11 YEAR VARIATION IN TRI-DIURNAL ANISOTROPY OF COSMIC RAY INTENSITY ON QUIET DAYS AT MID LATITUDE AND HIGH LATITUDE NEUTRON MONITORING STATION

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Abstract: The cosmic ray (CR) intensity data recorded with neutron monitoring stations located at high and mid latitude have been investigated on quiet days (QD) for studying the variation in tri-diurnal anisotropy during solar cycle 21 and 22. It has been observed that in spite of the abrupt changes in the amplitude and phase of tri-diurnal anisotropy in cosmic ray intensity, the amplitude to tri-diurnal anisotropy in cosmic ray intensity on quiet days in observed quite significant throughout period of investigation with small amplitude during the year 1981 as well as 1990. Further the phase shift to earlier hours during the period 1990-91 showing the dependence on the polarity of solar magnetic field, which is attributed to drift effect at mid latitude neutron monitoring stations. Thus tri-diurnal anisotropy clearly shows 11 year type variation at high and mid latitude neutron monitoring stations.

Keywords: Cosmic Rays / Geomagnetically quiet days / Higher harmonics

1 Introduction

The spatial anisotropy of the galactic cosmic ray intensity in the interplanetary space manifests itself as daily variation with a period of 24 hours (and its higher harmonics) due to the rotation of the Earth in the course of a day. The power Spectrum analysis as well as the Fourier analysis of the long term data of the 24-hour values of cosmic ray (CR) intensity observed by Earth based detectors have provided daily variation of extraterrestrial origin [1-3]. However, the amplitude of the fourth harmonics is still controversial [4-7]. Moreover, it has been observed that the amplitude and phase of tri diurnal anisotropy of CR intensity on quiet days vary considerably from one period to another. On the long term behaviour of the first three harmonics showed that high degree of year to year variability exists, a trend with solar activity was evident. The studies of the higher harmonics in the daily variation of cosmic ray provided valuable information as to the nature of the cosmic ray modulation in the heliosphere.

2 Analysis of the data

Solar daily variation has been studied in terms of helio-magnetic activity. A new concept of data analysis has been introduced for studying the long/short term daily variation in CR intensity recorded with neutron monitors. Fourier technique has been applied on different types of group of days chosen according to their different geomagnetic condition.

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

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

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

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

The pressure corrected hourly CR intensity data (corrected for meteorological effects) on geomagnetically five quietest days (QD) in every month for Deep River (Lat: 46.060N; Cutoff rigidity; 1.02 GV; Longitude; 282.50E; Altitude; 145m), Goose Bay (Lat: 53.330N; Cutoff rigidity; 0.52 GV; Longitude; 299.580E; Altitude; 2,5&9
46m) for the period 1978-94 and Inuvik (Lat: 68.350N; Cutoff rigidity: 1.02 GV; Longitude; 130.720E; Altitude; 21m), neutron monitoring stations for the period 1978-90, have been used in Fourier analysis. After applying the trend corrections, such a set of data have been subjected to Harmonic analysis for each day [8]. The average values of the amplitude and phase (local tine of the station) of the third (tri diurnal) harmonics on yearly basis have been obtained. According to solar geophysical data five quietest days are selected in a month; thus 60 quietest days are obtained in a year. These days are called international quiet days (QD). The days with extra ordinary large amplitude if any, have not been considered. Further, the variation in the tri-diurnal anisotropy with the reversal of polarity of solar magnetic field (PSMF) on 60 QD has been also investigated. Also all those days are discarded having more than three continuous hourly data missing.

The pressure corrected hourly CR intensity data (corrected for meteorological effects) on geomagnetically five quietest days (QD) in every month for Deep River (Lat: 46.060N; Cutoff rigidity; 1.02 GV; Longitude; 282.50E; Altitude; 145m), Goose Bay (Lat: 53.330N; Cutoff rigidity; 0.52 GV; Longitude; 299.580E; Altitude; 46m) for the period 1978-94 and Tokyo (Lat: 35.750N; Cutoff rigidity; 11.61 GV; Longitude; 139.720E; Altitude; 20m), Mount Nourikura (Lat: 36.120N; Cutoff rigidity; 11.39 GV; Longitude; 137.560E; Altitude; 27.7m) neutron monitoring stations for the period 1980-90, have been used in Fourier analysis. After applying the trend corrections, such a set of data have been subjected to Harmonic analysis for each day [8]. The average values of the amplitude and phase (local tine of the station) of the third (tri diurnal) harmonics on yearly basis have been obtained. According to solar geophysical data five quietest days are selected in a month; thus 60 quietest days are obtained in a year. These days are called international quiet days (QD). The days with extra ordinary large amplitude if any, have not been considered. Further, the variation in the tri-diurnal anisotropy with the reversal of polarity of solar magnetic field (PSMF) on 60 QD has been also investigated. Also all those days are discarded having more than three continuous hourly data missing.

3 Results and Discussion

The yearly average amplitude and phase of the third harmonics of daily variation along with average values of Ap indices on Quiet Days, solar wind velocity and PSMF in the northern and southern hemisphere of the Sun for Deep River and Goose Bay Neutron Monitoring Stations have been plotted in Fig. 1 during the period 1978-94 on quiet days. It is quite apparent from Fig. 1 at Deep River Neutron Monitoring Station, the amplitude of third harmonics of daily variation has quite abruptly increased during the years 1980 and 1985. The likely one of the cause for such type of variation could be the changing of geomagnetic threshold cut off rigidly from 1.02 GV to 1.15 GV in 1980 and from 1.02 GV to 1.12 GV in 1985 respectively [9-11] as it has been discussed in the case of change of diurnal anisotropy of cosmic ray intensity on QD [12]. Therefore, these type of variation in the amplitude of the tri-diurnal anisotropy on QD may be also attributed to the change in the rigidity spectrum. The amplitude of tri-diurnal anisotropy on QD has shown an exceptionally small value during 1981 and 1994, which is a period of minimum solar activity [13]. The amplitude of third harmonics of daily variation on QD is observed to be significantly low during 1981 as well as in 1990, which coincides with phase reversal of the solar poloidal magnetic field [14, 15]. Further, during the year 1985 and 1986, the year of minimum solar activity, the amplitude of third harmonics on QD significantly high, which support the earlier finding [15]. The error (=.006%) contained in the amplitude of third harmonics at Deep River Neutron Monitoring Station.

It is also observed from Fig. 1 at mid latitude neutron monitoring station that there is no systematic change in the phase of third harmonics of daily variation in cosmic ray intensity on quiet days. However, a slight change in the tri-diurnal phase is observed, when the polarity of solar magnetic field reversed its polarity during the periods 1979-80 and 1990-91 [14]. It shows that the phase of tri-diurnal anisotropy on quiet days has nearly the same value at both sides of reversal period. Whereas in both the cases during the succeeding years, i.e., 1980-81 and 1991-92, the change in the phase of tri-diurnal anisotropy of CR intensity has been found quite significant [10]. It is clear that there exist a 11 year type of variation in third harmonics of CR intensity on QD due to the variation of solar activity [11]. The polarity dependence of the phase shift change has been interpreted as a result due to the change of CR density distribution in space caused by the difference of CR drift motion in the positive and negative polarity state [12-14].

The existence of polarity dependence in the tri-diurnal variation may be defined as the state is positive, when the magnetic field is away from the sun at the north pole and toward the Sun at the south pole, while it is called negative, when the polar magnetic field are reversed [15-16].

In yearly average amplitude and phase of the third harmonics of daily variation along with average values of Ap indices on Quiet days and PSMF in the northern and southern hemisphere of the Sun for Inuvik Neutron Monitoring Station have been plotted in Fig. 2 during the period 1978-90 on quiet days. It is quite apparent from Fig. 2, that there is no systematic change in the amplitude of third harmonics on QDs. The amplitude of third harmonics of daily variation of QD is observed to be significantly low during 1981 as well as in 1990, which coincides with phase reversal of the solar poloidal magnetic field [15]. Further, the amplitude of third harmonics on QD is low during 1985 and 1986, the year
of minimum solar activity. The cause of such changes may be the increase of interplanetary magnetic field irregularities (IMF).

The amplitude of third harmonics of daily variation on quiet days during 1978 and 1990 (Maximum Solar activity period of solar cycle 21 and 22) having same values. A clear 11 year type variation is observed at high latitude neutron monitoring station.

It is also observed from Fig. 2 that there is no systematic change in the phase of third harmonics of daily variation in cosmic ray intensity of QD. However, in the year 1990, the phase shifted to later hours, when the polarity of solar magnetic field in the northern hemisphere has changed from negative to positive [9].

4 Figures

Fig.1 Amplitude (%) and phase (hrs) of third harmonics along with average value of Ap indices on quiet days, solar wind velocity and PSMF in the Northern and Southern hemisphere of the sun at Deep River (O) and Goose Bay (●) Neutron Monitoring stations during 1978-94.

Fig.2 Amplitude (%) and phase (hrs) of third harmonics along with average value of Ap indices on quiet days and PSMF in the Northern and Southern hemisphere of the sun at Inuvik Neutron Monitoring station during 1978-90.

5 References:


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