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Cosmic ray intensity variation with SSN and interplanetary parameters

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Abstract

In this work we have taken cosmic ray intensity (CRI) variation with different solar and interplanetary parameters. To see the CRI variation, with solar and interplanetary parameters we have taken CRI data from Masco NM from 2008 to 2022. Sunspot number (SSN) was taken from SILSO observatory. The interplanetary magnetic field (IMF) and proton flux of energy >10 MeV taken from Omniweb data services from 2009-2022. The IMF and proton flux was absent in the year 2008. We have employed the statistical methods to find out the correlation of solar and interplanetary parameters with CRI. By the statistical analysis we have found that the CRI has strong anticorrelation with SSN with correlation coefficient -0.92. Again, we have conferred that the CRI anticorrelated with IMF having correlation coefficient -0.76 and with proton flux have weak negative correlation with correlation coefficient -0.32. From these observations we have concluded that the CRI variation has inverse relation with solar and interplanetary parameters considered in this work, i.e. the solar activity occur on the solar atmosphere do not affect the CRI variation.

Keywords: Cosmic ray intensity, SSN, Interplanetary magnetic field, Particle flux.

INTRODUCTION

Outside the heliosphere, the strength of cosmic rays is constant, but when they approach the heliosphere, the interplanetary magnetic field causes modulation (Mavromichalaki et al., 1988; Agarwal et al., 1993). Forbush (1958; Rao, 1972; Moraal, 1976; King, 1979; Biber et al., 1983; Singh et al., 2013) was the first to bring attention to the inverse relationship between solar wind velocity and cosmic ray intensity. The magnitude of modulation fluctuates from cycle to cycle in the massive zone of the heliosphere and diffusive propagation of cosmic ray particles, where there is a time-lag in correlation between solar activity parameters and cosmic ray strength. The 11year changes in cosmic ray intensity seen on the earth is negative correlated with solar activity parameters also with some time-Lag (Forbush et al 1954). Numerous researchers have observed a kind of hysteresis effect between long-term disruption in cosmic ray intensity and solar activity parameters due to the time-lag between cosmic ray intensity and sunspot number. (Mavromichalaki et al., 1990; Neher et al., 1954; Moraal et al., 1976).

According to models of cosmic ray modulation, the observed reversal of the Sun's magnetic field polarity after every 11 years and the curvature and gradient drifts in the large-scale magnetic field of the heliosphere, the cosmic ray intensity curve also appears to follow a 22-year cycle, with an alternate maximum that is flat-topped and peaked (Jokipii et al., 1977; Jokipii & Thomas, 1981; Smith, 1990). It has also been suggested that disturbed GCR variations, which alter the global electric circuit and alter cloud properties, are the cause of Sun-climate correlations (Pittock 1978) since GCRs can interact with Earth's atmosphere through ionization processes (Harrison et al. 2011; Laken et al. 2012; Laken & Čalogović 2013). Numerous studies of all kinds have been conducted to comprehend a number of solar system mechanisms, which would be helpful in understanding our space weather and safeguarding man-made objects in orbit. When Oloketuyi et al. 2019 looked at how sunspot group numbers affected the different types of flares, they discovered that different classes of flares react differently to sunspot group emergencies. This study, however investigated the behavior of CRI with SSN, interplanetary magnetic field and proton flux that will broaden our understanding of cosmic ray intensity variation.

DATA AND METHOD OF ANALYSIS

Neutron monitors (http://www.nmdb.in) near Moscow (Rc=2.32GV) provided yearly mean values of cosmic ray data, which were used to analyze the long-term variation in cosmic ray through the years 2009-2022. The Sunspot Index and Long-term Solar Observations provided the yearly SSN used in this investigation. You can obtain international sunspot statistics from the World Data Center by visiting http://www.sidc.be/silso/datafiles. In this study most of the IMF and proton flux data have been taken from the database (https://omniweb.gsfc.nasa.gov/) on the annual average basis. Regression analysis techniques were used to examine the association between each variable and the CR data (a dependent variable). The correlation coefficient and regression equation were determined for each correlation. Using the Pearson correlation approach (e.g., Firoz et al., 2008).

RESULT AND DISCUSSION

We have conducted a thorough correlation analysis of solar activity parameters and cosmic ray intensity in the current paper. The correlation values that have been obtained are calculated for the years 2009–2022. For the majority of the era, the correlation coefficient is determined to be negative and high. For the present investigation we have chosen the CRI data observed by Moscow of cutoff rigidity 2.32 GV neutron monitor stations. In this view we have seen the subjective behavior of CRI with sunspot number, interplanetary magnetic field (IMF) magnitude and proton flux (PF). Figures depict the running cross-correlation function over the whole study period between several solar activity metrics (SSN, IMF and PF) and cosmic ray intensity (Moscow, yearly data). Understanding the cross-correlation function's ephemeral behavior with regard to time can be aided by this kind of computation.

Figure (1) illustrates the long-term link between solar activity cycles 24 and 25's sunspot number and cosmic ray intensity (Moscow), showing an inverse correlation between the two. The cross-correlation curve for the yearly average values of cosmic ray intensity and sunspot number (SSN) for the years 2009 to 2022 is shown in Figure (2). The correlation between the two variables is negative (-0.92).

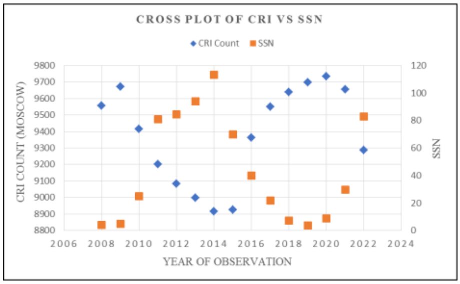

Figure-1 Shows relationship of cosmic ray intensity (Moscow) and sunspot number (SSN) for the period 2009-2022.

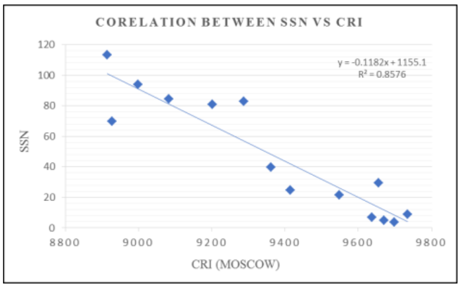

Figure-2 Cross-correlation curve for the Annual mean value of cosmic ray intensity (Moscow) and sunspot number (SSN) during 2009-2022.

Figure (3) shows the long-term variation of CRI and interplanetary magnetic field (IMF) magnitude during the selected time period. Again, we perform a correlation analysis between these two parameters and found that the CRI and IMF magnitude in nT was highly anticorrelated to each other and the correlation coefficient between CRI and magnitude of IMF was found to be -0.76. to see the statistical behavior draw the scatter plot between these two parameters shown in figure (4).

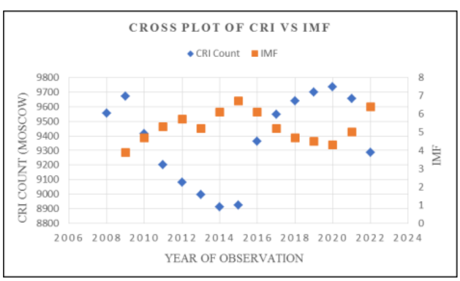

Figure-3 Shows relationship of cosmic ray intensity (Moscow) and IMF (nT) for the period 2009-2022.

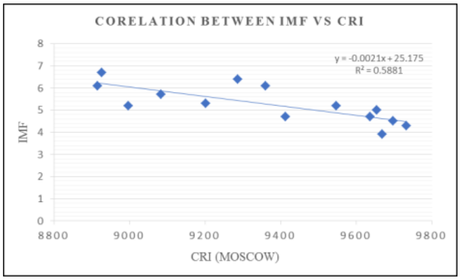

Figure-4 Cross-correlation curve for the Annual mean value of cosmic ray intensity (Moscow) and magnitude of IMF during 2009-2022.

Figure (5) shows long-term relationship of cosmic ray intensity (Moscow) and proton flux of solar activity cycle 24/25 which indicated that both are inversely correlated. Figure (6) shows Cross- correlation curve for the Annual mean value of cosmic ray intensity (Moscow) and proton flux of solar activity cycle 24/25. The correlation coefficient between cosmic ray intensity of Moscow (Rc= 2.32GV) and proton flux is (-0.32). Value of correlation coefficient is negative and moderate.

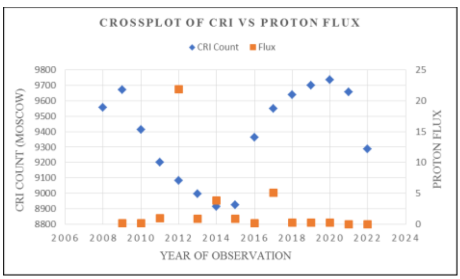

Figure-5 Shows relationship of cosmic ray intensity (Moscow) and proton flux for the period 2009-2022.

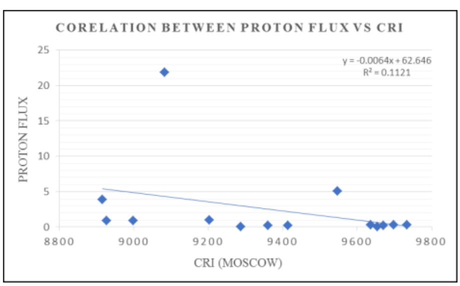

Figure-6 Cross-correlation curve for the Annual mean value of cosmic ray intensity (Moscow) and proton flux 2009-2022.

CONCLUSIONS

This research presents a correlative and linear regression analysis for the period 2009-2022 between solar activity, interplanetary parameters, and cosmic ray intensity. The examination of the aforementioned scattered diagrams reveals that there are significant correlation coefficients between the cosmic ray intensity and other solar interplanetary activity parameters. In solar cycles 24 and 25, solar activity significantly affects how intense cosmic rays are. Variations in interplanetary parameters and cosmic ray strength are anticorrelated, while variations in cosmic radiation at Earth rely on solar wind. Various statistical and numerical calculated values, along with a discussion, lead to the following conclusion:

1. There is an inverse correlation between Sunspot number (SSN) and cosmic ray intensity (CRI). During this period of investigation,

2. During the study we observed that the CRI shows the maximum variation of 2% in the year 2009 & 2020.

3. The magnitude of IMF shows a strong negative correlation cosmic ray intensity (CRI) for solar cycles 24/25.

4. A weak negative correlation have been found between cosmic ray intensity (CRI) and proton flux of energy >10 MeV during solar cycles 24/25.

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