IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⁜ Vol. 9, Issue 2, February 2022

DOI: 10.17148/IARJSET.2022.9225

Study of Cosmic Ray Intensity and Geomagnetic Storms in Relation to Various Interplanetary Parameters and their product functions for Solar Cycle 24

Chandni Mathpal[1], Lalan Prasad[2]

Department of Physics, Govt. P.G. College, Berinag-262531 Pithoragarh Uttarakhand, India[1,2]

Abstract: In this paper, we study the connection of cosmic ray intensity (CRI) and geomagnetic storms (GSs) with various interplanetary parameters (i.e. B, B_x, B_y, B_z, E_y) and their product functions (i.e. BV, B_zV, B^2V B_z^2V) for complete solar cycle 24. In order to find the association of CRI with various interplanetary parameters and their product functions, we incorporate the analysis technique by superposed-epoch analysis. The current analysis depict that various interplanetary parameters such as B_x and B_y are CR-effective. The peak values of CRI is found to be in good correlation with B_x and B_y (r= -0.85 for B_x and r= 0.71 for B_y). The interplanetary parameters such as B, B_z and E_y are found to be moderately correlated with CRI. We have obtained specifically good values of correlation coefficient between CRI and various product functions of interplanetary parameters (r= -0.61 for BV, r= 0.50 for VB_z, r= -0.52 for B^2V, r=-0.5 for B_z^2V). Besides this, we have obtained high values of correlation coefficient between Dst index and various interplanetary product functions (r= -0.82 for B_z^2V, r= -0.81 for B^2V, r= 0.84 for B_zV and r= -0.87 for BV). We statistically proved that various interplanetary product functions are highly geo-effective and CR-effective parameters. Moreover time-delay analysis has also been performed by the method of correlation coefficient between CRI, geomagnetic activity indices, vrious interplanetary parameters and their product functions. Beside this, we also compare the different geomagnetic activity indices (AE, Ap, AU, Kp) with Dst index.

Keywords Cosmic ray intensity, Interplanetary parameters, Interplanetary magnetic field, Geomagnetic storms, Interplanetary product functions.

1. INTRODUCTION

The study has been carried out to find the association of cosmic ray intensity (CRI) in relation to various interplanetary parameters (i.e B, Bx, By, Bz, Ey) and their product functions (i.e. BV, B_zV, B^2V B_z^2V) for complete solar cycle 24 (2008 to 2018). We also study the association of geomagnetic storms in relation to various interplanetary product functions. In one of our previous published paper, we statistically proved that various interplanetary parameters are highly geo-effective (**Mathpal et al., 2018).**

A geomagnetic storm is a short lived interuption of the earth's magnetosphere bring about by a solar wind shock wave and cloud of magnetic field that communicate with the earth's magnetic field. When the forceful solar wind gets closer to the earth, the dayside of the magnetosphere is compressed and vacillation in the geomagnetic field takes place. This vacillation in geomagnetic field is known as GS whose durability is measured by Dst or Kp index **(Gonzalez et al., 1994).** For our study we used the Dst index as a sign of GS. The Dst index is a measure of the deviation of northward component of magnetic field near the earth's equator. A perfect GS has three phases i.e initial, main and recovery phase. In the present paper, we have taken main phase to study the GSs. The main phase is caused by the inflation in magnetosphere due to the ring current (A ring of westward electric current created by energetic charged particle flowing around the earth at equitorial plane) injection which is caused by southward IMF and resulting strong convection. The minimum value of Dst during main phase is -50nT and approximately -600nT. The span of this phase is usually 2-8 hours. The day with Dst ≤ -50nT was taken as a trigger day for Super-posed epoch analysis. When a magnetic storm is in progress, it is depicted with the negative sign of Dst index. When the intensity of magnetic storm is very high, it is depicted with the more negative sign of Dst index. The positive value of the Dst index is due to the compression of magnetosphere which is due to increase in solar wind pressure. The durability of GS also depend upon the solar wind.

Solar wind can be described as the flow of charge particles originating from the upper atmosphere of the sun. Solar wind generally modify its speed, density and temperature with time and longitude. On account of its tremendous energy, its particle get away from the sun's gravity. The disruption in the earth's magnetic field whose intensity rely

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⁜ Vol. 9, Issue 2, February 2022

DOI: 10.17148/IARJSET.2022.9225

upon the nature of ejecta is produced, when the solar wind enters the interplanetary medium **(Cane and Richardson 1995; Loewe and Prolss 1997).** Slow solar wind and fast solar wind are the two major components of solar wind in which it can be categorized. The high speed solar wind stream (HSSWS) are found to be effacious in bringing forth immense temporary decline in CRI **(Shrivastava and Jaiswal, 2003).** HSSWS produces transient decrease in CRI and enhancement of geomagnetic activity **(Hatton, 1980).**

FDs can be major or minor, short or long lasting, with rapid or gradual recovery, two step or not, and so on. These fluctuations in cosmic rays are due to variety of solar sources and interplanetary situation arising before and during the event. **Cane, 2000** observed the two types of FDs. (i) Non-recurrent decreases promote by temporary interplanetary events connected to CMEs from the sun and have an unexpected beginning with asymmetric profiles. (ii) Recurrent decreases related to the co-rotating HSSWS and have gradual onset with symmmetric profiles (**Lockwood, 1971; Iucci et al., 1979).** Forbush effect is generally a storm in cosmic rays which appears simultaneously with a geomagnetic storm (**Belov, 2008).**

2.DATA AND METHOD

This paper presents a correlative study between the peak values of CRI, geomagnetic activity indices and the peak values of various interplanetary parameters (B, Bx, By, Bz, Ey) and their product functions (BV, B_zV, B^2V, B_z^2V) during the main phase of geomagnetic storm for complete solar cycle 24. In order to find out the variation of CRI and geomagnetic storm in relation to various interplanetary parameters and their product functions, we used a Chree analysis by the superposed epoch method. The occurrence days of GSs are used as a zero days with criteria Dst ≤-50nT. We used the pressure-corrected daily mean data of the CRI from the Moscow Neutron Monitor Station (cro.izmiran.rssi.ru/mosc/main.htm). The daily mean values of various interplanetary parameters are taken from the omniweb data center (omniweb.gsfc.nasa.gov/form/dx1.html). In order to calculate the correlation coefficient between these parameters, we used unbinned with a time resolution of one day (daily mean average).

3. RESULTS AND DISCUSSION

3.1. Interplanetary parameters (B, Bx, By, Bz, Ey) and CRI

Interplanetary magnetic field (IMF B) is a constituent of the sun's magnetic field that is fetch in to interplanetary space by the solar wind. The interplanetary strength and its vacillation are accountable for CRI modulation **(Sabbah, 1996; Sabbah, Darwsh and Bishara, 1998 ; Mishra and Mishra, 2005).**

We investigate the association of cosmic ray intensity (CRI) with the interplanetary magnetic field (IMF B) for the period 2008-2018. Fig. 1 shows the strongest increment in IMF B occurs on the happening day of GSs. No time delay is found between the extreme value of IMF B and least value of CRI. IMF B is found to be moderately correlated with CRI (r= -0.43). Our outcome is in good agreement with the results of **Kharayat et al., 2016; Agarwal and Mishra, 2008; Duggal et al., 1983.**.

Interplanetary magnetic field is supposed to be divide in to three components i.e Bx, By, Bz. The x and y components of IMF are not at all valuable for auroral activity and it is orient parallel to ecliptic plane while the third component of IMF B developed by waves and other disturbances in solar wind is the most valuable ingredient for auroral activity and is perpendicular to ecliptic plane.

From figure '1' it is clear that the strongest increment in B_x occurs one day after the minimum value of CRI which indicates that there is a time delay of 0 to 1 day between these two parameters. We have observed the high correlation coefficient between B_x and CRI (r= -0.85), which indicates that B_x is a CR-effective parameter.

Similarly, the strongest decrement in B_y occurs one day after the happening day of geomagnetic storm. Thus, we observed a time delay of 0 to 1 day between the strongest decrement in B_y and CRI. The correlation coefficient between B_y and CRI is found to be 0.71, which indicates that B_y is also a CR-effective parameter.

Likewise, we observed that the strongest decrement in B_z and CRI occurs on the happening day of geomagnetic storm. No time delay is found between the least value of B_z and CRI. A moderate correlation (r= 0.48) is found between B_z and CRI.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⁜ Vol. 9, Issue 2, February 2022

DOI: 10.17148/IARJSET.2022.9225

Further, we observed the association between E_y and CRI. The strongest increment in E_y occurs on the happening day of GS (Fig. 1). No time delay is found between the extreme value of E_y and minimum value of CRI. The correlation coefficient between these two parameters is found to be -0.48, which is moderate.

By their comparative study, we observed that all the interplanetary parameters such as B, B_x, B_y, B_z, E_y chosen in the given study, out of which B_x and B_y are found to be CR-effective parameters. Thus CRI modulation takes place mainly due to the enhancement in B_x and B_y.

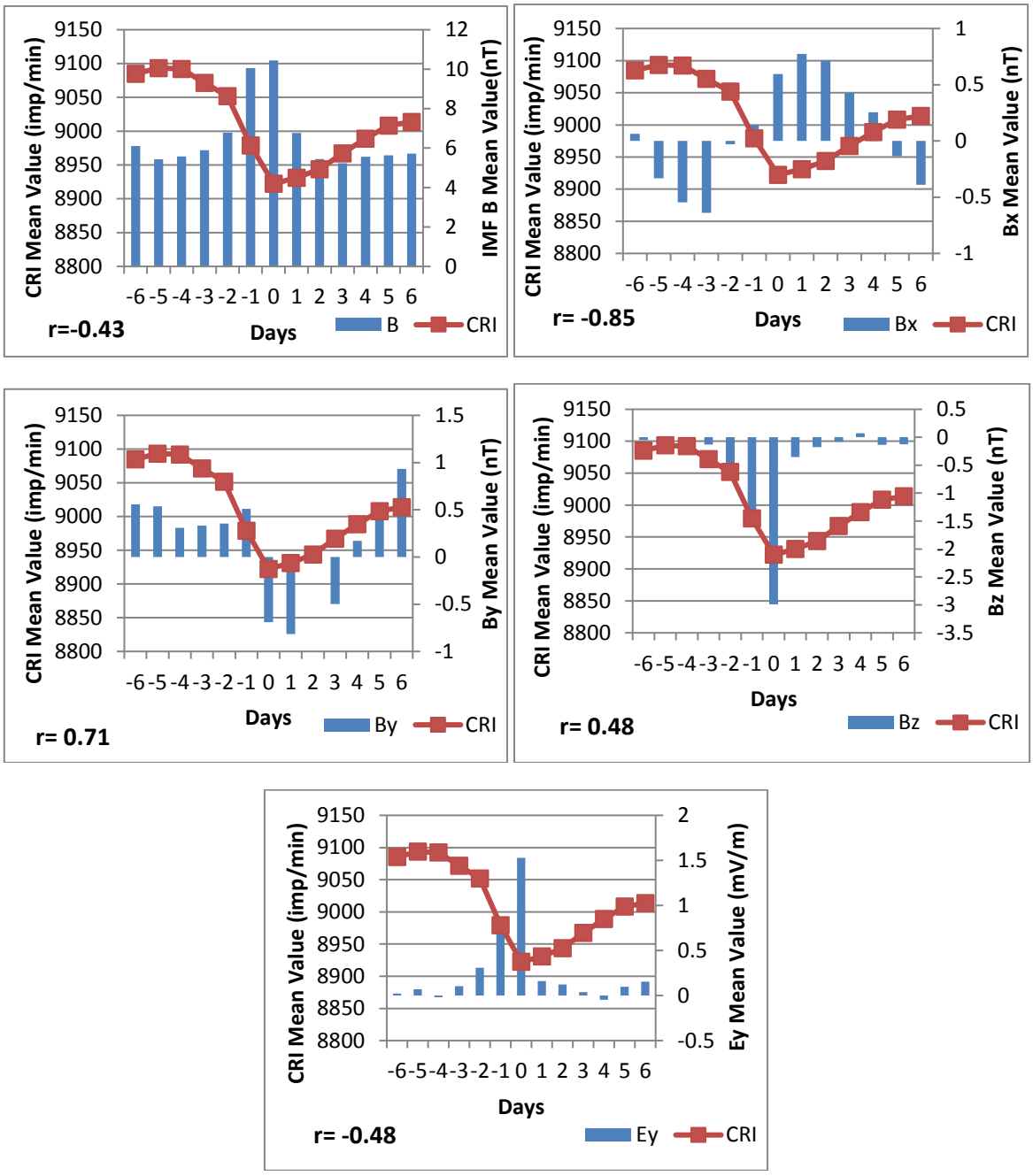

Figure 1 The conclusion of superposed epoch analysis from -6 to +6 days with respect to zero epoch day. The discrepancy of mean value of interplanetary parameters such as B, B_x, B_y, B_z, E_y and CRI is demonstrated where zero day accord with the trigger day of happening of GS during 2008-2018.

3.2. Interplanetary product functions (BV, B_zV, B^2V B_z^2V) and CRI

After investigating the association of CRI with various interplanetary parameters separately, we also study the variations of CRI with various interplanetary product functions (i.e. BV, B_zV, B^2V, B_z^2V) for a period of 11 years

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⁜ Vol. 9, Issue 2, February 2022

DOI: 10.17148/IARJSET.2022.9225

during 2008 to 2018 (Solar Cycle 24) by using Chree analysis. The correlation coefficient between CRI and various interplanetary product functions are found to be r= -0.62 for BV, r= 0.50 for VB_z, r= -0.52 for B^2V, r= -0.50 for B_z^2V. The correlation coefficient obtained in the study indicates that various interplanetary product functions are CR-effective parameters.

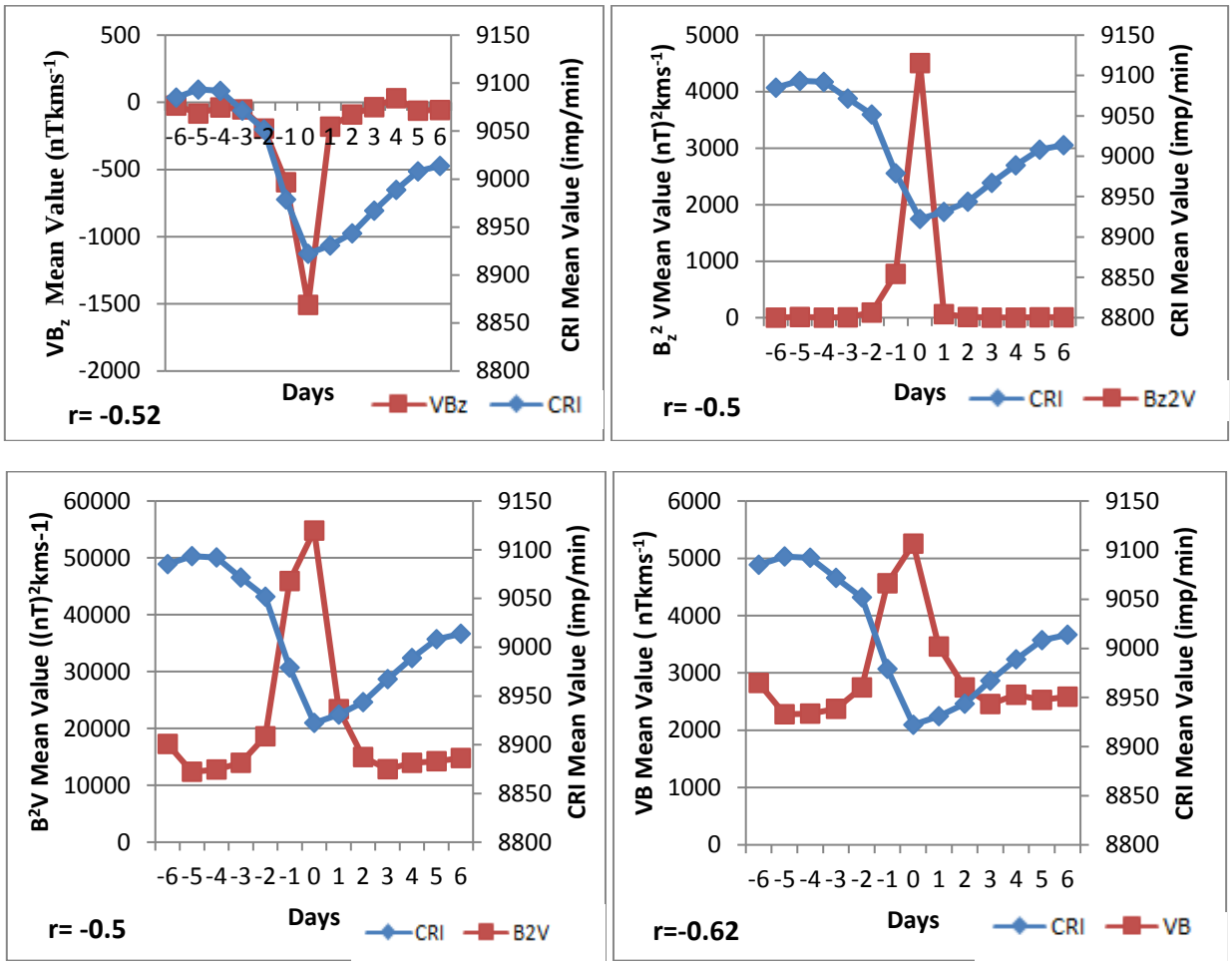

Figure 2 The conclusion of superposed epoch analysis from -6 to +6 days with respect to zero epoch day. The discrepancy of mean value of interplanetary product functions such as BV, B_zV, B^2V, B_z^2V and CRI is demonstrated where the zero day accord with the trigger day of happening of GS during 2008-2018.

3.3. Dst index and interplanetary product functions

Likewise, we study the dependence of geomagnetic storms on various interplanetary product functions. For our study, we used Dst index as a indicator of geomagnetic storms. The correlation coefficient between Dst index and various interplanetary product functions are found to be r= -0.82 for B_z^2V, r= -0.81 for B^2V, r= 0.84 for B_zV and r= -0.87 for BV.

The correlation coefficient obtained in our study strongly suggest that these introduced interplanetary product functions are highly geo-effective. Various researches has been done so far to find the association of CRI and geomagnetic storms with various interplanetary parameters and their product functions. Our outcomes are in good agreement with the results of **Pande et al 2017, Joshi et al 2011, Bhoj et al., 2019, Mathpal et al., 2018.**

No time lag is found between the extreme value of interplanetary product function VB, B^2V, B_z^2V and least value of Dst index.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⁜ Vol. 9, Issue 2, February 2022

DOI: 10.17148/IARJSET.2022.9225

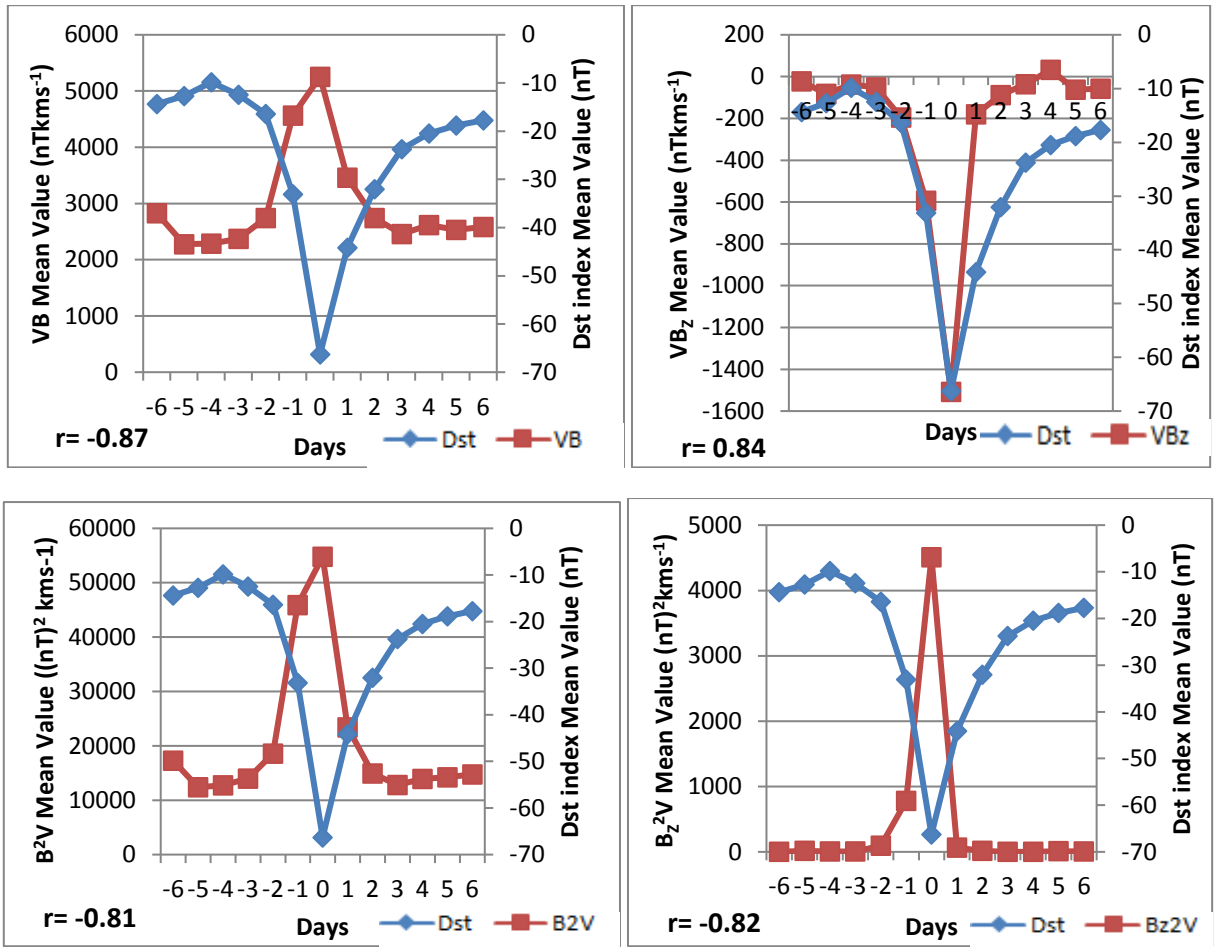

Figure 3 The conclusion of superposed epoch analysis from -6 to +6 days with respect to zero epoch day. The discrepancy of mean value of interplanetary product functions such as BV, B_zV, B^2V, B_z^2V and Dst index is demonstrated where zero day correspond with the trigger day of happening of GS during 2008-2018**.**

3.4. CRI and geomagnetic activity indices

Further, we studied the association of CRI with geomagnetic activity indices (Dst, AE, Ap, AU, Kp). The daily mean average values of CRI and geomagnetic activity indices have been studied for the complete solar cycle 24. The AE, Ap, Kp, AU indices are considered as a indicative of GS. The AE index is used to measure the durability of the electrojet (it is an electric current which ride about the E-region of the earth's ionosphere). Kp index is used to estimate the fluctuation of the extremely interrupted horizontal component of the magnetic field. The Ap index is a measure of the general level of geomagnetic activity over the globe for a given day.

An upper bound or utmost positive excursion in H is determined called AU index which measure the particular intensity of eastward and westward electrojets, while AE provides a measure of the all-inclusive horizontal current strength. Figure '4' represent the plot of CRI vs geomagnetic activity indices and it is clear that CRI start to decrease and reaches its minimum value on the occurrence day of geomagnetic storm (zero day), at the same time Kp index, AU index, AE index and Ap index start to increase and reaches its peak value on the occurrence day of geomagnetic storm simultaneously to indicates that no time lag is found between the peak value of geomagnetic activity indices (i.e. Kp index, AU index, AE index and Ap index) and least value of CRI. We also calculated the correlation coefficient between CRI and geomagnetic activity indices by using the pearson method. The correlation coefficient between CRI and geomagnetic activity indices are found to be 0.84 for Dst index, -0.69 for Kp index, -0.54 for AU index, -0.63 for AE index, -0.57 for Ap index. The correlation coefficient obtained in our study indicates that CRI is stongly correlated with Dst index. The other geomagnetic activity indices are also in good correlation with CRI. Our study strongly support the previous results of **Bhoj et al., 2019, Shrivastava et al., 2001, Kharayat et al., 2016, Kaushik et al., 2005, Firoz et al., 2009.**

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⁜ Vol. 9, Issue 2, February 2022

DOI: 10.17148/IARJSET.2022.9225

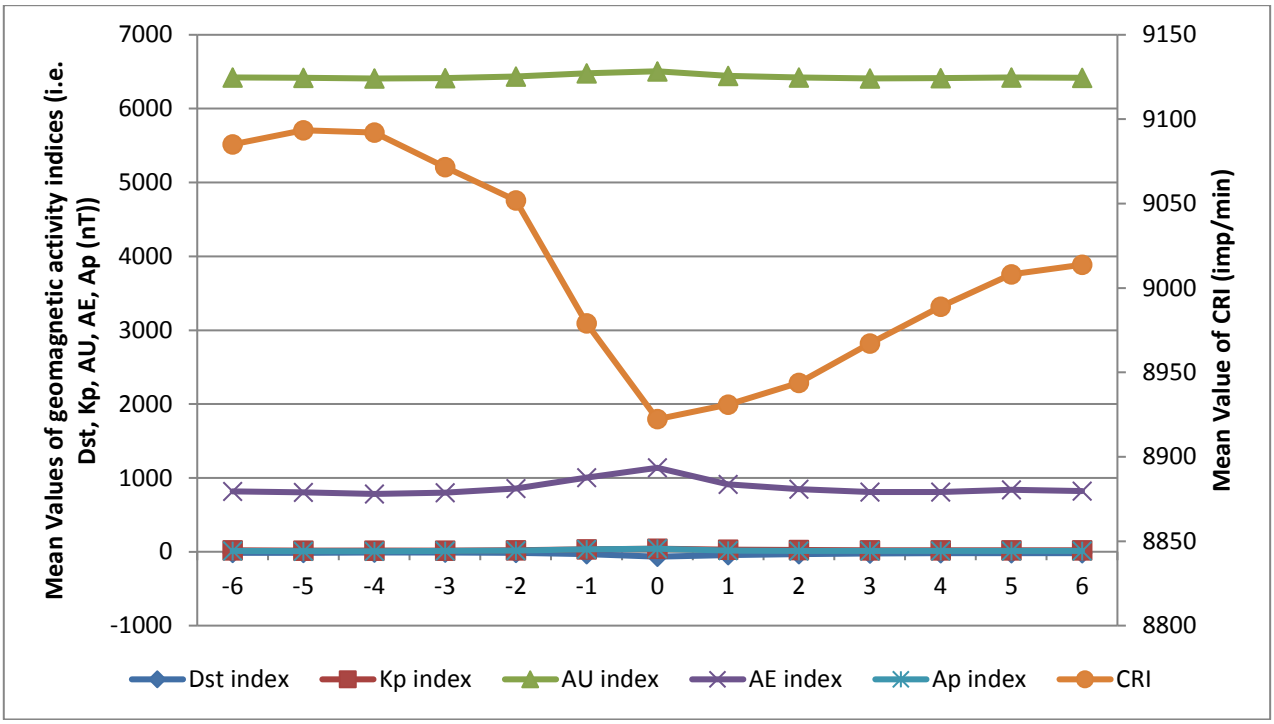

Figure 4 The conclusion of superposed epoch analysis from -6 to +6 days with respect to zero epoch day. The discrepancy of mean value of CRI and geomagnetic activity indices is demonstrated.

Table 1. Correlation coefficients between different parameters

S. No.	Parameters	Correlation Coefficient
1	CRI and B	-0.43
2	CRI and B_z	048
3	CRI and B_x	-0.85
4	CRI and B_y	0.71
5	CRI and E_y	-0.48
6	CRI and VB	-0.62
7	CRI and VB_z	-0.52
8	CRI and VB^2	-0.5
9	CRI and VB_z^2	-0.5
10	Dst index and VB	-0.87
11	Dst index and VB_z	0.84
12	Dst index and VB^2	-0.81
13	Dst index and VB_z^2	-0.82
14	CRI and Kp index	-0.69
15	CRI and Dst index	0.84
16	CRI and Ap index	-0.57
17	CRI and AU index	-0.54
18	CRI and AE index	-0.63

4. CONCLUSIONS

After the detailed analysis of our study various conclusions has been observed that are discussed below-

1) IMF B is moderately correlated with CRI having correlation coefficient -0.43.

2) Interplanetary parameters such as Bx and By are found to be CR-effective with correlation coefficient -0.85 for Bx and 0.71 for By.

DOI: 10.17148/IARJSET.2022.9225

3) North- south direction of IMF (Bz) and Ey are moderately correlated with CRI.
4) The correlation coefficient between interplanetary parameters and CRI are found to be 0.48 for Bz and -0.48 for Ey.
5) Interplanetary product functions are found to be CR-effective parameters.
6) The correlation coefficient of CRI with various interplanetary product functions are found to be -0.62 for BV, 0.50 for VB_z, -0.53 for B^2V and -0.50 for B_z^2V.
7) Interplanetary product functions (i.e. BV, B_zV, B^2V, B_z^2V) are found to be highly geo-effective.
8) The correlation coefficient of CRI with various interplanetary product functions are found to be -0.82 for B_z^2V, -0.81 for B^2V, 0.84 for B_zV and -0.87 for BV.
9) The correlation coefficient between CRI and Dst index is found to be 0.84, which indicates that CRI and Dst index are highly correlated with each other.
10) The correlation coefficient between CRI and other geomagnetic activity indices are found to be -0.69 for Kp index, -0.54 for AU index, -0.63 for AE index, -0.57 for Ap index, which indicates that all the geomagnetic activity indices are stonly correlated with CRI.

ACKNOWLEDGEMENTS

The authors would like to all those involved in this paper as well as the data providers as ACE OMNI data centre and Neutron Monitor Station, Moscow. Also thanks to the editor journal of Solar Physics for their regular update issues of content page service. Also thanks to CSIR, New Delhi and UCOST Dehradun, India.

REFERENCES

Agarwal, R., Mishra, R.K.: 2008, Astrophys. J. **51,** 269.
Belov, A.V., In: Gopalswamy, N., Webb, D.F. (eds.), 2008, Proc. IAU Symposium, vol. 257, p. 439.
Bhoj, C., Prasad, L., Pokharia, M., Mathpal, C.: 2019, J. Astrophys. Astr. **40**:26.
Cane, H.V.: 2000, Space Sci. Rev, **49,** 55.
Cane, H.V., Richardson, I.G.: 1995, J. Geophys. Res. **100,** 1755.
Duggal,S.P., Pomerantz, M.A., Schaefer, R.K., Tsao, C.H.: 1983, Journal of Geophysical Research:Space Physics,Vol **88**, 2973-2981.
Firoz, K.A., Kumar, Phani, D.V., Cho, K.-S.: 2009, Astrophysics and Space Science, **325 (2),** 185-193.
Gonzalez, W.D., Joselyn, J.A., Kamide, Y., Kroehl, H.W., Rostoker, G., Tsurutani, B.T., Vasyliunas, V.M.: 1994, J. Geophys. Res. **99,** 5771.
Hatton, C.J.: 1980, Solar Physics. **66,** 159-165.
Iucci, N., Parisi, M., Storini, M., Villoresi, G.: 1979, Nuovo Cimento B **2,** 225-229.
Joshi, N.C., Bankoti, N.S., Pande, S., Pande, S.: 2011, New Astronomy, 16 (6): 366-385.
Kaushik, S.C., Shrivastava, A.K., Rajput, H.M.: 2005, 29th International Cosmic Ray Conference Pune, 2, 151-154.
Kharayat, H., Prasad, L., Mathpal, R., Garia, S., Bhatt, B.: 2016, Solar Physics. **291,** 603-611.
Lockwood, J.A.: 1971, Space Sci. Rev. **12,** 658.
Loewe, C.A., Prolss, G.W.: 1997, J. Geophys. Res. **102,** 14209.
Mathpal, C., Prasad, L., Pokharia, M., Bhoj, C.: 2018, Astrophysics and Space Science. 363:177. Mathpal, C., Prasad, L.: 2018, Journal of Pure Applied and Industrial Physics. Vol.8(8),90-97.
Mishra, R.A., Mishra, R.A.: 2005, In Acharya, B.S., Gupta, S., Jagadeesan, P., Jain, A., Karthikeyan, S., Morris, S., Tonwar, S. (eds.): Proc.29th Internat. Cosmic Ray Conf., Tata Institute of Fundamental Research, Mumbai, 101.
Pande, S., Mathpal, M.C., Pande, B.: 2017, International Advanced Research Journal in Science, Engineering and Technology, Vol. 4.
Sabbah, I.: 1996, J. Geophys. Res. **101,** 2485.
Sabbah, I., Darwish, A.A., Bishara, A.A.: 1998, Solar Physics. **181**, 469.
Shrivastava, P.K., Droege, W., Kunow, H., Scholer, M.: 2001, Proc. 27th Internat. Cosmic Ray Conf., Hamburg, **SH2**, 3481.
Shrivastava, P.K., Jaiswal, K.L.: 2003, Sol. Phys. **214,** 195.

