Proceedings of ICRC 2001: 3819 © Copernicus Gesellschaft 2001

ICRC 2001

Long term trends in semi-diurnal anisotropy and effect of solar poloidal magnetic field inversion

S. K. Shrivastava and M. L. Chauhan

Department of Physics, Government Model Science College(Auto.), Jabalpur, (M.P.), India

ABSTRACT. The long term trend and effect of the reversal of polarity of Solar poloidal magnetic field (SPMF) on semi-diurnal anisotropy of cosmic ray (CR) intensity on quiet days for the period 1964-95, covering three solar cycles namely 20,21 and 22 have been studied using Deep River neutron monitor data. Semi-diurnal anisotropy shows sudden changes to early/later hours near to CR intensity minima or maxima. The amplitude of semi-diurnal anisotropy shows an increase followed by decrease during inversion of solar poloidal magnetic field (SPMF). The average vectors for negative polarity of SPMF in northern hemisphere (NH) during 1964-70 and 1980-90 are shifted to later hours relative to the average vectors for the entire period of observation.

1. INTRODUCTION

The interplanetary magnetic field (IMF) is believed to consist of two sectors of different field polarities north and south of the neutral sheet which lies approximately in the ecliptic plane. Studies of solar magnetic field have revealed that these field change sign in 11- year intervals. Since, the IMF is an extension of the solar magnetic field it will also reverse its sign every 11- year. The wellknown effect of drift motion of charged particles in inhomogeneous magnetic field may play an important role in the modulation of cosmic rays.

Potgieter et at (1980) has pointed out that during the periods when northern hemispheric field points towards the Sun, positively charged particles will flow from the ecliptic towards the solar poles leading to decrease in intensities of positively charged particles observed near the earth and thus, hardening of primary spectra of cosmic rays to which neutron monitors responds. Vice-versa a softening of spectra is observed with the reversal of polarity of solar poloidal magnetic field.

The effect of solar poloidal magnetic field inversion on semi-diurnal anisotropy of cosmic rays has been studied for a long period of observation covering three solar activity cycle, three solar poloidal magnetic field inversion and four solar activity minimum.

2. DATA ANALYSIS

The data corrected for pressure variations for Deep River Neutron Monitor (cutoff rigidity 1.02 GeV; lat 46.1^{o}N; long 282.5^{o}E; Alt 145m) have been used for the analysis. The data for 60 quietest days taking five quiet days in a month have been chosen from these data and the long term effects have been taken care of by applying trend corrections according to Yadav and Naqbi (1973). The data obtained in this way have been subjected to Fourier analysis to obtain the values of amplitude and phase in semi-diurnal anisotropy. The statistical errors in amplitude and phase of semi-diurnal anisotropies have also been determined. The days where diurnal or semi-dirunal anisotropy amplitude is high have not been considered.

3. RESULTS AND DISCUSSION

The plots of average annual semi-diurnal phase, semi-diurnal amplitude considering 60 quiet days (60QD) in a year and values of Ap-index are shown in Fig. 1 along with the polarity of solar magnetic field in northern hemisphere (NH) and southern hemisphere (SH) during the period of observation. The solar maxima ($\uparrow$), solar minima ($\downarrow$), CR intensity maxmia ($\Uparrow$) and CR intensity minima ($\Downarrow$) are also marked in Fig. 1., as per Ahluwalia (1997).

The phase of the semi-diurnal anisotropy has been observed to shift to early hour during 1967, 1981-82 and 1990-91. All these three epoch are either CR intensity minimum or very close to CR intensity minimum. The phase of the semi-diurnal anisotropy has also shifted to early hours in case of 1977 and 1995 which are the periods of maximum CR intensity or closer to it, these are also the epoch of solar activity maximum for the solar activity cycle (SAC) -21 and 23. However, the phase of semi-diurnal anisotropy shows a shift to later hour during 1964 and 1986 which are the periods closer to solar activity minimum and also CR intensity maximum of SAC-20 and SAC-22. The phase of semi-diurnal anisotropy shows a shift to early/later hours in alternate solar activity cycles. It is further, observable that during CR maximum of 1965 and 86 the polarity of solar poloidal magnetic field is negative in the northern hemisphere, whereas, it is positive during CR intensity maximum/solar activity minimum of 1976-77 and 1995.

Nagashima and Fujimoto (1989) using data for the period 1971-88 pointed out that the semi-diurnal anisotropy vector sudeenly changes their relative confugaration from the usual direction to another for the polarity reversal of polar magnetic field from positive to negative state in NH, which has occured in 1979-80. They further pointed out that the behavior of semi-diurnal anisotropy is different during solar activity minimum of 1975 and 1980. The period covered by them included one polarity reversal and two solar activity minimum whereas the present study confirms the results using data that covers three events of polarity reversal and four solar activity minimum.

The amplitude variation as observable from Fig. 1. shows that during the periods 1971-72, 1978-81 and 1991-92 the amplitude of semi-diurnal anisotropy first increases and then decreases. All these three periods are the consecutive epochs of solar poloidal magnetic field inversion.

The amplitude of semi-diurnal anisotropy is observed to be smaller during the years 1976,1986 as compared to its preceding two years. Further, during 1964 the value is small as well. These results are similar to the results obtained by Pransky et al (1991) using ionisation chamber data for the period 1954-89. These epochs for which the semi-diurnal amplitude is low are the periods of minimum solar activity. The decrease in semi-diurnal amplitude during solar activity minimum can be explained by decrease in regular component of the interplanetary magnetic field intensity.

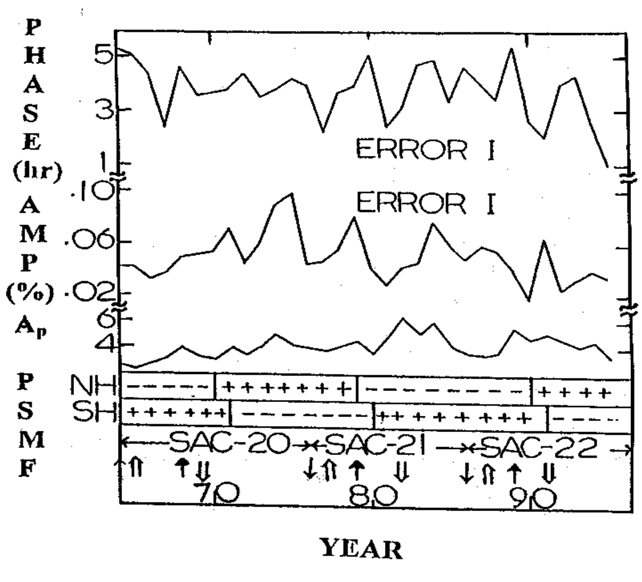

Fig. 1. Plot of annual average values of semi-diurnal phase and amplitude for the Deep River NM along with Ap index. The timings of solar activity minimum(↑), maximum (↓) and CR intensity minimum(⇓),maximum(⇑) are marked.

The semi-diurnal vector for the entire period of consideration i.e. 1964-95 has been divided into for four parts (I) 1964-70, (ii) 1971-79, (iii) 1980-90 and (iv) 1991-95. During the period 1964-70 and 1980-90 the polarity of solar poloidal magnetic field (SPMF) is positive in the northern hemisphere (NH) whereas it is negative for the remaining periods of 1971-79 and 1991-95.

Fig. 2. shows the plot of average annual semi-diurnal vector for these periods as well as the average annual semi-diurnal vectors for the entire period of consideration. It is observed that average annual semi-diurnal vector for the negative polarity of SPMF in NH (1964-70 and 1980-90) are shifted to later hours relative to the average annual semi-diurnal vector for entire period of consideration. The phenomenon is reversed

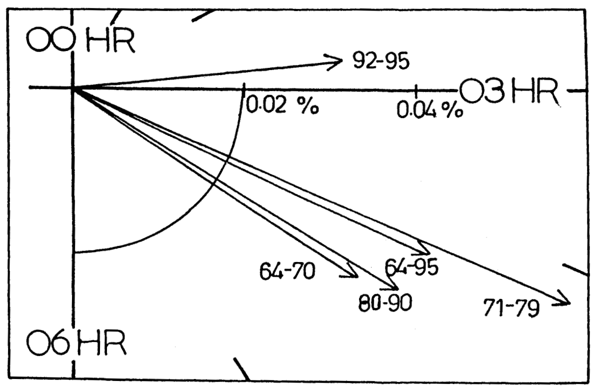

Fig. 2. The average semi_diurnal vectors for the duration of positive polarity of SPMF in NH (i.e. 1964-70 and 1980-90) and the negative polarity of SPmfin NH (1971-79 and 1992-95).

with the reversal of polarity of SPMF for the periods 1971-79 and 1991-95. Thus, it may be concluded that the phase of the semi-diurnal anisotropy has a oscillatory variation with respect to polarity of SPMF.

Kumar et al (1998) observed similar variation of diurnal anisotropy of cosmic ray intensity with respect to polarity of SPMF. Thus, confirming the dependence of diurnal and semi-diurnal anisotropy on magnetic polarity of the SPMF as pointed out by Munakata et al (1995).

4. CONCLUSION

(i) Close to period of cosmic ray intensity maximum the phase of the semi-diurnal anisotropy shows sudden changes to early/later hour.

(ii) The amplitude of semi diurnal anisotropy shows an increase followed by a decrease during inversion of solar poloidal magnetic field.

(iii) The average annual semi-diurnal vector for the negative polarity of SPMF in NH are shifted to later hours relative to the average annual semi-diurnal vector for the entire period of consideration. The phenomenon is reversed with the reversal of polarity of SPMF.

Acknowledgements. The author are indebted to Prof. M. Bercovitch abd Prof. J. H. KIng for providing the data which made this work possible.

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