and consequently in different places separated by several AU and it may appear in a variety of fashions. The association of FD with geomagnetic storm needs a detailed analysis to get forecasting of such storms and save humanity from their hazards.

Acknowledgements

The authors are indebted to various research groups working at different neutron monitor stations and the websites of Solar Geophysical Data Centre for providing related data.

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