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CORRELATIVE ANALYSIS OF LONG-TERM COSMIC RAY MODULATION WITH SOLAR ACTIVITY PARAMETERS

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ABSTRACT

In this correlative analysis we have taken data of Solar wind velocity (V), sunspot number (Rz) and cosmic ray intensity (CRI) for the solar cycle 22 to 24. We have taken the data of Oulu (0.81 GV), Kiel (R=2.29 GV) and Beijing (9.56 GV) neutron monitors for the analysis. These neutron monitors are well maintained station & provide reliable cosmic ray data for variation study. These three solar parameters show a negative i.e. anti-correlation among themselves. These solar parameters are again correlated with cosmic ray intensity for three successive solar cyclic 22 to 24.A detailed correlative study have been done by using the running cross correlation method. It has been found that the anti-correlation between sunspot number, solar wind speed and cosmic ray intensity is strong during the period from 1986 to 2010. Sunspot number show anti phase with cosmic ray intensity. A correlative analysis has been done between cosmic ray intensity and sunspot numbers for the solar cycle 22 to ascending phase of recent solar cycle24. Correlation between sunspot number and cosmic ray is found negative and high and the values of coefficient of correlation support the odd-even hypothesis in cosmic ray modulation. The 11-year modulation of the cosmic ray intensity shows some time lag from the solar activity.

KEYWORDS : Solar wind velocity, sunspot number, cosmic ray intensity, solar cycle

It has been known for the long time that the intensity as well as the energy spectrum of the Galactic cosmic ray(CR) is modulated by solar activity. Long-term variation in cosmic ray intensity modulation is one of the major fields of study because the long-term variation of cosmic radiation are still an unsolved problem. The details of the CR modulation and variation of time-lag factor are still a matter of great interest. It is now well established fact that there is an inverse correlation between cosmic ray intensity and solar activity(Lockwood and Webber 1992). Pressure corrected cosmic ray intensity data has been taken for mid latitude stations like Oulu, Kiel and Beijing. In this work we have done a systematic study to verify the long-term of profile of cosmic ray intensity in relationship with solar activity for 1986 to 2010, which cover the solar cycles 22;23 and 24. Generally sun spot number are used as one of the reliable and easily available solar parameters to measure solar activity. Unfortunately, no unique measure of solar activity, which can be used as solar parameter in cosmic ray studies, is appropriate. The sunspot number as an active and reliable parameter has been used mainly because solar wind speed emanate from sunspot regions. Galactic cosmic rays in the energy range from several hundred Mev to few Gev are subjected to heliospheric modulation because solar output and its variation affect their intensity and spectrum during 11-year solar activity cycle. It is also known that cosmic ray intensity variation show inverse correlation with sunspot number and solar wind speed for 11/22 year. But general it is seen that the maximum / minimum of sunspot number and solar wind speed do not coincide with minimum / maximum of cosmic ray intensity. Cosmic ray is one of the measure radiations in interplanetary medium, which is used as a tool to study the various activities in interplanetary medium as well as near the earth environment. Cosmic rays are being continuously detected since 1953 using the various ground based detectors. Time variation of cosmic ray intensity has been studies by a number of cosmic ray researchers Tiwari et al., 2011) Relationship of cosmic ray intensity with solar active has been studied since last three decades by a number of cosmic ray scientists (Gupta et al., 2006; Kane,2006,Mishra and Agarwal, 2007; Dwivedi et al., 2010). However, long-term modulation studies have still its relevance in recent days.

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METHOD OF ANALYSIS

In this study and correlative analysis we have taken data of solar wind velocity (V), sunspot number (Rz) and cosmic ray intensity (CRI) for the solar cycle 22 to 24. We have taken the data of Oulu (0.81 GV), Kiel (R=2.29 GV) and Beijing (9.56 GV) neutron monitors for the analysis. These neutron monitors are well maintained station and provide reliable cosmic ray data for variation study. In this study we have selected the monthly mean data and yearly mean data of above cited parameters. And most of the data solar plasma parameters have been taken from the website of Omni Web and Solar Geophysical data books(monthly publication of NOAA). The pressure corrected cosmic ray data of Oulu, Kiel and Beijing have been used.

RESULTS AND DISCUSSION

Using the twelve monthly mean values of sunspot number (Rz) and cosmic ray intensity (CRI); the correlation coefficients have been derived for the period of 1986 to 2010, which cover the solar cycle 22 to 24. Coefficient of correlation is found to be negative and high for the most of the period. However, it changes positive to negative and vice-versa quiet frequently. Fig.1 shows long term modulation of cosmic ray intensity (Beijing) and solar wind speed for the period 1986 to 2010. Fig. 2 shows cross Correlation curve for the yearly value of solar wind speed and cosmic ray intensity (Beijing) for the period 1986 to 2010 and correlation between CRI with solar wind speed is negative (-0.411). Fig. 3 shows long term modulation of cosmic ray intensity (Beijing) and Sunspot number (Rz) for the period 1986 to 2010 which shows that CRI and Rz are anti-correlated. Fig. 4 shows the correlation between sunspot number and cosmic ray intensity for Beijing neutron monitor data. Which shows negative correlation (-0.899) between both the indices. We have plotted the yearly values of correlation coefficient Rz Vs CRI (Oulu) and V Vs CRI (Kiel) in fig. 5, reveals that shape of curve for even solar cycle 22 is similar to next even solar cycle 24 similar variation trend is found for odd solar cycle 23. Our results indicate an odd-even hypothesis in this correlative analysis. These figures clearly demonstrate a good correspondence between cosmic ray intensity and sunspot number solar wind speed along with same peculiarities.

Therefore it is concluded that

1. Cosmic ray intensity (CRI) and Sun spot number (Rz) are anti-correlated.
2. Correlation between Cosmic ray intensity (CRI) and Solar Wind speed (V) is found negative.
3. Odd-even hypothesis is evident in correlative analysis.

Figure 1: Shows long term modulation of cosmic ray intensity (Beijing) and solar wind speed for the period 1986 to 2010

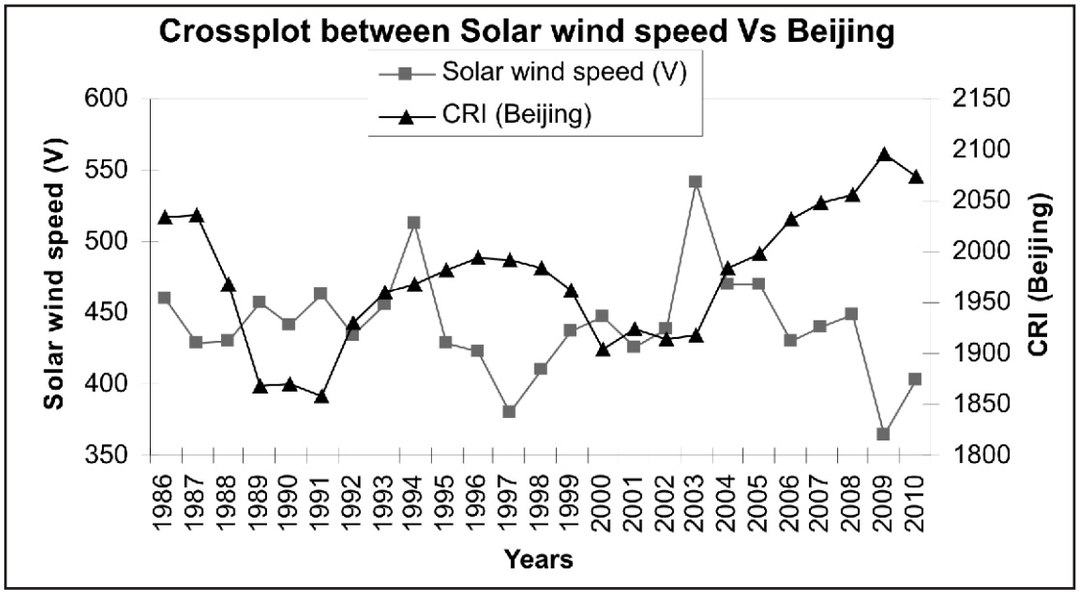


Figure 2: Cross Correlation Curve for the yearly value of solar wind speed and cosmic ray intensity (Beijing) for the period 1986 to 2010

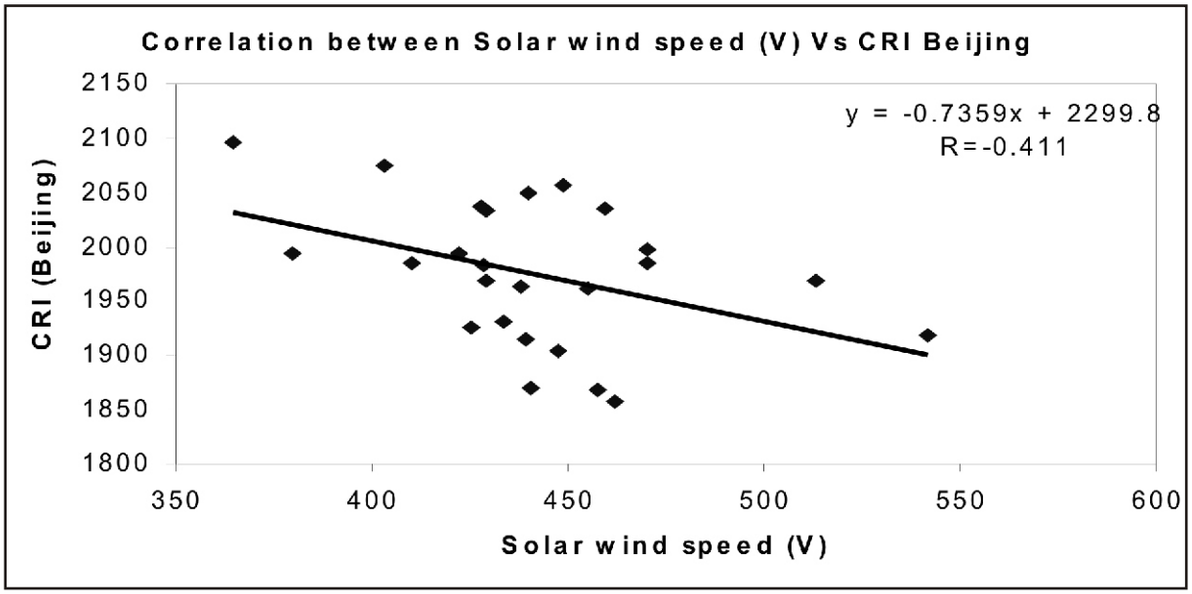


Figure 3: Shows long term modulation of cosmic ray intensity (Beijing) and Sunspot number (Rz) for the period 1986 to 2010

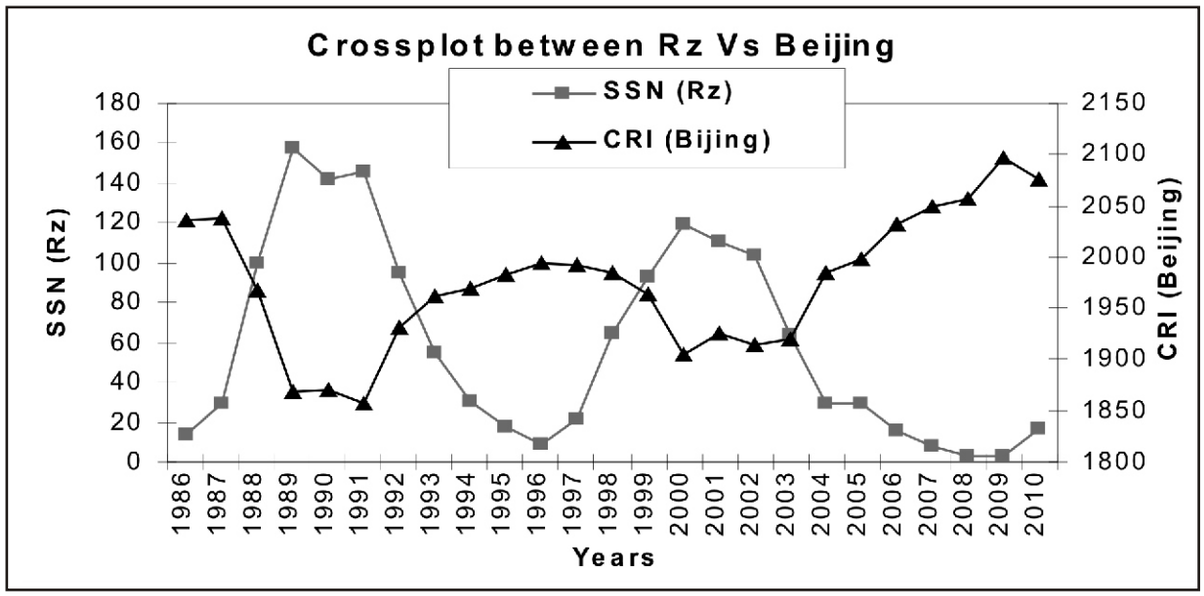


Figure 4: Cross Correlation Curve for the yearly value of Sunspot number (Rz) and cosmic ray intensity (Beijing) for the period 1986 to 2010

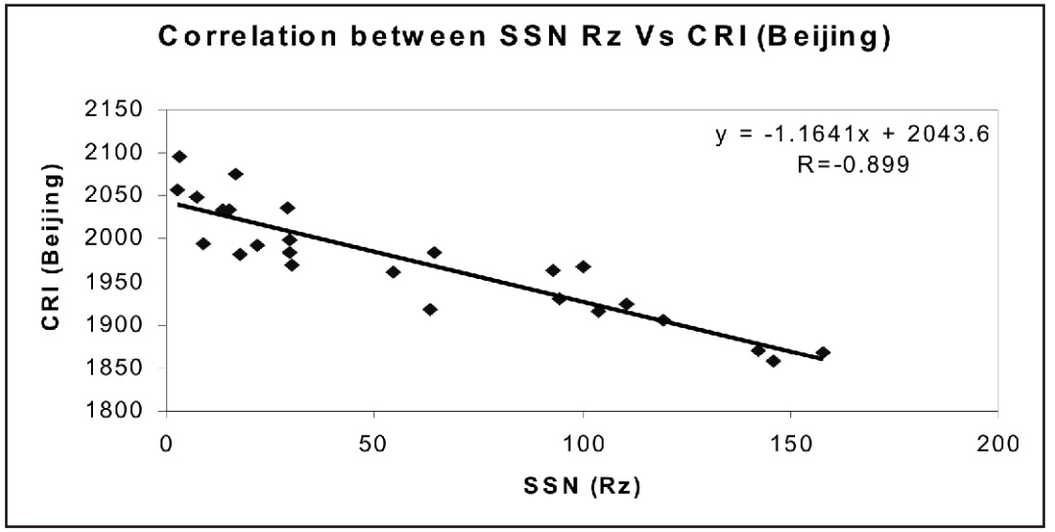
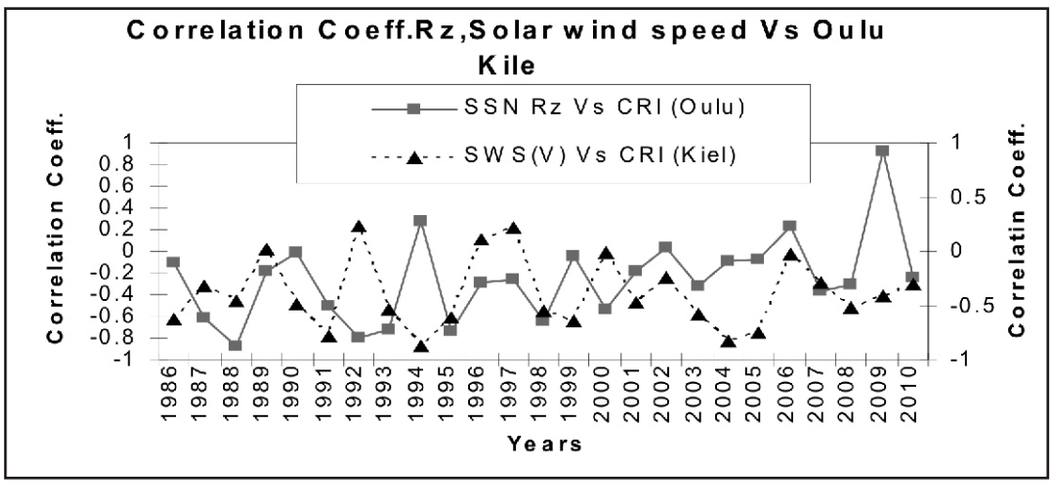


Figure 5: Correlation Coefficient between monthly value of sunspot number (Rz), solar wind speed and cosmic ray intensity (Oulu, Kiel) for the period 1986 to 2010



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