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Study of North-South Distribution of Soft X-Ray Solar Flares in Association with Coronal Mass Ejections during the Period 2005 to 2010

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Abstract. For the present study we have investigated the distribution of solar flares in the northern and southern hemispheres of the sun which are associated with coronal mass ejections (CMEs) during the period 2005 to 2010. The period of our investigation includes the descending phase of solar cycle 23 and ascending phase of solar cycle 24. Our analysis indicates that 31.14% of solar flares associated with CMEs are obtained in the northern hemisphere whereas 68.86% are in the southern hemisphere which clearly indicates the dominance of the southern hemisphere and asymmetry between the northern and southern hemispheres during 2005 to 2010. We also found 66.31% B-class, 24.87% C-class, 7.55% M-class and 1.17% X-class solar flares in association with CMEs by our rigorous study and temporal analysis of data.

Keywords: Solar Flare, Coronal Mass Ejection.

1. Introduction

Solar flares are among the most interesting and widely studied phenomena on the sun. Flares occur suddenly, releasing enormous amount of energy (of the order of 10^{23} to 10^{32} ergs) in a very short time (few seconds to minutes). They emit energy over a wide range of wavelengths extending from Radio, Visible, EUV, X-rays and γ-rays together with particle emission (Prasad L., et al., 2008). Solar flares are classified as A, B, C, M and X type according to their peak flux. A coronal mass ejection (CME) is dynamically evolving, most energetic and largest phenomenon associated with the eruption of plasma and magnetic field from the sun. CME continuously expanding in size, carry frozen-in magnetic fields (Aschwanden 2006). CMEs are responsible for convection of solar magnetized plasma into interplanetary space. Fast blast waves and certain CMEs were produced by sudden increment of the thermal pressure in the low corona suggested by flare cause CME scenario (Parker 1961; Wu, Dryer

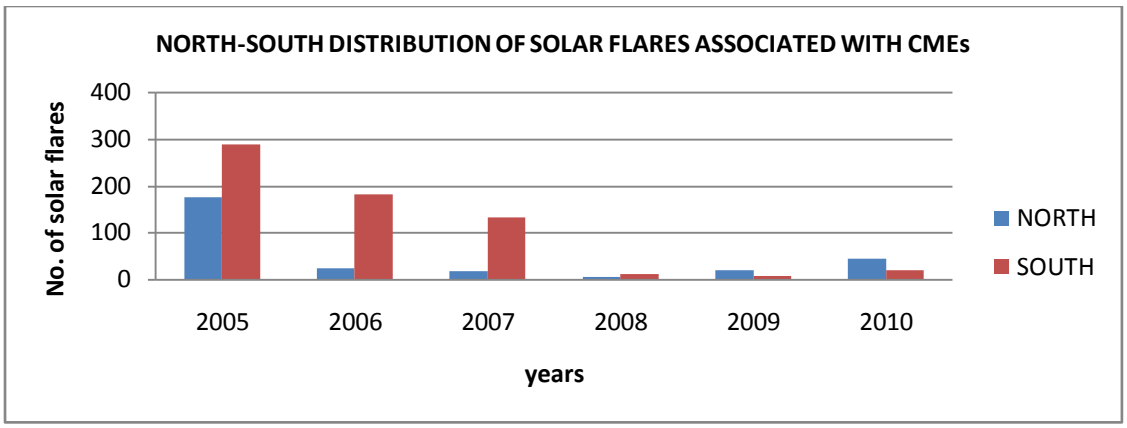
& Han 1983; Maxwell et al. 1985). This scenario is challenged by (Harrison 1986, 1995; Kahler et al. 1989) showing the asymmetry in locations between flare and CMEs. This finding rejects the flare cause CME scenario. CME-cause flare scenario suggests that flare appear as consequences of CMEs. Very energetic flares may still have some influence on the development of associated CMEs (Kahler 1992) where as flare and CME do not drive one another but closely related to each other (Harrison 1995). CMEs and flares are different manifestations of the same magnetic process supported by Harrison 1995 and his analysis indicates that the flare and CME are signatures of same magnetic "disease". Overall it is believed that flare and CMEs are closely related to each other. In 2004 Bhuwan Joshi and P. pant analyzed a data of solar flares during 1996 to 2003 and found that the northern hemisphere are more activated in producing flares than the southern hemisphere. Fast CMEs were associated with flares (Gosling et al. 1976). Higher speed and little acceleration is shown by flare associated CMEs (MacQueen & Fisher 1983). This is also supported by many authors (St. Cyr et al. 1999; Sheeley et al. 1999; Andrews & Howard 2001; Moon et al. 2002). Harrison in (1986) analyzed 48 flare-CME events and found that many flares occur near one leg of CMEs. 151 CME events are identified by Harrison and they found that 25 flares were within CME-onset windows (Harrison 1995). Lin and Jun (2004) found that the energy stored in magnetic structure are able to drive CME associated with flare. Latitudinal distribution of solar flares and their association with CMEs are analyzed by shrivastava et al. 2004 and according to their results solar flares in association with CMEs are equally distributed in the northern and southern hemispheres. They also found that flares associated with halo CMEs are responsible for producing forbush decrease (Fd) in cosmic ray intensity. Almost 57% of halo CME associated flares occur in the western hemisphere and almost 43% occur in the eastern hemisphere (Shrivastava et al. 2005). Yashiro et al. 2008 examined the statistical relationship between solar flare and CME during 1996 to 2007 and found that CME association rate increases with flares peak flux, fluence and duration. They also found that most frequent site is under the center of CME span. Recently Shrivastava et al. 2011 examined longitudinal distribution of solar flares and their association with CMEs and Fd. Their analysis show that 63% of solar flare associated with halo CME and Fd occur in the western hemisphere. They also found that almost 60% of solar flares associated with partial halo CMEs and Fd occur in the western hemisphere. For our study we have examined the latitudinal distribution of solar flares associated with CMEs and found the percentage of total flare obtained according to their class during 2005 to 2010.

2. Data Analysis

For the present study we have selected CMEs and flares data during period 2005 to 2010. The CME data is collected from CDAW website (http://cdaw.gsfc.nasa.gov/CME_list). The soft-X ray flares data are collected from NOAA website (http://www.ngdc.noaa.gov/stp/SOLAR/ftpsolarflares.html#xray). In this paper we have tried to associate those flares with CMEs which occurred within the temporal window $\Delta t=T_{CME}-T_{F,}$ where T_{CME} is the time of first occurrence of the CME and T_F is the lift-off time of associated X- ray flare by taking the maximum temporal window $\Delta t=+2$ h. Appling these conditions to our data selection we collected 941 flares associated with CMEs. Table 1 show the year wise distribution of solar flares associated with CMEs in the northern and southern hemispheres which indicate that the occurrence of solar flare is not uniform in both the hemispheres.

Table-1

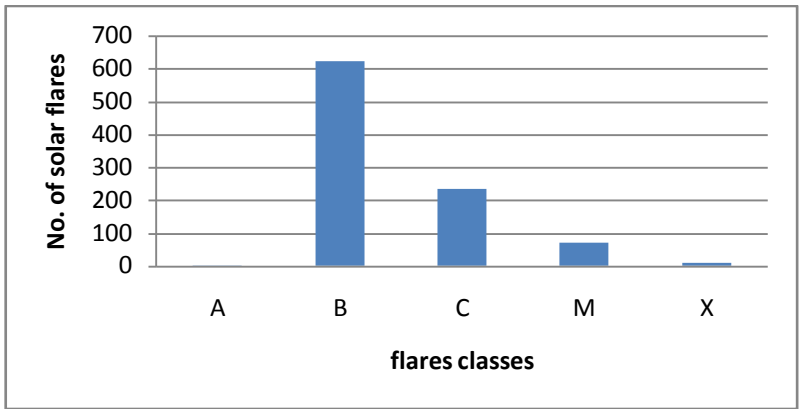
Year	Total no. of solar flares associated with CMEs	
	North	South
2005	176	289
2006	25	183
2007	18	134
2008	7	13
2009	21	8
2010	46	21
Total	293	648



Further we count solar flares association with CMEs in accordance with flares class A, B, C, M and X. Table 2 represented solar flares class during 2005 to 2010 in association with CMEs. Also the histogram is given for table 1 and 2.

Table-2

Flares classes	No of flares
A	1
B	624
C	234
M	71
X	11
Total	941



3. Result and Discussion

In our study during 2005 to 2010 only 941 solar flares associated with CMEs are found. Table 1 shows the year wise latitudinal distribution of solar flares associated with CMEs. The first column of table 1 represents the years, second and third column represents the number of solar flares associated with CMEs in the northern and southern hemispheres, and also histogram is given for Table 1. The distribution of soft X-ray flares class B, C, M and X during 2005 to 2010 in association with CMEs is given in figure-1. Figure 1 (a) represents the no. of B-class flares 55.91%, C-class flares 30.75%, M-class flares 11.40% and X-class flares are 1.94% during 2005. Figure (b) represents the no. of B-class flares 80.77%, C-class flares 17.31%, M-class flares 0.96% and X-class flares are 0.96% during 2006, figure (c) shows the no. of B-class flares 82.24%, C-class flares 13.82%, M-class flares 3.95% and X-class flares are 0% during 2007. Similarly figure (d), (e) and (f) shows the no. of A-class flares 5%, 0%, 0%, B-class flares 85%, 82.76%, 44.78%, C-class flares 5%, 17.24%,41.80%, M-class flares 5%, 0%, 13.43% and X-class flares is 0%, 0%, 0% during 2008, 2009 and 2010 respectly.

The total no. of A-class flares 0.11%, B-class flares 66.31%, C-class flares 24.87%, M-class flares 7.55% and X-class flares are 1.17% during the period 2005 to 2010 is given in fig-2.

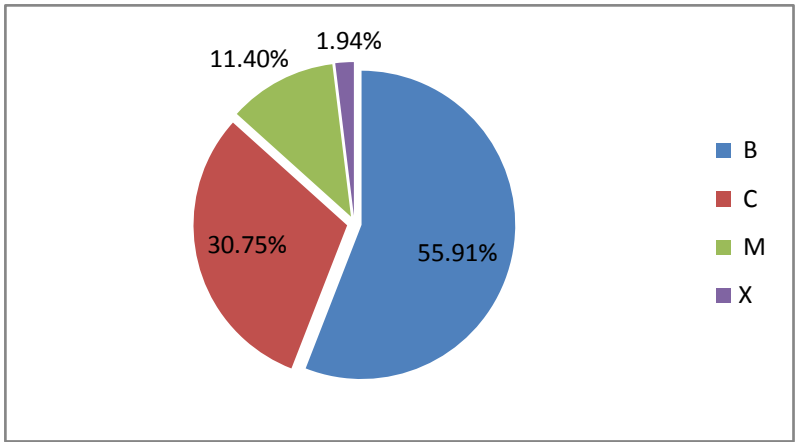


Fig.1 (a) Distribution of B, C, M and X-classes flares during 2005.

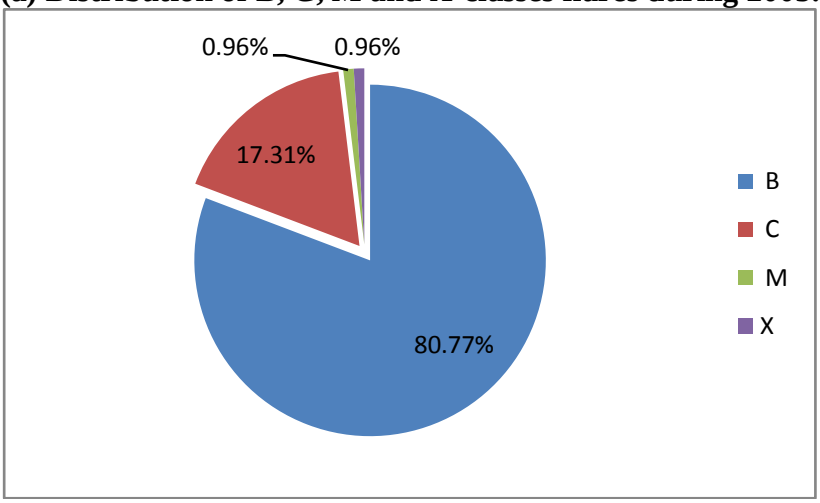


Fig.1 (b) Distribution of B, C, M and X-classes flares during 2006.

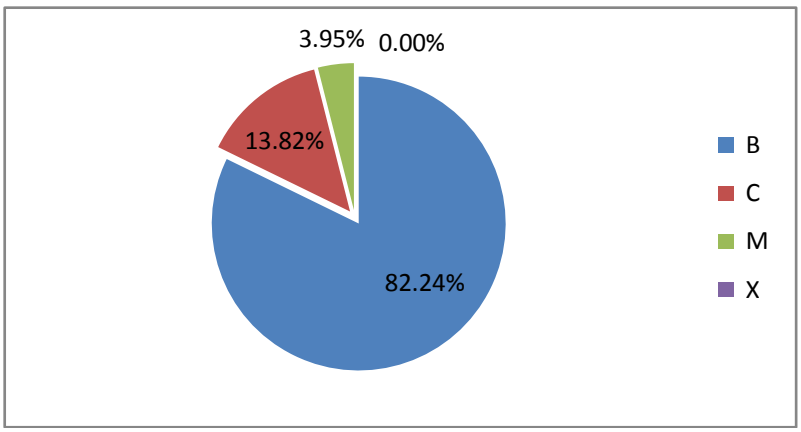


Fig.1 (c) Distribution of B, C, M and X-classes flares during 2007.

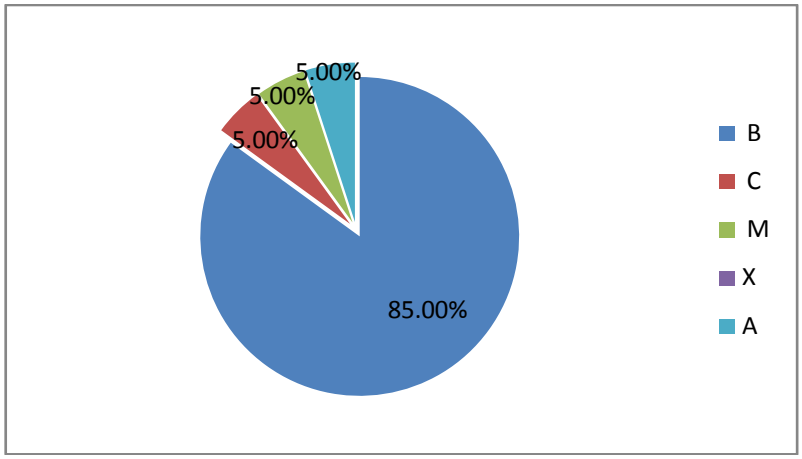


Fig.1 (d) Distribution of B, C, M and X-classes flares during 2008.

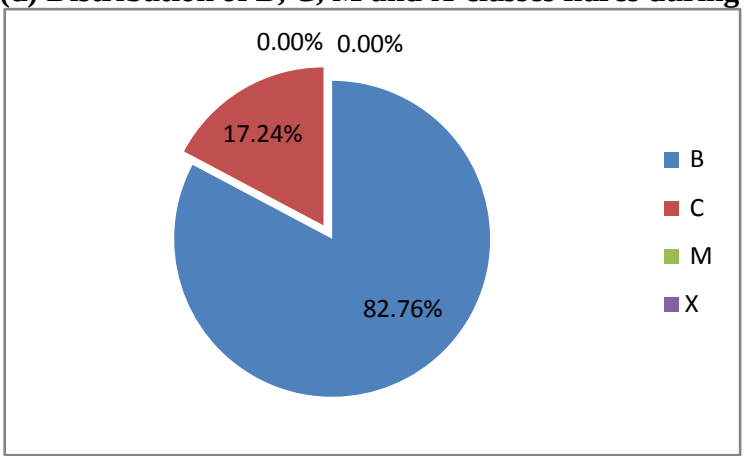


Fig.1 (e) Distribution of B, C, M and X-classes flares during 2009.

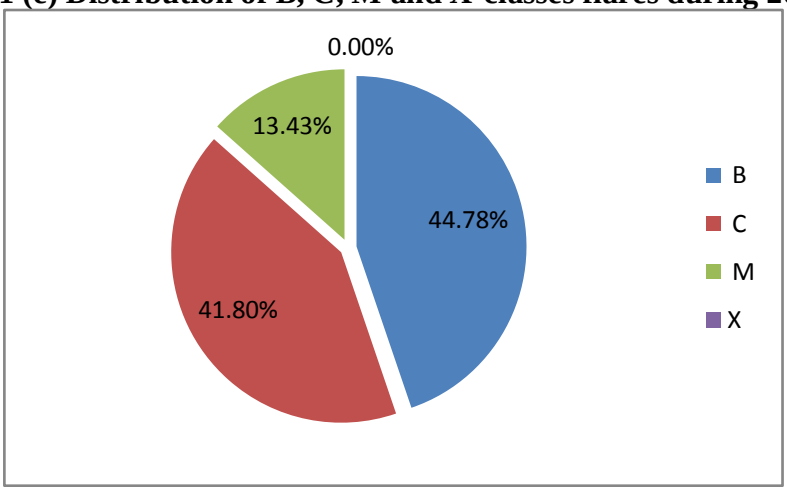


Fig.1 (f) Distribution of B, C, M and X-classes flares during 2010.

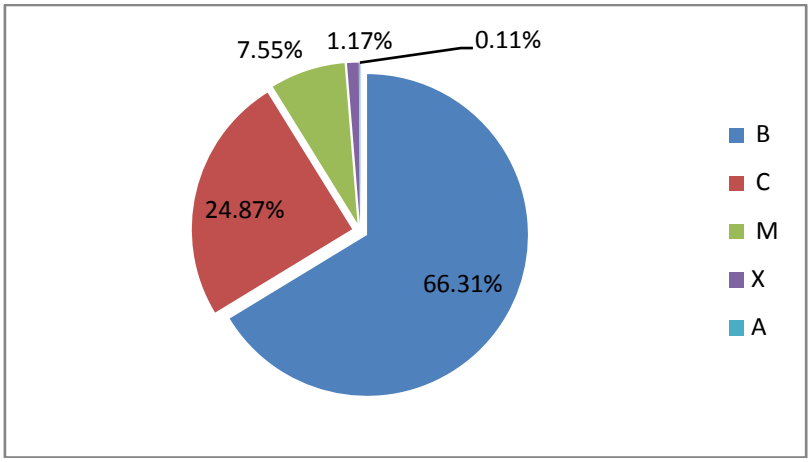


Fig.-2 Distribution of B, C, M and X-class flares during 2005 to 2010.

The north-south distribution of solar flares associated with CMEs shows a asymmerty in the northen and southern hemispheres, where the total no. of solar flares associated with CMEs in the northern hemisphere is 31.14% and in the southern hemisphere is 68.86% during the period 2005 to 2010. Figure-3 represents the percent distribution of solar flares associated with CMEs in the northen and southern hemispheres.

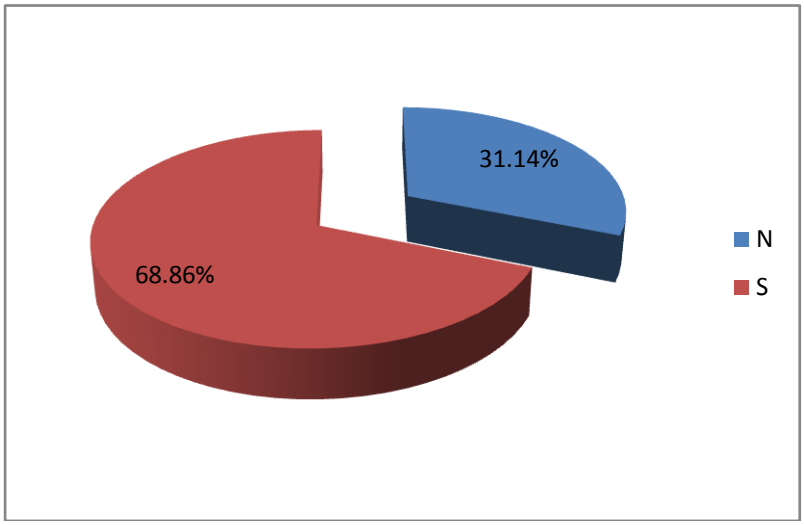


Fig. 3: The north- south distribution of solar flares associated with CMEs during the period 2005 to 2010.

4. Conclusions

From our study the following conclusions are obtained:-

(1) In our study we counted total 941 flares associated with CMEs. During 2005 to 2010 eventually the southern hemispheres produced more flares in association with CMEs. The southern hemisphere produced 68.86% solar flares in association with CMEs whereas the northern region produced 31.14% solar flares in association with CMEs which indicate the strong asymmetry between the northern and southern hemispheres.

(2) It is also concluded that $0\text{-}10^0$ belt produce more flares associated with CMEs during the period 2005 to 2010.

(3) We found the excess of B-class flares during the period 2005 to 2010. The percentage of B-class flares 66.31%, C-class 24.87%, M-class 7.55% and X-class are 1.17% are counted. During 2005 to 2010 only one flare of A-class in association with CME is obtained.

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