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A new concept of analysis of solar daily variation in cosmic ray intensity

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Abstract. A new concept of data analysis has been introduced for studying the long/short term daily variations in cosmic ray (CR) intensity recorded with neutron monitors/meson telescopes. Fourier Technique has been applied on four different types of groups of days chosen according to their different geomagnetic conditions. The selected groups are 60 quietest days (60 QD), 120 quiet days (120 QD), continuous quiet days (CQD) and All Days (AD) in a year. CQD is a new set of days selected on the basis of Ap and Kp values. These are the days when transient magnetic variations are regular and smooth continuously for a span of atleast three days. The criteria of selection is based upon the mathematical manipulation of Ap index. Thus, the consequences of the analysis are being discussed.

1 Introduction

Many workers have attempted to derive relationship between the mean daily variation and the level of solar and geomagnetic activity (Rao, 1972; Venkatesan and Badruddin, 1990 and references therein). Agrawal (1983) and Bieber and Evenson (1997) have studied daily variation in CR intensity for all days (AD) in a year; where as, Kumar et al (1981a, b, 98) have studied long/short term daily variation on geomagnetically quietest days (60 QD). Jadhav et al (1983) studied semi-diurnal variation during days of low and high amplitude anisotropic wave trains. Thus, a question arises as to what type of days will be more suitable for performing long/short term analysis of CR intensity. Therefore, apart from all days (AD) and sixty geomagnetically quietest days (60 QD) two more types of days; i.e., 120 QD and continuous quiet days (CQD) have been considered for the comparative studies of anisotropic daily variation over a period of 11/22 years.

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2 Experimental data and analysis

The data obtained from Deep River Neutron Monitor has been harmonically analysed through Fourier Technique after applying trend correction. The anisotropic modulation in CR intensity on long/short term basis has been studied for diurnal variation on days satisfying different criteria. The results thus, obtained, are presented in the accompanying papers (Dubey et al, 2001 (a, b)).

For the purpose of anisotropic studies four groups of days are selected:

(i) All days: This means all the 365/366 days in a year. The days are termed as AD. Of course, ignoring the days with abrupt changes.

Quiet days: Days on which the transient magnetic variations are regular and smooth are said to be magnetically quiet or calm or Q days. The criteria of selection is based upon Ap and Kp values. There are two types of Q days:

(ii) 60 Quiet days: According to solar geophysical data (SGD) lowest mean order number are the five quietest days in a month. These days are called the International quiet-quiet-days or QQ days. Thus, 60 Q days in a year; termed as 60 QD.

(iii) 120 Quiet days: First ten Q days in a month. Thus, 120 Q days in a year; termed as 120 QD.

(iv) Continuous quiet days: The need and criteria for the selection of this group of days is discussed in detail as follows:

2.1 Need for the selection of continuous quiet days:

(a) 60/120 quiet days selected in a year are discrete and scattered.

(b) In many cases the quiet days are preceded or followed by the days having larger values of geomagnetic disturbance index. Such days may be disturbed days.

(c) Kp is the mean standardized K-index from 13 observatories between geomagnetic latitudes 47 and 63 degrees. The scale is 0 (very quiet) to 9 (extremely disturbed) expressed in thirds of a unit e.g. 5_- is 4 and 2/3, 5_0 is 5 and 0/3 and 5_+ is 5 and 1/3. Ap is a daily index of

magnetic activity on a linear scale. It is the average of the eight values of an intermediate 3 hourly index ap. ap is computed from Kp for the 3 hour interval, A selected "quiet day" considered "not really quiet" is marked by the letter A if Ap>6 for that day, or marked by the letter K if Ap≤6 but with one $Kp \geq 3_0$ or two Kp values are ≥ 3. To avoid such days and to get a set of days having values of Ap index low continuously atleast for 3 days, a group of days called continuous quiet days (CQD) is being selected.

2.2 Criteria for selection of CQD

The mean of all Ap values for all the days in a year is calculated. All those days having Ap values larger than twice the annual mean values are discarded. Again, the mean of all remaining Ap values of this new set of days is calculated and all those days are discarded which have Ap index larger than twice the new mean value. This procedure is repeated till the number of discarded days becomes zero. Thus, the last set possesses almost a statistically normal distribution of Ap values. From this last set, the mean value of Ap index is calculated and only those days having Ap values less than the mean for atleast three continuous days are chosen. This set of days is termed as continuous quiet days (CQD).

3 Results and Discussion

The variation of mean values of Ap index with the number of iterations performed for the years 1986 and 1991 is depicted in Fig 1. It is clearly observable that the mean Ap index gradually reduces as the number of discarded days becomes zero. It is apparent from Fig 1 that the mean values of Ap index are higher for the year 1991, the period of maximum solar activity as compared to 1986 the period of minimum solar activity. Further, the distribution of the number of days with Ap index after different iterations of discarding process for the years 1986 and 1991 is depicted in Fig 2. The outermost dashed curve represents the original distribution. It is clearly observable from the curves for years 1986 and 1991 that the distribution is spread initially over a wide range of Ap index; whereas, the distribution curves become more and more regular with each iteration performed during minimum as well as maximum solar activity periods. Finally, when the discarding process is over, the curves have most regular and symmetrical distribution about the mean. During the year 1986, the mean of Ap stabilises after larger number of iterations; whereas, in case of the year 1991, it requires lesser number of iterations. The reason for this is quite obvious that the level of solar activity is low during the year 1986, while it is high during 1991.

The occurrence of days (%) has been plotted histographically with amplitude (%) and phase (hrs) at ground, of diurnal anisotropy in CR intensity on (a) 60 QD, (b) 120 QD, (c) CQD and (d) AD for all the four phases of solar activity cycle (SAC) i.e., ascending phase of SAC, solar maxima period, descending phase of SAC and solar minima. One of them is shown in Fig 3 drawn for minimum solar activity period. It is observed from the histograph, that the phase has occurred within the time interval near the corotational/azimuthal/90°E of Sun-Earth line/18 Hr direction in space value on maximum number of days in case of 60 QD and this trend is almost same when AD are selected. The frequency distribution over different range intervals is well scattered when 120 QD and CQD are selected. A secondary peak is also observed in case of 60 QD, 120 QD and AD. It is evident from the plot that the amplitude peak is quite distinctly sharp. However, it becomes quite wider when AD are selected for analysis. As the level of the solar activity is low, the trend for the distribution of amplitude remains the same for all the four groups.

It is observed that the general trend as shown by the distribution for the phase and amplitude for all the four types of days is quite comparable. The distribution in most of the cases is sharper in case of 60 QD; whereas, some of the finer features of anisotropic variations are suppressed in AD. In some cases sharper peaks are also seen in case of CQD, because of sustained quiet conditions and small deviations on a day-to-day basis are suppressed. The statistical errors are found to be comparatively larger in case of 60 QD but are low in case of AD. The distributions are more regular and symmetrical in case of 60 QD.

4 Conclusion

Investigations of the four groups of days for four different phases of SAC have shown that 60 QD are most suitable for the long/short term anisotropic studies in CR modulation.

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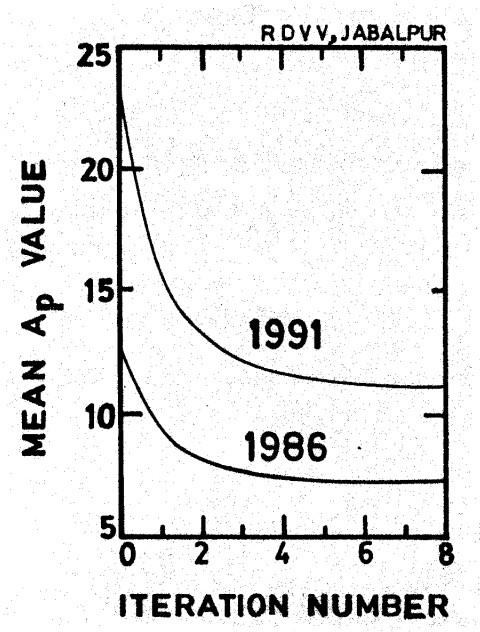

Fig 1. The mean value of Ap-index, after different iterations of discarding process, plotted for the years 1986 and 1991.

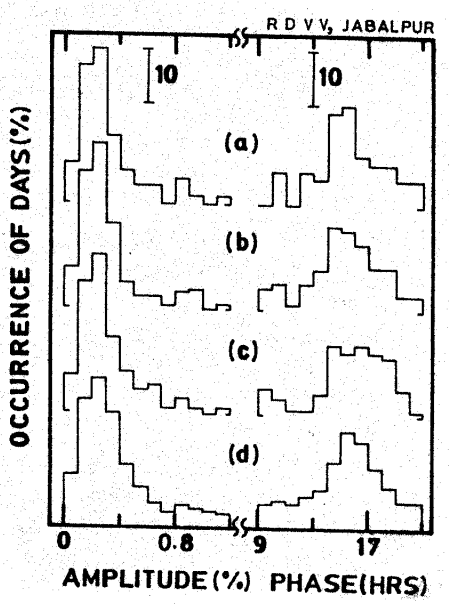

Fig 3. The amplitude (%) and phase (Hrs) of the diurnal anisotropy in CR intensity plotted histographically during 1986 for (a) 60 QD, (b) 120QD, (c) CQD and (d) AD.

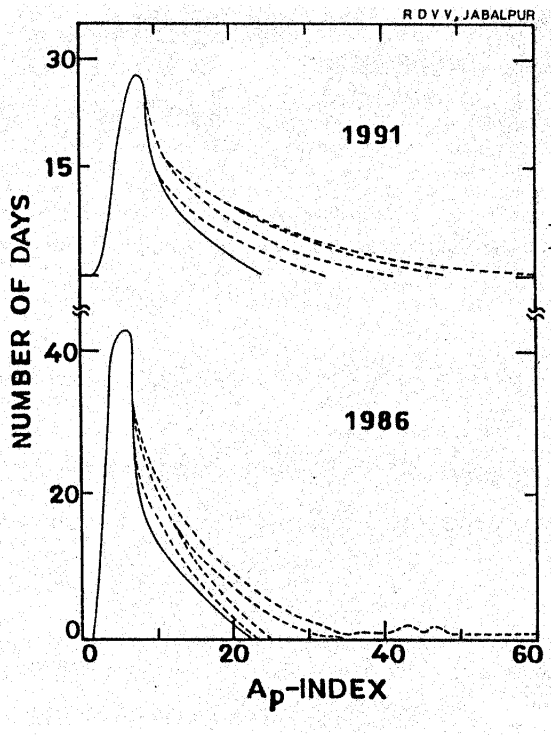

Fig 2. The distribution of Ap-index, after different iterations of discarding process, plotted for the years 1986 and 1991.