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 295–298

30TH INTERNATIONAL COSMIC RAY CONFERENCE

On the relationship of Forbush decrease event of May 2005 with solar parameters

MANJULA JAIN[1], M.L. CHAUHAN[1], S.K. SHRIVASTAVA[1], M.K. RICHHARIA[1] & ALKA JAIN[1]
[1] *Department of Physics, Government Model Science Collage, Jabalpur, M.P. India*
rainbow_mjain@yahoo.com.in

Abstract: A strong Forbush Decrease (FD) was observed by ground based neutron monitor at Oulu in the mid of May 2005. The onset of FD took place on May 13 and attained its maximum on May 15, 2005. The event was in response to 221 X-ray flares out of which 13 were of M class and they were followed by coronal mass ejection (CME). This has caused a rapid decrease in galactic cosmic ray intensity called Forbush Decrease. In the present paper the effect of various parameters such as sun spot numbers (SSN), solar wind velocity and the geomagnetic index Dst, on the FD has been studied. The results clearly indicate a strong relationship between geomagnetic activity and FD on short term basis. The period under investigation is found to be full of large solar activities inspite of the declining phase of solar cycle 23.

Introduction

Forbush Decreases are characterized by a rapid reduction (within a few hours) in cosmic ray intensity (CRI) followed by a slow recovery, typically lasting several days at 1AU near earth regions. This reduction is about from 3-20% observed by worldwide neutron monitor stations. Research of the FDs is carried on more than 60 years since the beginning of regular cosmic rays observations [1].

Various causes have been proposed from time to time for the worldwide decrease in CRI such as solar flare [2], CME [3], high speed solar wind streams [4] originated from coronal holes or some other active regions on the solar disc. Effects of magnetic clouds and related shocks on cosmic ray density have also been studied [5]. Forbush effects of values greater than 5% in magnitude are seldom encountered without magnetic storm and in these cases the geomagnetic activity is always enhanced [6]. This analysis shows that the phenomenon of Forbush effect is a result of the storm in interplanetary space and very often it appears simultaneously with a geomagnetic storm. Hence all the three kinds of disturbances –in the solar wind, in the magnetosphere and in cosmic rays- are closely connected, therefore, it is essential to study them altogether. In a recent paper, an intense solar activity was reported [7] to be the main cause of the Forbush effect (~8%) on 16 July 2005. The decrease of CRI on 16-17 July appeared to be a consequence of limb and backside solar activity including both solar flares and coronal mass ejections. The massive compression of the magnetosphere and enormous intensification of the large scale magnetospheric current system reflected in Dst leads to a significant effect on cosmic ray measurement near Earth [8] (FD~16%) on 15 July 2000.

Occurrence of major FD during the epoch of minimum solar activity period made us to look into the changes taking place over the solar disc and in the interplanetary medium and to study the probable causes for it. In the present paper, the large FD (~18%) event of May 15, 2005 has been studied on the basis of data taken from neutron monitor at Oulu. The effect of various parameters like Sun Spot Numbers (SSN), Disturbance during storm time (Dst values) and solar wind velocity on FD has been worked out. Here Dst is used as an indicator of the geomagnetic activity to derive its relationship with cosmic rays. Efforts have been made to find the possible correlation of FD with Dst index and solar wind velocity. At that time intense solar activities were observed and it was found that they certainly have some relation with this event.

Observations and analysis of data

We selected an extremely large FD event of 15th May 2005 from Oulu neutron monitor station and analyzed data related to solar flare, CME, SSN, solar wind velocity and geomagnetic ring current index Dst with cosmic ray intensity. The pressure corrected daily CRI variation for the month of May 2005 has been taken and the plots of average values of Dst index and solar wind velocity with CRI are evaluated. The Dst index primarily measures the ring current magnetic field and it is used as an indicator of the geomagnetic activity. The solar wind velocity is the signature of inter-planetary shocks likely to be aroused from solar flares and CMEs. The solar activity is further investigated through a systematic study of SSN for the event period.

Discussion

On May 13, 2005 there was a huge flare on the sun, which produced emissions of various kinds. First the flare was detected in the X-ray and radio range. The GOES-12 satellite recorded 221 X-ray flares and among these, 13 were M-class events with peak activity being around the beginning of the month and mid month. Figure 1 shows the sudden increase in X-ray flux measured by the GOES satellites.

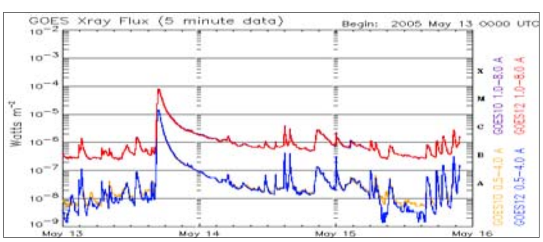

Figure 1: X-Ray Flux variation from May 13 to May 16, 2005

The effect of CME passing the Earth is the de-crease in cosmic ray flux i.e. Forbush decrease.. When CME hit the Earth, the magnetic field of CME deflects the galactic cosmic rays and the secondary particle flux (neutron) decreases.

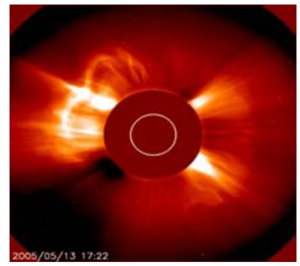

Figure 2: Coronal Mass Ejection by SOHO image

The magnetograms of various magnetometers show the impact of CME and the disturbed earth's magnetic field afterwards. The maximum distortion of the earth's magnetic field was at about 7.00 UT on May 15, 2005, the Forbush decrease was also at the maximum at this time. This implies that the particle density of the CME reached its peak at this time. Some thing notewor-thy: the proton flux already started increasing only a few hours after the flare occurred, indicat-ing that those particles were traveling at really high speeds. 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 as seen in figure 3.

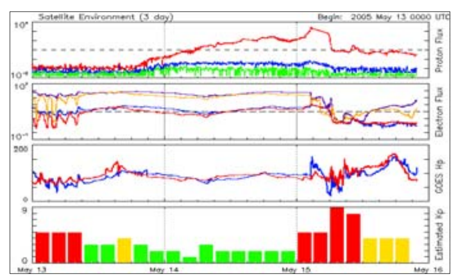

Figure 3: Proton Flux, Electron Flux, GOES Hp and Estimated Kp values from May 13 to May 16, 2005

Figures 4(a), (b) and (c) represent the daily varia-tions in Dst values, solar wind velocity and cos-mic rays for May 2005 respectively. The graph 4(a) shows the magnetic effect at low latitudes. It can be seen that there is a large increase in Dst (-113 nT) during the period between 13 to 15 May. This has caused a geo magnetic storm on May 15 classified as an extreme event, measuring G-5, the highest level on the NOAA Space Weather

Scales. This event registered a 9 on the K-index, which measures the maximum deviation of the magnetic field in a given three hours period. It was forecast by NOAA as a result of a solar flare that occurred on May 13. A rise in solar wind velocity in the second week of May, shown by graph 4(b), indicates the arrival of a CME that took place on 13th May The maximum velocity exceeded 600 km/sec which gradually decreased to 405 km/sec on 15th May. Figure 4(c) clearly gives the sudden decrease in CRI followed by slow recovery that is FD on 15thMay.Its magnitude is about 18% which is one of the extreme values ever recorded Thus heightened solar activities in the form of solar flare along with CME created disturbed situation in the interplanetary space as well as in geospace that is reflected in these graphs.

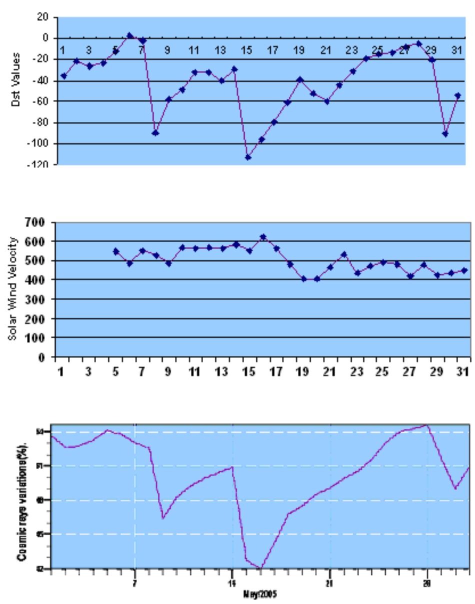

Figure 4: (a), (b) & (c) respectively for Dst values, Solar wind velocity & CRI in the month of May 2005

The data for the CRI in impulse per minute is recorded by Moscow neutron monitors and sun spot numbers have been analyzed in figure 5. It is evident from the graph that when the SSN are less the CRI is more and when SSN increase there is a sudden decrease in CRI that is they have opposite trend in their event period. However, it is observed that there is a phase leg between these two parameters of about 4 days, which is probably the time taken by the CME to reach the earth's atmosphere.

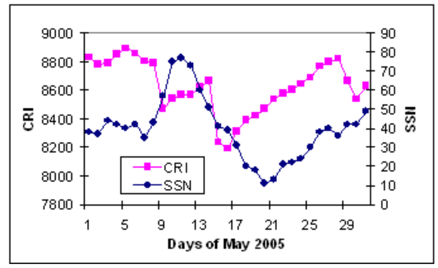

Figure 5: Cosmic ray intensity and Sun spot numbers for May 2005.

A large FD observed during Feb 1 to 14, 1986 in the declining phase of solar cycle 21 was also found mainly due to the solar flare generated shock waves perturbation as well as CME also contributed for the same [9]. In a recent study, a relation of occurrence of solar flare having optical importance ≥ 2B, with FD from 1986 to 2000 was investigated [10]. A similar FD of about 16%, which took place in Oct - Nov 2003 was studied [11] and mentioned that during this period complex plasma and magnetic disturbance were formed as result of gushing solar wind. Hence the CME initiated by solar flare at a very high speed caused that FD.

According to a solar physicist at the solar and astrophysics laboratory. Lockhead Martin Advanced Technology Center (LMATC) in the United States, the solar flares are expected to be at its maximum intensity by the year 2010 [12]. If a solar flare or a CME collides with the Earth, it can cause a geomagnetic storm further causing a telecommunication blackout. Therefore FD is a phenomenon, which may help us in getting a warning about this damage.

Conclusion

In this paper a major Forbush decrease event has been analyzed. It is concluded that the value of Dst index shows a significant transient decrease in similar pattern as that of Forbush decrease i.e. cosmic ray intensity shows a decrease during the low Dst values. Large scale magnetospheric current systems as reflected in Dst values support the concept of simultaneity of geomagnetic effects and decrease in cosmic ray intensity near earth regions.

The FD is also correlated with solar wind velocity because in the above study, we are able to find that there was a continuous rise in velocity of solar wind just before the onset of FD. But it is clear that magnitude of FD cannot uniquely be derived from solar wind parameters. However the solar wind disturbance is able to create a magnetic storm, that necessarily affect the cosmic rays and thus Forbush decrease of large magnitude corresponds to a magnetic storm.

The variation in SSN with CRI as reflected in the graph is a clear indication of the dependence of CRI on solar flare. Since there was an CME also we can infer that a number of extreme events characterized by rather peculiar properties have taken place in a time period very close to the minimum of the 23rd cycle of solar activity. The out come of these analyses is that extreme solar events influence cosmic rays in a dynamic way.

Acknowledgements

We are grateful to the research groups working at Oulu and Moscow Neutron Monitor stations for providing relevant data and various related websites.

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