International Journal of Innovative Research & Growth
A Peer Reviewed Journal
ISSN: 2455-1848
Journal homepage: http://www.ijirg.com/ijirg/
Volume: 10 Issue: 10, August 2021

Radio bursts related geomagnetic storms with coronal mass ejections, x-ray solar flares and solar wind disturbances: a survey

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Article Info
Received 15 June 2021
Received in revised form 15 July 2021
Accepted for publication 11 August 2021
DOI: 10.26671/IJIRG.2021.10.10.101
Citation:
Gour, P. S., Soni, S. (2021). Radio bursts related geomagnetic storms with coronal mass ejections, x-ray solar flares and solar wind disturbances: a survey. *Int J Innovat Res Growth*, 10, 48-55.

Abstract:
In this survey we have studied radio bursts related geomagnetic storms having magnitude ≤-90nT observed during the period of 1997-2011 and analyzed with coronal mass ejections, X-ray solar flares and disturbances in solar wind plasma parameters. From the analysis we have found total number of radio bursts related geomagnetic storms ≤-90nT, observed are 42. Out of 42 geomagnetic storms 37 (88.09%) geomagnetic storms are found to be associated with coronal mass ejections (CMEs). We have further observed that the majority of geomagnetic storms are related to halo CMEs (67.57%). Further we have observed weak positive co-relation with co-relation 0.28 between the magnitudes of radio bursts related geomagnetic storms and speed of associated coronal mass ejections by statistical method. Out of 42 geomagnetic storms 05 (11.90 %) geomagnetic storms are found to be associated with X class X-ray solar flares. 25 (59.52%) geomagnetic storms are found to be associated with M class X-ray solar flares and 07(16.67%) geomagnetic storms are found to be associated with C class X-ray solar flares. 05(11.90%) are found to be associated with B class X-ray solar flares. We have selected jump in different plasma parameters events associated with RB related GMS and studied statistical behavior of these events with coronal mass ejections. By the analysis we observed that the peak value of jump in solar wind plasma temperature (JSWT), jump in solar wind plasma pressure (JSWP), jump in solar wind plasma velocity (JSWV) events are moderately correlated with CMEs and magnitude of jump in solar wind plasma density (JSWD), JSWV are weakly correlated with CMEs with correlation coefficient 0.26.
Keywords: - Coronal mass ejections, X-ray solar flares, Geomagnetic storms, solar wind Plasma parameters.

1. Introduction

Coronal mass ejections (CMEs) are a key aspect of coronal and interplanetary dynamics .They can eject large amounts of mass and magnetic field into the heliosphere causing major geomagnetic storms and interplanetary shocks. The key properties of CMEs have been reviewed their source, regions there manifestations in the solar wind and their geoeffectiveness. The measured properties of CMEs include their occurrence rate, locations relative to the solar disk, angular widths, speeds and masses and energies (Webb, 2002, Gopalswamy et al .2003 Yashiro et al 2004). Halo CMEs which appear as expanding, circular brightening that completely surround the coronagraphs occulting disks This suggests that these are normal CMEs seen in projection (Burkepile et al 2004) to be moving outward either toward or away from the earth .CMEs which have a larger apparent angular size than typical limb CMEs but do not appear as complete halos are called partial halo CMEs.. Coronal mass ejections (CMEs) that appear to surround the occulting disk of the observing coronagraphs in sky plane projection are known as halo CMEs (Howard et al., 1982). Halo CMEs are fast and wide on the average and are associated with flares of greater X-ray importance because only energetic CMEs expand rapidly to appear above the occulting disk early in the event (Gopalswamy et al., 2007). Extensive observations from the Solar and Heliospheric Observatory (SOHO) mission's Large Angle and Spectrometric Coronagraphs (LASCO) have shown that full halos constitute ∼3.6% of all CMEs, while CMEs with width ≥120° account for ∼11% (Gopalswamy, 2004). Recently Gopalswamy et al. (2007) analyzed 378 halo CMEs covering almost whole of solar cycle 23 and found that∼71% of front side halos are geoeffective.

Solar flares were one of the first strong disturbances discovered on the sun and they were considered as the important source of almost all interplanetary and geomagnetic disturbances during long time. Later, in the beginning of 1970s, other powerful solar processes such as coronal mass ejections (CMEs) were discovered, and after the landmark paper by Gosling (1993) the situation has significantly changed, and now CME is considered almost as the unique cause of all interplanetary and geomagnetic disturbances. Nevertheless the solar flares are often considered as a precursor of solar activity and used for prediction of interplanetary and geomagnetic disturbances (Park et al. 2002, Yermolaev et al. 2005).

It is generally believed that the occurrence of a geomagnetic storm depends upon the solar conditions, particularly the southward interplanetary magnetic field (IMF) component. Some researchers have suggested a relationship between geomagnetic storms and solar wind parameters (Weigel 2010). Wu & Lepping (2006) investigated geomagnetic activity induced by interplanetary magnetic cloud (MC) during the past four solar cycles, 1965~ 1998 and found that the intensity of geomagnetic storms is more severe in a solar active period than in a solar quiet period. Echer et al. (2008) also identified the interplanetary causes of intense geomagnetic storms and their solar dependence occurring during the solar cycle 23 (1996~2006). The study of various geomagnetic indices with disturbances in different parameters of solar wind plasma indicates that geomagnetic activity is related to variety of solar wind plasma/field parameters via solar wind velocity, solar wind plasma density, magnetic field strength, its north-south component and various combinations of these parameters (Akasofu, 1983).

In this work we have studied radio bursts related geomagnetic storms, (magnitude ≤-90nT) and associated disturbances in solar wind plasma parameters e.g. jump in solar wind plasma velocity (JSWV), jump in solar wind plasma density (JSWD) ,jump in solar wind plasma temperature (JSWT) ,Jump in solar wind plasma pressure (JSWP) with coronal mass ejections.

2. Sources of Data

In this investigation hourly Dst indices of geomagnetic field have been used over the period 1997 to 2011 to determine onset time, maximum depression time, magnitude of geomagnetic storms. This data has been taken from the NSSDC Omni web data system which been created in late 1994 for enhanced access to the near earth solar wind, magnetic field and plasma data of Omni data set, which consists of one hour resolution near earth, solar wind magnetic field and plasma data, energetic proton fluxes and geomagnetic and solar activity indices. 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. The data of X ray solar flares radio bursts, and other solar data, solar geophysical data report U.S. Department of commerce, NOAA monthly issue and solar STP data (http://www.ngdc.noaa.gov/stp/solar/solardataser vices.html.) have been used. To determine disturbances in solar wind plasma parameters, hourly data of solar wind plasma velocity density, temperature and pressure has been used and these data has also been taken from omni web data also.

3. Data Analysis and Results

In this study we have studied radio bursts related geomagnetic storms of magnitude ≤-90nT observed during the period of 1997-2011 and analyzed with coronal mass ejections, X-ray solar flares and disturbances in solar wind plasma parameters. From the data analysis we have found total number of radio bursts related geomagnetic storms observed during the above time span are 42. Out of 42 geomagnetic storms 37 (88.09%) geomagnetic storms are found to be associated with coronal mass ejections (CMEs). We have 37 geomagnetic storms, which are associated with coronal mass ejections out of which 25 geomagnetic storms (67.57%) are related to the halo coronal mass ejections and 12(32.43%) geomagnetic storms are found to be associated with partial halo coronal mass ejection (Figure-1). To study the relation between different parameters we have applied Karl person correlation formula.

3.1 Geomagnetic Storms and CMEs

To know the possible statistical behavior between radio bursts related geomagnetic storms and speed of associated CMEs, a scatter plot has been plotted between magnitude of radio bursts related geomagnetic storms and speed of associated CMEs (Figure-2). From the figure weak positive correlation with correlation coefficient 0.28 has been found between magnitude of radio bursts related geomagnetic storms and speed of associated CMEs.

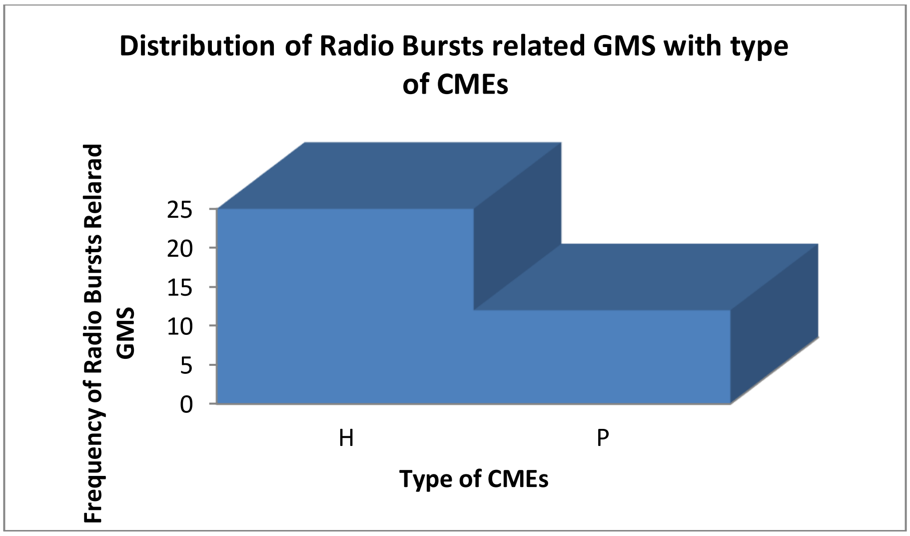

Figure-1 -Distribution of radio bursts related geomagnetic storms with coronal mass ejections.

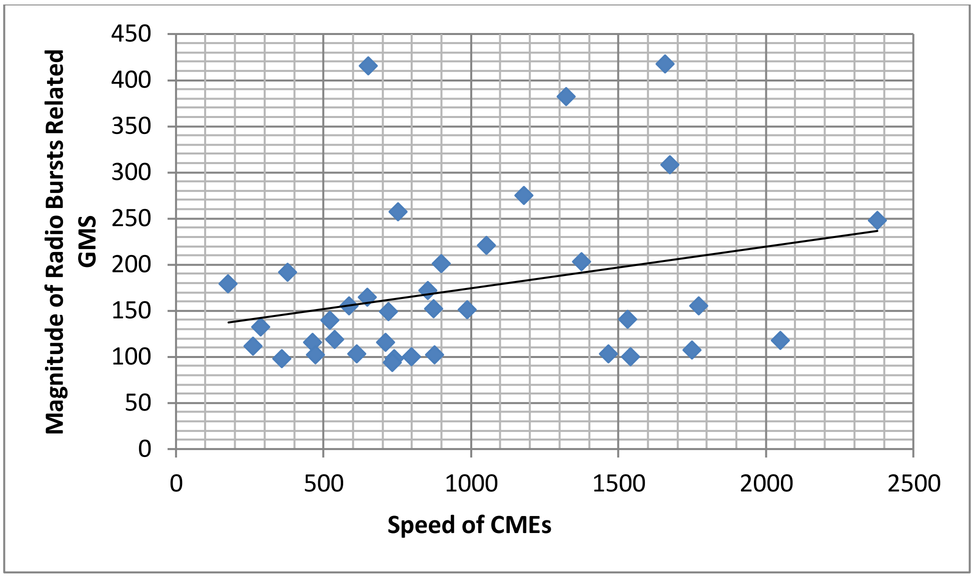

Figure -2 - The figure shows scatter plot between speed of CMEs and magnitude of radio bursts related geomagnetic storms.

3.2 Geomagnetic Storms and Solar Flares

From the data analysis it is observed that 42 geomagnetic storms have been identified as being associated with radio bursts and all the geomagnetic storms have been found to be associated with X ray solar flares of different categories (Figure-3). Out of 42 geomagnetic storms 05 (11.90 %) geomagnetic storms are found to be associated with X class X-ray solar flares. 25 (59.52%) geomagnetic storms are found to be associated with M class X-ray solar flares and 07(16.67%) geomagnetic storms are found to be associated with C class X-ray solar flares. 05(11.90%) are found to be associated with B class X-ray solar flares. From these results it is concluded that radio bursts related geomagnetic storms are closely related solar flare.

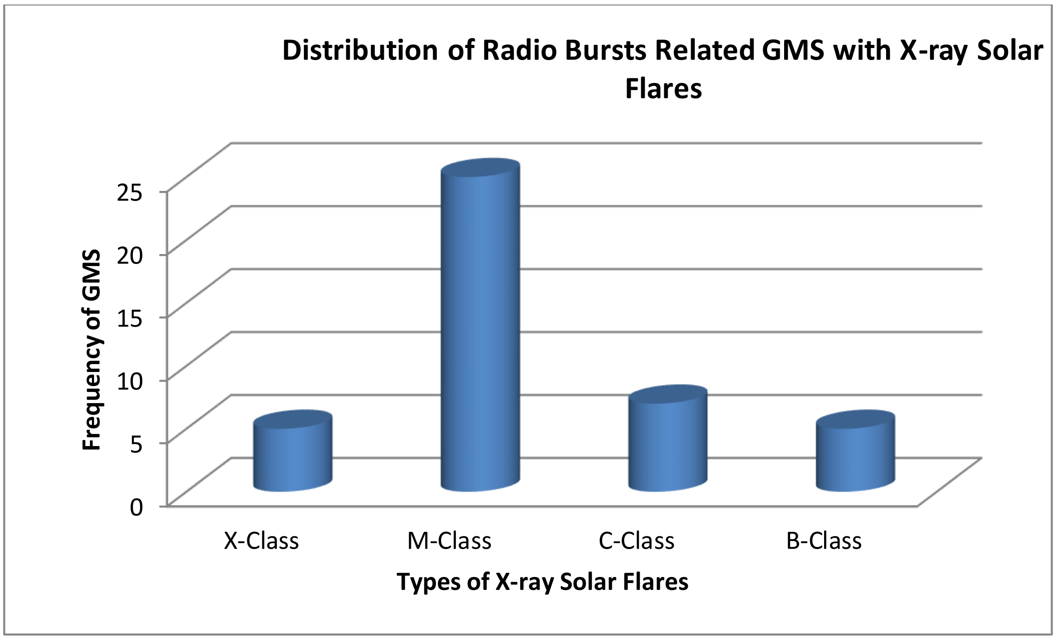

Figure-3 -The figure shows distribution of radio bursts related geomagnetic with X ray solar flares of different categories.

3.3 Plasma Parameters Associated with RB Related Geomagnetic Storms (GMS) and CMEs

We have selected those jumps in solar wind plasma temperature (JSWT), jump in solar wind plasma pressure (JSWP), jump in solar wind plasma velocity (JSWV), jump in solar wind plasma density (JSWD) events which are associated with radio bursts related geomagnetic storms and studied statistical behavior of these events with coronal mass ejections.

- To know how the peak value of JSWT events and magnitude are correlated with speed of coronal mass ejections, we have plotted a scatter diagram (Figure-4&5) between these parameters and found that peak value and magnitude of JSWT events are moderately correlated with CMEs speed with correlation coefficient 0.38 and 0.36 respectively.

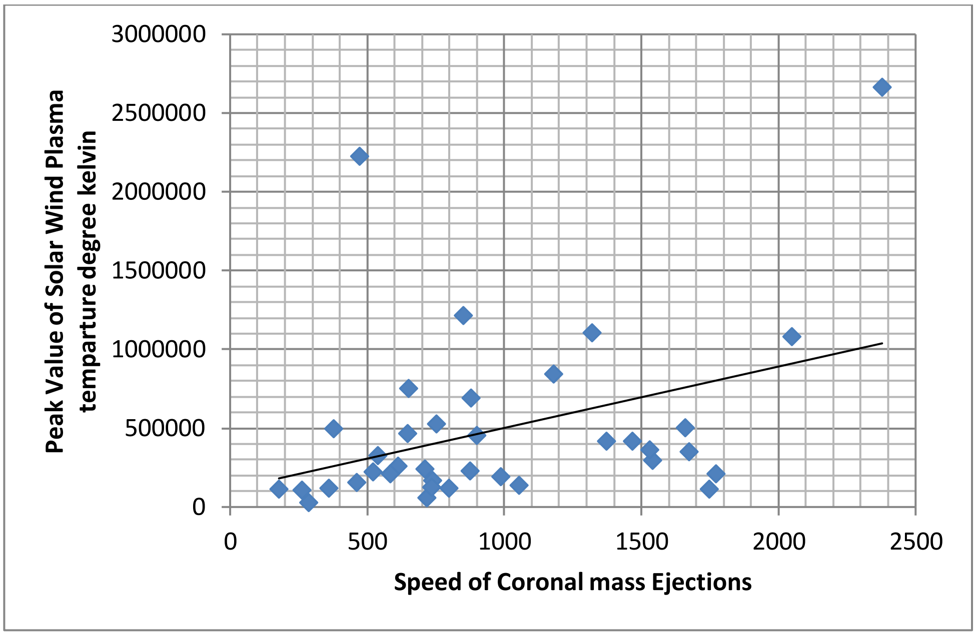

Figure-4 -The figure shows scatter plot between speed of CMEs and peak value of jump in solar wind plasma temperature (JSWT) Associated with RB related GMS.

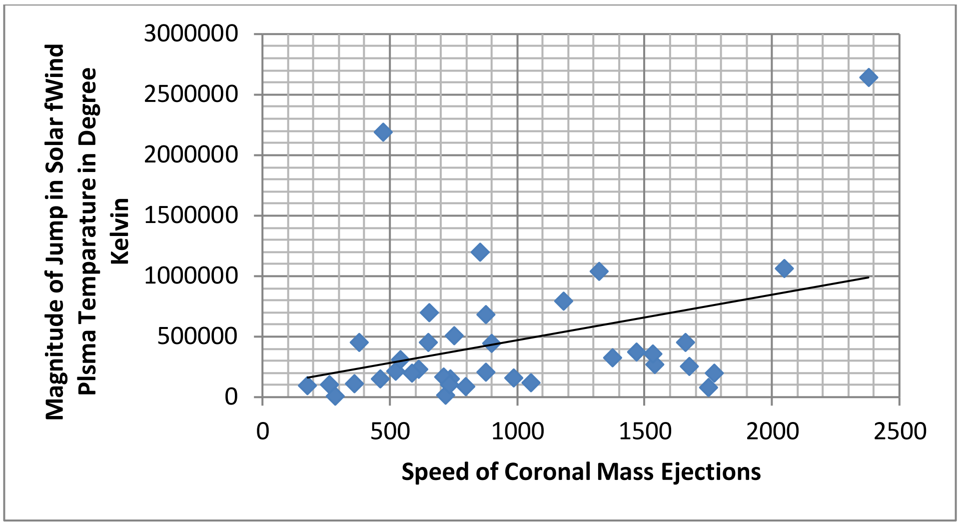

Figure -5 - The figure shows scatter plot between magnitude of JSWT Associated with RB related GMS and speed of CMEs.

➢ To see how the peak value of JSWD events and magnitude are correlated with speed of coronal mass ejections, we have plotted a scatter diagram (Figure-6&7) between speed of CMEs and peak value and magnitude of JSWD events. It is inferred from the scatter plot that peak value and magnitude of JSWD events are weakly correlated with CMEs speed with correlation coefficient 0.16 and 0.26 respectively.

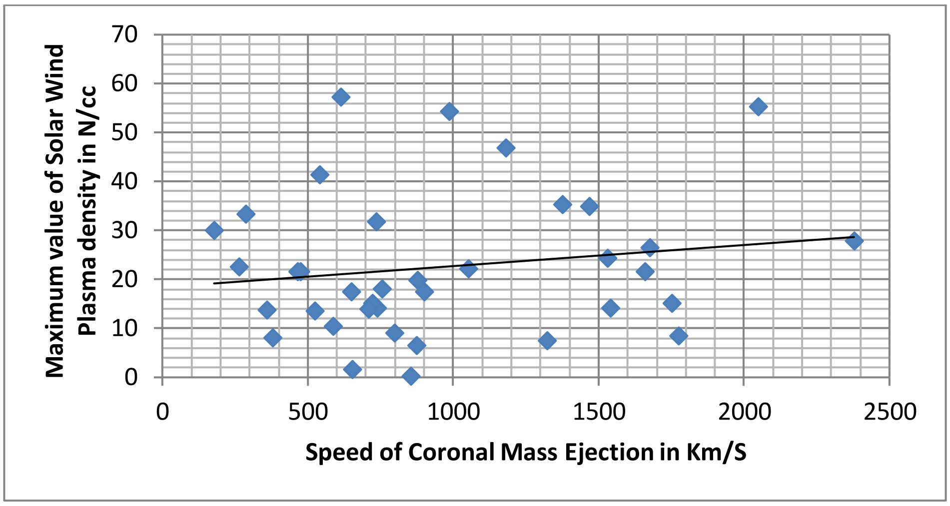

Figure-6 -The figure shows scatter plot between speed of CMEs and peak value of JSWD events Associated with RB related GMS.

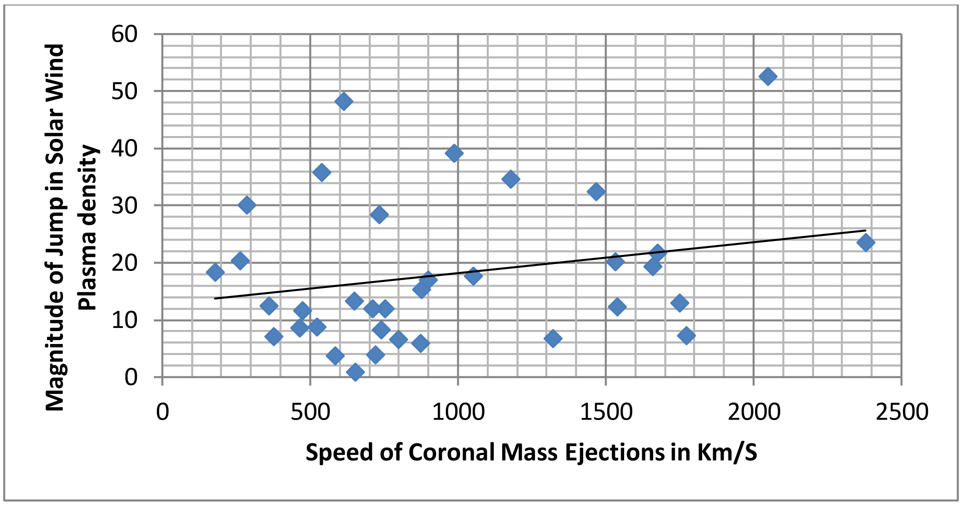

Figure -7 - The figure shows scatter plot between magnitude of JSWD Associated with RB related GMS and speed of CMEs.

➢ To see how the peak value of JSWV events and magnitude are correlated with speed of coronal mass ejections, we have plotted a scatter diagram (Figure-8&9) between speed of CMEs and peak value and magnitude of JSWV events. It is inferred from the scatter plot that peak value of JSWV events are moderately correlated with CMEs speed with correlation coefficient 0.44 and magnitude of JSWV events are weakly correlated with correlation coefficient of 0.26 with speed of CMEs.

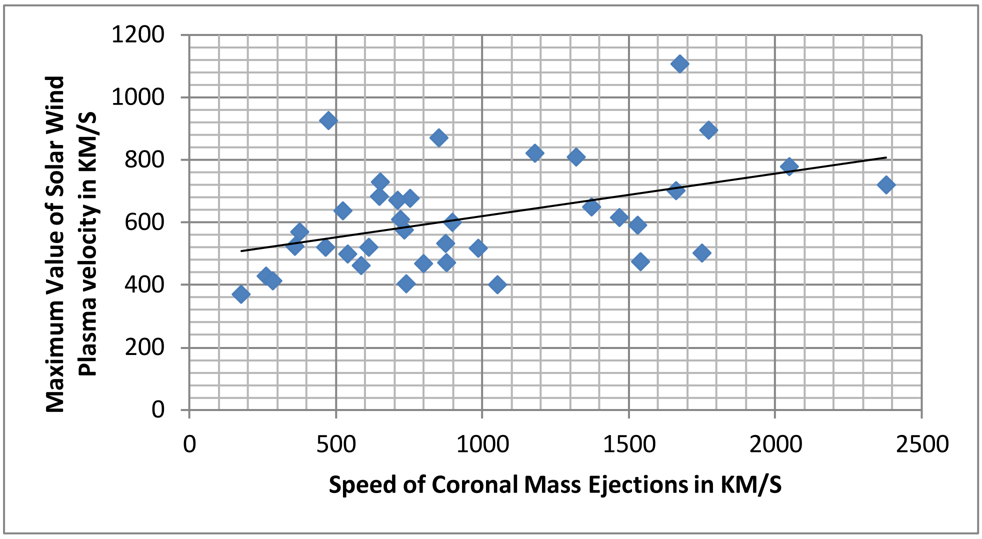

Figure-8 -The figure shows scatter plot between speed of CMEs and peak value of JSWV events Associated with RB related GMS

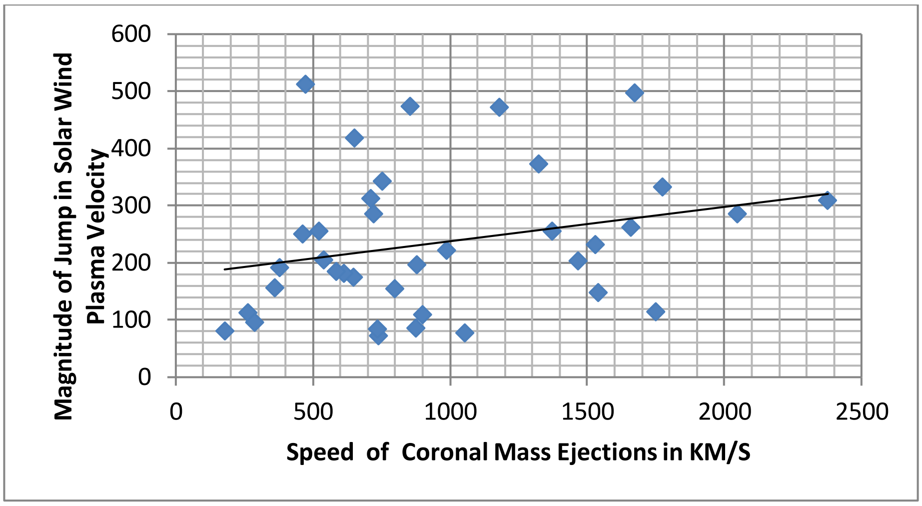

Figure -9- The figure shows scatter plot between magnitude of JSWV events Associated with RB related GMS and speed of CMEs

➢ To know how the peak value of JSWP events and magnitude are correlated with speed of coronal mass ejections, we have plotted a scatter diagram (Figure-10&11) between speed of CMEs and peak value and magnitude of JSWP events. It is inferred from the scatter plot that peak value and magnitude of JSWP events are moderately correlated with CMEs speed with correlation coefficient 0.40 and 0.41 respectively.

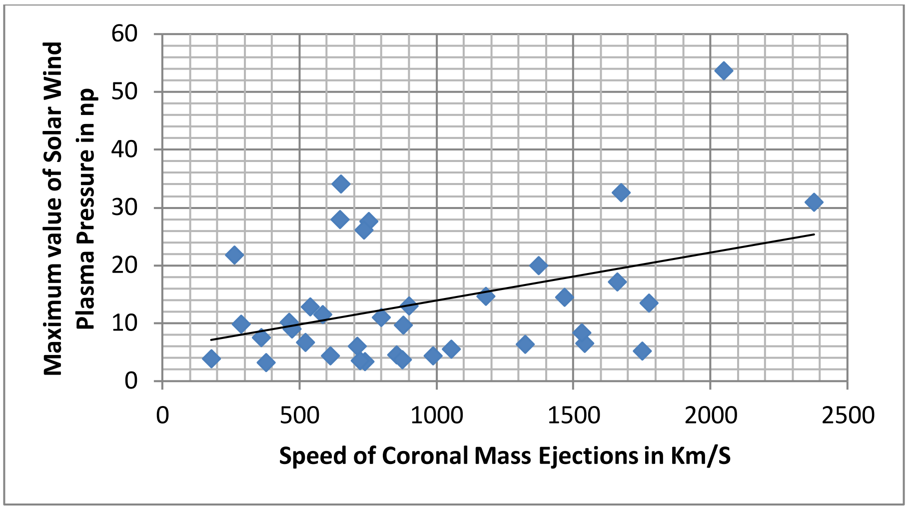

Figure-10 -The figure shows scatter plot between speed of CMEs and peak value JSWP events Associated with RB related GMS.

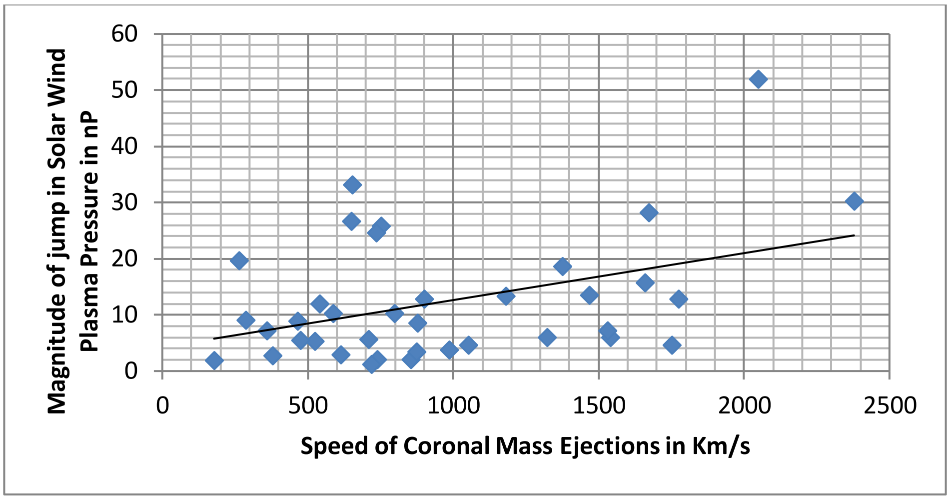

Figure -11 - The figure shows scatter plot between magnitude of JSWP Associated with RB related GMS and speed of CMEs

4. Conclusion

In this survey we have analyzed radio burst related geomagnetic storms having magnitude ≤-90nT with coronal mass ejections, solar flares and solar wind plasma parameters from 1997-2011. By the analysis of data collected from different sources within prescribed time period we have concluded that most of the radio burst related geomagnetic storms are associated with CMEs, solar flares and plasma parameters as well. Further we have concluded that coronal mass ejections (CMEs) are responsible for geomagnetic storms particularly halo coronal mass ejections.

Acknowledgement

The authors are very thankful to Prof. P. L. Verma to provide a continuous sport and encouragement for this.

Conflict of Interest

The authors declare that there is no conflict of interest in this manuscript.

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