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Study of time lag in long-term cosmic ray intensity variation with Sunspot number

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Abstract

The relationship between the long-term variations of the cosmic ray intensity & Sunspot number (Solar activity) considering the different time lags has been investigated for the period 1986 to 2009. Several aspects of the long-term variations of cosmic ray intensity have been studied, adopting the K-series analysis during the ascending & descending phase of two successive sunspot solar cycles (22, 23). Correlative analysis is the basis & has been applied for several time intervals. On the overall, from the correlative analysis it has been observed that the second parts of ascending phase for sunspot cycles are more effective in cosmic ray variation. The cumulative results of these effects produce long-term trends in cosmic ray intensity.

1. Introduction

Generally sunspot numbers are used as one of the reliable & easily available solar parameters to measure the solar activity. The sunspot numbers form active & reliable parameters mainly because solar flares emanate from sunspot regions. Therefore, one can say that the sunspot area is a better measure of the active region of the solar disk. It is well known that cosmic ray intensity variation shows inverse correlation with sunspot number for 11 years variation. But, generally it seems that the maximum / minimum of sunspot numbers do not coincide with minimum / maximum of cosmic ray intensity.

A time lag of 2 to 10 months has generally been found, which also forms another aspect in long-term cosmic ray variation. Recently Popielawska[1], Shrivastava[6], Singh *et al*.[8] have reported a detailed study considering a lag between cosmic ray intensity data & sunspot numbers, to show the correlation between cosmic ray & sunspot numbers for all phases of successive sunspot cycles. For further verifications of the results a detailed study has been made in this paper to derive the best correlation coefficient after dividing each sunspot cycle in four different phases.

2. *Data & Methods of Analysis:* The pressure corrected monthly mean values of cosmic rays are obtained from the data of Climax (2.9 GV) & Calagory (1.08 GV) neutron monitors for the period of 1986 to 2009. The mean values of sunspot numbers have been taken from the "Solar Geophysical report as (India) reliable solar parameter to derive the aspect of time lag in long-term cosmic ray intensity & the techniques of K-series have been adopted.

The series is a modified version of moving average techniques, which shows long-term profile of data set. In this way one can exclude the short-term fluctuations of noise in data set. This technique was adopted for the first time by Shea & Smart in 1985 for deriving the long-term profile of cosmic ray intensity & its relationship with sunspot numbers. From K-series analysis one can obtain the best correlation coefficient disregarding the lag interval.

In this analysis, a correlative study has been done considering zero month lag. First, monthly mean values of cosmic rays are correlated with monthly mean values of sunspot number & is said to be zero lag.

3. **Results & Discussion**

To observe the relationship between cosmic ray intensity & Sunspot numbers for the two successive solar cycles (22-23), the correlation coefficient between the monthly mean values of these two parameters has been derived. The pressure corrected monthly mean cosmic ray values of two neutron monitors such as Climax (2.9 GV) & Calagory (1.08 GV), are taken into consideration. It has been observed that the long-term cosmic ray intensity is generally anti-correlated with sunspot numbers[3], Shrivastava[4], Shrivastava *et al*.[5]. It has also been observed that the exact month of solar activity maximum / minimum does not coincide with cosmic rays minimum / maximum, such a difference in mean values of sunspot numbers with cosmic rays mean values is known as time lag.

The average mean values of sunspot numbers Rz, have been taken as a solar activity parameters to derive the correlation coefficient considering zero time lag. Studies on long-term modulation of galactic cosmic rays require an extended set of homogeneous data free of terrestrial induced effect. Good quantitative results could be derived from the data of neutron monitors. Fig. 1 & fig. 2 illustrate the yearly mean values of sunspot numbers along with cosmic ray intensities for the period 1986 to 2009, which cover the solar cycles 22, 23. Fig. 1 & fig. 2 show the 11-years modulation cycles for Climax & Calagory neutron monitors respectively. Ascending & descending phases of sunspot cycles are well noticed in these 11-years modulation cycles, one can clearly observe the anti-correlation of sunspot numbers (Rz) with cosmic ray intensity from fig. 1 & fig. 2 & also some deviation (time lag) in cosmic ray maxima with sunspot minima for all the sunspot solar cycles. In this study, all the sunspot cycles have been divided in ascending & descending phase are again divided into two parts as part I & part II. Fig. 3 shows the results of correlation for all phases. A good anti-

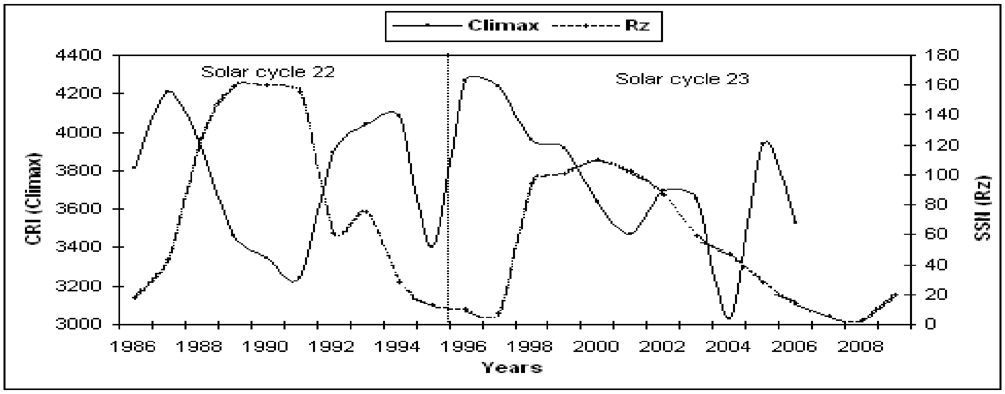

Fig 1. Yearly mean values of sunspot numbers (Rz) & Cosmic Rays Intensity data of Climax station for the period 1986 to 2009.

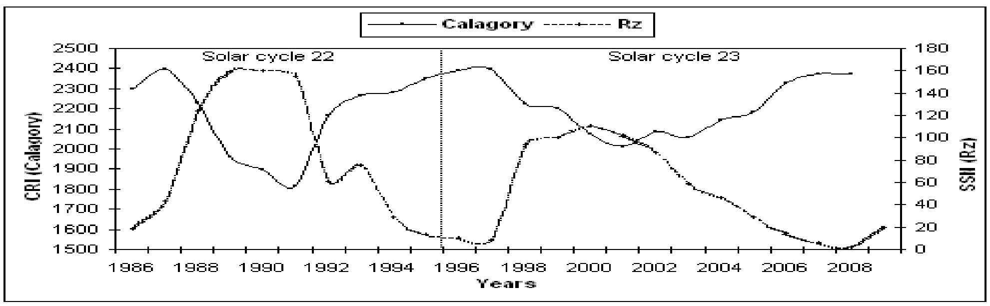

Fig. 2. Same as Fig 1, but for Calagory neutron monitor stations.

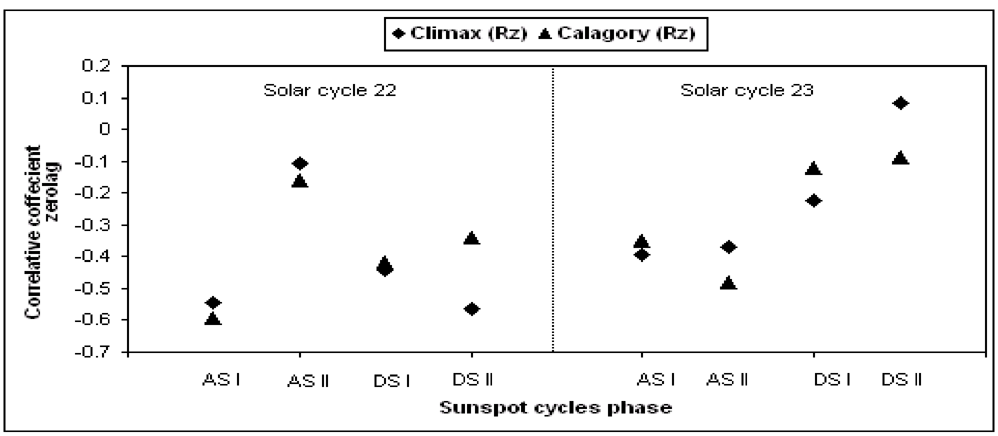

Fig. 3. Correlation coefficient between Rz & Cosmic rays at zero time lags for ascending phase I & II, & descending phase I & II, covering solar cycle 22 & 23.

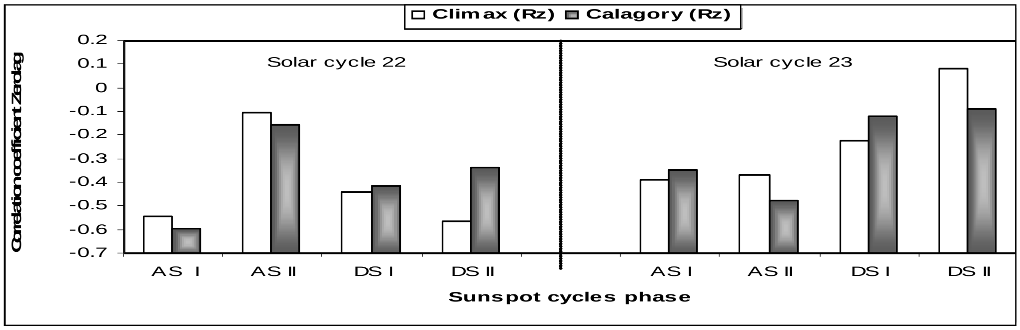

Fig. 4. Histogram showing the zero time lag which give best correlation between Rz & CRI for ascending & descending phase of solar cycle 22 & 23.

correlation is observed between Rz & Cosmic ray intensity at neutron monitor energies. It is always found that r ≥ 0.4. Correlation coefficient for that second part of ascending phases is generally found to be higher than for another interval.

Earlier works[1], Shrivastava[6], Singh *et al.*[7] had reported high anti correlation between Rz & cosmic rays for all the phases of solar cycles 22, 23. The present analysis has been undertaken to derive the new aspects in long-term cosmic ray intensity & to look into the problem in more detail[2].

In K-series analysis, time lag correlations have been obtained which has been depicted in Fig. 4. In this analysis, averages of monthly data have been obtained after dividing the solar-cycle into ascending & descending phases. Two phases of ascending & two of descending have been obtained in each case of Climax Rz & Calagory Rz where in last correlation (r ≥ 0.4) has been obtained between CRI & Rz.

In solar cycle 23, correlation between CRI & Rz is gradually increasing because in solar cycle 23, more solar flares are emitted from ascending to descending phase regions respectively.

The results of time-varying rigidity dependent effects on time lag analysis are presented for all solar cycles using the data from Climax/Calagory pair of neutron monitors stations for the period 1986 to 2009.

The cosmic ray modulation depends upon various factors, namely, the magnitude & direction of regular magnetic fields, the level of magnetic disturbances, the solar wind speed, the size & sign of the heliomagnetosphere. In the quiet heliosphere the cosmic rays propagate inward by a combination of random walk & guiding centre drift which are coherent over large distances.

The response of cosmic rays particles to solar activity during ascending phases of solar cycles is different from that related to descending phases.

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References

1. Popielawska B, *Planet & space Sci.* (U.K.), *40,* 811 (1992).
2. Shea M.A. and Smart D.F. Proceeding of 19th international conference on Cosmic Rays, *Layolle, USA,* Vol *4.* P. 501 (1985).
3. Shea M.A. and Smart D.F. Proceeding of 21st international conference on Cosmic Rays, *Adelaide, Austrila* Vol *6,* P. 13 (1990).
4. Shrivastava P.K. Proceeding of 21st international conference on Cosmic Rays, Adelaide, Austrila Vol 6, P. 65 (1990).
5. Shrivastava P.K, Agrawal S.P. "Indian J. Radio & Space Phys 22, 26 (1993).
6. Shrivastava P.K. Proceeding of 25th international conference on Cosmic Rays, Durban, South Africa Vol. *2,* P.65 (1997).
7. Singh, M., Nigam S.K., and Shrivastava P.K., *Proc. Nal. Acad. Sci. 68,* 111 (1998).
8. Singh, M., Nigam S.K., and Shrivastava P.K., "The aspect of time lag in long-term cosmic ray intensity variation". Indian *Journal of Radio Space Physics.* Vol *28,* pp. 211-215 (1999).