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Ground Level Enhancements and their Relation with Coronal Mass Ejections and Disturbances in Solar Wind Plasma Parameters

KEYWORDS: Ground Level Enhancements, Coronal Mass Ejections, Solar wind plasma parameters.

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ABSTRACT *We have studied Ground Level Enhancements in cosmic ray intensity magnitude ≥100% observed during the period of 2000-2012 with Coronal Mass Ejections and disturbances in solar wind plasma parameters (solar wind velocity, density and interplanetary magnetic field) .We have found that all the Ground Level Enhancements are associated with halo and partial halo coronal mass ejections .The association rate of halo and partial halo coronal mass ejections have been found 81.18% 18.18% and respectively .We have determined negative correlation with correlation coefficient -0.47 between magnitude of Ground Level Enhancement and speed of associated CMEs .Further we have concluded Ground Level Enhancements are closely associated with the disturbances in solar wind plasma parameters. We have determined negative co-relation between magnitudes of Ground Level Enhancements and peak value of jump in solar wind plasma density ,average interplanetary magnetic field and positive correlation between magnitude of Ground Level Enhancements and peak value of solar wind plasma velocity with co-relation co-efficient, 0.65 between magnitude of Ground Level Enhancements and peak value of jump in solar wind plasma velocity , -0.42 between magnitude of Ground Level Enhancements and peak value of jump in average interplanetary magnetic field and -0.25 between magnitude of Ground Level Enhancements and peak value of solar wind plasma density*

1-Introduction

Ground Level Enhancements (GLEs) are increases of cosmic ray intensity measured on the earth's ground. Solar energetic particles (SEPs), solar flares, and/or coronal mass ejections (CMEs) are also normally observed when GLEs occur, suggesting that these are causing GLEs or are caused by the same process in the sun or its corona. Registration of GLE events by ground-based neutron monitors began in the early 1940s. Since then Ground Level Enhancements have been studied by several scientists with different solar interplanetary parameters to explain the origin, causes and characteristics of GLE [Meyer et al, 1956; Park, 1957; Dorman and Venkatesan, 1993; Kudela et al, 1993; Reames, 1995; Shea et al., 1999; Miroshnichenko, 2001; Duldig, 2001; Smart and Shea, 2002; Cliver et al, 2004; Gopalswamy et al., 2005]. Gopalswamy et al. [2005] have studied Ground Level Enhancements with coronal mass ejections and inferred that GLE are often associated with faster coronal mass ejections and metric Type II bursts. A few researchers [Kudela et al, 1993; Reames, 1999] insisted that GLE events are the relativistic counterparts of solar energetic particle events and caused by the sporadic emission of solar relativistic charged particles. Reames [2009] further attempted to explain the concepts of GLEs and their probable release time from the origin. He concluded that energy release of solar flare contributing to GLE occurrence and found that the initial solar particle release times occur, after the start times of radio emission. In another study, Firoz et al. [2010b] proposed that since solar flares are able to release relativistic high-energy particles, GLEs can be studied as the consequence of solar flares. Several researchers [Cliver, 1982; Cane et al, 2002] also agreed that the particle acceleration in solar flares might play an important role in GLE production. Ultimately, solar flares seem to be the main agent that might produce the enhancement in cosmic ray intensity .Aschwanden [2010] reviewed a few aspects of flare observations of GLE events such as the relative timing of the release of GLE-associated particles during solar flares and found that, for most of the cases, the solar particle release times of GLE-producing particles overlap with the intensive phase of gamma ray and X-ray emission in solar flares. Reames [1999] implied that solar energetic particle (SEP) acceleration might take place in flare sites. In addition, both of their studies supported the statements that, since GLEs are the relativistic SEPs, most of the GLEs are consistent with SEP accelerations during intensive phases of the flares, while some of the GLEs could be subjected to the prolonged acceleration in coronal mass ejection (CME) driven shocks. In this context, Firoz et al. [2010a] concluded that CME-driven shocks with the solar flare are the main cause of GLEs. In this investigation we have studied GLEs observed during the period of 2000-2012 with coronal mass ejections and disturbances in solar wind plasma parameters to know the possible relationship between GLEs and disturbances in solar wind plasma parameters.

2-Experimental data

In this study Ground Level Enhancements have been studied with coronal mass ejections and disturbances in solar wind plasma parameters observed during the period of 2000-2012. The data of GLEs have been taken from Oulu super neutron monitor. The data of coronal mass ejections (CMEs) have been taken from SOHO – large angle spectrometric, coronagraph (SOHO / LASCO) and extreme ultraviolet imaging telescope (SOHO/EIT) data. To determine disturbances in solar wind plasma parameters, hourly data of solar wind plasma velocity, density, average interplanetary magnetic field has been used. These data has also been taken from omni web data(http;//omniweb.gsfc.nasa.gov/form/dxi.html)).

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Table1-Ground Level Enhancements and their association with Coronal Mass Ejections and Disturbances in Solar Wind Plasma Parameters for the period of 2000-2012.

Date	Magnitude of GLEs in %	CMEs Type	Speed of CMEs in 1/100 Km/s	Peak value of Solar Wind Density in n/cc	Peak value of Solar Wind Velocity in1/100 km/s	Peak value of IMF in nT
14.07.2000	30	H	16.74	26.6	7.82	13
15.04.2001	57	P	11.99	9.7	8.33	3.1
18.04.2001	5	H	24.65	29.6	5.19	23.8
04.11.2001	3	H	18.1	39	4.04	8.1
26.12.2001	5	P	14.46	5.5	4.5	7.3
24.08.2002	5	H	19.13	3.8	4.15	8.1
28.10.2003	5	H	24.59	1.8	8.06	19.3
02.11.2003	6	H	25.98	1.4	6.9	5.6
17.01.2005	3	H	25.47	55.7	7.98	36.8
13.12.2006	92	H	17.74	6.7	9.55	5.1
17.05.2012	16	H	15.82	7.7	4.1	8.9

3-Data Analysis and Results

The association between Ground Level Enhancements and coronal mass ejections (CMEs), disturbances in solar wind plasma parameters for the period 2000-2012 are given in Table No.1. From the data analysis it is observed that all the Ground Level Enhancements are found to be associated with halo and partial halo coronal mass ejections. The association rate of halo and partial halo coronal mass ejections have been found 18.18% and 81.81 %respectively. From the data analysis given in Table-1, it is observed that Ground Level Enhancement which has large magnitude are associated with such CMEs which has slow speed and those which has small magnitude are associated with such CMEs which has fast or higher speed. We have found negative correlation with correlation coefficient -0.47 between magnitude of Ground Level Enhancements and speed of associated CMEs [Fig-1].

From the data analysis of Ground Level Enhancements and disturbances in solar wind plasma density given in Table 1 ,it is observed that some GLEs which have large magnitude are associated with relatively lower peak values of jump in solar wind plasma density and GLEs which have lower magnitude are associated with relatively higher peak values of jump in solar wind plasma density but no any definite relationship has been found between these two events.Negaive correlation with correlation coefficient -0.25 has been found between these two event[Fig-2]..

From the data analysis of Ground Level Enhancements and disturbances in interplanetary magnetic fields given in Table 1,it is observed that GLEs which have large magnitude are associated with relatively lower peak values of jump in interplanetary magnetic fields and GLEs which have lower magnitude are associated with relatively higher peak values of jump in interplanetary magnetic fields but no any definite relationship has been found between these two events.Negaive correlation with correlation coefficient -0.42 has been found between these two events [Fig-3].

From the data analysis of Ground Level Enhancements and disturbances in solar wind plasma velocity given in Table 1,it is observed that some GLEs which have large magnitude are associated with relatively lower peak values of jump in solar wind plasma velocity and GLEs which have lower magnitude are associated with relatively higher peak values of jump in solar wind plasma velocity .Positive correlation with correlation coefficient 0.65 has been found between these two events[Fig-4]

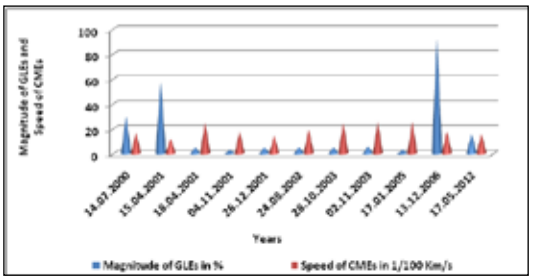

Fig-1-Bar diagram of magnitude of GLEs≥100% and Speed of Associated CMEs observed during the period of 2000-2012

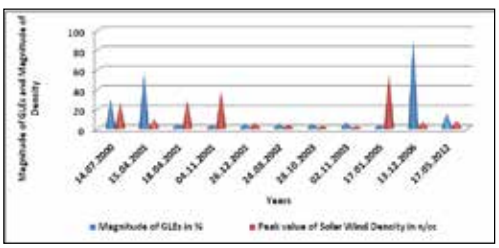

Fig-2-Bar diagram of magnitude of GLEs≥100% and peak value of solar wind plasma density observed during the period of 2000-2012.

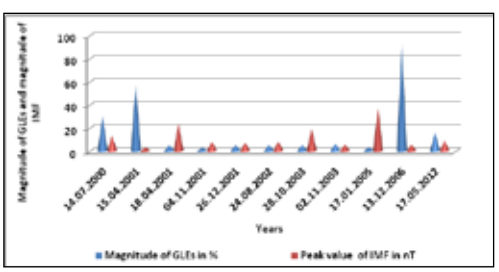

Fig-3-Bar diagram of magnitude of GLEs≥100% and peak value of interplanetary magnetic fields observed during the period of 2000-2012.

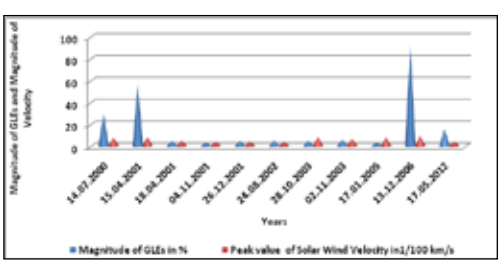

Fig-4-Bar diagram of magnitude of GLEs≥100% and peak value of solar wind plasma velocity observed during the period of 2000-2012.

4-Cconclusion

From our study all the Ground Level Enhancements observed during the period of 2000-2012 have been identified as being associated with halo and partial halo coronal mass ejections .The association rate of halo and partial halo coronal mass ejections have been found 81.81 % and 18.18% respectively .We have determined negative correlation with correlation coefficient -0.47 between magnitude of Ground Level Enhancement and speed of associated CMEs .Further

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we have concluded Ground Level Enhancements are closely associated with the disturbances in solar wind plasma parameters. We have determined negative co-relation between magnitudes of Ground Level Enhancements and peak value of jump in solar wind plasma density ,average interplanetary magnetic field and positive correlation between magnitude of Ground Level Enhancements and peak value of solar wind plasma velocity with co-relation co-efficient, 0.65 between magnitude of Ground Level Enhancements and peak value of jump in solar wind plasma velocity , -0.42 between magnitude of Ground Level Enhancements and peak value of jump in average interplanetary magnetic field and -0.25 between magnitude of Ground Level Enhancements and peak value of solar wind plasma density.Thes results shows that Ground Level Enhancements mainly caused by coronal mass ejections and strongly related to disturbances in solar wind plasma velocity and interplanetary magnetic fild.

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