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Association of solar activity with cosmic ray intensity during rising phase of solar cycle 24

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Abstract
We have studied the correlative relationship of the recorded time series of cosmic ray intensity and solar activity parameters during rising phase of solar cycle 24. The monthly and annual mean values of cosmic ray intensity counts have been used. The monthly mean values of sunspots numbers, solar flux (2800 MHz) and solar flare index have been used as solar activity parameters. The behaviour of cosmic ray intensity (solar cycle 24) with solar parameters have been studied by using running cross-correlation method. Cosmic ray neutron monitor intensities at Oulu and Climax were well anti-correlated with sunspots numbers but highly correlated sunspots number with solar flux (2800 MHz) and solar flare index are negative correlated with cosmic ray counts. A possible application of the results to space physics is discussed.

Keywords: solar activity, cosmic rays and solar cycle.

1. Introduction

Cosmic rays are mostly of extra-galactic origin and should show a constant intensity level at the Earth [1]. But the intensity is considerably modulated by the heliospheric environment and considerable changes are observed [2-4]. On long time scales, there are the forbush type decreases of several percent, lasting for a few months. On a long-term basis, there is a distinct 11-year variation, anti-correlated with solar activity. The cosmic ray intensity is maximum at sunspots minimum. In this analysis, we have analyzed a correlative study of cosmic ray intensity and solar activity during rising phase of solar cycle 24. The monthly mean variation of neutron monitor count rates of cosmic ray intensity has been used. The monthly mean values of sunspots numbers, solar flux (2800 MHz) and solar flare index of solar activity have been used. The behaviour of cosmic ray variation with solar activity for solar cycle 24 has between studied by using the running cross-correlation method [5-6].

2. Data and Methods

The worldwide network of ground based neutron monitors detectors provides very stable and reliable records of intensity of cosmic ray particle of different cut-off rigidity for more than 50 years periods. Most of the data were obtained from the NOAA website http:// www.ngdc.noaa.gov/stp/ (SPDIR). The daily values of solar activity parameters have been taken from solar geophysical data books and internet websites. We have used the monthly mean of solar flare index data available at website www.ngdc.noaa.gov / stpflare-index.html. Monthly mean values of cosmic ray intensity data have been taken from Moscow and Oulu neutron monitor stations.

3. Results and Discussion

In this analysis, we have used the monthly mean of solar flare index and sunspot numbers for the period of 2008-2010 covering the rising phase of solar cycle 24. Here we have performed the scatter diagram (fig.1.) between sunspot numbers (SSN) and solar flare (SFI) shows the correlation coefficient, which has been found to be 0.75. From this analysis we have observed that sunspot numbers and solar flare are positively (high) correlated with each other for the solar cycle 24.

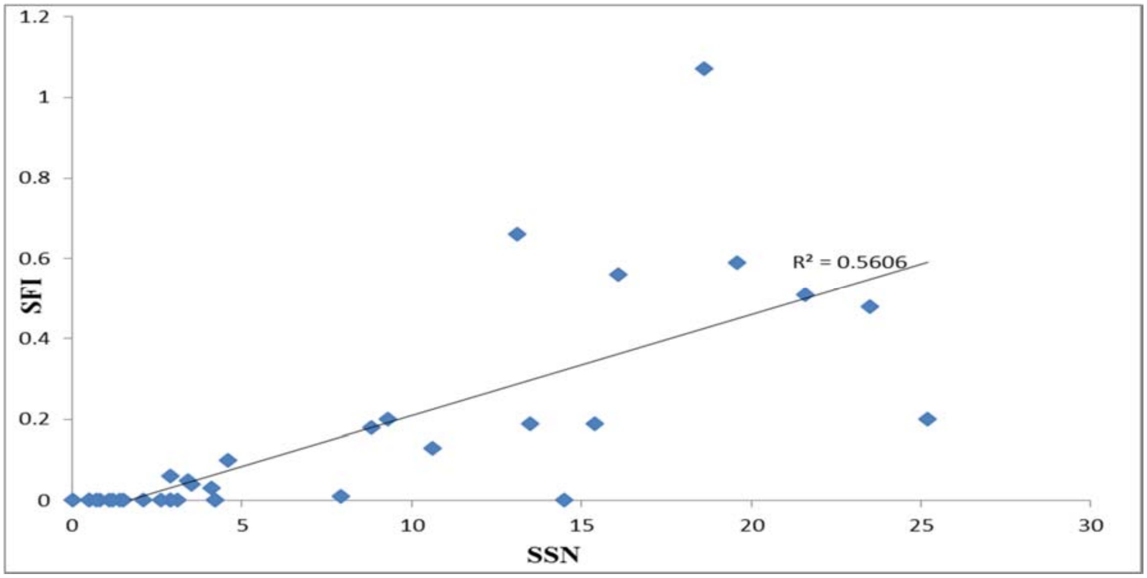

Fig 1: Show the scatter plot between the SSN and Solar Flare

The time variation of cosmic ray intensity along with sunspot numbers has been studied and shown in fig.2. In this analysis we have plotted the normalized monthly count rates (% CRI) of two different neutron monitors situated at Oulu and Moscow. Low and middle latitude cosmic ray neutron mointors are measured by these stations. In this work, we have taken sunspot numbers (SSN) as a parameter for the rising phase of solar cycle 24.

It is clear from fig.2. that the intensity variation of Oulu and Moscow neutron monitor stations have almost similar pattern during the whole period of study. Whereas the difference in counting rate between high and middle cut-off rigidity stations indicate the rigidity dependence of neutrons. Rigidity dependence is found maximum during the period of high solar activity as seen in fig. for the interval June 2011-Jan 2012 and during the year 2014.

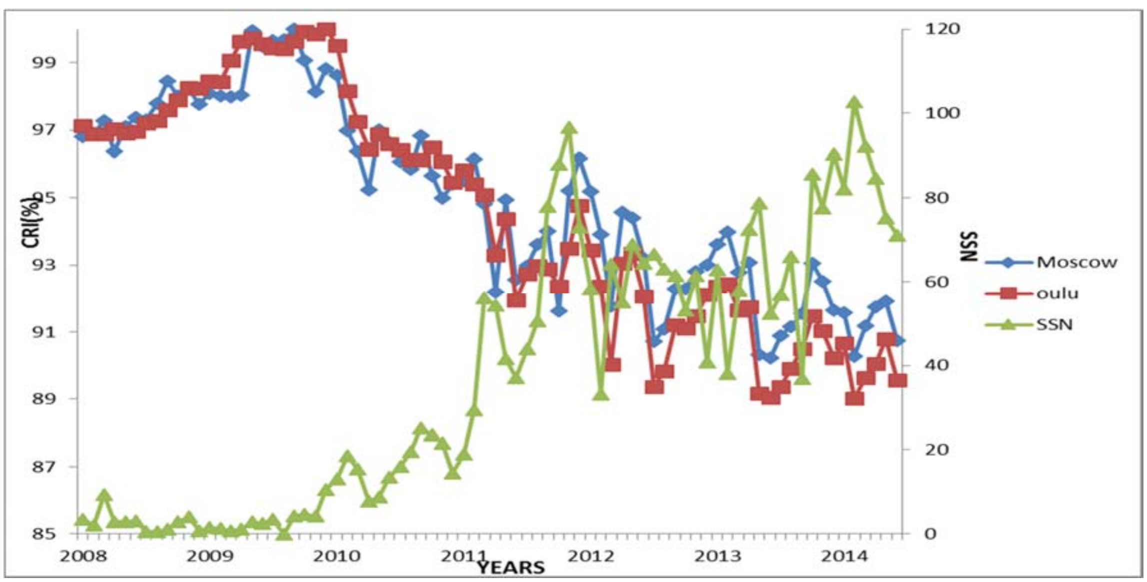

Fig 2: Linear plot between monthly mean values of cosmic ray intensity and sunspot numbers for the year 2008-2014

The long term modulation of cosmic rays has been reported to be direct consequences of large no. of solar flare. Flares of long duration and those having higher brightness are more effective in producing cosmic ray decreases in the present study we have used the solar flare index (SFI) as an parameter of flare activity, which give proper weights to the energetic and long-lived solar flares.

Here we have performed the scatter diagram between cosmic ray intensity (CRI) and solar flare index (SFI). Fig. 3(a) shows the negative (high) correlation between CRI (Moscow) and SFI for the period 2008-2010. One can see from figure that these parameters are inversely correlated for this period of rising phase of solar cycle 24. Correlation coefficient is r = -0.370. We have sketched the scatter diagram between CRI (Oulu) and SFI for the same period and correlation coefficient is r = -0.216 in fig. 3(b). At low solar activity, cosmic ray modulation is not derivable by solar flare during solar cycle 24.

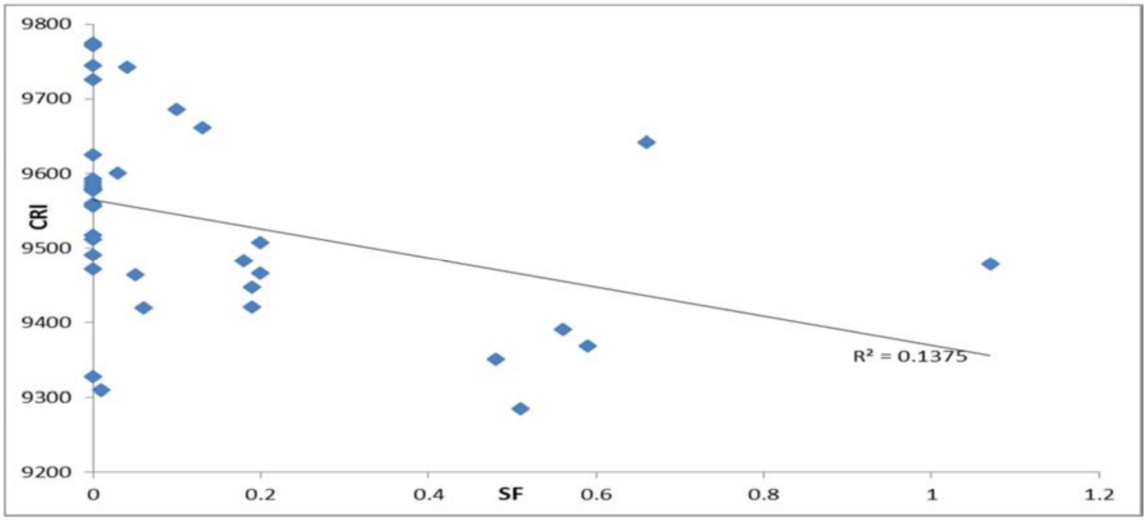

Fig 3(a): Show the scatter plot between the solar flare and CRI (Moscow)

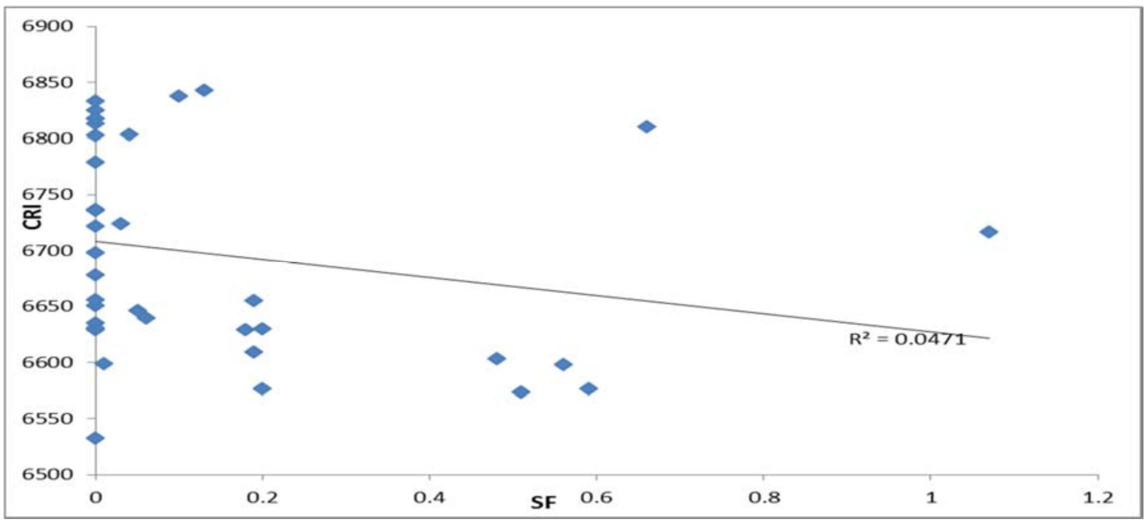

Fig 3(b): Show the scatter plot between the solar flare and CRI (Oulu)

The solar activity as measured by sunspot numbers shows inverse correlation with cosmic ray intensity. Besides the sunspot numbers, many other solar parameters has been used to study their relationship with cosmic ray modulation. As we know generally grouped solar flares, solar radio flux (2800 MHz) for rising phase of solar cycle 24. It is obvious from the fig.4 that both these parameter are highly correlated (positive). The correlation coefficient is r = 0.97.

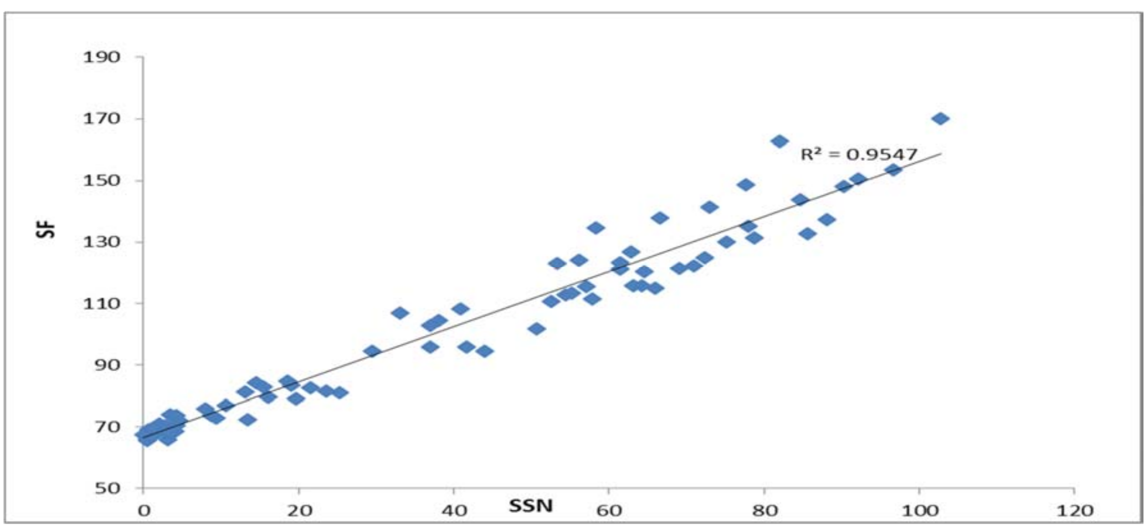

Fig 4: Show the cross plot between the SSN and Solar Flux

4. Discussion

The correlation coefficient between sunspot number and CRI at Oulu and Moscow are -0.8767 and -0.8477 respectively, for rising phase of solar cycle 24 will be found. Sunspots generally show inverse correlation with CRI (Oulu and Moscow) during the period 2008-2014. High positive correlation ($r > 0.9$) between SSN and solar flux (2800 MHz) has been observed during the interval 2008-2014. A negative correlation between SFI and CRI has been found during rising phase of solar cycle 24 (2008-2010). A positive correlation between SFI and SSN has been found during the interval 2008-2010. The effects of energetic solar flares in the modulation of galactic cosmic rays have been explained with the help of solar flare index (SFI). Significant negative correlations between SFI and CRI ($r \approx -0.283$) have been found during rising phase of solar cycle 24. Energy dependence in CRI / SFI relationship have also been examined by taking CRI data of low and middle cut-off rigidity stations. The correlation coefficients are nearly the same for low and high energy cosmic ray particles. During solar cycle 24, minimum solar activity (almost negligible) and high CRI are observed. The results may lead to an easy way to predict

5. References

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