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Behaviour of Cosmic Ray Intensity (CRI) with Solar Flare Index and CMEs

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Abstract: ***This study elucidates the intricate relationship between cosmic ray intensity (CRI), coronal mass ejections (CMEs) and solar flares as pivotal factors influencing solar cosmic rays and their interaction with Earths geomagnetic activity. Through a meticulous analysis of pressure - corrected data from the Moscow Neutron Monitor Station and solar activity indices, the research delineates a strong inverse correlation between CRI and both solar flare index SFI and the number of CMEs across solar cycles 23 and 24. The findings, underpinned by correlation coefficients ranging from - 0.76 to - 0.87, underscore the significant impact of solar events on cosmic ray modulation. This comprehensive investigation not only reaffirms the Forbush decrease phenomenon but also contributes to our understanding of solar - terrestrial interactions, highlighting the pivotal role of CMEs in cosmic ray deflection and the broader implications for space weather forecasting and geomagnetic storm prediction.***

Keywords: Cosmic Ray Intensity (CRI), Solar Flare Index and CMEs.

1. Introduction

Coronal mass ejections (CMEs) and Solar flares are the fundamental sources of solar cosmic rays. CMEs and Solar flare, both of them are vigorous events which expel enormous quantities of material from the sun at a speed of about 400–1000 km/s. When such a great magnetic disturbance arrives at earth, brush off some of the incoming cosmic rays which result in the decrement in their rate of deflection. The decrease in the observed CRI with increase in solar cosmic rays was discovered by Scott. E. Forbush known as forbush decrease (FD: Forbush 1938). Thus, the large magnetic field of CMEs can deflect the CRs and thus causes FDs. This indicates that CMEs are most effective in causing FDs (Jothe et al.2010; Shrivastava et al.2011). As soon as FDs was discovered, many researchers began probing for the cause of this decrease and their relationship with geomagnetic activity (Barouch and Burlaga 1975; Cane and Richardson 1995; Kaushik et al.2001; Prasad et al.2013). CMEs are large - scale phenomena that change the configuration of the interplanetary magnetic field (IMF) and clearly modulate the cosmic - ray intensity on short - term timescales (Cane 2000). Correlative analysis of long-term cosmic ray variation in relation with interplanetary magnetic field reported by Sarver Khan et al., 2019. CMEs also contribute to longer term modulation, in particular by contributing to the propagating barriers (GMIRs) that are believed to be the cause of the long - term modulation (Newkirk et al.1981, McDonald & Burlaga 1997, Cliver & Ling 2001b). Correlative analysis between the CRI and SA parameters SSN, GSF, and Ap have been performed for low and medium cut - off rigidity stations (Hatton 1980, Mavromichalaki et al.1998). Generally, SSNs have been used as a representative SA index for various studies (Dorman & Dorman 1967, Singh et al.2005). Later on, other types of solar indices like 10.7 - cm solar flux, grouped solar flares (GSF), solar flare index (SFI), sunspot area, grouped sunspot numbers, coronal index (CI), etc. have been used arbitrarily, mostly without assigning any physical reason for the choice of a particular index or the combination of indices (Chattopadhaya et al.2003). The Correlatives analysis of long - term modulation of Cosmic Ray Intensity (CRI) variations with solar active parameters such as CMEs, sunspot numbers (SSN), solar flare index (SFT) and interplanetary magnetic field (IMF) and from the correlative study they have found that inverse or anti co - relation between Cosmic Ray Intensity (CRI) with sunspot numbers (SSN), solar flare index (SFT) and interplanetary magnetic field (IMF) (Puspraj Singh et al., Nand Kumar Patel et al.). The comparative study of the behavior of CRI with geomagnetic storms, southward component of IMF, i. e. |Bz|, IMF B, solar wind speed (V) and V·|Bz| for two consecutive odd solar cycles 21 and 23 (Chandrasekhar Bhoj, et al.2019).

2. Data Analysis

For the study of cosmic rays, the pressure - corrected data (yearly mean) has been taken from Moscow Neutron Monitor Station (http: //cro. izmiran. rssi. ru/mosc/main. htm) while the data for solar flare index (SFI) index is obtained from the Omni web data center (http: //omniweb. gsfc. nasa. gov/cgi/nx1. cgi). The CME data used in this study is collected from LASCO and SOHO available in CME catalogue that can be found at http: //cdaw. gsfc. NASA. gov/CME. The correlation coefficient of Cosmic Ray Intensity with solar flare index and number of CMEs has been calculated using the method of "minimizing correlation coefficient method".

3. Results and Discussion

(I) Correlative study of Cosmic Ray Intensity (CRI) with Solar Flare Index (SFI):

In this study we have analysis between yearly average values of cosmic ray intensity (CRI) and yearly average values of solar flare index (SFI), during the period of 1996 - 2008 and 2009 - 2019. We have plotted a liner graph between yearly average values of cosmic rays intensity (CRI) and yearly average values of solar flare index (SFI), it is shown in figures (1&2). From the figures it is observed that inverse correlation has been found between yearly average values of cosmic ray intensity (CRI) and yearly average value of solar flare index (SFI) and it is found that the variation of higher values of cosmic ray intensity (CRI) with lower values of solar flare index (SFI) and the variation of lower values of cosmic ray intensity (CRI) with higher values of solar flare index (SFI). We have found the strong negative correlation between the yearly average values of cosmic ray intensity (CRI) and the yearly average values of solar flare index (SFI), during the period of 1996 - 2008 with correlation coefficient - 0.76. And we have also found very strong negative correlation between the yearly average values of cosmic ray intensity (CRI) and the yearly average values of solar flare index (SFI), during the period of 2009 - 2019 with correlation coefficient - 0.84.

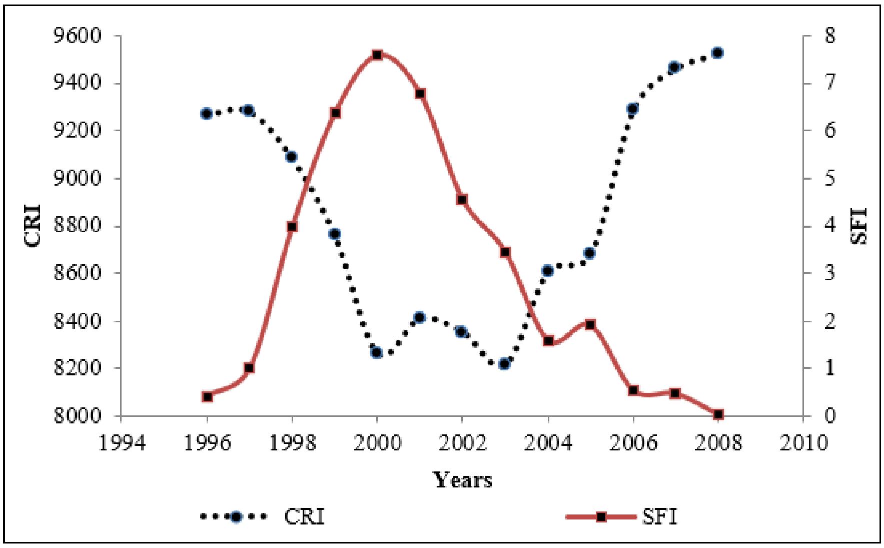

Figure 1: Shows the linear diagram between the yearly average values of CRI and SFI, during the period of 1996 - 2008.

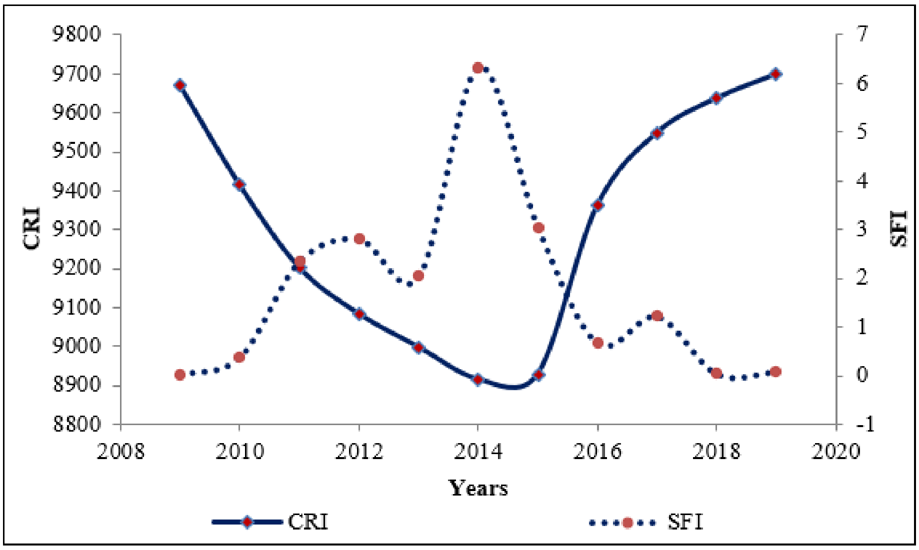

Figure 2: Shows the linear diagram between the yearly average values of CRI and SFI, during the period of 2009 - 2019.

(II) Correlative study of Cosmic Ray Intensity (CRI) with Number of CMEs:

We have analysis between yearly average values of cosmic ray intensity (CRI) and numbers of CMEs, during the period of 1996 - 2008 and 2009 - 2019. We have plotted a liner graph between yearly average values of cosmic rays intensity (CRI) and yearly average values of numbers of CMEs it is shown in figures (3&4). From the figures it is observed that inverse correlation has been found between yearly average values of cosmic ray intensity (CRI) and yearly average value of numbers of CMEs and it is found that the variation of higher values of cosmic ray intensity (CRI) with lower values of numbers of CMEs and the variation of lower values of cosmic ray intensity (CRI) with higher values of numbers of CMEs. We have found the strong negative correlation between the yearly average values of cosmic ray intensity (CRI) and the yearly average values of numbers of CMEs, during the period of 1996 - 2008 with correlation coefficient - 0.86. And very strong negative correlation has been found between the yearly average values of cosmic ray intensity (CRI) and the yearly average values of numbers of CMEs, during the period of 2009 - 2019 with correlation coefficient - 0.87.

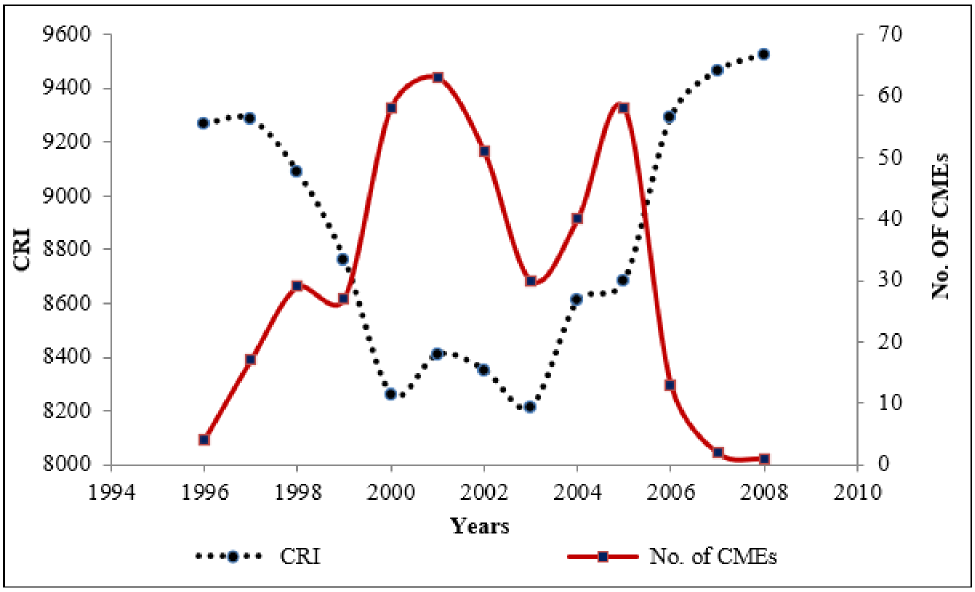

Figure 3: Shows the linear diagram between the yearly average values of CRI and numbers of CMEs, during the period of 1996 - 2008.

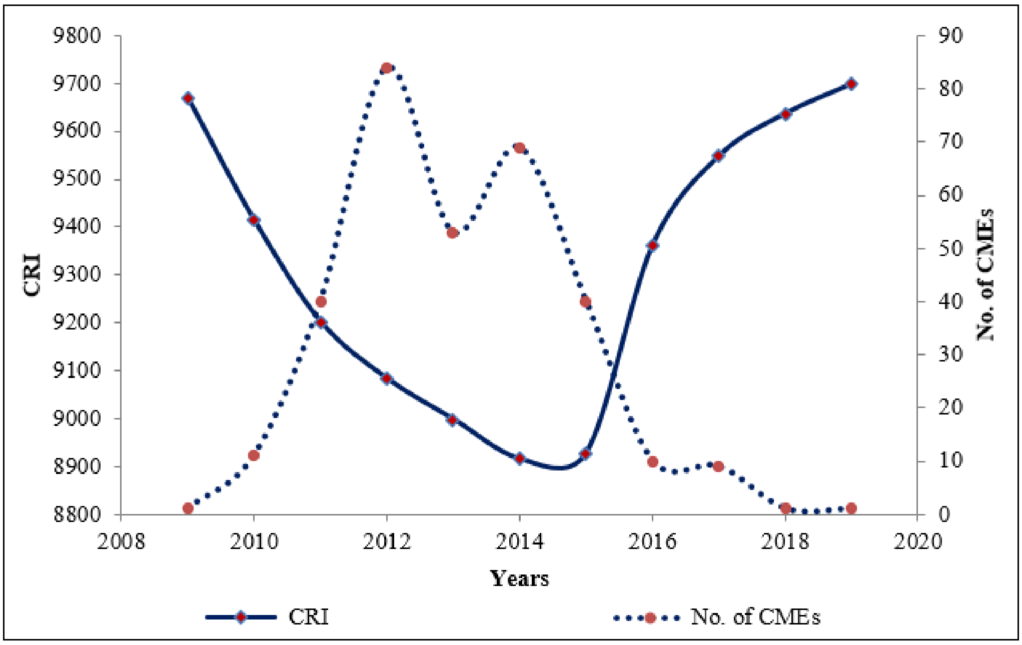

Figure 4: Shows the linear diagram between the yearly average values of CRI and numbers of CMEs, during the period of 2009 - 2019

4. Conclusions

- From the comparative study we have found that inverse correlation between yearly average values of cosmic ray intensity (CRI) with yearly average values of solar flare index and numbers of CMEs.
- We have found the high negative correlation of cosmic ray intensity (CRI) and solar flare index (SFI) for the solar cycle 23rd with correlation coefficient - 0.76. And we have also found very high negative correlation between cosmic ray intensity (CRI) and solar flare index (SFI) for the solar cycle 24th with correlation coefficient - 0.84.
- We have found the strong negative correlation between cosmic ray intensity (CRI) and number of CMEs for the solar cycle 23rd with correlation coefficient - 0.86. And very strong negative correlation has been found between cosmic ray intensity (CRI) and number of CMEs for the solar cycle 24th with correlation coefficient - 0.87.
- The correlation coefficient of cosmic ray intensity (CRI) with solar flare index and number of CMEs for the solar cycle 23rd and solar cycle 24th is observed high which obviously displays that both of these parameters are strongly correlated for both the solar cycles.
- The findings, underpinned by correlation coefficients ranging from - 0.76 to - 0.87, underscore the significant impact of solar events on cosmic ray modulation.

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