29th International Cosmic Ray Conference Pune (2005) **00**, 101-104

Solar activity and cosmic ray intensity variation

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In this correlative analysis we have taken monthly data of Grouped Solar Flare Index (GSF), instead of sunspot numbers, and cosmic ray intensity (CRI) for the solar cycles 20 to 23. These three solar parameters show a positive and high correlation amongst themselves. These solar parameters are again correlated with cosmic ray intensity for three successive solar cycles 20 to 23. We have used sunspot number and grouped solar flares as reliable solar parameters. A detailed correlative study has been done by using "the running cross correlation" method. It has been found that the anti-correlation between GSF and CRI is strong during the period from 1950 to 2003. Pressure corrected cosmic ray intensity data have been taken for mid latitude station Kiel. However, other stations give same result as for the mid latitude station. From statistical and correlative analysis, we observe a negative and high correlation between solar activity and cosmic rays. Our results support the earlier findings which were observed for solar cycle 18 to 20. The observed cosmic ray modulation for these periods, when compared with other solar activity indices, shows the appropriateness of the (GSF) as solar activity index instead of sunspot numbers. The effects are found to be distinctly different in the four solar cycles 20 to 23, when the most appropriate solar activity index (GSF) in used, which necessitates further studies on short-term basis.

1. Introduction

Generally sunspot numbers 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 numbers as an active and reliable parameter have been used used mainly because Grouped Solar Flare 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 well known that cosmic ray intensity variation shows inverse correlation with sunspot number for 11/22 year. But generally it is seen that the maximum / minimum of sunspot numbers do not coincide with minimum/maximum of cosmic ray intensity. Popielawska [1] and others [2-3] have reported a detailed study, considering a cosmic ray intensity data and sunspot numbers to show the correlation between cosmic ray and sunspot cycle. Recently, a new statistical technique, namely "running cross correlation" has been used to study the correlation between sunspot number (SSN) and CRI. In the present paper an attempt has been made to study the correlation between CRI and solar activity represented by SSN, GSF and by employing them the statistical technique for the period 1950-2003 (solar cycle 20, 21, 22 and 23).

2. Discussion

The pressure corrected monthly values of cosmic rays are obtained from the data of Kiel neutron monitors for the period 1950-2003. The mean values of sunspot number have been taken from the solar geophysical data. The variation of cosmic ray intensity is mainly due to the outward correlation of solar outputs which are usually associated with sunspots. However, sunspots are the solar surface feature and are not directly connected in any manner with the continuously variable interplanetary parameters. The grouped solar flares are routinely generated by giving weightage of the importance and duration. The group of index solar flare index was first introduced in 1952 by including Q = it, to quantify the daily flare activity scale and t the duration (in minutes) of the flare. It is expected than this relationship gives (roughly) the total energy emitted by the flare. In general sunspot numbers are used as an index of solar activity which is available for a long period of time. For the present study the CRI data have been normalized.

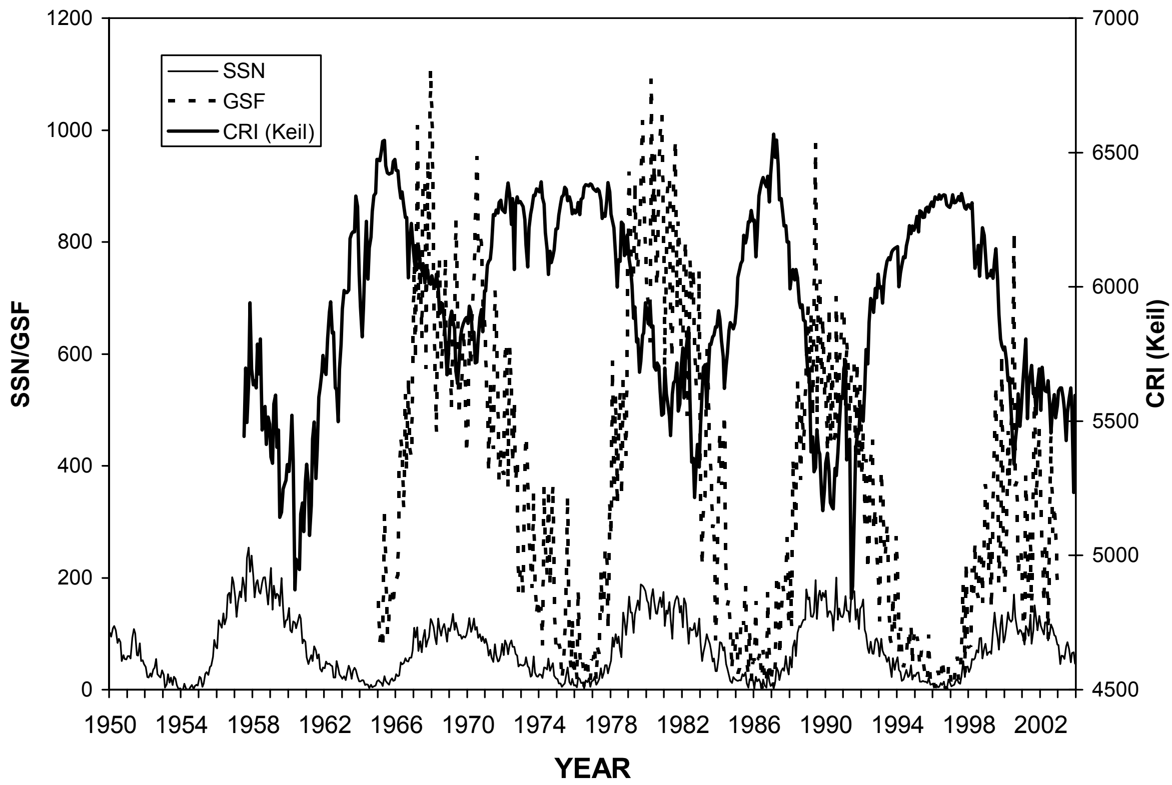

Figure 1. Shows long–term variation of CRI along with SSN and GSF.

Then the window shifted in time by a small time step Δt ∠T, and we determine the new value of cross correlation coefficient for each month between CRI and GSF. The width of time window Δt has been chosen to be 50 months. This, value was found to match two contradictory requirement i.e. (i) uncertainties of the calculated c(t) are smaller for large T and (ii) T should be small in order to reveal the fine structure of the cross correlative function. However, no time shift between the two data series has been used while calculating the correlation coefficient.

To observe the relationship between cosmic ray and sunspot number for the solar cycle (20 to 23). The correlation coefficient between the monthly mean values of these two parameter has been derived. The pressure corrected monthly mean cosmic ray values of one neutron monitor namely Kiel which is a mid latitude station have been taken.

It has been observed since last 4-5 decades that the long term cosmic ray intensity are generally anti-correlated with solar activity. It has also been noticed that the exact month of solar activity maximum / minimum does not coincide with cosmic ray minimum / maximum.

In the earlier studies even though the correlative analysis has been performed for a much longer period but that was done by using SSN and the CRI data. As such the long-term variation of GSF with CRI for the Kiel neutron monitor is shown for the period 1950-2003. The general inverse relationship of GSF with CRI is clearly seen from Figure 1. Moreover, qualitatively the level of anti-correlation is also seen to change with time.

To quantitatively observe the change in correlation coefficient between GSF and CRI for Kiel, we have performed "running cross-correlation analysis between these two parameters. The running cross-correlation function (CF) between GSF and CRI for Kiel is shown in Figure (2) from the period 1967-2001 one can see a quasi periodic behaviour of cross-correlation function with a period of about 5.5 year (half of the 11-year cycle). It is observed from Figure (2) that the anti-correlation between GSF and CRI is strong ≈ 0.8 during ascending and descending phase of GSF cycle, while it becomes weak $| c \| \approx 0.2$-0.4 during maxima and minima of the solar cycle. This is expected, because during maximum and minimum phase of solar activity cycle the time variation CRI is small.

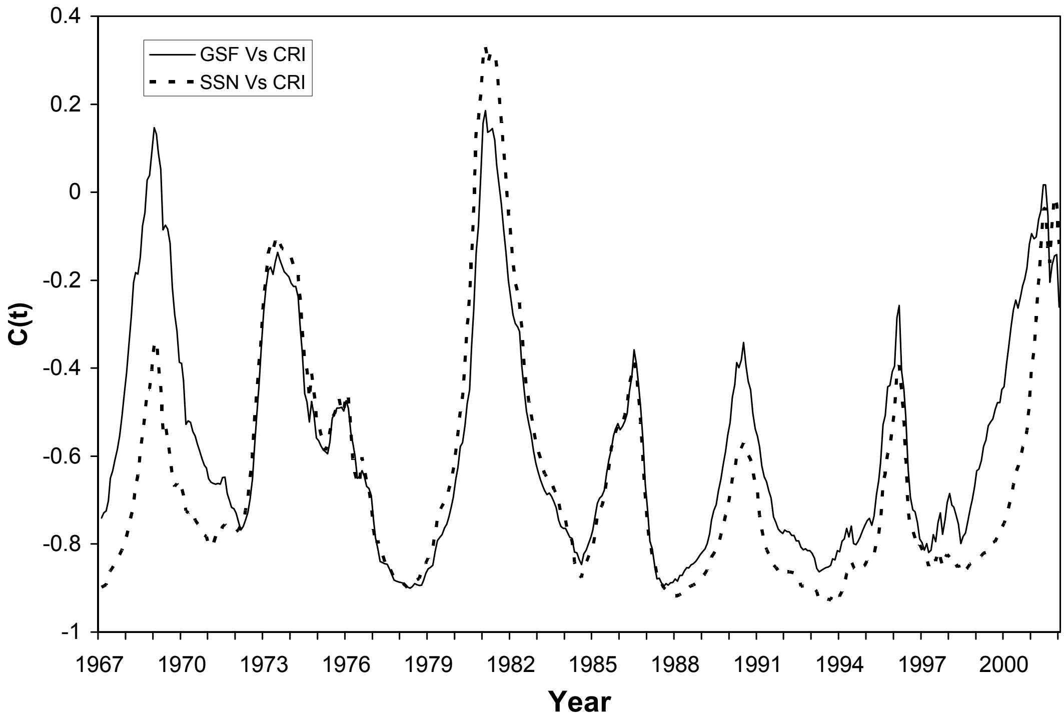

Figure 2. Shows running cross correlation function between grouped solar flare (GSF) and cosmic ray intensity (CRI) of Kiel as well as between SSN and CRI.

However, it is seen from Figure (2) that the anti-correlation between GSF and CRI remain continuously higher through the level of anti-correlation goes down (r = 0.3) during the particular period of 1981. It is inferred from Figure (2) that the energies and long-lived important solar flares (suitably included in the preparation of GSF) are much more effective. We find that GSF is generally smaller in solar cycle 22, than in cycle 21 for the same values of SSN.

3. Conclusions

It is concluded from this analysis that GSF is a better index to choose for any long–term studies of cosmic ray variation. It is also noted that the observed difference in cross–correlation function for the solar cycle 20, 21, 22 and 23 using GSF can be further investigated on a short–term basis for the entire period of 1967-2001 by using the data on a day–to–day basis particularly, in the light of the fact that the depth of modulation is larger in solar cycle 22 than in solar cycle 21 though GSF is showing a reverse tendency.

4. Acknowledgements

The author is thankful to the World Data Centre–A for providing the data for the present study. I am also thankful to Prof. D.P. Tiwari, Dept. of Physics, A.P.S. University, Rewa (M.P.) and Dr. Pankaj K. Shrivastava, Deptt. of Physics, Govt. Model Science College, Rewa (M.P.) India for helpful discussion and suggestions. I also thank Mrs. Meera Gupta for her help in data collection.

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