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Variations of Cosmic ray intensity in relation to Sunspot Number and Solar Wind Parameters over the period 1996-2019

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ABSTRACT

Variation of Solar Wind Parameters (Proton density, Speed of SW and IMF-B_z) are changes with Cosmic ray intensity during solar cycle 23 and 24. In this work, we using the cosmic ray intensity (CRI) variation data from Oulu (Rc = 0.81GV) neutron monitors and solar-interplanetary activity data used from OMNIWeb data centre for the analysis. The work includes solar wind speed, interplanetary magnetic field (B_z) and solar wind proton density selected indices during the period 1996-2019. Variation of solar wind plasma and interplanetary magnetic field coefficients has been studied with CRI. The study of the correlation between Sunspot number and cosmic ray intensity has been analyze and found inversely correlated with coefficient r = - 0.87. It is found that there is a linear negative correlation between Solar wind speed verses the cosmic ray intensity with correlation coefficient r=-0.53. The interplanetary magnetic field (IMF-B_z) shows a high negative correlation (r = -0.90) with Cosmic ray intensity for the solar cycle 23 and 24. The weak positive correlation coefficient has been found yearly average value of Cosmic ray intensity (CRI) with proton density (r = 0.19) for the study period. The solar wind index shows very remarkable relationship with CRI.

Keywords: Cosmic ray intensity (CRI), Interplanetary magnetic field (IMF), Heliosphere, Solar Cycle, Sunspot number, Solar wind parameters.

I. INTRODUCTION

Throughout the journey of cosmic rays to Earth, these rays are modulated by various indices like interplanetary magnetic field (IMF) and solar wind conditions and vary according to the solar magnetic cycles [1].The solar magnetic field play the key role in variation of cosmic rays intensity as well as solar cycle activity, called cyclic variation of 11-years of sunspot numbers which is reliable indicators of solar activity.

Sunspots are clear appearances of the sun based on magnetic field. The variation in cosmic ray intensity is appearing on changes in the solar wind structure and interplanetary magnetic field in the solar source variability. Solar wind velocity and the IMF as the key parameters in plasma .The flow of the solar wind and plasma in the interplanetary medium is strongly associated to the cosmic ray intensity variation [2].The solar outputs of the sun in form of various interplanetary features like IMF, SW velocity, density etc. are strongly related to the disturbances in Earth's magnetic field. The solar outputs and their variability control the structure of the heliosphere and produce changes in cosmic ray intensity [3-4]. Singh R.P., et.al (2011) has been studied correlative analysis of long–term cosmic ray modulation with solar activity parameters and found that anti-correlation between cosmic ray intensity and sunspot number, solar wind speed and odd-even hypothesis evidence [5-7]. Solar wind parameters like solar wind dynamic pressure, which depends on solar wind velocity and density and the dawn-dusk component of the electric field which depends on the velocity and IMF (B_z) component [8]. Changes in any of these parameters will cause corresponding changes in the strength, location and distribution of currents which in turn cause magnetic field variations in the Earth's surface. A heliospheric interface is formed when the solar wind interacts with the interstellar cloud. The structure of the interface depends on the parameters of the Solar wind and their changes over the time and continues rise of solar wind temperature for a long period influence the global climate [9-10].

In this study we have calculate the correlation between cosmic ray intensity and solar–interplanetary parameters during the period of solar cycles 23 and 24 i.e. 1996 to 2019 for Oulu (R_c = 0.81GV) neutron monitors. In the present paper, using "Cross - correlation method" and regression analysis, with the availability of CRI, solar activity and solar wind parameters data for solar cycles 23/24, we have tried to investigate the appropriateness of solar parameters relationship for long-term basis cosmic ray intensity variability studies.

II. DATA SELECTION AND ANALYSIS

The corrected for pressure yearly average data of cosmic ray intensity from Oulu (R_c = 0.81GV) neutron monitors have been used and taken data from website: http://cr0.izmiran.ru/oulu/main.htm. In this study most of the IMF and solar wind plasma parameters data have been taken from the database (https://omniweb.gsfc.nasa.gov/) on the annual average basis. Then we use a statistical technique to correlate and analyze them. The cross correlation method used for this correlative study. The study mainly focused on solar cycle 23 and 24 and also the relation to Solar wind plasma parameters and cosmic ray intensity variations.

III. RESULTS AND DISCUSSION

The variations in cosmic ray intensity are anti-correlated with SSN (R_z) and these variations are produced changes in solar wind plasma velocity (V) and interplanetary magnetic field (IMF) with solar wind proton density. The correlation coefficients have been derived for the period of 1996 to 2019 to using the annual mean values of cosmic ray intensity (CRI) and sunspot numbers (R_z), which cover the solar cycle 23 and 24. The coefficient of correlation is found to be highly negative for this study period.

Figure (1) Shows long-term relationship of cosmic ray intensity (Oulu) and sunspots number(R_z) of solar activity cycles23/24, which indicated that CRI and R_z are inversely correlated. Figure (2) shows cross-correlation curve for the yearly average values of Sunspot number (SSN) and cosmic ray intensity (Oulu) for the period 1996 to 2019 and correlation between cosmic ray intensity with sunspot number is negative (-0.87).

Figure (3) shows long-term relationship of cosmic ray intensity (Oulu) and solar wind speed (V) of solar activity cycle 23/24, which cover time period 1996 to 2019.Figure (4) shows Cross-correlation curve for the Annual mean value of cosmic ray intensity (Oulu) and solar wind speed (V) for period 1996 to 2019.which shows that CRI and SW Speed (V) are anti- correlated and correlation coefficient is (-0.53).

Figure (5) shows long-term relationship of cosmic ray intensity (Oulu) and interplanetary magnetic field (B) of solar activity cycle 23/24.which indicated that both are highly negative correlated. Figure (6) shows Cross- correlation curve for the Annual mean value of cosmic ray intensity (Oulu) and interplanetary magnetic field (B) of solar activity cycle 23/24,.The correlation coefficient between cosmic ray intensity of Oulu(R_c=0.81GV) and IMF is (-0.90). Value of correlation coefficient is negative and high.

Figure (7) shows long-term relationship of cosmic ray intensity (Oulu) and solar wind proton Density of solar activity cycle 23/24, which shows positive correlation. Figure (8) shows Cross- correlation curve for the Annual mean value of cosmic ray intensity (Oulu) and solar wind proton Density of solar activity cycle 23/24. From the scattered graph it is found that CRI shows positive correlation with solar wind proton density is (0.19) for the solar cycles 23 and 24. Value of correlation coefficient is Positive and low.

Figure1: Shows long-term relationship of cosmic ray intensity (Oulu) and sunspot number (SSN) of solar activity cycle 23/24.

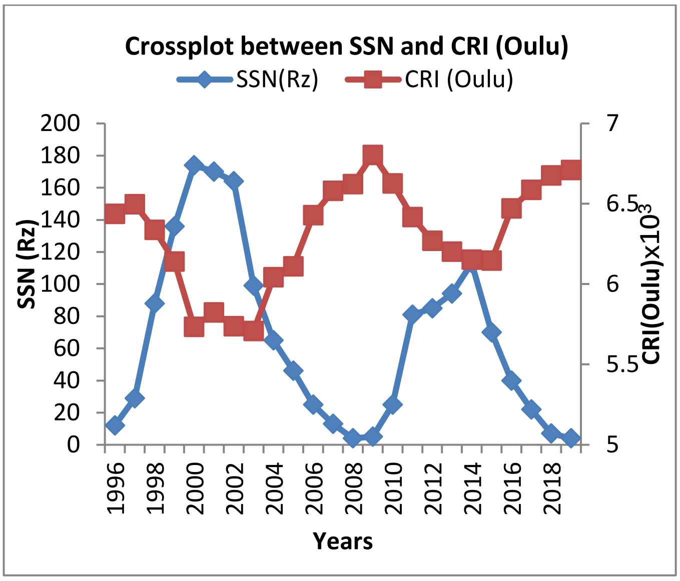


Figure 2: Cross- correlation curve for the Annual mean value of cosmic ray intensity (Oulu) and sunspot number (SSN) of solar activity cycle 23/24.

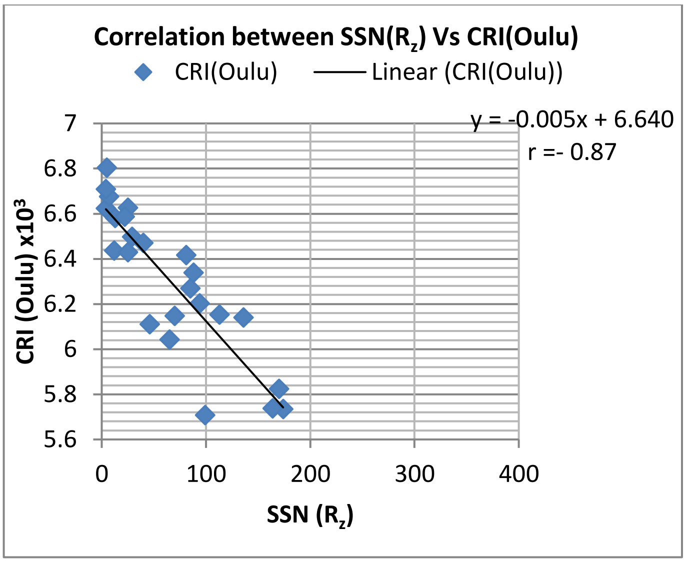


Figure 3: Shows long-term relationship of cosmic ray intensity (Oulu) and solar wind speed (V) of solar activity cycle 23/24.

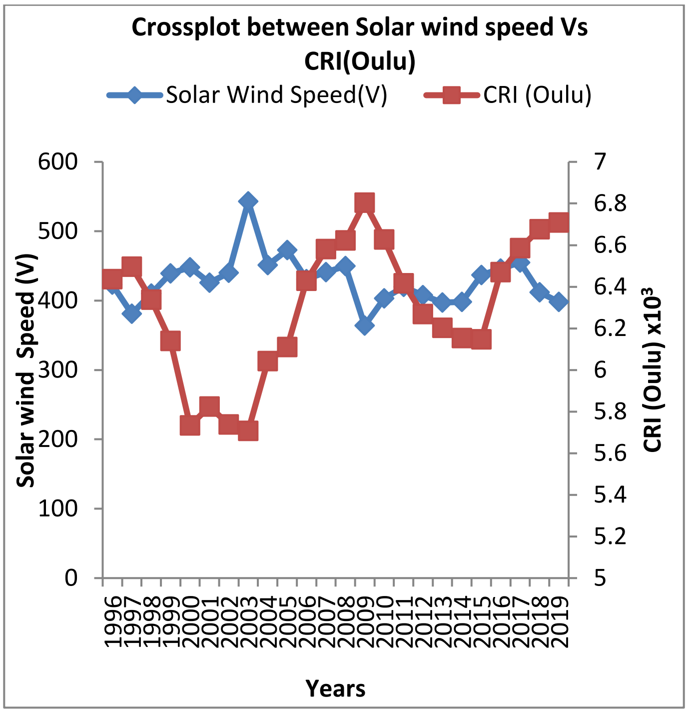


Figure 4: Cross- correlation curve for the Annual mean value of cosmic ray intensity (Oulu) and solar wind speed (V) of solar activity cycle 23/24.

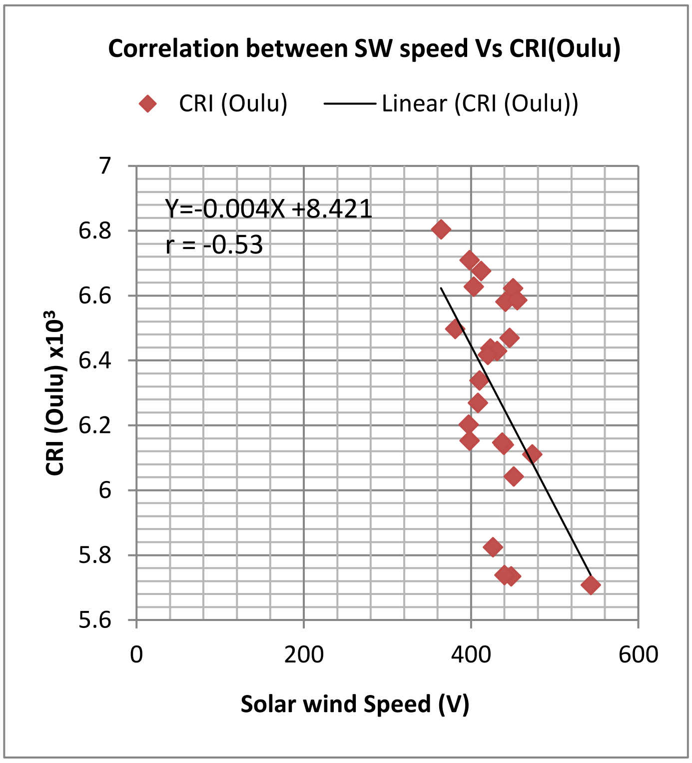


Figure 5: Shows long-term relationship of cosmic ray intensity (Oulu) and interplanetary magnetic field (B) of solar activity cycle 23/24.

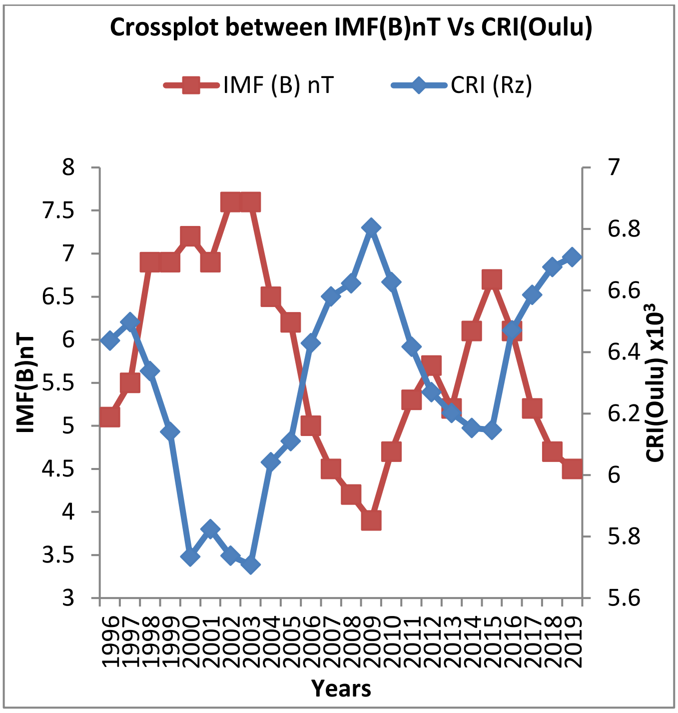


Figure 6: Cross- correlation curve for the Annual mean value of cosmic ray intensity (Oulu) and interplanetary magnetic field (B) of solar activity cycle 23/24.

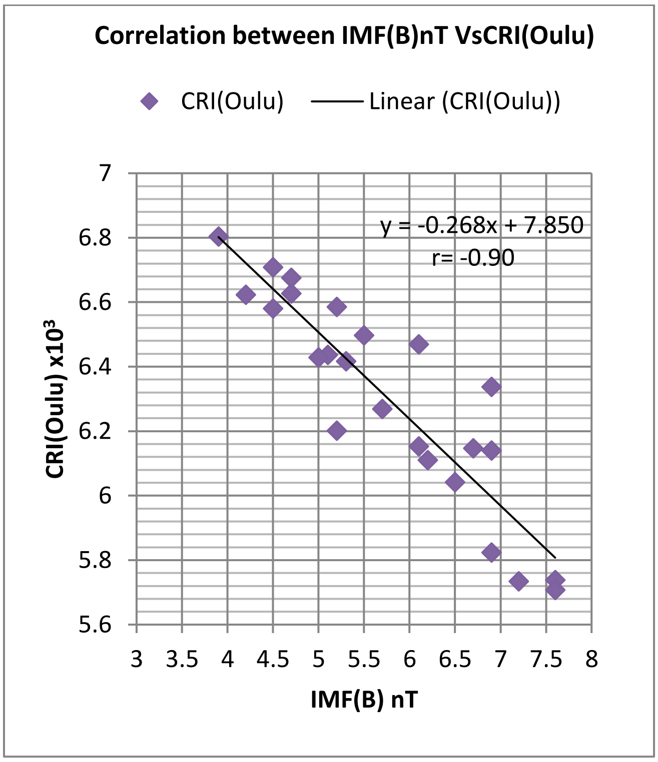


Figure 7: Shows long-term relationship of cosmic ray intensity (Oulu) and solar wind proton Density of solar activity cycle 23/24.

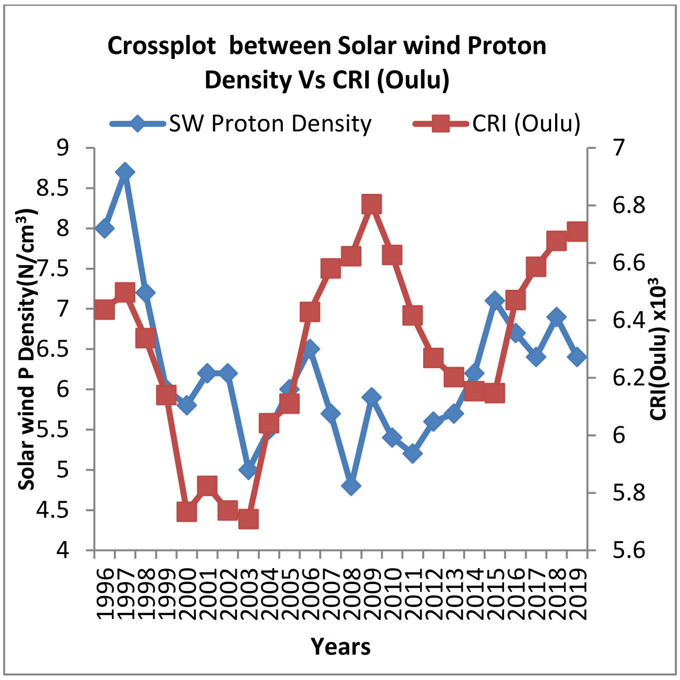
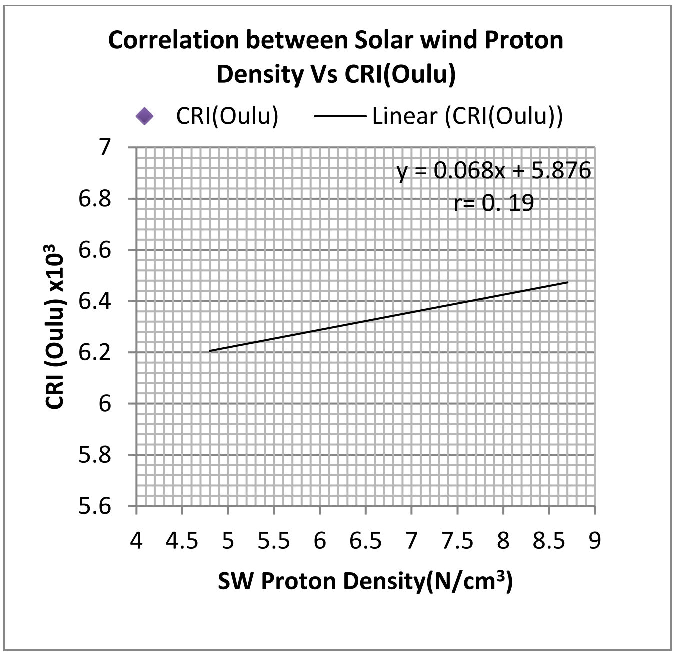


Figure 8: Cross- correlation curve for the Annual mean value of cosmic ray intensity (Oulu) and solar wind proton Density of solar activity cycle 23/24



IV. CONCLUSIONS

In this paper, a correlative and linear regression analysis is done between cosmic ray intensity, solar activity and solar wind parameters for the period 1996-2019. From the above scattered diagrams it is found that from the analysis the relationship of cosmic ray intensity with different solar-interplanetary activity indices has been distinct correlation coefficients. The solar activities play the significant role in modulating cosmic ray intensity in solar cycles 23/24. Cosmic ray intensity variation and solar wind are anti-correlated but the variation of CR at Earth is depends on the Solar wind. Based on the various statistical and numerical calculated value and discussion, it is concluded that:

1. Cosmic ray intensity (CRI) and Sunspot number (R_z) are inversely correlated.
2. The Solar wind speed (V) shows a negative correlation with cosmic ray intensity (CRI) for solar cycles 23/24.
3. The correlation between IMF and Cosmic ray intensity are highly anti-correlated and also the coefficient of correlation is high (r=-0.90) during the solar cycles 23 and 24 (1996-2019).
4. A weak positive correlation coefficient r=0.19 found between Comic ray intensity and Solar wind proton density during the solar cycles 23/24.

V. ACKNOWLEDGMENT

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