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Study and effect of different heliospheric parameters on cosmic ray anisotropy

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We studied the cosmic ray data as well as sunspot number, solar wind velocity and geomagnetic activity index data to examine effect of different solar heliospheric parameters and correlation between quiet day diurnal variations during the time interval 1964-1995. The amplitude of cosmic ray diurnal anisotropy significantly remains constant during quiet days. The diurnal time of maximum either shifts towards earlier hours or remains in the azimuthal/corotational direction. The solar wind velocity positively correlated with geomagnetic activity index during quiet days. The sunspot shows the ~11-year periodicity; whereas the diurnal cycle shows the ~22-year periodicity. Our observations suggest that the direction of the anisotropy of quiet days contribute significantly to the long-term behaviour of the CR diurnal anisotropy.

1. Introduction

It has been observed on a day-to-day basis there are large variations in the daily variation of Cosmic Ray intensity, which indicate that continued and large variation occur in the interplanetary medium. The study of daily variation of cosmic ray intensity recorded by ground based monitors, meson telescope and underground meson telescopes have revealed the detailed characteristics features of the anisotropy. It has been recognized that the days with low value of geo-magnetic disturbances represented by five most quiet days in every month be better suited for understanding the nature of daily variation of Cosmic Ray intensity on long term basis. The result of power spectrum and harmonic analysis for the different worldwide Cosmic Ray station showed that the observed daily variation is of extra- terrestrial origin. The characteristics of diurnal anisotropy similar to the semi-diurnal anisotropy and is independent of the rigidity and latitude dependence is much steeper than that for diurnal variation.

Kumar et al. [1] and Richharia and Shrivastava [2] clearly shows that magnetically most quiet days are most effective by the solar polar magnetic field reversal as compared to all days, which comes from the facts that these days are least affected by the disturbances in interplanetary medium and hence these days are best suited for understanding the anisotropy on long term as well as short term basis. An attempt was made to find out the most suitable index of the solar activity in order to reproduce to a certain degree the modulation of the cosmic ray intensity [3]. The contribution of more than one solar, interplanetary or geophysical parameter to the cosmic ray modulation process as solar flares, sunspot number, proton events, geomagnetic index etc. have also been reported [4].

Very little to understand about day-to-day variation in the various harmonics of C.R. Intensity. Therefore, the investigation cosmic ray variation in relation to solar interplanetary and geo-magnetic parameters needs a further rigorous study. Therefore the study of the amplitude and phase of first harmonic on quit days at different latitude during different solar activity period provide an important tool, which is helpful for the knowledge of energy spectrum of the primary anisotropy. Further, we can also learn about the various factor influences the CR intensity arising from the electromagnetic condition of interplanetary space. The boundaries to the extension of the solar corona may be betterly estimated by studying the long-term trend in the various harmonics of the daily variation of CR intensity and present investigation /study is one of the steps in that direction

2. Data and Analysis

Pressure corrected data of Deep River neutron-monitoring (NM) station (cutoff rigidity 1.02 GV; latitude 46.1º N; longitude 282.5º E; altitude 145 M) has been Fourier analyzed after applying trend corrections to obtain the first harmonic at ground for the period 1964-95. According to solar geophysical data five quietest days are selected in a month; thus 60 quietest days in a year. These are called International Quiet Quiet days or QQ days. The study of diurnal variation has been performed on 60 QQ for the period 1964-95. The days with extraordinarily large amplitude, if any, have not been taken into consideration. Also all those days are discarded having more than three continuous hourly data missing. The data related with interplanetary magnetic field (IMF) and solar wind plasma (SWP) parameters for each corresponding quiet days have also studied in the present analysis.

3. Results and Discussion

To study the effect of different heliospheric parameters on cosmic ray diurnal variation during 1964-95 the following parameters were studied: the amplitude (%) and phase (Hr) of cosmic ray intensity registered by Deep River neutron monitor, sunspot number (Rz_{QD}), geomagnetic activity index (Ap_{QD}), and the interplanetary medium parameter: solar wind velocity (V_{QD}) during quite days. The amplitude R_{QD} (%), time of maximum T_{QD} (Hr), solar wind velocity V_{QD} (km/sec.), sunspot number (Rz_{QD}) and geomagnetic activity index (Ap_{QD}) during quiet days are plotted in Figure 1-6.
It is clearly seen from Figure 1 that the amplitude (R_{QD}) of the diurnal anisotropy on quiet days remaining

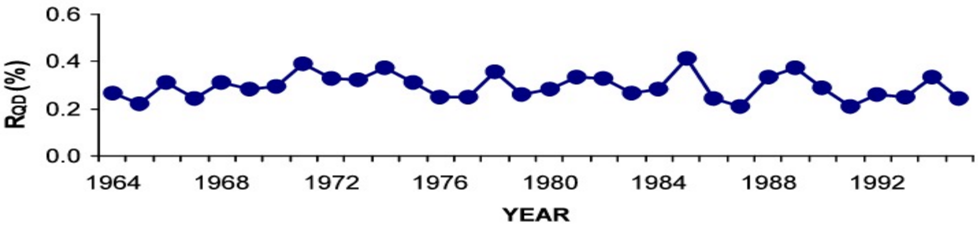

Figure 1: The long-term variation of cosmic-ray diurnal anisotropy amplitude R_{QD} (%) for the period 1964-1995.

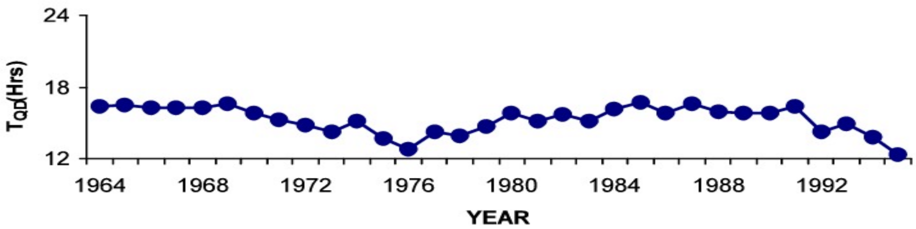

Figure 2: The long-term variation of time of maximum T_{QD} (Hr) of cosmic-ray diurnal anisotropy for the period 1964-1995.

almost statistically constant during the entire period of investigation i.e. 1964-1995. The time of maximum (T_{QD}) of quiet day diurnal anisotropy as depicted in Figure 2 gradually shifts towards earlier hours till 1976 and then towards corotational/ 18 Hr direction till 1991. Again it started shifting towards earlier hours. The time of maximum (T_{QD}) remains to its minimum (1200 Hr direction) during 1976 and 1995; whereas the sunspot numbers as shown in Figure 3 are found to be minimum during 1964, 1976, 1985 and 1995. Thus the sunspot shows the ~11-year periodicity; whereas the diurnal cycle shows the ~22-year periodicity. As depicted in the Figure 4 the solar wind velocity does not seems to affect either the amplitude or the time of maximum of the diurnal anisotropy on quiet days.

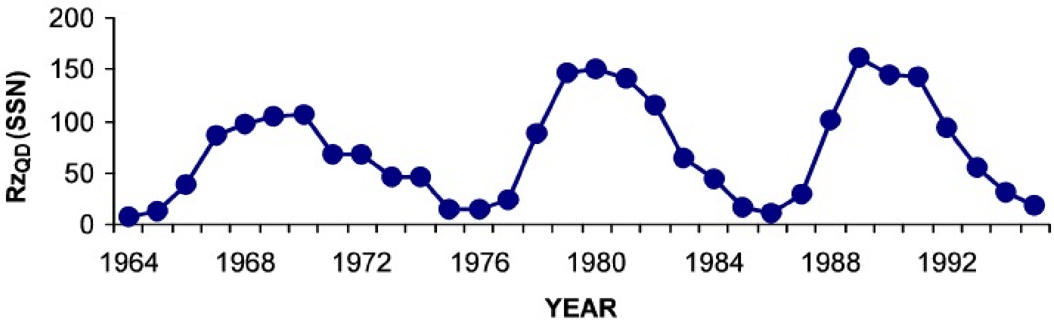

Figure 3: The long-term variation of sunspot number (Rz_{QD}) during quiet days for the period 1964-1995.

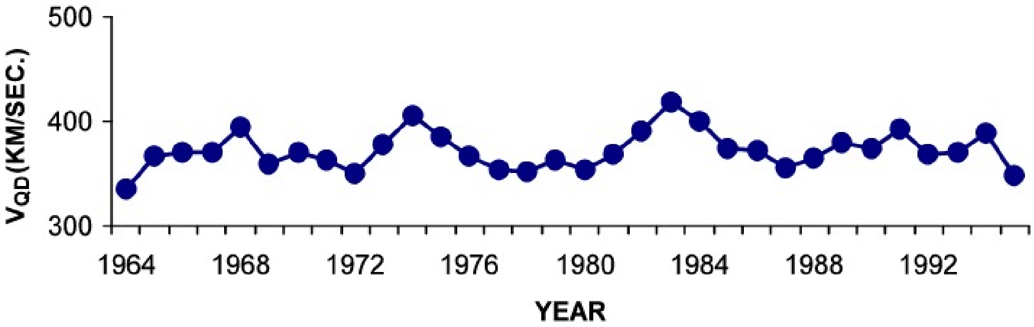

Figure 4: The long-term variation of solar wind velocity (V_{QD}) during quiet days for the period 1964-1995.

In general there is a correlation between the long-term variations of Ap and the observed GCR modulation [5, 6 and references therein]. In an earlier analysis [7] it was noted that a subsidiary maximum appears in the annual mean solar diurnal anisotropy data, "when (the solar wind bulk velocity) V>470 km/s or when B has large values. It is shown that Ap is most responsive to the changes in the fine structure of B [8]; this point has been emphasized also by Lockwood et al. [9].

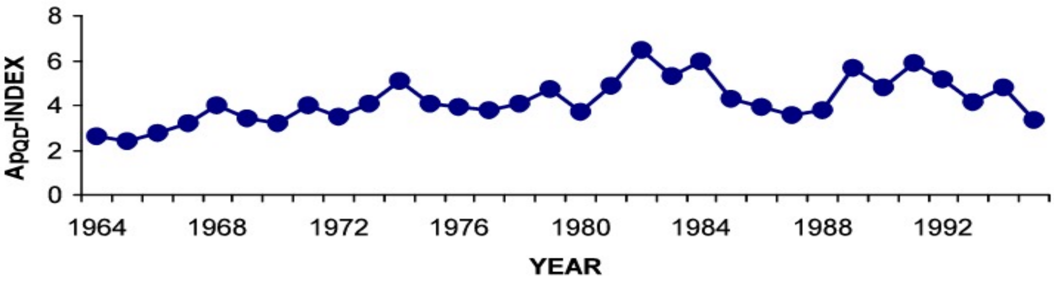

Figure 5: The long-term variation of geomagnetic activity index (Ap_{QD}) during quiet days for the period 1964-1995.

It is noted form the plot depicted in Figure 5 that the geomagnetic activity index (Ap) has found to its lowest value during 1964 and has its highest value during 1982-1984. The amplitude (A_{QD}) and time of maximum (T_{QD}) doesn't seem to be affected in context with the Ap-index. However, the solar wind velocity (V_{QD}) seems to have good correlation with Ap-index. The geomagnetic activity index (Ap_{QD}) found to remain low during the years when solar wind velocity also remains low; whereas Ap-index found to remain high during the years when solar wind velocity also remains high.

4. Conclusions

- The amplitude of the diurnal anisotropy significantly remains constant on quiet days during 1964-1995 covering three solar cycles 20, 21 and 22.
- The time of maximum of the diurnal anisotropy found to shifts towards earlier hours or towards corotational direction on geomagnetically quiet days.
- The solar wind velocity has a positive correlation with geomagnetic activity index (Ap_{QD}).
- The sunspot shows the ~11-year periodicity; whereas the diurnal cycle shows the ~22-year periodicity.

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